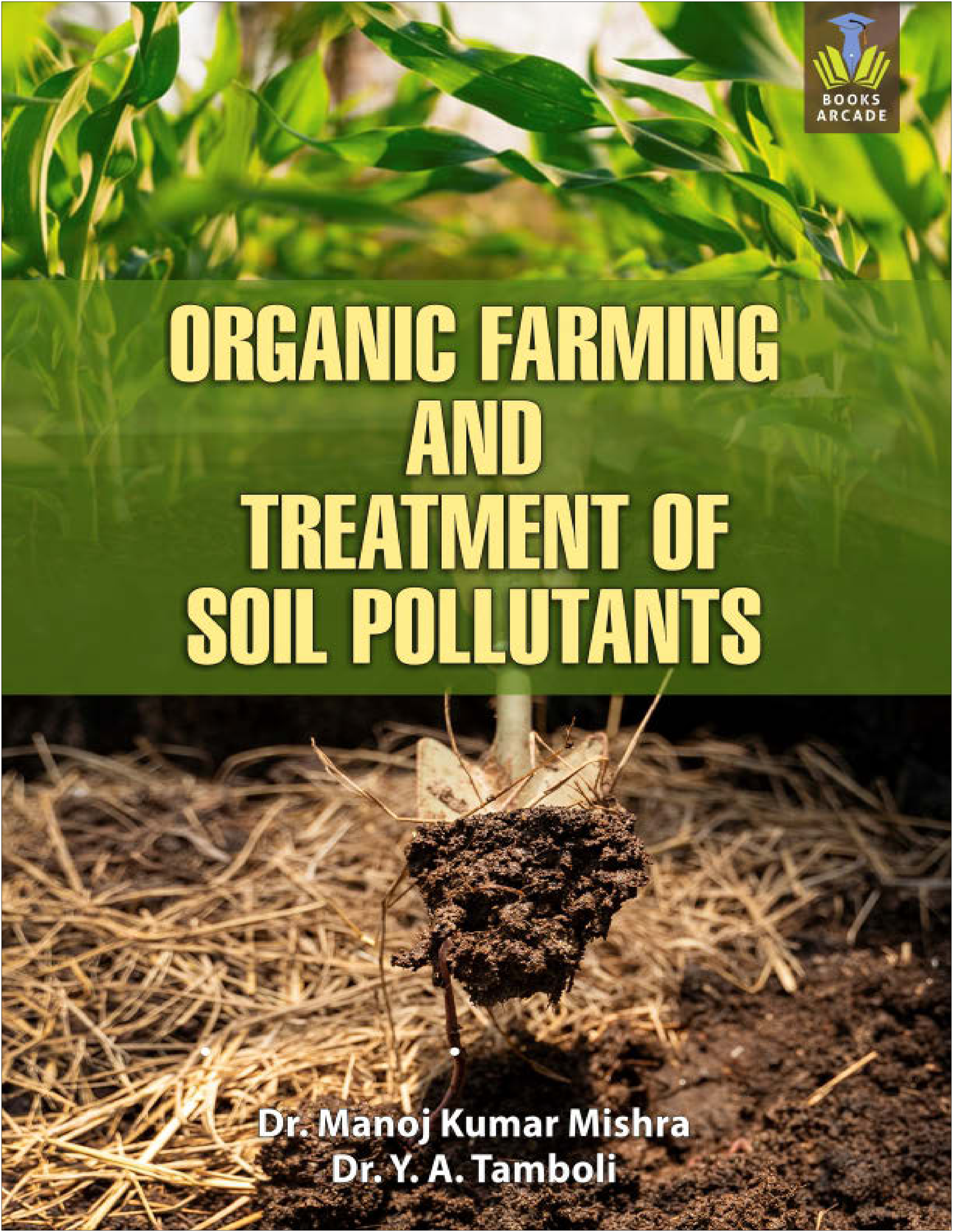

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ORGANIC FARMING AND TREATMENT OF SOIL POLLUTANTS

Dr. Manoj Kumar Mishra
Dr. Y. A. Tamboli

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KRISHNA NAGAR, DELHI

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CONTENTS

CHAPTER 1

AGRICULTURAL SUSTAINABILITY AS A CENTRAL SCIENCE

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ABSTRACT:

The growing artificialization of human civilization may be used to explain serious global challenges including poverty, disease, food prices, climate change, the global market, pollution, insect adaptability and resistance, soil degradation, declining biodiversity, and desertification. As most problems are now interconnected, the traditional firefighter method is no longer effective. In that regard, the organization of real scientific and political organizations is probably out of date and has to change to address contemporary issues. Surprisingly, since agronomists are taught to coordinate the input of several disciplines, including plant biology, soil science, climate science, ecology, and chemistry, agronomy emerges as a vital science to address contemporary social concerns.

KEYWORDS:

Agronomy, Artificialization, Climate Change, Industrial Revolution, Sustainable Agriculture.

INTRODUCTION

Current severe issues that endanger our planet include starving people in developing countries, ill and obese people in developed countries, rising food prices, climate change, rising fuel and transportation costs, market flaws on a global scale, pesticide pollution around the world, pest adaptation and resistance, loss of soil fertility and organic carbon, soil erosion, declining biodiversity, and desertification. The "artificialization" of society may be used to explain the majority of present human problems. With the advent of agriculture, one of the oldest human traditions, artificialization first appeared. Wheat was domesticated in the early prehistoric period, about 8,000 years. During that period, people gradually transitioned from a nomadic lifestyle that included hunting and eating wild plants and fruits, which is characteristic of animal behavior, to a more established lifestyle that involved cultivating crops, harvesting them, and storing the food.

In order to trade items with other tribes, tribes quickly devised money, first in the form of salt or shells. The financial market officially got started at that point. Territories and boundaries were also created by tribes. It marked the emergence of countries. Early social behaviors already had advantages, such a reliable supply of food during the winter, as well as disadvantages, including battles to capture more prosperous lands. Since social groupings and countries were autonomous and tiny for a considerable amount of time prior to the beginning of the industrial revolution about 1850, the negative effects on society were constrained and restricted. Due to the slow and mostly local nature of the transportation of food, products, and people, negative effects on society were equally constrained in time[1].

The industrial revolution saw a sharp growth in artificialization. The invention of motorized boats, vehicles, and aircraft made it possible to move products quickly across great distances. Social groups and nations started to rely more and more on other nations for food and products, losing their growing sense of independence. The huge advantages of this global conduct include medicine, which has considerably extended human life expectancy. Yet, this also had unfavorable effects on the globe, including the First and Second World Wars, Chernobyl, and more recently, climate change, impoverished nations, and sick and obese affluent individuals.

Until recently, social problems were mostly resolved using the "fireman" approach or, in a more medical context, the "pain-killer" approach in which an individual problem is resolved by an individual remedy. Such a strategy is ineffective now for at least two reasons. First, all processes, mechanisms, and actions are intricately linked, as shown in Figure 1. For instance, food production is directly related to politics, money, market, health, climate change, and transportation. Applying a solution to only one component of this system will not thus be effective since the remedy will ultimately have detrimental effects on other components. Now, only approaches that take into account the whole system and all of its linkages will have a chance of working. Second, the fireman strategy ignores the root of the issue. It solely addresses the detrimental effects. Here, identifying the causes of the issue and foreseeing possible future issues are clear solutions[2].

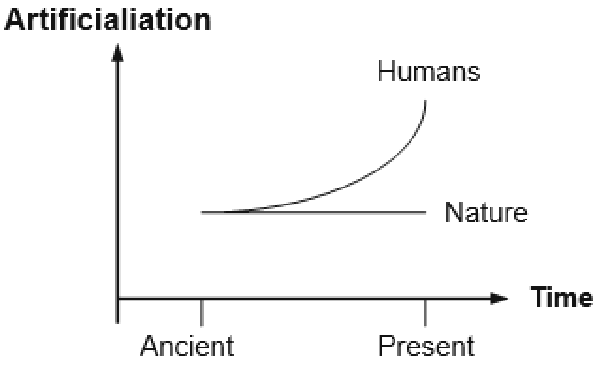

Figure 1: Illustarte the growing artificialization of human behavior.

DISCUSSION

These findings allow for the provision of two pieces of guidance. First, it's likely that the actual borders, names, and areas covered to differentiate amongst government entities are out-of-date. The majority of agricultural difficulties are related to health, economics, and transportation, hence an agriculture department shouldn't be isolated from other departments. Hence, departments' names, structures, operating systems, and areas of expertise should change to reflect the origins and relationships of contemporary problems. Second, in a similar vein, the separation of the sciences into fields like physics, biology, and chemistry is out of step with the manner that genuine scientific problems are resolved, which involves the contributions of several fields. Hence, scientific disciplines' names, structures, methods, and domains should develop to reflect current, related scientific problems[3].

Due to new technology, automation, increasing chemical usage, specialization, and government policies that promoted maximum output and lowering food costs, food and fiber productivity have improved dramatically. Fewer farmers can now produce more food and fiber at less rates because to these innovations. Despite the fact that these advancements have greatly decreased hazards in farming and had numerous good benefits, they are still quite expensive. Topsoil loss, contaminated groundwater, air pollution, greenhouse gas emissions, the decline of family farms, disregard for the living and working conditions of farm laborers, new dangers to public health and safety resulting from the spread of new pathogens, economic concentration in the food and agricultural industries, and the dissolution of rural communities are prominent among these.

For the last forty years, there has been a rising movement to challenge the need for these exorbitant prices and to provide creative alternatives. Now, the movement for sustainable agriculture is gaining recognition and support within our systems for producing food. Three key objectives of sustainable agriculture are social equality, economic viability, and environmental health as shown in Figure 2. The achievement of these objectives has been aided by a variety of ideologies, laws, and procedures, but most definitions of sustainable agriculture have a few fundamental themes and guiding principles[4].

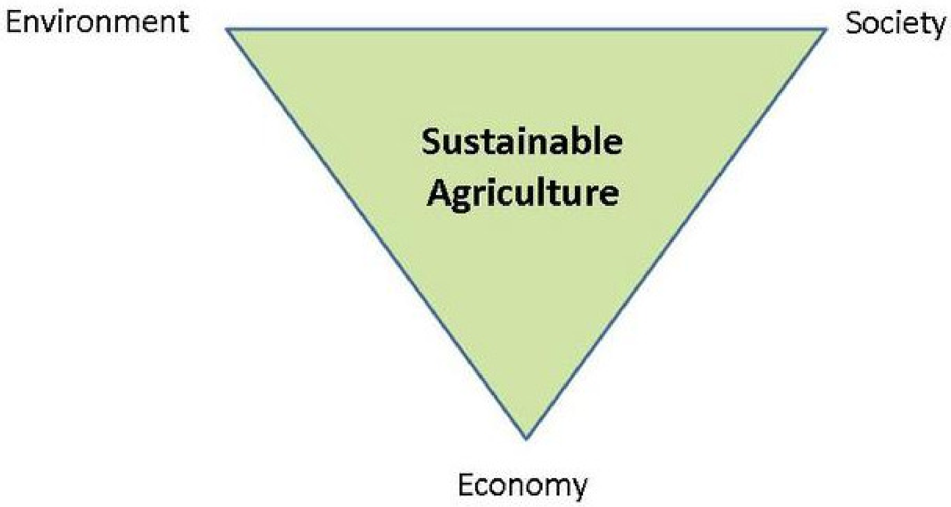

Figure 2: Environmental, social, or economic issues are equally important in sustainable agriculture.

Due to the fact that when industrial farming began in affluent countries about 1960, food production was not truly a concern, agronomy has long been seen as a soft "side" subject. Agronomists now suddenly seem to be the finest scientists to address the pressing social problems of food, climate change, health, and poverty. In fact, agronomists are often called upon to address problems that require for the combined expertise of several scientific disciplines, including geology, sociology, economics, plant biology, soil science, and climate science. Also, they deal with very complicated study items whose behavior is seldom repeatable. As a result, sustainable agriculture today seems to be a key science. Hence, the science of sustainable agriculture is best suited to address present problems, foresee potential problems in the future, and define creative techniques that will make the planet safer for our children[5].

The foundation of agricultural sustainability is the idea that we must satisfy our needs today without jeopardizing the capacity of future generations to satisfy their own needs. Hence, short-term economic gain is just as important as long-term stewardship of both natural and human resources. Stewardship of human resources involves taking into account social duties such as workers' living and working circumstances, the requirements of rural communities, and the current and long-term health and safety of consumers. Land and natural resource stewardship include preserving or improving the quality of these resources and using them in ways that enable future regeneration. Concerns concerning animal welfare must be taken into account when making stewardship decisions in agricultural operations that use cattle.Understanding sustainability requires a perspective on agroecosystems and food systems. Individual fields, farms, and ecozones are all included in the widest definition of an agroecosystem. Agroecosystems, as well as the components of food distribution and consumption, are a part of food systems that similarly connect farmers with local communities and the world's population. Our focus on a systems viewpoint enables a thorough understanding of our agricultural production and distribution businesses, as well as how they impact local people and the environment. On the other hand, a systems perspective also equips us with the means of evaluating how human civilization and its institutions affect agriculture and the sustainability of the environment[6].

Our understanding of many natural and human systems has taught us that robust, adaptable, and diverse systems are often those that endure throughout time. Since most agroecosystems deal with factors like climate, insect populations, political situations, and other factors that are sometimes extremely unpredictable and seldom steady over time, resilience is essential. It may not always be feasible or desirable for an agroecosystem to resume the same shape and function it had before to a disturbance, but it may be able to alter itself and take on a new form in the face of changing circumstances, making adaptability a vital component of resilience. The more diversity there is in a food system, whether in terms of crop varieties or cultural knowledge, the more tools and ways it will have to adapt to change. Diversity is often associated with adaptation. A strategy that considers both the agroecosystem and the food system calls for multifaceted efforts in research, instruction, and action. Moving toward greater agricultural sustainability requires the involvement of not just scholars from diverse fields but also farmers, workers, retailers, customers, lawmakers, and anyone who have an interest in our food and agricultural systems.

Ultimately, there is no one, clearly defined endpoint for sustainable agriculture. Science's knowledge of what defines sustainability in terms of the environment, society, and economy is always changing and is impacted by current concerns, viewpoints, and beliefs. For instance, although it wasn't seen as a pressing problem 20 years ago, agriculture's capacity to adapt to climate change is now getting more attention. Moreover, the specifics of what makes up a sustainable system may vary depending on a variety of factors such as soil types, climate, labor expenses, as well as from one cultural and ideological standpoint to another, making the word "sustainable" itself a contentious one. Hence, rather than thinking of agricultural systems as falling into a sustainable or unsustainable dichotomy, it is more practical and germane to conceive of them as being along a continuum from unsustainable to very sustainable.

Natural resource management and sustainable agriculture[7]

Future generations will be less able to produce and thrive if the natural resource base is harmed in the process of producing food and fiber. The depletion of natural resources caused by unsustainable agricultural and forestry methods is thought to have had a significant impact on the fall of ancient civilizations in Mesopotamia, the Mediterranean area, the Pre-Columbian southwest United States, and Central America. A sustainable agricultural strategy aims to use natural resources in a manner that will allow them to recover their capacity for production while also minimizing negative effects on ecosystems outside of a field's edge. Considering how to take use of already-existing natural processes or how to construct their agricultural systems to integrate essential ecosystem activities are two ways that farmers attempt to achieve these aims. It is often feasible to sustain an economically viable production system with fewer potentially damaging interventions by constructing biologically-integrated agroecosystems that depend more on the internal cycling of nutrients and energy. By using natural mechanisms to control insect populations, for instance, farmers striving for a better degree of environmental sustainability may be able to minimize their usage of harmful pesticides. This might happen, for instance, by spreading ground covers between rows or hedgerows along field boundaries, creating habitat for insects and birds that feed on the pests, or by growing more diversified crop mixtures that fool or scare away pests. By preserving as many crop types and animal breeds as feasible, we may maintain a high level of genetic diversity and increase the genetic resources available for breeding disease and pest resistance[8].

In addition to caring for soil to ensure that it maintains its integrity as a complex and highly organized entity made up of mineral ppapers, organic matter, air, water, and living species, resource conservation is essential for agricultural output. Farmers that are concerned about long-term sustainability often place a high priority on soil stewardship because they understand how good soil supports healthy crops and animals. Focusing on preserving or even growing soil organic matter is often necessary to keep the soil working. In addition to serving as a critical source and sink for nutrients, a substrate for microbial activity, and a buffer against changes in acidity, water content, pollutants, etc., soil organic matter also plays other important roles. Moreover, the accumulation of soil organic matter might lessen the impact of a rising CO2 concentration and subsequent climate change. Inducing a better soil structure, which improves water penetration, reduced runoff, better drainage, and higher stability, reduces wind and water erosion, is another crucial role played by soil organic matter.

The functioning of agroecosystems has been cut off from the internal cycling of important plant nutrients like nitrogen and phosphorus due to a significant dependence on artificial fertilizers. While phosphate minerals are now mined for fertilizer, it is anticipated that the world's supplies would only last for another 50 to 100 years. As a result, phosphate prices are predicted to increase unless new deposits are found and improvements in phosphate recovery from waste are developed. Important components of sustainable agriculture include recycling nitrogen and phosphorus at the farm and regional levels, increasing fertilizer application efficiency, and depending on organic nutrient sources animal and green manures. A diversified agriculture with increased spatial integration between crop and animal production helps to recycle nutrients. These factors suggest that broad mixed crop-livestock systems, especially in emerging nations, may have a considerable impact on future agricultural sustainability and world food security[9]–[11].

CONCLUSION

For agriculture to be really sustainable, social, economic, and environmental sustainability must all work together? For instance, in order to survive, poor farmers are often compelled to exploit natural resources like soil fertility, even when doing so may eventually harm their ability to earn a living. Societies may only encourage more sustainable farming systems by developing policies that incorporate social, environmental, or economic concerns.

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CHAPTER 2

SOIL IS THE MOTHER OF NEED

ABSTRACT:

Future population growth will almost entirely take place in emerging nations, where soil and water resources are already severely depleted. Global warming, soil degradation, pollution, the scarcity of fresh water, urbanization, industrialization, and rising fertilizer costs are all anticipated to aggravate the strain on restricted soil resources. In order to increase agricultural yields and soil resources, I will outline five principles of sustainable agriculture. Enhancing soil organic carbon and soil structure, establishing a favorable nutrient budget, restoring degraded soil, adjusting agriculture to climate change, and using land-saving technology are the tenets.

KEYWORDS:

Agriculture, Crop Yield, Fertilizer, Pollution, Soil Erosion.

INTRODUCTION

By 2050, the 6.75 billion people who lived on the planet in 2008 are expected to increase to 9.2 billion. Future population growth will mostly be concentrated in emerging nations, where soil and water resources are already severely depleted. According to projections, between 2008 and 2050, the population of the region will rise from 827 to 1,761 million people in sub-Saharan Africa, from 364 to 595 in the Middle East and North Africa, from 35 to 45 in Oceania, from 579 to 769 in Latin America and the Caribbean, from 342 to 445 in North America, and from 3,872 to 4,909 in Asia. Contrasting with expected decreases in Europe's population from 731 million in 2008 to 664 million in 2050, as well as a rise in the world's population from 6,750 million in 2008 to 9,191 million in 2050, are these tendencies in regional population growth. In order to fulfill the needs of the growing population for food, feed, fiber, and fuel, the strain on restricted soil resources is anticipated to be increased by a number of interrelated causes. Global warming, soil degradation, dwindling freshwater supplies, pollution and contamination of water resources, urbanization and urban sprawl, decreased usage efficiency, and rising costs of energy-based inputs like fertilizer and irrigation water are notable examples of these causes[1], [2].

To boost agronomic output in Asia and Africa's emerging nations, it is imperative to remove biophysical and socioeconomic obstacles. Since there are no limitations connected to the soil or plants, climatic parameters, such as solar radiation, soil and air temperatures, and evapotranspiration, define the maximum production potential of an ecoregion. Contrarily, a variety of variables, such as drought stress, poor soil fertility, agricultural techniques, and alternatives for managing soil and water, influence the on-station crop yield when suggested management measures are used. Social, economic, and institutional aspects including land tenure, market and infrastructure, support services, etc., influence the agricultural yield that can be produced, as shown Figure 1. The prevailing agricultural method has an impact on the real farm produce.Loss of water and nutrients due to runoff and soil erosion, as well as the kind and degree of soil deterioration. Between "on-farm" production and "maximum yield potential," there is a significant "yield gap" in developing nations. Using suggested measures for sustainable management of soil resources is necessary to close the production gap. The following five principles of sustainable agriculture serve as the foundation for the recommended practices[3]–[5].

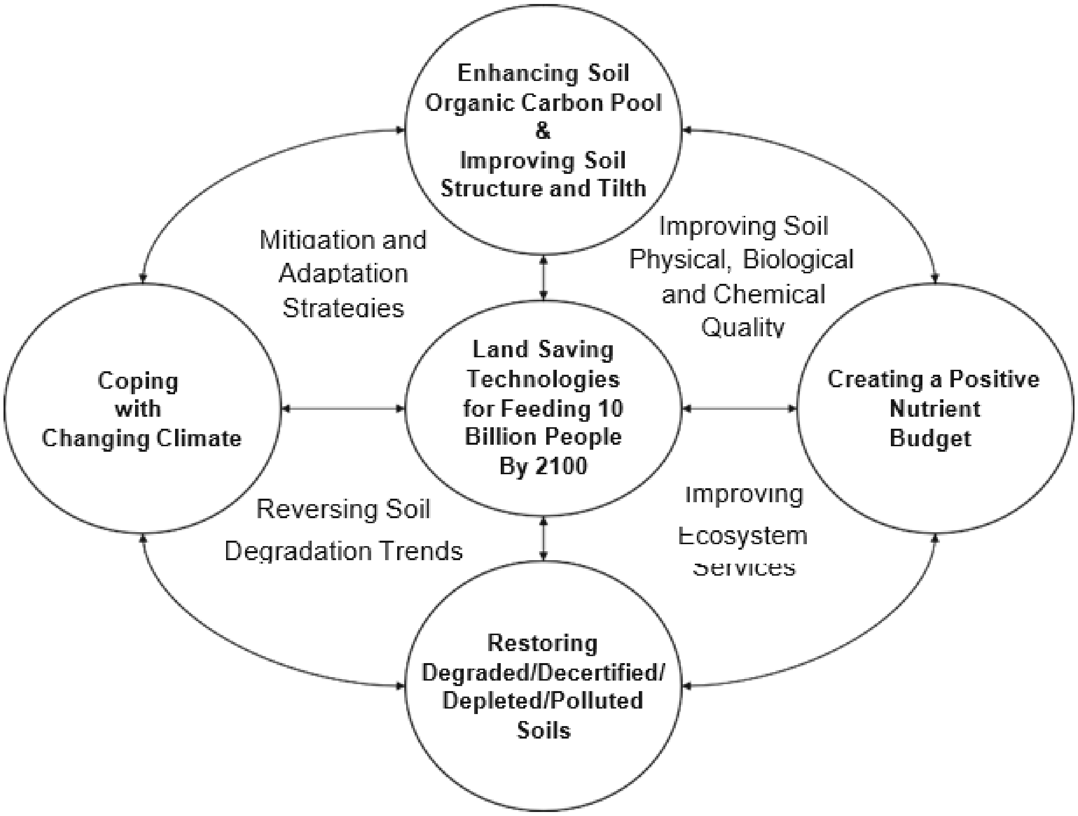

Figure1: Illustrate the Five principles of sustainable farming.

Loss of water and nutrients due to runoff and soil erosion, as well as the kind and degree of soil deterioration. Between "on-farm" production and "maximum yield potential," there is a significant "yield gap" in developing nations. Using suggested measures for sustainable management of soil resources is necessary to close the production gap. The following five principles of sustainable agriculture serve as the foundation for the recommended practices[3]–[5].

DISCUSSION

Increased Soil Organic Carbon and Improved Soil Structure

For the main tropical soils, it is crucial to raise organic carbon levels in the root zone over the critical minimum of 1.2%. Raising the proportion of organic carbon involves keeping the ecosystem's C budget positive.

The activity and species variety of the soil fauna, as well as the concentration of organic carbon, all influence soil structure.

An increase in organic carbon and the resulting enhancement of structure and tilth improve nutrient and water availability and storage, as well as soil aeration. Increased root development, improved water and nutrient absorption, and increased root growth all depend on the general physical condition of the soil.

Establishing a Beneficial Nutrient Budget

Since the 1960s, the majority of farmland soils in South Asia and sub-Saharan Africa have suffered a negative nitrogen budget of 30–40 kg of NPK/ha/yr on a continental scale. The prevalence of extractive farming practices, such as the removal of crop residues for fodder and fuel and the use of animal dung for domestic cooking, as well as the low or nonexistent application of chemical fertilizers and the unbalanced application of nutrients for example, the application of N rather than P and K due to subsidies for N are the main causes of the negative nutrient budget. Other inputs, such as the adoption of better cultivars, have little effect on soils that have exhausted their natural nutrient supplies[6], [7].

Rehabilitation of Soil

For a growing population with rising aspirations for high standards of life, it is crucial to restore the condition of degraded, desertified, depleted, and poisoned soils. Restoring degraded and desertified soils improves the environment in addition to increasing net primary productivity and agronomic output. This is especially true in relation to water quality through the decrease in trans- port of dissolved and suspended loads and the resulting decrease in nonpoint source pollution, as well as in relation to air quality through a decrease in wind erosion, the decrease in emission of trace gases and aerosols, and the decrease in efflux of particulate material. Because of how soil restoration affects the global C cycle, it is also strongly related to climate change.

Shifting Climate and Agriculture

Agronomic methods must be adjusted to distribute risks in order to lessen the negative effects of climate change. Ex-ante risk management strategies include mulching, no-till farming, deferred fertilizer application, integrated nutrient management options, runoff management, and adequate weed control. Strategies for managing plants include variety selection, staggered planting dates, low-planting densities, bunch planting, intercropping, and farming system management strategies like diversification, agroforestry, and mixed farming[8].

Land-saving Innovations

It is crucial to boost productivity per unit area of existing land via agricultural intensification due to the declining availability of per capita land area and supply of fresh water resources for agriculture. In order to conserve land for nature conservation, it is important to actively cultivate the best soils employing optimum management methods. The amount of land needed per person may be reduced to less than 0.03 hectares by using specialized technologies that draw on ancient wisdom while also using cutting-edge scientific discoveries. In comparison to the current cultivated land area of 1.5 billion hectares, with 10 billion people by the year 2100, this would still equate to 3 billion ha of agriculture. Enhancing the legitimacy of the agricultural profession requires putting these five principles into practice. Farmers in developing nations that lack resources are at the lowest rung of society. Small-scale landowners work in a menial job that provides a miserable level of life. The standard of life must be raised by replacing the labor-intensive hoe and escaping the poverty cycle[9], [10].

In that it may satisfy all human wants without being greedy, soil, the basis of all terrestrial life, is Mother Nature. A paradigm change is necessary to maintain, enhance, and restore this potential. This shift suggests that the soil surface must be protected against wind and water erosion in order to prevent the loss of water, carbon, and nutrients from the ecosystem. It also suggests that biosolids must be applied to the soil in order to strengthen elemental cycling. It also suggests that the activity and species diversity of the soil fauna must be encouraged. Finally, it suggests that the soil must become a sink for atmospheric CO2 and CH4 in order to reduce emission of other greenhouse gases. Finally, it suggests that the soil's capacity to denature and the conceptual paradigm change demands that advised management methods be widely used. These include integrated nutrient management, which combines biological N fixation, recycling, and the prudent use of chemical fertilizers and amendments; no-till farming with residue mulch, cover crops, and manuring; water harvesting, recycling, and conservation in the root zone for improving productivity per unit consumption of fresh water and more effectively utilizing rainfall; and building upon traditional knowledge and using modern technology[11], [12].

CONCLUSION

Farmers must be included at all phases of decision-making when determining the priorities for research and practice in order for these technologies to be successfully implemented. While the mother of all requirements, sustainable soil management is up to the farmer to execute. In order to effectively address the difficulties of a changing environment and human needs and ambitions, it is important to put "soil and farmer" at the center of the activity.

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CHAPTER 3

TECHNOLOGY WITHOUT INTELLIGENCE

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ABSTRACT:

Despite notable gains in crop yields in the latter part of the 20th century, agricultural intensification is blamed for a number of environmental issues including pesticide pollution of water sources, faster soil erosion, loss of biodiversity, and the production of greenhouse gases. Feeding the 6.5 billion people on the planet now and the 10 billion people projected by the end of the twenty-first century would require improving freshwater quality and quantity, restoring damaged soils, increasing biodiversity, reducing global warming, and achieving human fairness. Knowing that prudent and sustainable management of the world's soils holds the key to finding the answers to these concerns is encouraging. Yet whether or not we can learn from our previous errors will determine whether or not this endeavor is successful. The misuse of technology, not the technology itself, is the issue.

KEYWORDS:

Soil degradation, Pesticide pollution, Water Biodiversity, Technology.

INTRODUCTION

The problems were brought on by excessive fertilization, overuse of pesticides, excessive application and use of water of poor quality and free electricity for pumping irrigation water, excessive and unnecessary plowing of delicate soils on sloping terrains, landforming with bulldozers and construction equipment, extractive farming practices that result in a negative nutrient balance, and soil mining for brick making. Scientists studying soil have the knowledge to bring life to the desert.

To do this, it is important to use no-till farming techniques with residue mulch and cover crops, wise fertilizer use, integrated nutrient management, precision farming to meet the needs of the soil, water harvesting and recycling, drip irrigation, retiring marginal lands for nature conservation, restoring wetlands, and utilizing integrated watershed management techniques. Every misuse of technology is a mistake that the world can no longer afford. There are nine human errors enumerated, including seven that Mahatma Gandhi previously noted[1].

Notwithstanding the great advances achieved in generating high crop yields throughout the second half of the 20th century, the expansion and intensification of agriculture are blamed for a number of environmental issues. These include non-point source pollution and eutrophication of natural waters caused by the transport of dissolved and suspended loads from agricultural lands, reduction in biodiversity due to monocropping, contamination of natural waters and air due to the use of fertilizers and pesticides, accelerated soil erosion, and sedimentation of waterways and reservoirs due to unnecessary and excessive plowing, and emission of greenhouse gases. Vandana Shiva's essay "The Violence of Green Revolution" issued a caution on the social and human impacts of the Green Revolution. These concerns are entirely reasonable since, for whatever reason, damaging the environment, polluting the climate, destroying soils, causing the extinction of animals, and producing social and gender inequality is not acceptable. Such reality checks are crucial for maintaining the scientific community's focus and for keeping their feet firmly planted on the earth.

One of our professional objectives as soil scientists is to create and encourage the use of soil, water, and crop management technologies, which supports the idea that having access to enough food and a clean environment are two fundamental human rights that must be protected. As preventing mass hunger of billions of people was the aim of the Green Revolution in the 1960s and 1970s, its accomplishments are totally justified and a real success story. Also, sub-Saharan Africa must replicate the results seen in Asia. The latter suggests that, particularly in sub-Saharan Africa, the usage of fertilizers, pesticides, and irrigation will need to be expanded. Hence, the important issue that must be critically and honestly answered is: How can food production be increased, hunger and malnutrition eradicated, and the environment improved? Even if it's a big task, there is no other option. Feeding the 6.5 billion people on the planet now and the 10 billion people by the end of the twenty-first century, restoring the quality and quantity of fresh water, increasing biodiversity, reducing global warming, and achieving socioeconomic, gender, and ethnic fairness are all necessary[2], [3].

It is encouraging to know that intelligent and sustainable management of the world's soils holds the key to these problems' solutions, no matter how challenging and complex they may be. Such foundation gives soil scientists a fantastic chance to rise to the occasion and take on the task. But, the outcome of this endeavor will rely on our capacity to draw lessons from the past. So, it's critical to pinpoint the reasons behind the Green Revolution technology's negative impacts on soil, water, biodiversity, climate, and society as a whole.

The problem, according to a critical analysis of the cause-effect link, is not with technology per se but rather with misuse of it. The problems were brought on by overfertilization, overuse of pesticides, excessive application and use of contaminated water and free electricity for pumping irrigation water, excessive and unnecessary plowing of fragile soils on sloping terrains, landforming with bulldozers and construction machinery, extractive farming practices that result in unfavorable nutrient balances, and soil mining for brickmaking. The management of soil and natural resources has an influence on how we decide to utilize the technology, much as nuclear energy may be used to either provide electricity or cure sickness or to destroy nature and civilization.

The state of social soil care is reflected in environmental and soil deterioration. People, countries, and civiliza- tions "scribe their history on the soil a record that is paper to read by those who understand the plain language of the country," as Lowdermilk put it. According to Aldi E. Stevenson, "Nature is impartial. All environmental problems are the result of human mishaps with nature. Man has taken the power away from nature to either make the planet arid or to make the desert blossom[4].The expertise to make a desert blossom is held by soil experts. Important technological advancements that can help with this include no-till farming with residue mulch and cover crops, prudent fertilizer use and integrated nutrient management, precision farming to meet the needs of the soil, water harvesting and recycling along with drip irrigation/fertigation, retiring marginal lands for nature conservation and restoring wetlands, and using integrated watershed management approaches to improve water resources.

Traditional farming in developing nations must be transformed via the use of integrated pest management, biotechnology, and transgenic plants, in addition to methods for the sustainable management of soil and water resources. In fact, the proper use of biotechnology may aid in the creation of novel genotypes with a high potential for productivity under biotic and abiotic challenges. Mother Nature has always altered species to encourage and assist the adaption of plants and animals to certain ecological niches from the origin of life on Earth. There are 8.4 million different living forms, according to ancient Hindu texts written between 1500 and 2500 B.C. "One life form transforms into another until it achieves completion." Hence, collaborating with nature to create plants that can better endure biotic and abiotic challenges is advantageous, consistent with natural processes, and suitable.

DISCUSSION

For a very long time, people have fantasized about computers with human intellect and talents. Our human imaginations have envisioned what it would be like to have sentient, intelligent, human-like machines coexist with us for well over a century, from the early Greek myths of Hephaestus and his automatons to the Golem of Eastern European Jewish tradition to well over a hundred years of science fiction stories, novels, and movies. The term "robot" was originally used in 1920 in Karel apek's play R.U.R. which also offered us a name for the inventions of our imagination. The search for an intelligent machine in many ways contributed to the creation of the contemporary computer. The Turing Test, after its namesake inventor, offers a way to judge clever computers. Alan Turing's ideas formed the foundation for programmable machines as well as the fundamental ideas of artificial intelligence[5], [6].

Nonetheless, despite decades of technological progress and a nearly exponential rise in computer power, data, knowledge, and capacities, we are still far from realizing the goal of Artificial General Intelligence machines that can match human competence in all respects. Not even close, really. We can communicate with gadgets that do not comprehend what we are saying. If your GPS tells your vehicle to do so, some of them will gleefully drive into a wall. Images are being detected by machines, but they cannot identify them. And although we have incredible computers that can defeat world champions in games like Go, chess, and multiplayer ones, they are unable to respond to a simple query like "how long should I cook a 14 pound turkey?" We are experts in computers. Big data has been a challenge. We are finding out how to learn. How to develop universal intellect is a mystery to us.

The fact that we often confuse the numerous products of our search for the intelligent machine with the search itself contributes to this disconnect. It is not a technology to use artificial intelligence. The point is lost when the issue of whether or not a certain technology is AI is raised. The path is artificial intelligence. The search for an intelligent machine is at hand. Although each of the technologies we created along the way to that objective is beneficial in and of itself, taken as a whole, they have not yet succeeded in bringing us there. Determining that artificial intelligence is not a technology much as the Space Race is not a technology is crucial in light of this.

Huge technological developments have taken place since the 1950s to aid us in the development of artificial intelligence. In the 1950s through the 1970s, when AI was still in its infancy, we developed computers that could play games, comprehend elementary logic, have simple dialogues, do modest machine translation tasks, and even use primitive neural networks. Interest in AI restarted in the late 1980s with the broad use of computer desktops on knowledge workers' desks and the creation of expert systems, after a downturn in interest brought on by the under-delivery of over-promised AI benefits. IBM's Deep Blue defeated Garry Kasparov in the late 1990s. It seemed that we had gotten back on track with AI development. Yet when AI failed to once again live up to some of the promises, corporate and investment interest in the technology declined[7].

Yet the dream persisted, and in the middle of the 2000s, a passionate interest in AI returned. We were able to fulfill some of the promises made by AI in the past thanks to the almost endless capacity of cloud computing and GPUs, the ubiquity of large data and our expertise in using it, and the development of improved neural network algorithms. AI is back in style. It's fashionable. The cash is coming in. Businesses are putting artificial intelligence first as if the past stigma never happened. AI is still a hot topic with no signs of slowing down. Despite billions being spent and thousands of the world's top brains working on the problem, artificial general intelligence remains a mystery. Is our modern technology outdated? Is there an issue with our data? Do we not yet have sufficient computational power? Maybe the AI train is moving forward and we've just reached the newest stop. We've made some progress in this wave, but we still have a ways to go before we reach the objective of AI. We must go on to the next station.

Using AI Is Not A Technology

Is AI a trend toward reaching machine intelligence or is it the technology that humans employ to make machines intelligent? John McCarthy claims that AI is truly a science. It is a subject of research. Therefore, it could be more beneficial to consider AI as a target. If artificial intelligence is seen as a collection of technologies, then there is no end to the debate over what constitutes AI. Are software robots made of AI? AI is used in self-driving cars? Is artificial intelligence present in computer vision? Character recognition is it an AI? If you consider it to be technology, there will always be room for debate and interpretation. Even if we aren't quite there yet, if you think of it as a goal or quest, then it is something we are always working toward. Even if you consider artificial intelligence to be a discipline, like physics, such disciplines have objectives. To fully comprehend the nature of the world is the aim of physics. Every technology we've created in our search for physics comprehension is something we can utilize in our daily lives. These technologies, however, are results of our effort to grasp physics; they are not physics itself. Machine learning, computer vision, and robotics are not AI; rather, they are technological consequences of our effort to develop or comprehend AI[8]. There have been significant advances in the sector thanks to the search for artificially intelligent machines. As previously mentioned, modern technologies enable self-driving cars, chatbots that can converse in multiple languages at once, systems that can aid in the diagnosis of diseases like cancer or diabetes, the recognition and classification of images, the understanding and generation of natural language, and an almost infinite number of applications across a wide range of industries. These applications are often categorized as "narrow AI". No one has yet attained AGI, which is regarded as "strong AI," therefore it goes without saying that any application of AI now in use is constrained. Because of this, the phrase "narrow AI" is both meaningless and harmful. The cognitive technologies that have been created in the pursuit of the intelligent machine are what people mean when they refer to limited AI. Use the phrase "cognitive technology" instead of "narrow AI." It more clearly conveys the meaning. You should inquire when someone uses the terms "generic AI" or "strong AI" to determine if they are referring to the technologies that implement the intelligent machine or the end result itself. The first is a science, whereas the second relates to application technology[9], [10].

AI may be seen from the same viewpoint as the space race, which wasn't a technological advancement. Our efforts to reach space led to the creation of many wonderful innovations, including heated blankets, microprocessors, infant formula, and velcro. The objective was to send humans in space, on the moon, and perhaps travel between stars. The advancements made in the pursuit of the objective have been beneficial to society. All of these technologies that make up various parts of the effort to accomplish that aim are what result from the race.

CONCLUSION

AI's ultimate objective and the underlying science supporting our grasp of what it takes to make a computer clever are both making intelligent machines. Many of the technological advancements that have led to AI, such as self-driving cars, picture recognition technologies, or natural language processing and creation, reflect our intended result. AI is not a technology, as smart people and businesses are aware of. They do not inquire as to whether a certain implementation is or is not AI. Instead, they question the technology's transformational impact. They query what gain they stand to gain from robots that are capable of thinking and behaving like people. How can AI provide potential to significantly boost productivity, save costs, boost customer happiness, enhance current goods and services, and generate new business prospects? Because an organization's core purpose and goal are more important than its technology at the end of the day. Similar to previous organizations, AI is characterized by the overarching goal rather than the technology.

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CHAPTER 4

TRANSGENIC COTTON FOR SUSTAINABLE PEST MANAGEMENT

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ABSTRACT:

During the last ten years, transgenic cotton has drastically changed how pests are controlled in this crop. One of the first extensively grown transgenic Bacillus thuringiensis plants with insect and herbicide tolerance was cotton. Growers have access to over 300 transgenic cotton varieties that produce single or dual Bt proteins that target lepidopteron larvae as well as pyramided types with herbicide resistance. Transgenic plant deployment across large agricultural regions, as those devoted to cotton, has raised concerns due to potential detrimental effects of these plants. Bt cotton has been grown on over 8% of the world's 33.8 million hectares, and this number is expected to rise in coming years. Hence, the weediness, gene flow, and effects of Bt and Ht cotton on nontarget species have been carefully examined during the last ten years.

KEYWORDS:

Agriculture, Bt Cotton, Herbicide, Management, Tolerant Cotton, Sustainability.

INTRODUCTION

Despite reasonable worries about possible hazards, the findings do not indicate a major adverse effect or the development of cotton pest field resistance. Four adverse effects on natural enemies were identified as nontarget impact results, and they are detailed below. While there is limited information on the hazards of gene flow, over 333 published findings have not shown any weediness or gene flow.

Considering insect resistance, a number of variables, such as species biology and interactions with the ambient circumstances population, underpin resistance manifestation in field populations. The adoption of single or dual Bt protein types may experience some failure owing to resistance based on the population's gene frequency that confers resistance, according to modeling of the development of Bt protein resistance in a field population. As a result, planting transgenic cotton calls for diligence and effort, including establishing required refuges and keeping an eye on weed and insect resistance. Beyond an introductory section, this paper is divided into seven sections that cover: What is a transgenic plant, conventional and transgenic plant breeding techniques in insect-resistant cotton, herbicide-tolerant cottons, potential nontarget effects of Bt cottons, resistance and resistance management, the perspective of Bt cotton in Brazil, and the future of transgenic and pest management in cotton[1].

In 2007 and 2008, it is predicted that cotton was grown on more than 33.8 million hectares in over 80 countries, producing more than 26.2 million tons. Despite all of the technology used in the field and the factories, growing cotton and producing its products continue to be top commodities and a substantial source of income for around one billion people. To enable cultivation of the crop across a wide geographic range, hundreds of cot- ton varieties have been created. Yet, due to a variety of significant pests, the cotton crop is also exposed due to its wide dispersion, which may significantly reduce global output and profitability, as show in figure 1.

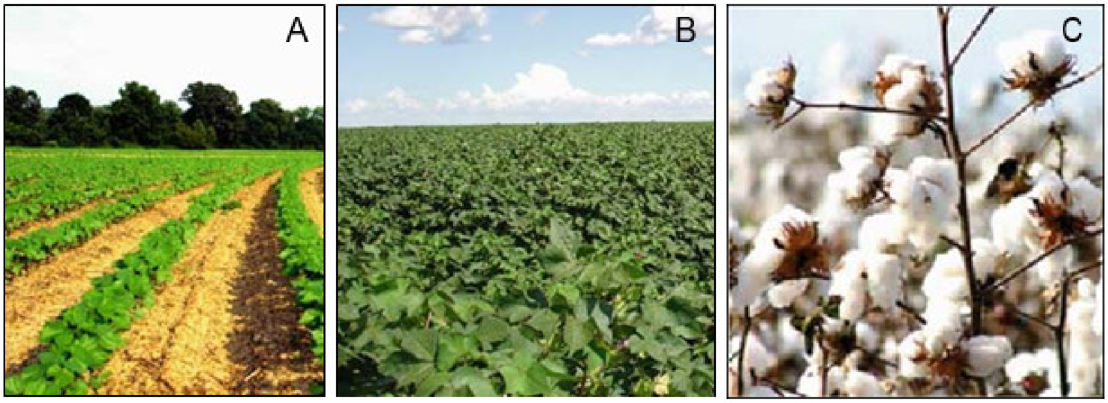

Figure1: Early season, creation of bolls, and harvest season are the three phenological phases of cotton plants, respectively.

As a consequence of the heavy pesticide usage in cotton pest control, human and environmental pollution, insecticide-resistant bugs, and a loss of profitability are some of the adverse effects. Because of this, the development of alternative strategies to lessen insect assault is still encouraged due to the economic and environmental implications of pest control in cotton. The fast adoption of lepidopteran-resistant transgenic Bt cotton across the globe is evidence that it is generally a cost-effective solution against the main lepidopteran species. Since the plants themselves manufacture the Bt proteins that are poisonous to insects, no extra machinery is needed, making the technique available to both big and small farms. Bt cotton also makes it simple to incorporate with overall management plans since it does not conflict with other pest control methods.

Nonetheless, there has been much discussion about the possible harm that plant transgenesis might do to the flora and fauna, particularly to species that are connected to transgenic plants, such as herbivores, helpful arthropods, and wild ancestral plants. There have been a number of studies of the data that assess the potential ecological implications of transgenic crops. Many arthropod species' abundances have varied between transgenic and nontransgenic cotton fields, although these variations are uncommon and may be explained by a variety of factors. For instance, fewer or no longer present Bt-susceptible hosts may be the cause of decreased parasitoid abundance in Bt crops[2].

In Bt transgenic insect-resistant farms, higher nontarget herbivore abundance is often correlated with lower pesticide inputs. According to the findings thus far, genetically modified Bt cotton is safe, although care should always be used throughout lab testing, field trials, and commercial evaluations. In their examination of the nontarget consequences of transgenic commercial crops, Marvier et al. reached the same results. Despite the fact that this field is still relatively new, a cursory search of the Web of Science database for "transgenic plant and impact" and "transgenic crop and impact" turned up 338 and 163 papers, respectively. It demonstrates the great interest in this topic and the enormous effort put out to compile scientific evidence for important judgments.

The creation and use of Bt transgenic cotton, which is intended to fend against lepidopteran pests, are discussed in this paper. The ramifications of this technology for cotton pest management are important and provide potential to enhance integrated pest control in cotton, particularly in relation to beneficial and nontarget pests of transgenic cotton in a multipest environment like cotton. This paper will present the development of Bt-transgenic cotton and its impact on pest management for agronomists and other academic readers due to the numerous recent literature reviews, and entire books that have already been published on the development and impact of transgenic crops. We do not want to provide in-depth information or discussions on arthropod pests to experts[3].

DISCUSSION

Plant Transgenic

Commonly used phrases include "transgenic plants," "plant-incorporated protectants," and "genetically modified" creatures. Genes from unrelated animals that have been transgenetically inserted into the genome of an animal or plant are referred to be genetically modified organisms. In genetically modified organisms plants, the transformed plant typically contains a gene from a foreign organism, such as a virus, bacterium, animal, or other unrelated plant, that will produce the desired character response, such as plants that are tolerant of herbicides and resistant to insects and viruses. By introducing foreign genes and/or boosting the expression of certain genes already present in the plant, genetic engineering has made it possible to change plants help reduce soil salinity and increase drought tolerance, among other things. Similar to this, unwanted genes may also be silenced, including those that produce poisonous substances in cotton seeds like gossypol and those that give soybeans their taste. The ability to modify varieties to lessen their vulnerability to environmental constraints like water scarcity and soil salinity that are becoming increasingly important with global climate changes is also provided by the identification and understanding of the mechanisms regulating genes involved in cotton plant responses to environmental stresses. Since Mendel's "Experiments on Plant Hybridization" in 1866, the genetic modification of plants has been touted as the most significant advancement in plant trait enhancement. Moreover, genetic engineering of crops will probably be the 21st century's breakthrough in enhancing food production via increased yield, increased stress tolerance, and other plant features including nutrition and secondary chemicals with therapeutic use[4].

Traditional and Transgenic Cotton Plant Breeding Techniques for Insect Resistance

Hybridization, mutation, and multiline back-crossing are a few traditional techniques that have been employed to enhance agronomic features in cotton, and they still hold a lot of interest today. Pedigree selection, back-cross, cultivar selection, bulk population selection, single lock descendant, and forward crossing are all cultivar selection techniques that have been applied alone or in combination. According to Bowman, cultivar development is the focus of almost 45% and 100% of effort from corporate and public breeder programs, respectively, in the US, the country where transgenic cotton has made the most strides. Traditional plant breeding and selection techniques may take a long time and are often inaccurate.

Although insecticidal qualities may be regulated by a single gene, the majority of agronomic varietal features are controlled by many genes. Biotechnology makes it possible for genetic information to be transmitted horizontally from one species to another, allowing for the direct transmission of better features without linkage drag the transfer of bad traits along with favorable ones.Cotton types with early maturation and heat tolerance have been generated by conventional plant breeding techniques, which depend on natural mutation. Hybrid vigor, multiline back-crossing, and cultivar reselection have all been used to increase yields. These traits are beneficial because early maturity of the bolls prevents damage from mid- and late-season pests such bollworms, boll weevils, plant bugs, and stinkbugs; and high yield makes up for losses brought on by pests[5].

In the nations that permit the technique, transgenic cotton types are farmed on a sizable scale, and there is a tendency to extend that area by at least 16% during the 2008 season. Such extensive planting raises two main issues. Because selection and reselection methods concentrate on specific established cultivars and repetitive use of the same parent lines in pedigree selection, the most popular breeding method in the United States, there are very few varieties of planted transgenic cotton, reducing genetic diversity a concern even before considering the release of transgenic crops. Low genetic diversity significantly increases the strain on pest populations and increases the crop's danger of being attacked by these resistant pests. Hence, to increase genetic diversity in transgenic crops, continued funding for traditional breeding initiatives is required. A second factor driving the development of transgenic cultivars is the high demand for transgenic crops. This further reduces the genetic diversity of cotton since the creation of trans-genic variations already accounts for about half of the plant breeding effort and only private enterprises are engaged. Even Nevertheless, a lot of traditional breeding research is still being done despite significant private company investment in cotton genetic engineering.

Transgenic techniques may hasten the creation of new varieties, however to enhance the agronomic features of transgenic varieties, both transgenic and traditional techniques are required. For instance, back-crossing is required to introduce the resistance trait into top commercial varieties since the altered Coker variety is not a commercial variety. All of the earliest transgenic cotton varieties—Bollgard, Roundup Ready, or Bollgard/Roundup Ready released in 1996, 1997, and 1997, respectively, were created by conventional back-crossing, as were almost all later types. In order to combine Bt protein expression with acceptable agronomic traits, traditional breeding will still be important[6].

Material is screened following back- or forward-crossing in transgenic breeding. The most popular selection technique for transferring a few chosen features into superior varieties is back-crossing. Forward selection further enhances the features in top cultivars. With the exception of the inherited superior characteristic, the backcrossed cultivar should be identical to the recurrent parental cultivar. Theoretically, after three generations and five back-crossing generations, it is conceivable to recover, on average, more than 93% of the genes of the recurrent parent line. The creation of stacked or pyramided cotton varieties is the best illustration of the relationship between genetic engineering and conventional breeding the expression of two Bt Cry genes with the same insect resistance function, and "pyramided" refers to when two genes with different functions are inserted, such as a glyphosate-tolerant gene and an insect resistance gene.

Bollgard Cottons

The transformation event 531 of cotton, which was carried by by Agrobacterium, created the present commercial types of BollgardXR. Gossypium hirsutum L. cv Coker C312 has the PV-GHBKO4 vector plasmid. The majority of cotton genetic transformation is limited to Coker 312 or closely similar variants since it is difficult to regenerate cotton from undifferentiated callus tissue. The resistance trait must then be passed on by back-crossing to higher-yielding and better-adapted elite varieties as the Coker line is not nurtured. Two plant gene-expression cassettes are included in the plasmid vector PV-GHBKO4. One cassette contains the Cry1Ac Bt insecticidal protein, while the other cassette contains the selectable marker that is controlled by the nopaline synthase gene and the 35S promoter of the cauliflower mosaic virus. This plasmid vector also includes bacterial antibiotic-resistant genes to combat A. tumefaciens' potential to cause sickness. Kanamycin and neomycin resistance is conferred by the nptII gene, while streptomycin and spectinomycin resistance is conferred by the aad gene. The two antibiotic-resistant genes lack regulatory plant sequences and are connected to the bacterial promoter. As a result, they aren't useful, and the protein isn't produced in cotton plants that have undergone transformation[7].

Originally, the native Bt coding gene sequence used to alter cotton produced lower levels of protein production than anticipated. The poor expression of the crystal protein gene may be explained by the fact that the mRNA species for this gene were too short to generate toxin proteins, according to a Northern blot study. Crystal protein genes' coding area seems to prevent effective expression in plants, according to a chimeric transgene in plants. Whereas conventional plant genes have a high G+C content, cry protein genes are rich in A+T. In order to replace the bacterial codons with plant-preferable codons, a resynthesized gene removes possible polyadenylation signal sequences and ATTTA sequences in A-T-rich areas. Expression was 1,000-fold boosted by these gene changes. Also, by altering the Cry1Ac1 gene, Bollgard was able to produce the Bt protein Cry1Ac at its optimum level. The full-length Bt protein produced in Bollgard cotton is a hybrid molecule made up of amino acids 467–1178 of the Cry1Ac protein and amino acids 1-466 of the Cry1Ab protein [from B. thuringiensis subspecies kurstaki strain HD-1]. As a result, there is a little difference between native Cry1Ac and the Cry1Ac protein produced in Bollgard. The soybean alpha subunit of the beta-conglycin gene's nontranslated region, which supplies the mRNA polyadenylation signals known as the 7S terminator sequence, and the CaMV promoter 35S with a duplicated enhancer region regulate this Cry1Ac1 modified gene.

Cottons Tolerant of Herbicides

While herbicide-tolerant cottons are not directly related to the management of arthropod insects in cotton, they do provide producers the chance to concurrently address two of the most important issues with cotton production insects and weed competition with little danger of yield loss. Herbicide-tolerant cottons have improved pest control in cotton cultivation as well as contributed significantly to soil conservation techniques including less tillage that assist both soil and water conservation[8]. Currently, there are four types of cotton that can withstand the use of herbicides: LibertyLinkXR versions that can withstand glu- fosinate ammonium; Roundup ReadyXR and Roundup Ready FlexXR varieties that can withstand the herbicide glyphosate. Additional varieties, including 2,4-D-tolerant ones intended to reduce the impacts of drift and provide a different method for controlling dicotyledoneous weeds, are now being developed.

Cottons that are Roundup ReadyXR are resistant to glyphosate [N-. Because of Roundup ReadyXR's shortcomings, a novel event trans-formation was created that increased glyphosate tolerance via reproductive development. Roundup Ready FlexXR cotton, also known as Roundup ReadyXR Flex, is the name of this new phenomenon. Roundup ReadyXR Flex cultivars permit the topical administration of glyphosate throughout the whole growing season, up to just before harvest. The current Roundup ReadyXR cotton types were created by transforming the Coker 312 variety via the use of A. tumefaciens to produce cotton lines 1445 and 2698 that were tolerant to glyphosate and had the EPSPS gene. The 5-enolpyruvylshikimate-3-phosphate synthase enzyme from A. tumefaciens strain CP4 is encoded by the EPSPS gene[9].

Planting Roundup cotton resulted in less herbicide treatments than traditional weed management methods, according to studies of application techniques in field testing, and with a comparable net profit. Moreover, the RRF permits several intelligent glyphosate treatments with efficient weed control beyond the four-leaf stage. Over 800,000 hectares of Roundup Flex cotton were estimated to have been planted in the first year it was commercially available, mostly in the United States, with smaller amounts planted in Australia and China. The glu- fosinate detoxification process identified in the fungus Streptomyces hygroscopicus served as the basis for the transgene's development. The phosphinothricin acetyl transferase enzyme, which transforms the herbicidal chemical into a harmless acetylated form, is encoded by the bar gene, which mediates this route. The PAT protein, which is encoded by the BAR gene and confers tolerance to the active component L-phosphinothricin in glufosinate ammonium, is expressed by the LLCotton25 event. L-phosphinothricin is converted into a non-toxic metabolite by the PAT enzyme in plants that have undergone transformation. The bar/pat gene system has been utilized to develop glufosinate tolerance in various crops, including cot- ton, ever since it was discovered.

A broad-spectrum postemergence contact herbicide and plant desiccant, glufosinate ammonium. Plants transform glufosinate into the phytotoxin phosphinothricin. The herbicide works by preventing glutamine synthase from doing its vital job of assimilating ammonia. We may now utilize glufosinate ammonium as an alternate herbicide for cotton weed management. The 2,4-D detoxifying gene is expressed in cotton lines that have been genetically edited by Australia's Commonwealth Scientific and Industrial Research Organization and have a high chance of being commercialized. A. tumefaciens transformation was used to create the 2,4-D-tolerant cotton line. This transformation included the plasmid pJP4 from Ralstonia eutrophus, modified to carry the genes for neomycin phosphotransferase II and 2,4-D monoxygenase. It has been discovered that the tfdA gene encodes a 2,4-D dioxygenase, which uses two intricate 2,4-DCP malonyl and sulfate glucoside routes to break down 2,4-D into the inert chemicals glyoxylate and 2,4-dichlorophenol. The cotton plants that were obtained were resistant to broadleaf weeds in wheat, maize, sorghum, and pastures at three times the recommended field concentrations. In Australia, cotton cultivars with tfdA gene-based 2,4-D resistance have been created and field-tested. The 2,4-D herbicide selectively kills grasses and, when used close to cotton, causes phytotoxicity due to severe vapor drift. Hence, 2,4-D-tolerant cotton provides another way to directly administer herbicides to reduce dicotyledonous weeds while also reducing toxicity from drift.

Possible Bt Cotton Nontarget Impacts

No other agricultural technology has undergone as extensive risk assessment studies before deployment as Bt crops, with hundreds of publications and dozens of book exploring the possibility of nontarget consequences by Bt cotton. Yet the preventive approach is entirely reasonable. Similar to the term "potential" says that we are examining something that has a chance of occurring, making it a perceived risk with unknown consequences. This implies that, as has been the norm since the development of Bt cotton began, we must thoroughly analyze the risk on a case-by-case basis. In a classic risk assessment, a putative agent's risk is calculated by multiplying its hazard by how much it is exposed to the target organism. There is a significant chance that Bt will come into contact with a variety of interesting species due to the broad planting and expression of Bt proteins across the majority of the plant. Toxicities of the Bt proteins to diverse organisms must also be taken into account on a case-by-case basis since the degree to which the organ- isms in question are actually exposed to the proteins will vary substantially with the ecology of the species.

Weediness, gene flow/out-crossing, and influence on nontarget species are the three main areas of the possible impact of Bt cotton on the environment. The bulk of research on the unintended consequences of Bt cotton and other genetically modified plants have focused on the possible detrimental impacts on natural enemy populations, which is significant for an IPM strategy. Tritrophic interactions between Bt cotton, herbivores, and natural enemies have been studied in detail. The majority of these studies compared conventional cotton with Bt cotton under an insecticide regime, with the researchers believing that this comparison is more accurate since it replicates how insect populations are exposed to Bt technology in the field. All investigations conducted under these circumstances have shown that the effects of the insecticides outweigh the effects of the Bt cotton.

For 21 foliage-dwelling and 65 ground-dwelling arthropods, for instance, species abundance and dynamics throughout three seasons were assessed. These arthropods are significant for cotton pest management. The findings revealed no variations in the communities of ground-dwelling arthropods across the cotton genotypes, but there was a shift in the abundance of one predator that lives in the foliage: the convergent ladybird Hippodamia convergens Guerin-Meneville. Convergent ladybird populations were noticeably higher in non-Bt cotton. The mechanism causing the population shift was examined, and the findings showed that the number of lady birds based on Bt cotton has not decreased. Figure 1, shows showing the probable effect of host/prey quality and possibly direct protein exposure to the third trophic level. A toxicity test on adult ladybirds Harmonia axyridis and H. convergens obtained from the field revealed that the pesticide -cyhalothrin, used to combat bollworms in non-Bt cotton, was the source of the shift after other potential effects were ruled out. H. axyridis was completely destroyed by -cyhalothrin at the lowest suggested dosage, however H. convergens did not die even at the maximum indicated dose. These findings imply that competition alleviation was responsible for the shift. Early season use of the pesticide lowered the better rival, H. axyridis, enabling immature H. convergens individuals to thrive while the competition was repressed in untreated Bt cotton fields. While seldom the other way around, insecticide usage in non-Bt cotton is sometimes claimed to explain higher populations in Bt cotton.

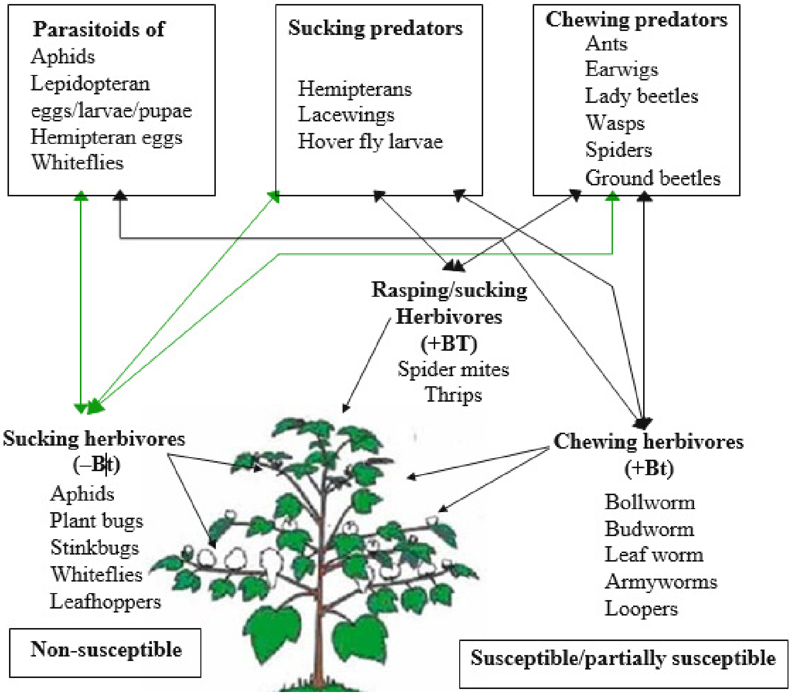

Figure 1:Illustrating the possible influence of host/prey quality and potential direct protein exposure to the third trophic level.

The impacts of Bt cotton in the field cannot be distinguished from population-level, prey-mediated, or direct Bt protein effects. Considering all of these potential mechanisms of action, the effects on certain predator taxa in connection to Bt cotton have ranged from an increase to a decline. Other than the disruptive impact of pesticides, a number of confounding factors, such as tiny plots, the number of seasons observed, the number of samples obtained throughout the crop season, and certain agronomic techniques, may contribute to the lack of consistency. As many research can only identify differences in abundant species, the statistical power of many investigations is also under dispute. It is significantly harder to notice a modest alteration or changes in uncommon taxa. Although though transgenic cotton has a far less ecological impact than any insecticide-treated cotton, it is still crucial to understand if and how Bt cotton affects the neighborhood, even if the impact is minimal. Thirteen publications on the impact of Bt cotton on insect communities have been published since Torres. Just four of them do not take pesticides into account. Cui and co examined how Bt cotton affected the richness and stability of invertebrate communities in Chinese cotton. They came to the conclusion that Bt cotton is, if anything, more stable. Invertebrate communities in Australian cotton were studied at four locations over three seasons by Whitehouse et al. With conventional and Bt cotton that hadn't been sprayed, they discovered a 4.5% alteration in the species makeup. The significant decrease in Helicoverpa that was seen in Bt crops, and it may essentially represent how the invertebrate population reacted to this loss. Four species groups exhibited a slight but constant decline in abundance in Bt crops when the abundance of important species was compared across all locations. None of these animals were directly impacted by the Bt Cry proteins utilized in these tests, including the two flies and the two hemipteran species. As damsel bugs are generalist cotton predators, a decrease in Helicoverpa, one of their prey species, may have had an impact on their population. As it is uncertain what function frit flies serve in cotton, the cause of the decline in their population and its effects are also unknown. Working with U.S. cotton, Naranjo also saw a modest decline in the number of Nabis alternatus Parshley and Hippodamia convergens ladybugs in Bt cotton throughout the growing seasons from 1999 to 2003. In a further research, Naranjo found that despite these modifications, the ecological roles played by the communities of conventional and Bt arthropods were identical.

The transgenic crop was just a minor part of the variation in the arthropod populations in the conventional and vip plots, according to Whitehouse et alanalysis .'s of unsprayed plots of vip and conventional cotton. As a result of indirect plant-mediated variables, density responses to prey availability, and the lack of insect damage, Dively also observed a very little difference between the VIP and conventional communities.Certain groups have received a lot of attention from laboratory research on the negative impact of Bt proteins or Bt-reared prey on natural enemies, while others have received none. In three laboratory investigations on cotton, only four arthropod predators were shown to be negatively impacted by Bt proteins or Bt-reared prey. The predators, including the predatory heteropterans Geocoris punctipes and Orius tristicolor White, the ladybug Propylea japonica, and prey-fed Bt cotton, were adversely impacted. Subsequent research found that the impact on C. carnea was caused by poor prey quality rather than the toxicity of the Bt protein.

When kept in the lab and fed beet armyworm larvae raised on Bt cotton, G. punctipes and O. tristicolor from the field showed decreased survival rates. In these studies, the authors identified issues with the caging technique, particularly with the size and amount of moisture provided to the predators. Predator survival rates may vary depending on these factors. In a protracted field investigation, Torres and Ruberson assessed the growth and procreation of G. punctipes during two Bt cotton growing seasons when fed juvenile S. exigua larvae. Contrary to Ponsard et alresults, .'s neither the presence of Bt or non-Bt cotton plants nor the acquisition of the protein by prey had an impact on the predator's life history. No discernible detrimental effects were seen in Orius species when fed either pollen obtained from Bt plants or prey that had been fed on Bt plants[10].

When predators were raised on second-instar Spodoptera litura from Bt cotton as contrasted to non-Bt cotton, weight increase and survival of the ladybird P. japonica were decreased. On the other side, the authors of this same research presented data from comparisons between several dual gene-expressing organisms. Even though the S. litura prey raised on the dual-gene plants had 26% more protein than those raised on the single-gene plants, P. japonica reported higher weight increase and larval survival when fed prey from this Bt cotton compared to ladybird larvae given prey from the single-gene plant. Thus, prey with higher levels of Bt protein to the third trophic level provided superior growth and survival for predator larvae. This finding implies that variables other than the proteins themselves were influencing survival and weight growth, and contaminated prey were influencing the results of these studies during the brief assessment periods. Moreover, this same predator, P. japonica, showed comparable growth, survival, and fecundity rates as predators bred on prey from non-Bt plants when fed either the cotton aphid Aphis gossypii Glover grown on Bt cotton types or the plant-hopper Nilaparvata lugens Sta l.

It is often noted that Bt crops have lower densities of lepidopteran parasitoids than conventional crops. The host lepidopteran larvae susceptible to Bt proteins die before the parasite could finish development, and poor host quality slows parasitic growth, as possible explanations for this discrepancy. Pests that are partly sensitive to Bt and are fed Bt plants or a diet that contains Bt proteins often enable parasitoids to successfully complete development even if they experience sublethal effects such delayed larval development and decreased pupal and adult weight. Similar reaction has also been seen for parasitoids that are raised on hosts that have been exposed to Bt formulations, where hosts often pass away before the parasitoid has fully developed. Instead of being a direct result of the Bt protein, these negative impacts seem to be the result of decreased host compatibility. There are no harmful sublethal consequences when parasitoids grow in host species that are resistant to Bt but are still sensitive to it. Adult parasitoid parasites may consume protein directly without it having any negative effects on their survival. Thus, it has not been discovered that Bt proteins generated by transgenic plants directly harm parasitoid larvae. Sublethal effects seem to be the result of impaired host quality. Due to a complete failure of parasitism, parasites that are particular to hosts targeted by Bt proteins, such the bollworm complex, are at danger for population decline or non-lethal consequences brought on by subpar hosts.

The outcomes for hosts treated with pesticides or raised on standard resistant varieties, which kill the host during parasite development or degrade the host quality, are comparable to our findings. There is minimal proof that Bt proteins are hazardous to species that are not their targets. Nontarget herbivores may acquire the Bt Cry proteins generated in Bt cotton plants, but nonsusceptible herbivores lack the particular binding sites and the protease to activate the protoxin. The Bt protein may also pass through the digestive systems of at least some nontarget species, where it is then secreted in the form of feces or honeydew. Herbivores that inhabit cotton plants engage in a variety of feeding habits, which have a direct impact on how much protein they consume from the plants. Moreover, Bt protein accumulation in herbivores may or may not occur, affecting whether or not Cry protein is transferred to higher trophic levels. While indirect consequences from ill or subpar food would be predicted, predators eating on contaminated prey items are unaffected. Since most predators in cotton fields engage in polyphagous feeding strategies, the effect of poor prey can be mitigated by consumption of prey items not targeted by Bt proteins in the diet, as demonstrated by field surveys. As a result, there is no net adverse effect on predator population dynamics.

Resistance and Management of Resistance

An environment that is conducive to the selection of Bt resistance is created by the season-long and systemic production of Bt proteins in plants, as well as the extensive geographic adoption of Bt cotton. Lepidopteran pest species of cotton, such P. gossypiella and A. argillacea, are also common across several cotton-producing areas and are almost monophagous on cotton. If Bt cotton was only grown, these pests would be under strong selection pressure to evolve resistance. Nevertheless, since there are alternative non-Bt hosts that these pests may reproduce on either during the Bt cotton season or in between cotton seasons, there should be less pressure on the polyphagous pests like Helicoverpa punctigera, Heli- virescens, and H. zea to develop resistance.

Nevertheless, if the area planted with Bt cotton was much larger than that of alternative food plants and/or if another Bt-transgenic host crop was planted in the same region, favorable circumstances for resistance would still exist. In addition, H. armigera is infamous for acquiring resistance to chemical pesticides, while having catholic feeding preferences. Thus, methods have been developed to lessen selection for resistance to Bt proteins in two scenarios: when solely Bt cotton is planted and when it coexists with other crops.

Bt-transgenic plants, like maize or corn. Both of these possibilities are possible, for instance, in the Brazilian Midwest, where Bt cotton is grown in continuous farms with 1,000 ha each and Bt corn/maize is grown nearby. It is quite difficult to control the system to postpone resistance in such a setting. Depending on the architecture of the plants, the expression of the Bt protein varies. For instance, there is practically little Bt protein expression in pollen and very less in petals and bracts. Thus, sublethal dosages may increase the chances of survival for members of the population who sometimes consume these portions. Environmental elements and agricultural practices including temperature, rainfall, soil quality and salinity, variety, and the usage of growth hormones may also have an impact on how proteins are expressed in plants. Moreover, not all of the Bt cotton plants in a field will express the Bt proteins. Just a tiny portion will process zero. These plants provide opportunities for larvae that are receptive.

The industry is taking a cautious approach to managing resistance as a result of the lessons gained from its experience with chemical pesticides. Despite the enormous success of Bt cotton and other crops bearing Bt genes, experts and firms that created the Bt technology are always on the lookout for resistant individuals in field-targeted insect populations. However, in order to maintain the crop's effectiveness, the technology's owners and regulatory bodies are requiring farmers who plant their altered kinds to adhere to a tight code of practice[11].

As Bt protein formulations have recognized environmental benefits over conventional pesticides for pest control, they are often used in agricultural, forestry, and urban settings. As a consequence, a few species of lepidopteran larvae resistant to commercial formulations of B. thuringiensis have been found.

In response, methods for postponing the development of resistance in Bt crops have been created. Moreover, cross-resistance of Cry proteins in Plutella xylostella has been related to resistance to commercial Bt formulations. This finding and others raised questions about how to control insect resistance for Bt crops. The Spodoptera exigua from Arizona used in the research demonstrated that various field populations had varying degrees of sensitivity to BollgardXR. Using three populations of S. exigua, further laboratory selection over three generations revealed an increase in resistance to BollgardXR of 32%, 298%, and 716%, indicating a species with a high capacity to acquire resistance.

The issue is significantly more challenging when the bug H. armigera is involved. The ability of H. armigera to tolerate Cry1Ac has steadily increased in the Chinese provinces of Hebei and Shandong. If adequate resistance management is not implemented, models based on data from this area predict substantial levels of resistance to this protein within 11–15 years. Moreover, Gunning et al. reported that field populations with a resistance factor of 150 and 275 for LC50 and LC99, respectively, may be chosen from those with considerable variation in Cry1Ac susceptibility. That is, 70% of the larvae that fed on Bt cotton were able to survive. The H. armigera-selected strain seems to have a distinct form of resistance from those previously described based on changes to the receptor-binding site or adjustments to the proteases that cleave the protoxin: enhanced esterase sequestration of the protoxin in the gut of the larvae. In Australia, Cry1Ac Bt cotton has been grown for seven seasons, but no H. armigera field failures have been reported, and the monitoring program shows that the frequency of genes that confer resistance to the Cry1Ac protein is quite low.

In Australia, BollgardXR II, which also includes the Cry2Ab protein, has taken the place of IngardXR, which solely contains the Cry1Ac protein. The initial frequency of the allele for Cry2Ab resistance, however, was extremely high in wild field populations, indicating that the likelihood of gaining resistance to this gene is greater than anticipated. Despite this, there is no proof from comprehensive monitoring systems that this frequency is rising in field populations.

The homozygous resistant population of H. armigera to Cry2Ab was selected in the lab, demonstrating that the resistance was caused by a single autosomal gene and that it was recessive. Homozygous people that are resistant to Cry2Ab do not experience any negative effects when eating Cry2Ab cotton leaves, but they continue to be susceptible to Cry1Ac. They also do not exhibit cross resistance with the commercial Bt product DipelXR, which contains both Cry1 and Cry2 proteins. These and other findings support the idea that Bt cottons that produce two proteins are essential for transgenic crops to control resistance. IRM will be more challenging if H. armigera ups its esterase response and neutralizes Cry1Ac proteins, since this would put important selection pressure on the second protein, Cry2Ab.

We draw attention to this aspect because the dual-protein strategy's premise is that by having one Bt protein active at one binding site and another active at a different binding site, the combination of the two modes of activity should postpone resistance relative to a single protein. Consequently, for the dual protein method in IRM to be effective, the two proteins' distinct mechanisms of action are essential. When one of the proteins is neutralized by an esterase reaction, the dual-binding site approach is broken, and the only protein in the dual variety that can give protection, thus turning the construct into a single protein. This calls for extremely careful monitoring of H. armigera's susceptibility to Cry2Ab. Resistance-monitoring systems targeting significant pests have been created globally in Bt cotton producing areas concurrently with the establishment of Bt cotton. Hence, numerous variables that might promote selection for resistance have been looked at and action has been taken to prevent future development of pest resistance to Bt cottonminimize their impact. The gene deployment strategy is a set of eight techniques with this potential, but few of them have been used owing to a lack of knowledge in the field and technical viability. A high dosage expression of Cry proteins in plants much higher than LC50 toxic to the target pests, refuge areas planted with non-Bt cotton and managed in accordance with the recommendations, and dual proteins expressed with stacked genes are required, according to results from modeling the gene frequency of resistance in P. gossypiella, H. virescens, and H. armigera [12].

In a bioassay in which they are given pure Cry protein generated by the plant, major target pests are collected in large numbers from regions where the Bt crop has been widely used to evaluate their survival. Before to the planting of Bt cotton, a baseline of the pest's sensitivity to Bt must have been established. With the use of bioassays of captured insects, the baseline susceptibility data are utilized to monitor changes in the population's susceptibility to Bt. There has been research on the key target pests of transgenic cotton's baseline susceptibility. Also, when there is a difference of more than 10 times between tested populations and the control, it is believed that resistance to Bt-derived commercial items is developing. Because to the variation across the Bt subgroups and insect tolerance, differences less than ten times are not considered to be credible.One issue with resistance monitoring is that by the time it is discovered, it is already too late. Stodola and Andow created the F2 screening test to address this issue. Here, field-collected eggs are developed into adult moths that pair off for mating. After being grown to maturity, the pair's offspring mate with each other and their siblings. The resistance of the progeny of these unions is then evaluated. One in 16 of the F2 generation would be resistant if a recessive resistance gene was present in one of the field-collected eggs.

Biotech firms strongly advise and support resistance-monitoring programs for H. virescens, H. zea, H. armigera, and P. gossypiella as well as Cry1Ac, Cry2Ab, and Cry1F. Also, all sectors engaged in the cotton industry urge producers to disclose control failures so that the reasons may be looked into. Since a swift corrective action plan may be created if resistance is found, the monitoring program is crucial to IRM. Moreover, due to the difficulty in monitoring the sizable regions where Bt cotton has been planted, all cotton producing sectors must be included. For instance, Bt cotton is grown on 44% and 66% of the land in India and China, respectively. In each nation, it comes out to be more than three million hectares.

The most effective techniques for managing resistance are structured refuges paired with high-dose approaches, and producers of Bt cotton must use them. If an organized refuge/high-dose approach is to be effective in postponing the development of resistance, many factors must be taken into account. The size of the region, the configuration of the refuge fields, the distance between the crops nearby, the fields, and pest biology. The higher-dose strategy also presupposes that Bt resistance is recessive and is conferred by a single locus with two alleles, resulting in three genotypes , such that when resistant survivors from Bt cotton fields cross with susceptible survivors from non-Bt cotton fields or from other non-Bt crops, the offspring are susceptible. Resistance genes in the field are often partly or entirely recessive, and this has been shown in populations chosen in a lab. The high-dose strategy also anticipates that there will be considerable random mating between resistant and susceptible individuals and that there will be low initial resistance allele frequency.

Only partly resistant heterozygotes or populations with resistant homozygotes will see a rise in resistance allele frequencies over time. By enabling them to mate with susceptible people and produce heterozygotes, field-adopted refuges and other advised techniques assist lower the population of resistant homozygous people. The potency of these heterozygotes will thus have a significant influence on the pace of resistance development. Only in the F2 generation will there be a chance of 1/16 animals being homozygote resistant if heterozygous individuals are created and mate with susceptible individuals raised in the refuge. The high concentration of protein produced in the plants will destroy the remaining 6/16 RS and 9/16 SS. A subpanel of the US Environmental Protection Agency suggests a ratio of 1 RR moth to:500 SS adult moths in an area to preserve such proportions and the viability of the refuge as a delaying tactic for resistance.

Hence, the effectiveness of a refuge depends on the presumption that a large dosage eliminates all het- erozygotes, significantly delaying the emergence of a population that is resistant. If 10% of the population is vulnerable, over 90% of heterozygotes are eliminated, and there are originally 10-3 resistant alleles in the population, Roush predicted that resistant individuals will appear after 40 generations or after over 100 generations in places that adopt a 50% refuge. Nevertheless, the researchers pointed out that when single-protein variations are used, resistance may be acquired in roughly 20 generations in species that demonstrate possibly reduced heterozygote mortality, such the Helicoverpa species. The basic objective of the organized refuge/high-dose approach is to keep the population composed of those who have susceptibility genes.

Biological and environmental factors constantly interact and may change the outcomes, even when predictions made by models are accepted. The cautious approach has been the major driving factor behind IRM since its introduction because of these and other uncertainty. Those that are only partly resistant may survive if the protein dosage is ineffective or the protein's expression is very variable, which will raise the frequency of resistant alleles in the population of the target pest. The numerous IRM technique is crucial for this reason. Compared to a large dosage, the protein's modest dose has certain dangers. Assuming that plants express at least25 times more protein is required than is desirable to kill a target larva that is sensitive. The majority of cotton types that are grown around the globe only express one protein, which is reason for worry. For H. virescens, H. armigera, P. gossypiella, and A. argillacea, Bt plants generate a high dose of this protein; however, the dosage is not high for H. zea and several other lepidopteran cotton pests. Since the proteins produced in Bt cotton plants must reach a particular level of expression, dual protein expression is thought to be a more effective technique than single protein expression in slowing the development of insect resistance. In order to reduce cross resistance, it is most crucial that they be as unrelated as possible, particularly in terms of the method of action.

In several Chinese cotton types, gene-stacking with the Bt Cry and Cowpea Trypsin Inhibitor genes has been used. Dual proteins like the BollgardXR II and WideStrikeXR variants are expected to become more popular in other areas. BollgardXR II's Cry2A protein was chosen because it did not exhibit immunological cross reactivity with the Cry1Ac protein that was previously present in BollgardXR. It has been shown that additional proteins with insecticidal activity may be fused into Bt plants to increase the toxicity of the Cry proteins and to improve IRM. This is demonstrated by the commercial exploration of the Cry and CpTI combination in China. The galactose-binding domain of the innocuous ricin B-chain provided additional binding sites for the protein, increasing the protein's toxicity substantially more than Cry1Ac alone. Moreover, this fusion increased the protein's resistance against insects that are typically resistant to Bt. VipCotXR will also soon be available on the market. Even with the utilization of reduced refuge regions, dual proteins, which impose two modes of action on the target pest, have the potential to greatly delay resistance in pests.

Although the refuge's general instructions for growing Bt cotton are almost the same throughout all locations, there are some differences when it comes to planting multiple transgenic Bt crops and particular advice from committees in charge of approving Bt crop production in each nation. For instance, the Brazilian National Biosafety Committee concluded that, given the available choices, only the 20:80% BollgardXR I refuge approach was practicable in Brazil.

The development of Bt cotton began in the U.S. and Australia, where refuge tactics have been developed. As a result, all other nations who are growing Bt cotton based their suggestions on research and models of American production techniques. A section of the field that was sown with a non-Bt crop makes up the structured refuges. The 05:95% refuge, in short, entails growing non-Bt cotton in a band that is at least 45 meters wide in 5% of the land. Sterile insects, pheromone, or any insecticide for lepidopteran larvae targeted by Bt cotton are not permitted in this non-Bt region. Nevertheless, any pesticide employed must not be effective against the pest that Bt cotton is designed to eradicate. To match phenology, the same cotton kind should ideally be utilized, such as the maturity date, blooming season, etc. Similar agronomic measures, such as fertilization, irrigation, weed control, and termination techniques, should be used to the crops as well. The refuge region must also be near the Bt crop and cannot be more than 800 meters away from it or be divided from it by natural features like huge rivers, dense vegetation, or planted woods etc.

A non-Bt variety must be used in 20% of the land to meet the requirements of the 20:80% refuge. With a few exceptions, almost all procedures and observations advised to 05:95 are applicable to 20:80 refuges. Insecticides may be used to treat the 20% non-Bt cotton region if necessary, but not Bt products or pheromones for Bt cotton target species. The 20% refuge area should be no farther than 800 meters 1,609 meters at the most from Bt farms.

The 05:95% embedded refuge entails planting non-Bt cotton in 5% of the area inside a field of Bt cotton rather than at the boundary of the field or some distance away. Consideration should be given to all advice on cultivars, agronomic methods, and land area for 20:80% refuges and 05:95% non-embedded areas. The in-field embedded refuge has only been used in areas where pink bollworm is the primary pest targeted by Bt cotton, such as Arizona in the United States, since it is only advised for this pest. In order to create an in-field refuge, at least one row of non-Bt cotton must be planted for every six to ten rows of Bt cotton. One row of the planter may be filled with Bt cotton seeds, and the other rows can be filled with non-Bt cotton, to begin the seeding process. The implanted rows are grown using the same agronomic methods, such as pesticide treatments, as non-Bt cotton, with the exception of Bt products.

Because the target pests utilize both plants as hosts, changing refuge deployment is necessary when planting other Bt crops next to Bt cotton. For example, if Bt maize is planted in cotton-growing regions, a refuge of 50% non-Bt maize is advised to postpone the development of bollworm and corn borer resistance, as compared to a refuge of 20% advised for regions not farming Bt cotton. The IPM framework, which also handles volunteer Bt plants growing outside of the growing season, must include the IRM program. This is especially true in tropical areas, where old plants and seedlings may continue to thrive throughout the year as weeds in other agricultural fields and serve as hosts for pests since they are not destroyed by cold temperatures. Hence, crop cultural management is crucial.

Use a nonselective herbicide other than glyphosate when planting herbicide-tolerant varieties before sowing the subsequent crop, establish a planting window when cultivating multiple Bt-crops in the same area, synchronize the seeding period, and make crop residue destruction mandatory to prevent continuing generations on other host crops and residues. These are just a few of the recommendations made regarding the management of the crop to enhance IRM. Generally, compared to other annual crops, mostly grasses, cotton is a long-season crop, maturing after more than five months. Hence, in the connection between other non-Bt and Bt crops acting as sources and cotton acting as a sink host. While using pesticides, it's crucial to keep in mind the limitations mentioned above for refuges in addition to the cultural advice. Last but not least, favor variety producing multiple proteins wherever possible, particularly in light of the fact that many transgenic cotton cultivars have been created in various nations using Cry1Ac, Cry2Ab, Cry1F, Cry1A+CpTI, VIP, Arrowhead PI, and pea lectin.

Brazilian Perspective on 7 Bt Cotton

Brazil's first commercial Bt cotton planting season covered 120,000 hectares, and it is anticipated that a half million hectares would be planted in the 2007/2008 growing season. As there were only two Bt cotton types available in the first season—Acala DP90 B and NuOpal—finding certified seeds posed the most obstacle. The Northeast, Central, Midwest, and Amazonian areas of Brazil are the four major cotton-growing regions. These areas have a variety of target and nontarget Bt cotton pests and a wide range of varying environmental conditions. As a result, each location has its own difficulties and pest control techniques for Bt cotton.

Brazil's Northeast cultivated 353,581 hectares and produced 29% of the country's cotton in 2007. Nonetheless, while being in the Northeast area, the western portion of the Bahia state, which by planting 257,377 hectares is the second-largest producer state in Brazil, is more comparable to the Midwest region in terms of climate, cotton types, and technological utilization. As a result, the actual size of the north-eastern climatic and agricultural system is only 76,891 hectares. The majority of agriculture in the Northeast region is family-run, with tiny landholdings, no big equipment, and substantial external inputs. The unpredictable rainy season is the greatest barrier to extensive cotton growing in this area. In comparison to other Brazilian cotton-growing areas, pest issues in the Northeast region are very minor. The main culprits of output loss are cotton boll weevils, aphids, cotton leafworms, and pink bollworms. The degree of farmer knowledge and the scarcity of funding provide the biggest obstacles to the use of technology in this region. The requirement to incorporate the Bt genes into varieties suitable for the local environmental circumstances and cropping strategy may further delay the introduction of Bt cotton. It seems doubtful that private seed corporations would find the region's modest seed market to be alluring. Thus, because the Embrapa Cotton Research Centre is the primary source of seed production and commercialization for this region, the development and acceptance of transgenic cotton varieties in the Northeast region would likely be dependent on public Brazilian national biotechnology laboratories like these.

In 2007, 66,450 hectares were planted in the Central area, which is made up of the states of Sao Paulo and Parana. Farms of a size of 10 to 15 ha, with some farms having a size of over 500 hectares, are what characterize the cotton production in this area. During the 2007–2008 growing season, farmers are expected to increase the amount of Bt cotton planted since they often employ cutting-edge technology. Limiting elements in this area include Pests and illness. Boll weevils, cotton leafworms, tobacco bud-worms, and pink bollworms are the main pests. The most frequently planted types are vulnerable to the aphid-transmitted blue disease. The adoption of Bt cotton is slowed significantly by the region's ongoing boll weevil infestation.

In Brazil, the Midwest cultivates the most land and produces the highest yields of cotton. Cotton is grown on farms with land sizes ranging from 5 hectares to over 10,000 ha. The majority of farms in Mato Grosso, the top producer, are greater than 1,000 hectares. The area is part of the Cerrado ecosystem, which has dry winters and humid summers. The cotton harvesting season spans the hot, humid summer from May to August, depending on the local altitude. The cotton growing season begins in November and ends in April. All agricultural activities, including their own gin- ning, are conducted by farmers or associations of small farmers using contemporary technology. Inhibiting elements include bugs and illnesses. There may be a need for up to seven fungicide applications, depending on the variety that is planted. Most producers choose the blue disease-prone cultivar because to its high production and high-quality fiber. Aphids are thus regarded as major pests in these regions. Armyworm species, cotton leaf worms, tobacco budworms, and pink bollworms are the most common lepidopteran pests. In certain places, the boll weevil is nonexistent, and farmers use methods intended to reduce its spread. The Meridian area and this are projected to have Brazil's highest Bt cotton adoption rates.

Cotton is mostly grown in the southern states of the Amazonian region, such as Tocantins and Acre, as well as the most southern reaches of Amazonian and Para' states. Apart for the states of Tocantins and Acre, very little Bt cotton is grown in the other regions. Just the first generation of Bt cotton is now accessible, despite Brazil permitting it to be planted 10 years after it was first grown in other significant producing nations. The careful identification of locations thought to be hotspots of native or naturalized cotton species was another characteristic of Bt cotton in Brazil. To prevent out-crossing with local species, transgenic cotton has been banned in some regions. These spaces, nevertheless, are minuscule in comparison to the remaining space that is open.

It is anticipated that Brazil will plant more Bt cotton in the next seasons than ever before, although this might be hampered by the lack of commercially accessible Bt cultivars that can handle the various environmental conditions in the various areas. Another issue that can prevent Brazil from adopting Bt cotton is the boll weevil's mid- to late-season incidence, which necessitates several sprayings. Moreover, Bt cotton will still need pesticides to manage nontarget pests including mites, thrips, stemborers, and a number of hemipterans, including Aleyrodidae, Aphididae, Pentatomidae, Miridae, Cydnidae, and Pyrro-choridae. Furthermore, aphids, whiteflies, and cicadellids must be vigorously controlled in cotton cultivars that are vulnerable to viral infections. Nonetheless, based on the pest report,

There is anticipated to be a significant decrease in the usage of insecticides in Brazil as a result of the plex that exists in each cotton-producing area of the country and the adoption of cotton varieties with the stacked genes Cry1Ac/Cry2Ab or Cry1F/Cry1Ac. This might decrease by at least 50% for the Northeast area, from five to six sprays to three. The primary purposes of the remaining sprays will be to manage aphids and boll weevil. Depending on the choice of resistant cultivars or those vulnerable to viral infections and boll weevil infestations, pesticide usage in the Midwest might decrease from 10-17 treatments to 5-10 applications. By eliminating only two sprays, bt cotton is anticipated to have the least negative effects in the Meridian area. The majority of insecticides in this area are used to manage boll weevil infestations, which are widespread there.

CONCLUSION

The ideal cotton production system envisioned for the future to satisfy consumer and environmental needs combines' productivity with sustainability. Improvements in growing techniques and genetics will be necessary to achieve sustainable and profitable yields, and these advances will differ greatly from place to region. Development of transgenic varieties that combine novel genes conferring desirable traits specifically, genes that not only facilitate cultivation practices like insect control and weed management, as shown in this review, but also to address market and environmental demands is one contemporary method for increasing the productivity of cotton. Environmental effects that have a negative influence on production and that can be seen, quantified, and shown will add value to the finished product for the market. Based on a decrease in the use of chemicals and petroleum in equipment, the adoption of Bt and herbicide transgenic cotton has decreased operating costs and energy input in the system. The greatest fiber quality is needed to get the highest pricing per unit yield while using the least amount of input, rather than high yields, in order to maximize income.

The development of cultivars that are more drought resistant and water efficient is a major focus in biotech labs all over the globe. Expanding into new areas and soils previously thought to be unsuitable or previously only grown with intensive irrigation and fertilization is guaranteed by transgenic cotton that is resistant to drought and soil salinity. In many regions of the globe, agricultural activities will be governed by water availability in the future. Cotton is one of the annual crops whose production in Africa and many other regions of the globe with variable rainfall would benefit greatly from decreased water requirements and better drought tolerance. A 5–10% boost in yield is anticipated when utilizing drought-tolerant cultivars. This is the next frontier that has to be conquered, according to biotech corporations. Similar to how improved physiological nitrogen absorption systems may lessen the need for nitrogen fertilizers.

With the introduction of cultivars expressing different genes from those presently on the market, pest control of insects and weeds using transgenic crops will become more secure. As previously stated, several forms of intervention are needed to maintain. Insect resistance management and pest control will benefit from the vulnerability in insects targeted by the proteins produced in the plants, as well as new stacked genes, new Bt proteins, or proteins from other sources such protease inhibitors. Similar to new cotton varieties, herbicide selection options for managing weed resistance will be provided by cotton types that are tolerant to several herbicides. Changes in farming techniques that were previously impractical on the current scale have been made feasible by the new herbicide-tolerant cultivars. New cotton varieties with novel features created by several biotech firms will provide producers more alternatives that are better suited to their field settings in addition to enhancing cotton cultivation's agronomic elements.

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CHAPTER 5

USING SUSTAINABLE SOIL AND WATER MANAGEMENT TO PRODUCE CROPS

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ABSTRACT:

For intensive crop production, tillage-based soil management often causes soil deterioration and ultimately crop productivity loss. Moreover, intense cropping forces farmers to pay high prices for labor, gasoline, agrochemicals, and other production inputs. Heavy tillage increases soil carbon loss and greenhouse gas emissions, mostly CO2, which have an influence on soil productivity as well as atmospheric quality, which is what causes "climate change." This paper examines conservation agriculture as a workable approach for long-term crop production and agricultural growth. When compared to tillage-based agriculture, conservation agriculture has been found to be primarily associated with the following benefits: improved soil structure and stability; increased drainage and water-holding capacity; decreased risk of rainfall runoff and pollution of surface waters with pesticides of up to 100%; reduced risk of fertilizer pollution of surface waters of up to 70%; and approximately a quarter to a half lower energy consumption and lower CO2 emissions.

KEYWORDS:

Agriculture, Conservation agriculture, Soil erosion, Soil organic matter, Sustainability.

INTRODUCTION

Crop residues are also more often naturally left on the soil's surface to preserve it and to encourage the carbon cycle's conversion of carbon from plant biomass to humus and organic matter. While there is a broad variety of reactions among various species, most organism groups are more abundant in conservation agriculture than in tillage-based systems. The changes in the physical environment influence many distinct groups of creatures. Crop rotation, effective weed control, crop residue management, mulching, the introduction and maintenance of cover crops, adjustments to seeding and transplanting equipment are all necessary for the practice of conservation agriculture. Notwithstanding the advantages associated with conservation agriculture, there is still a lot of doubt, particularly in Europe, concerning the practice's appropriateness for the soil, climate, and cropping systems there. Yet, adopting sustainable agriculture systems that can simultaneously fulfill farmers' economic requirements, consumer concerns, and limit environmental damage will be more essential than ever[1].

Several energy-intensive agricultural techniques were implemented in the second half of the 20th century as part of the contemporary scientific strategy to increase yields. The abundance of inexpensive gasoline fostered these behaviors as well. The mainstays of the prevailing production paradigm were heavy tillage, regular weed control, copious fertilizer, and surface water movement over huge fields through pumping. Particularly in mainstream contemporary agriculture, plow-based soil cultivation has grown so widespread that the word "tillage" is sometimes used as a synonym for "agricultural." Yet, ongoing soil disturbance brought about by agriculture, especially soil inversion, has resulted in soil compaction, deterioration of soil structure, and a decline in the amount of organic matter in the soil. Due to the employment of high energy-consuming equipment, this has led to a variety of environmental effects, including soil deterioration, water and wind erosion, eutrophication, an increase in carbon emissions emitted from the soil, and a general decline in beneficial soil organisms and animals. During the ages, earth built up and offered a growing environment for plants, as shown in figure 1. Plants then protected the soil from erosion. Humans' agricultural endeavors have been upsetting this connection. While rainfall events have grown more irregular and storms have increased in frequency, climate change has also made degradation and variability issues worse. One method to agricultural production that has lately gained popularity is known as "conservation agriculture," which is described by the Food and Agriculture Organization as a system based on little soil disturbance and permanent soil cover paired with diverse rotations with legumes.

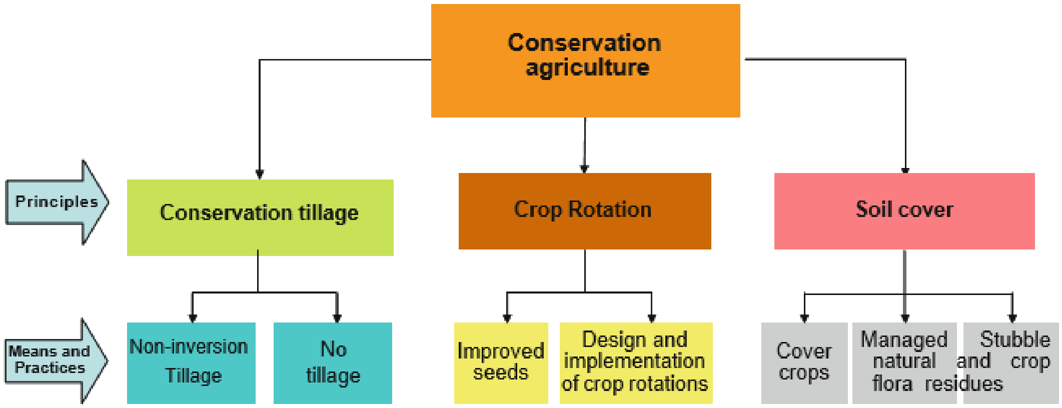

Figure 1: The three conservation agriculture tenets, together with the primary methods and strategies required to implement each tenet.

In fact, the term "conservative agriculture" refers to a collection of agricultural techniques aimed at improving the sustainability of food and agriculture production by preserving and maintaining the existing soil, water, and biological resources in order to minimize the need for external inputs. Its key characteristic indeed, one of its core tenets is the preservation of a permanent or semipermanent soil cover, whether it be a living crop or dead mulch, which shields the soil from sunlight, rain, and wind and provides food for soil organisms[2].

Various terms, such as "organic farming" and "conservation tillage," have been used to emphasize particular differences between CA and "modern" industrial agriculture. While organic farming shares CA characteristics such as biodiversity, biological cycles, and soil biological activity, the minimum use of off-farm inputs does not adhere to CA ideals. The loss of the pest and disease control traditionally provided by conventional tillage, particularly during the transition period, demands the employment of chemical inputs, which are best used sparingly as part of an integrated pest management system to promote a healthy biotic community. This biotic community is crucial because it offers "biological tillage," which takes the place of traditional tillage. So, CA is not the same as organic agriculture even if it more consciously leverages natural processes than contemporary plow-based agriculture. The term "conservation tillage" designates a group of procedures used by contemporary plow-based conventional plowing to improve water infiltration and lessen erosion risk. When there is a cover of crop residues covering at least 30% of the soil surface and certain conservation objectives, such as the preservation of time, fuel, earthworms, soil water, and nutrients, this phrase is often used to describe no-tillage, direct drilling, or minimal tillage practices.

Conservation tillage approaches may be a step toward CA agriculture since they still rely on tillage as the component that gives the soil structure.

According to the FAO definition, CA attempts to enhance and more effectively use existing soil, water, and biological resources via integrated management of those resources in combination with outside inputs. CA, also known as "resource efficient" or "resource effective" agriculture, helps to environmental preservation as well as increased and maintained agricultural production. In actuality, CA is the cornerstone of resource-conservation methods that have been shown to increase yields while decreasing energy, water, and nutrient use, as well as their negative effects on the environment. CA underlines that maintaining the standard of life on our planet depends on the soil, which is a living system. The following is a description of CA's guiding principles and the supported activities[3]:

1. Ensuring adequate live and/or residual biomass to improve soil and water conservation and reduce soil erosion via zero tillage systems. These practices encourage little mechanical disturbance of the soil.
2. Encouraging the growth of a healthy, living soil via crop rotations that include legumes, cover crops, and integrated pest management techniques, which employ fertilizers, insecticides, herbicides, and fungicides more effectively by matching them to crop demands.

DISCUSSION

The ability of the soil to work within the confines of the ecosys- tem to sustain biological productivity, to preserve environmental quality, to promote plant and animal health, and to support crop development and production has been characterized as soil quality. Agriculture-related activities, particularly tillage, which may lead to processes that harm the natural soil ecosystem, can lower soil quality. The original soil structure is destroyed by plow-based tillage, which breaks up the macroaggregates into microaggregates and alters numerous physical properties. This is particularly true when multiple tractor passes are performed to prepare a seed bed or to maintain a clean field. They include pore space and size distribution, water holding capacity, soil water content, and the stability of aggregates > 2 mm, which is usually regarded as a critical indication of soil quality. Increased runoff and inadequate infiltration result from this. All crops need healthy soil to grow. It controls soil aeration, gaseous exchange rates, water transport and storage, soil temperature, root growth and penetration, nutrient cycling, resistance to structural deterioration, and soil erosion. In contrast to soils with poor structure, which may lack macropores and coarse micropores inside the huge clods, excellent structure soils have a high porosity between and between aggre- gates, allowing for better drainage and aeration. [4]Mottles that are orange and eventually grey start to appear as oxygen loss rises. Aeration problems may cause wilting and limit plant water absorption. Moreover, it may decrease how well plants absorb some nutrients, including nitrogen, phosphorus, potassium, and sulfur. Moreover, insufficient aeration slows down the decomposition of organic wastes and might lead to hazardous chemical reactions for plant roots.

Moreover, the presence of soil pores promotes the growth of superfi- cial roots across the rooting zone of the soil. Firm, compacted soils prevent roots from penetrating and growing, severely limiting a plant's capacity to use available water and nutrients, as well as lowering fertilizer effectiveness and raising a plant's vulnerability to root infections. The bulk density at the surface of soils treated in accordance with CA principles has dramatically lowered. This happens because non-tilled soils have an existing mulch layer on top of them, which supplies organic matter and food for the soil fauna, which in turn causes the surface soil to become looser due to burrowing activities. Moreover, the bulk density of non-tilled soils is often lower than that of tilled soils below the subsurface layer. No-tillage significantly minimizes compaction by reducing the number of passes made over the ground; as a result, the FAO has included "limiting in-field traffic" to its list of CA's components. Instead of planting on the flat, this is accomplished by having field traffic follow permanent rails that may be paired with a permanent bed planting method[5].

A significant contributor to the depletion of organic matter is intensive plow-based plowing, which exposes physically protected organic material, speeds up oxidation over time, and reduces soil biological fertility and resilience. It is known that extensive annual cropping without cover crops, with high tillage, reduces soil organic matter. This is crucial in the tropics because excessive soil tillage causes harm after only one or two decades because organic matter decrease is processed more rapidly there due to low carbon levels. Tillage may also change the location of SOM within the soil matrix, either by releasing organic material during aggregate disruption or by occluding materials during the production of the aggregates. The loss of SOM decreases the soil's fertility and ability to deliver nutrients, increasing the need for synthetic fertilizers and the ease with which other main and minor elements are leached by crops. As a consequence, the need for fertilizer input to maintain nutritional status increases[6].

In order to maintain SOM content, CA adoption entails managing cover crops, agricultural residues, and crop rotation with little soil disturbance. Cover crops may have an impact on how soil aggregates and related Carbon and Nitrogen pools, which may have an impact on the quality and productivity of the soil. According to Reicosky et al., conservation agricultural methods improve SOM content when the accumulation rate increases from 0 to 1.15 t C ha-1 per year, with the maximum values under temperate climatic conditions. Several investigations have produced comparable findings indicating that organic C accumulates at a rate of 0.1 to 0.5 t ha-1 per year. Since organic matter plays so many different roles in the soil, this component is crucial. Most biological, physical, and chemical activities that jointly affect soil health are controlled by it. In addition to encouraging infiltration and water retention, it also aids in the development and stabilization of soil structure, lessens the negative effects of wheel traffic and cultivators, and lowers the likelihood of wind and water erosion. Furthermore, organic matter is a significant storehouse of plant nutrients and a source of C.

Surface cover reduces the amount of soil surface dispersion caused by rain or irrigation, which helps to avoid erosion and compaction. By preventing the huge raindrops from hitting and compacting the soil surface, it also lessens crusting. Moreover, it performs the function of a sponge, holding onto rainwater so that the soil may absorb it. Improved aggregate stability from crop residue management reduces soil separation and increases penetration rates.

Water Protection

On a worldwide scale, agriculture is thought to be the greatest consumer of freshwater and one of the main contributors to the deterioration of surface and groundwater resources via erosive processes and chemical run-off. In some situations, soil sediments are the primary water flow pollutants. Simulated rainfall in Germany on a silty soil cultivated with a plow resulted in sediment losses of 6,400 kg ha-1. Quine and Walling calculated that soil erosion results in the loss of 27-86% of the eroding silt from the field. Agrochemicals, infections, organic debris, and heavy metals are all associated with this movement of soil and water and have all been reported to harm the aquatic ecology on several occasions. Freshwater fish, invertebrates, and phytoplankton have all shown reactions to sediments that are both sublethal and lethal. Eutrophication, a global phenomenon when industrialized methods of contemporary farming are used, is a direct result of the leaching of inorganic fertilizers, organic debris, and pesticides into the water[7].

It is generally known that CA has a role in lowering the likelihood that these contaminants will end up in surface and ground water. In the US, it has been shown that CA reduces run-off by 15 to 89% as well as dissolved nutrients, pesticides, and sediments. Sediment loss was 1,152 and 532.82 kg ha-1 per year for chisel-plow and disk vs. not tilled, respectively, in a 15-year research evaluating several CA methods. The pace and percentage of rainfall infiltration, as well as groundwater recharge, river flow rates, and the need for irrigation, are all impacted over time by plow-based agriculture.

Rose and Carter investigated the relationship between tillage and pesticide leaching, and although they came to the same conclusion as Flury that soil cultivation was a significant factor in determining pesticide-leaching losses, the impact of using CA was very varied. A pesticide used to manage grass weeds may have a severe effect on CA during the first year of transition if it is administered just before a big downpour and then soaked straight into the pores. On the other side, having earthworms around may result in increased levels of organic matter that absorbs agrochemicals, which helps stop pesticides from migrating. Only in the United States have studies been done to assess the decreased risk of pesticide contamination in surface waterways as a result of CA adoption. Throughout a three-year period of CA, direct drilling decreased pesticide run-off by 70–100% and isoproturon leaching by 100–%.

Air Defense

The average temperature in Europe has grown by 0.95°C during the last 100 years, and it is likely to increase by 2–6°C over the course of the next century. The major cause of global warming is the significant amount of CO2 emissions that are released into the atmosphere as a result of the combustion of fossil fuels. Agriculture uses energy in the production of arable crops, as well as in the manufacture, shipping, and use of agrochemicals and the decomposition of soil organic matter, all of which contribute to CO2 emissions. Regarding the latter, soil constitutes the largest C-releasing surface, releasing around 1,500 Gt annually, or about three times as much carbon as is stored in biomass and twice as much as is found in the atmosphere. Hence, each change in soil management in agricultural systems causes changes in the total C stock.

Using CA may cut CO2 emissions in a variety of ways. Systems based on plowing use more energy than noninversion soil cultivation techniques and, generally, little mechanical soil disturbance. Due to residue management and cover cropping, which provide increased nutrient recycling and soil microbial activity, CA may minimize the usage of fertilizers. California can significantly cut CO2 emissions by encouraging SOM-building. In compared to conventional plow-based soil management, there is evidence of greater levels of C in the soil where CA was applied: in the UK, it was 8% higher, corresponding to 285 g SOM/m2, and in the Netherlands, it was 0.5% higher over the course of 19 years of research. SOM in the 0-30 cm layer of a loamy soil during six years of continuous row cropping decreased by 19% with mouldboard plowing, 7% with chisel plowing, and 0.4% with no-till in a long-term, plow-based tillage research at Drabble.

When CA principles were used, a number of investigations carried out in Scandinavia similarly discovered increases in SOM in the top surface layers. According to Lindstrom et al., CA has the potential to increase carbon dioxide levels by 0.1 to 1.3 t ha-1 year, whereas intensive cultivation methods significantly lower them. In this sense, the soil may function as a crucial "carbon sequestration sink," regulating the atmospheric CO2 concentration. Methods of CA-based soil management are anticipated to conserve a total of 23.8 kg C ha-1 year[8].

Biodiversity

Due to the use of inorganic fertilizers, pesticides, plant breeding, soil tillage, liming, and irrigation, agricultural production has grown and the value of soil biodiversity in agriculture has not been properly considered. The variety of soil fauna, plants, vertebrates, birds, and mammals within a habitat or a management system of a territory used for agricultural activities is often referred to as soil biodiversity.

In terms of the soil fauna, untouched soil or soil systems maintained employing CA approaches have greater levels of microbial mass diversity and biological activity than those that get extensive cultivation. According to Cochran et al., because bacteria are the principal food supply for protozoa, management techniques that promote bacteria would be anticipated to support protozoa as well. Moreover, mesofauna was more plentiful when CA was used compared to compacted soil. The physical disturbance of the soil brought on by plow-based tillage is one of the factors contributing to the detrimental impacts on microarthropod populations. Abrasion during tillage operations or being stuck in soil clods following tillage inversion may kill some people in the beginning.

In many soils, earthworms make up a significant portion of the macrofauna and have an impact on soil characteristics via their eating, casting, and burrowing activities. They may alter the physical composition of the soil, reducing the likelihood of erosion. Earthworm populations almost always rise with little soil disturbance, particularly when it's accompanied with the return of agricultural residues and extra organic manure supplies. Reducing tillage intensity promotes earthworm populations, as shown by a number of study plot examples. The two extremes of agricultural soil management techniques are moldboard plowing and no-till, and populations often behave similarly in systems with intermediate degrees of soil disturbance and surface residue. Due to the absence of mechanical mixing by tillage instruments, earthworms may be especially crucial in no-till systems for incorporating plant wastes and other materials into the soil. Similarly, gastropods, isopods, and myriapods have all been discovered. Many research on the impact of CA on the quantity of arthropods have been undertaken in North America and Europe, with contradictory results that point to an increase.

The Use of Conservation Agriculture in Orchards and Annual Crops

Multicropping, which simultaneously accounted for herbaceous annual and perennial species as well as woody plants on the same farm, has been the foundation of the majority of agricultural systems across the globe for many years. Agriculture's industrialization decreased the number of farmed species at the farm level, caused farming to become more specialized, and promoted large-scale monoculture. This was originally advantageous since it enhanced yields, which in turn raised the earning potential of agricultural fields. Unexpected issues with hard-to-control illnesses and weeds have therefore emerged; nevertheless, the biggest detrimental effect has been linked to the yearly deep plowing. Particularly, the quick loss of organic matter has decreased soil fertility and, in certain circumstances, even accelerated desertification. Due to this, there has been an increase in interest in the need of maintaining soil fertility and therefore production. Consequently, CA methods offer increasingly popular options designed to maximize agricultural resources by lowering the need of external inputs[9].

Annual Crops

While there was considerable opposition in the past due to management constraints, CA approaches have recently seen an increase in use in annual crops. In the case of wheat, it was weed control and a lack of adequate sowing equipment; in canola, it was a suitable seed bed and effective pest control management; and in maize, it was a lack of acceptable hybrids, tools, and equipment, as well as a planned program of weed and pest management. Vegetable crops were particularly difficult to transplant, with outcomes sometimes being disappointing, especially in compacted and dry soil where plant survival was severely hampered by a lack of soil-to-seed or-transplant adhesion. Moreover, on a no-tilled soil, weed control may be more challenging, yet in certain cropping systems, advancements in weed management have allowed for sufficient control, as in the case of South Asia's biennial rice-wheat cycle[10].

There are a number of factors that need to be taken into account for the proper application of CA to annual crops. Particularly significant factors are soil type, genotype, rainfall, and soil water retention ability. In this context, contentious findings about the adoption of CA have been gathered in a number of studies: According to Chastain et al., mulching with plant remains has no effect on wheat production or growth in humid settings. On the other hand, greater soil water content, lower soil temperatures, and higher water penetration rates into the soil have all been linked to increased wheat production in other research. According to Papendick and Miller, mulching with straw may enhance wheat output by 20% as a result of an extra 20 mm of rainwater in a region with little rainfall.

Conservation Agriculture's Spread

Even in industrialized countries with competent agri-cultural extension agencies and trained farmers, the adoption of CA has not happened quickly. This is most likely because farmers are always drawn to quick fixes and tangible rewards, but the full technical and financial benefits of CA can only be realized in the medium- to long-term, after its principles have been well ingrained into the agricultural system. Worldwide, it is estimated that 95 million hectares have been affected by CA's dissemination. Almost 47% of the technology is used in South America, 39% in the US and Canada, 9% in Australia, and 3.9% in the rest of the globe, which includes Europe, Africa, and Asia. The largest area of CA in the world is in the United States, although it's noteworthy to note that no-tillage farming makes up roughly 22.6% of total agriculture in this nation. Early CA use in Europe was voluntary and motivated by the desire to lower crop-establishment expenses. Soil erosion or deterioration was not cited by farmers as a top concern. Regarding the appropriateness of CA for our climatic conditions and cropping system, there is still a lot of doubt in Europe. One of the primary complaints of the CA method is the great diversity of soil types, the perceived high prices of no-tillage equipment, and the rigorous hands-on management required[11], [12].

In the next ten years, agriculture will need to produce more food with fewer acres of land and bought production inputs, while yet having little negative environmental effect. Considerable data suggests that CA may provide a variety of agro-environmental advantages. It has been shown that the CA system is both theoretically and practically capable of:

1. To lessen herbicide mobility and persistence as well as the usage of fossil fuels, farm costs, CO2 emissions, soil erosion, soil water evaporation, and nitrate levels in the soil profile.
2. To boost the soil's macroporosity, biopores, aggregate size, stability, water-holding capacity, SOM and N content in the top soil layers, P and K stratification, enzymatic activity, earthworm population, and biodiversity.

In all nations and locations where CA systems have seen substantial rates of adoption, the shift from traditional farming practices has reversed the long-term trend of diminishing crop yield and produced a type of cropping that is economically, environmentally, and socially sustainable. Yield improvement may take longer than expected over the first few years of the change. It has been said, nonetheless, that yields in the CA may be on par with or higher than yields from plow-based conventional systems. But, a few details need to be taken into consideration. Weed management is one of the most crucial challenges in many CA systems, thus it's vital to understand the biology and ecology of all the weeds that are present as well as how to mechanically and chemically eradicate them. Herbicide application should be done with more precision.

In California, managing cover crops is very different from how it is done in traditional plow-based systems. In fact, killing green manure cover crops and leaving plant residues on the soil's surface might cause problems, particularly with sowing and the early growth of the following crop, especially in high- or low-residue producing locations. Equipment that is suitable for CA must be continuously developed if it is to be implemented effectively. In fact, there are several factors to take into account when selecting a no-till seeding machine or planter, including the kind of soil, the crop being planted, and the spacing between rows of crops. Negative instances of some pests happen under certain conditions, such as in suitable moist places, necessitating increased use of preventives and more exact therapeutic techniques.

CONCLUSION

In comparison to traditional farming, crop rotation under this method is significantly more crucial. Rotation has a significant favorable effect on weed, insect, and disease control as well as crop nutrient management by enabling more crop variety. Before entering CA, a sufficient degree of expertise is necessary, and all components of the production system must be seen as interrelated in order to prevent failures. The greatest impediment to the adoption of this novel strategy in agricultural operations continues to be the barrier of mental shift. Failure is often due to ignorance of where to start. Farmers should plan the shift far in advance and get the fundamental information before trying to use the technology on their own farms.

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CHAPTER 6

RECURRENT MASS SELECTION FOR COMMON WHEAT IMPROVEMENT

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ABSTRACT:

The quest of sustainable wheat production is very relevant in terms of the economy, society, and environment. Yield levels and their stability are influenced by biotic and abiotic stressors that are constantly changing and fluctuating. New wheat cultivars must constantly undergo genetic improvement in order to provide greater and more consistent yields. Wide adaptability, abiotic stress like drought and salinity, tolerance, polygenic non-specific disease resistance, pyramided disease resistance, etc. are examples of targeted features. Breeders face enormous obstacles as a result of the complex, polygenic genetic mechanisms involved in broadly specified breeding goals like these. Thankfully, a wide range of biotechnological tools that are growing more complex are becoming accessible. New opportunities for the selection of sustainability traits are created by improvements in our understanding of the mechanisms that govern these traits, in combination with adaptable and unambiguous genetic markers and generation acceleration methodologies. However, in order to fully utilize the new technology, breeding methodologies must also be modified.

KEYWORDS:

Breeding, Disease Resistance, Genetic, Male Sterility, Population Improvement.

INTRODUCTION

A self-pollinating organism under recurrent selection is given a potent breeding tool. Continued cross-hybridization increases heterogeneity and creates novel gene linkage connections. Continued inbreeding facilitates accurate progeny testing, fixes beneficial genes in the homozygous condition, and aids in the weeding out of harmful recessive genes. The application of the technique has previously been hampered by the difficulty of randomly intercrossing large numbers of chosen wheat plants, but this issue has been resolved by the use of genetic male sterility in conjunction with the hydroponic culture of tillers that are cut and pollinated at anthesis. Hence, enormous F1 populations may be created by randomly intercrossing hundreds of chosen genotypes[1].

At Stellenbosch University, a recurring wheat mass selection program is being run with the aim of improving and evaluating the approach. A medium-sized breeding program was started with a very diversified base population. As a result of the expertise we obtained, we were able to simplify its implementation. Below, we analyze the present procedure and the advancements achieved. In comparison to traditional wheat breeding methods, recurrent mass selection has proven to be a simple yet highly effective technique. These benefits include decreased operational costs, accelerated selection progress, maximization of crossover and genetic recombination potential, and suitability for broad breeding strategies.

The first step in traditional wheat selection procedures is the creation of designed crosses, which are often single, triple, back, or double crosses. The second phase includes random inbreeding or the production of homozygotes through androgenesis or wide crosses, as well as the development of inbred/homozygous lines through single plant selection in the early segregating generations, bulk propagation in the early generations followed by single plant and line selection in the later generations. The last stage of inbred/homozygous line progeny testing is the same for all four approaches. The success of advanced lines during the previous season is often used to design annual crossings, giving the approaches a cyclical long-term aspect. Regularly occurring new variants may be introduced, often by a prebreeding procedure that restricts the cotransfer of undesirable chromatin and protects prior selection gain.

Limitations on genetic recombination chances and the difficulty of balancing simultaneous severe selection of basic qualities with high heritability and complex features with low heritability are drawbacks to these techniques. In conventional breeding, backcross breeding in which a specific, desired characteristic is introduced into a genetic background that has been scientifically and economically validated is often used as a supplement. The goal might be to improve a genotype that is otherwise superior but lacks a crucial characteristic, to allow prebreeding during the introgression of a novel trait, to establish multilines, or to create near-isogenic lines. The backcross strategy has significant limitations in that it may impose selection ceilings and, if employed carelessly, may significantly reduce the genetic variety of a breeding population[2].

Genes are quickly fixed by self-fertilization after the first cross in traditional breeding of self-pollinating crops, and heterozygosity is cut in half with each succeeding filial generation. This drastically lowers the possibility of genetic recombination. The polygenic recombination potential of a cross cannot, however, be sufficiently investigated in a single cycle of crossing and selection when dealing with polygenic characteristics. A well-known breeding method for improving the genetic makeup of cross-pollinating species is recurrent mass selection. The basic goal is to steadily raise the frequency of desirable genes in a breeding population in order to optimize the chances of extracting better genotypes. It was created largely for the development of quantitatively inherited features. A more thorough investigation of the polygenic recombination potential is possible because to the breeding population's intrinsic high degree of heterozygosity as well as the huge number of cross combinations.

While autogamous crops may benefit from recurrent mass selection in the same ways, the difficulties of intercrossing in each cycle and the little quantities of seed produced have discouraged its usage. Hallauer concluded as a result that recurrent selection processes should preferable be combined with other selection techniques and that its results could not reasonably be anticipated to be directly helpful for the creation of commercial cultivars. Pilot experiments that used recurrent selection on self-pollinating small grain cereals typically had favorable results, although they tended to be short-term, had a limited number of intercrosses, and focused on a particular feature. The efficiency of recurrent selection for genetic improvement of grain protein, kernel weight, grain yield, or disease resistance in several studies with crops including soybean, barley, wheat, and oat was highlighted in outstanding overviews by Wiersma et al., D'az-Lago et al., and Liu et al. For complicated features that are challenging to breed, impressive selection progress was documented traditional methods, such as oat grain yield, oat groat oil content, and oat crown rust partial resistance. In China, minor and major genes for scab resistance, enhanced salt tolerance, drought tolerance, and yield potential were pyramided through recurrent selection based on the Taigu source of male sterility. Nevertheless, the strategy's utility was diminished and the need for a comprehensive approach to its usage in cultivar improvement was highlighted as a consequence of the concentration on single attributes often leading to unfavorable associated changes in unselected qualities.Wallace and Yan emphasized the value of a systemic approach to plant improvement rather than a narrow one. The living plant is a complex biological system that is driven and controlled by several, interconnected systems in the areas of genetics, epigenetics, and environmental factors. According to availability, metabolic pathway needs, plant defense requirements, and stress tolerance mechanisms, photosynthate is distributed for biomass buildup and harvestable product. Selection for a particular feature is thus likely to have an effect on related pathways, impacting plant performance as a whole. Breeding should be less focused on narrowly defined aims and more holistic and multidisciplinary in order to breed and select these genotypes since they seem to be better able to maximize their responses to the physiological demands of a particular environment. A wide variety of biotic and abiotic stressors pertinent to the desired producing location should be administered during selection. This might facilitate the creation of extensively adaptable genotypes when combined with recurrent or convergent breeding techniques.

In order to accommodate recurrent selection in self-pollinating species that are challenging to cross and yield few seeds per cross, Jensen proposed the diallel selective mating system. By fusing recurrent selection principles with traditional breeding techniques, this approach enables the simultaneous genetic input of a wider variety of parents, dismantles linkage clusters, and encourages genetic recombination to release genetic diversity. In addition, Jensen recommended using male sterility to encourage crossover and noted that breeding material should be chosen in certain conditions to enhance the genotypic expression of the desired features. The majority of existing grain breeding programs worldwide, according to McProud, are cyclical in character and may include a component of recurrent selection. Through crosses, these programs generate variability, which is then used to produce and test inbred lines. Thereafter, superior lines are crossed to support a subsequent round of selection.

Even though they have proved effective, these programs are constrained by lengthy selection cycles, and breeders must be on the lookout for genetic bases that are too restricted and a lack of new variability introgressions. In order to continue selection progress, new valuable variation must be introduced in a regulated way that minimizes the entrance of harmful genes and maintains current beneficial gene combinations. Recurrent introgressive population enrichment is a recurrent selection technique that Falk created and tested in barley to overcome the aforementioned issues with traditional breeding techniques. The method is based on a recessive male sterility gene that couples tightly with a recessive, xenia-expressing reduced endosperm gene during a coupling phase. Most of the time, F2 seeds with reduced endosperm grow into male-sterile plants.

The F2 is planted in the field in May of Year One, the F3 is produced in an off-season nursery, and the F4 is tested in an unreplicated field experiment. Crosses and F1 multiplication are carried out in growth rooms during the off-season. Selected lines are slated for further testing in multiple-location trials and supply male parents in the next cycle of crosses. As crosses are done yearly, the female selection cycle is shorter than the male selection cycle, which lasts for two years. Just a small number of crossings are done with the elite population each year, yet this results in the introduction of around 6% new alleles at a time throughout the course of eight generations of crosses with the elite population. Male sterile assisted recurrent selection is used commercially by wheat breeding business World Wide Wheat. The recurrent process is said to enable for more quick and effective cultivar development than traditional pedigree breeding.

Recurrent selection requires careful assembly of the base population to ensure that it has enough genetic diversity. It ought to provide for the genetic advancement of adaptability, production, and processing traits specific to the crop and the intended production area. North

Dakota State University started a recurrent selection effort to increase spring wheat kernel weight in 1967. The ten best lines were interbred in the 45 potential cross combinations after being selected from a screening of roughly 100 cultivars and breeding lines for kernel weight. This created a base population. Manual crossings of representative numbers of chosen plants from the segregating generations produced subsequent cycles[3].

A recurrent selection breeding population segmenting for male sterile and male fertile plants using the dominant male sterility gene. In their arrangement, chosen male flowering plants spontaneously pollinated chosen female flowering plants. Many novel cultivars were published by a limited, national network of Chinese researchers that sought recur- rent selection-based applications. A germplasm source that tests for the presence of the dominant Ms3 male sterility gene was created and registered by Cox et al. A very heterogeneous base population was created over the course of many years by combining several sources of various disease- and insect-resistant, quality, and yield genes as parents. Using fans and manual agitation, cross-pollination of male sterile spikes by fertile plants was improved.

Using the dominant male sterility gene Ms3, Marais et al. created a population for recurrent selection that included 50% male sterile plants. To accomplish extensive random intercrossing of the chosen plants in a greenhouse, they created a basic hydroponic system. By mating a source with the D2-type of cytoplasmic male sterility with 30 different elite cultivars and lines coming from six different Chinese provinces, Liu et al. generated a recurrent selection base population. To easily acquire female plants for use in recurrent selection applications, male sterility genes are available. To apply a hybridization approach, however, a variety of chemical hybridizing agents have been reported, offering an alternative to the use of genetic or cytoplasmic male sterility.

Recurrent selection seeks to retain genetic variety while increasing the frequency of desirable genes in the base population. The amount of variation available, the heritability of the trait, and the initial frequencies of advantageous alleles all play a role in the progression of selection. For complicated, quantitatively inherited features, consistent selection progress may be maintained for many cycles, according to previous research. Variation for unselected characteristics may similarly be preserved within the recurrent population if appropriately controlled to minimize sampling effects. Continual introduction of fresh, beneficial genes into the base population must also be allowed for. Backcrosses to the base population must be used in order to do this without undoing the selection progress previously made.

Long-Term Rust Resistance

Commercial wheat production depends on high-yielding cultivars that are cultivated across huge plots of land and often for several years in a row. Resistance to rusts is often built on a small number of key genes that are under intense selection pressure from the pathogen and may thus be transient. There are "arms races" between wheat breeders and the pathogen as a consequence, which makes it necessary to continuously look for new, efficient rust resistance genes to use and influence pathogen development in certain directions. The great genetic variety seen in natural grass populations, land races, and crop mixes that has traditionally acted as a barrier against the transmission and development of a virus stands in sharp contrast to this circumstance.

It has been suggested that genotypic variety of resistance should be brought back into commercial wheat production today. The utilization of species combinations, cultivar mixtures, and clean and dirty multiple lines are suggested methods for doing this. A cultivar combination is a very straightforward tactic that significantly lessens the harm caused by rust diseases, although it may jeopardize uniformity. Strategies to regulate interfield variety and regional deployment that reduce disease development are often not well-accepted by farmers. To address the agronomic and technical drawbacks of cultivar combinations, several lines were created. The technique is constrained in terms of genetic advancement with selection for nondisease features since it takes time and effort to generate the near-isogenic or phenotypically comparable components and maintain many lines. Several lines, however, are allegedly effective in halting the course of illness[4].

Recurrent selection may be used to create and maintain open-pollinated cultivars in cross-pollinators. Breeding cultivars that would resemble contemporary land races is achievable when the same theory is applied to self-pollinators. According to the kind of the pathogen population, multiple varied resistance genes may be introduced into the recurring base population and chosen to create various gene frequencies. The "land-race" cultivar's base population may undergo continual resistance diversification while also being chosen for uniformity and enhanced agronomic performance. New foundation seed may routinely be produced from the base population to counteract changes in the frequency of the resistance gene caused by natural selection. A "land-race" cultivar might have a considerably greater variety of genotypic combinations of resistance genes that also utilize complementarity, interaction, and additive effects of genes than a multiple line because of the high degree of variability and recombination in the base population.

Pyramiding universally effective resistance genes in a single genotype serves as an alternative to intracultivar genotypic variation. This may also serve as a more resilient barrier to pathogen adaptation, which requires simultaneous mutations at several loci by the pathogen in order to get around the complex, polygenic resistance. The usage of the same genes simultaneously in cultivars with single gene resistance makes both the multiple line and gene pyramid tactics challenging and complicated by the need for in-depth knowledge of the dynamics of the pathogen population. Pyramiding of major resistance genes is challenging because the gene with the strongest effect hides the presence of genes with weaker phenotypic expression. Pyramiding of major resistance genes is therefore best accomplished with the use of markers, which make it possible to identify all genes present. The majority of resistance-pyramid initiatives rely on backcrosses or convergent crosses, which impose a yield limit and make it difficult to add to already-existing gene pyramids. On the other hand, recurrent selection permits continuing pyramiding without sacrificing selection progress for other features[5].

A more practical strategy for developing sustained rust resistance may be to pursue lasting resistance. A number of genes, each having a negligible impact on the overall resistance phenotype, are required for polygenic, nonspecific resistance to exist. If one of the components becomes virulent, the impact on phenotype should be minimal. It is hypothesized that polygenic, nonspecific resistance is inadequate and exerts a little amount of selection pressure on the pathogen. Previous experience has shown that polygenicity is not always required for partial or lasting resistance. Similar to adult plant resistance, which is often only partial and likely to last a long time, it may either be race-specific or race-neutral.

Durable resistance, by definition, keeps working even after being widely used for a considerable amount of time. Since that durability is hard to quantify. It is difficult to breed for and often requires selection of subordinate qualities. It is necessary to employ a pathotype that is virulent on all the parents throughout the seedling stage when breeding for persistent, polygenic resistance, or to exclude cross-progenies containing particular resistance genes beforehand. The selection process must next concentrate on factors including the length of incubation and the quantity and size of uredia. In regions where many rust diseases are significant, efforts to create long-lasting resistance may need to concurrently target all of them, which may be challenging.Mild recurrent mass selection against susceptibility was shown by Parlevliet and van Ommeren to be a potent technique for the development of partial resistance genes. Its incorporation in commercial breeding is constrained by the shadowing impact of race-specific resistance genes on phenotypic selection for long-lasting resistance. Prior genetic investigation of suitable segregating populations may help to overcome this by identifying and tagging quantitative trait loci for lasting resistance, allowing marker-assisted breeding of the trait.

In the end, combining one or more genes for long-lasting resistance with significant race-specific genes would be the most suitable approach for attaining long-term genetic control of rust infections. This may be done by stacking the target genes in a single genotype, mixing genotypes with different resistances in a multiple line, or creating a cultivar that is based on a land race. Such approaches will be technically difficult and, inevitably, heavily reliant on the availability of closely related molecular markers. While being often used in gene pyramiding and the establishment of numerous lines, back- or convergent-crossing strategies impose yield ceilings. On the other side, recurrent selection offers a very efficient alternative method of gene pyramiding and breeding for land-race cultivars that does not restrict the genetic advancement of any other feature. Additionally, rust resistance, wider disease and pest resistance, wide adaptation, yield, and quality are all breeding goals that may best be met using recurrent selection as a breeding strategy. It allows a breeder to concentrate on certain breeding aims at a given moment without sacrificing the chance to later select for other qualities since it is a population improvement technique. Variation for unselected and uncorrelated qualities should stay unchanged, allowing for prolonged and intensive recombination and exploitation, provided the population is big enough and selection bottlenecks are avoided[6].

DISCUSSION

The Recurrent Mass Selection Breeding Plan

The suggested recurrent mass selection method for wheat by Marais et al. A breeding cycle is demonstrated to last four years, with separate treatment given to the male and female components. According to this plan, male candidates are chosen based on their performance in a single, non-repeated row at a single location. This enables a breeding cycle of four years, which is advantageous in the early phases of selection in a base population with a high degree of heterogeneity.

The base population may be enriched for simple, highly heritable characteristics without losing heterogeneity for complicated variables with low heritability thanks to strict initial selection. On the other hand, extending the breeding cycle might boost selection gain for quantitative characteristics with low heritability and enable greater sampling of the target mega environment.

Cross-making and Hydroponic Upkeep of Cut Tillers

Selected plants' male sterile and fertile spikes are clipped off at flowering time and preserved in a hydroponic solution to encourage intercrossing. Only the female tillers are kept alive until the seeds mature. Galvanized iron trays that can hold 230 female spikes each with dimensions of 600 mm x 450 mm x 160 mm. On each side of the main tray, in two narrower trays that are lifted by roughly 600 mm each, are up to 70 male spikes. To change the nutritive solution without removing the female spikes, the main tray is equipped with input and output holes. During the course of six weeks, enough spikes are gathered to fill 1-2 containers.

The Reproduction Cycle

Both the male sterile and male fertile components are selected. But only the male fertile populations are tested in the field. The F1 through F5 stages of the male fertile plants are quickly completed. The superior selections are employed as male parents for hybridization after the F6 rows have been assessed for yield, agrotype, disease resistance, and quality. A group of lines with economic potential are also chosen at this time, in accordance with financing requirements, and given as an annual nursery to nearby wheat breeders. If this hadn't been the case, a typical breeding effort for a self-fertilizing crop would have used sophisticated progeny testing and selection of the F5-derived lines.

Before field planting in May of the following year, the F1 male plants are promoted to the F4 stage; this is made feasible by cultivating two single seed descendent populations in an uncooled greenhouse over the summer. In order to produce F6 seed for unreplicated trials in May of the third year, the F5 is cultivated under irrigation throughout the summer. Hence, single-seed descent and summer planting provide generation acceleration similar to doubled haploid technology. The fact that it is far less expensive and can handle higher quantities than doubled haploids is an advantage. Moreover, seedling leaf and stem rust resistance and quality sedimentation) screening and selection may be done at the beginning of each cycle of single-seed descent. As a consequence, a significant part of lines that are lacking in these areas may be eliminated early on, increasing the process' efficiency. Strict selection need not limit population size since bigger numbers may only participate in the first single-seed descent stages. The ability to reduce the selection cycle to only four years is made feasible by single-seed descent, which has a significant impact on the amount of selection gain that may be realized. The anticipated time between the making of a cross and the release of a cultivar may be shortened proportionately and is comparable to the length of the breeding cycle in doubled haploid breeding[7].

Single-seed descent inbreeding is the optimal method for generation acceleration in a warm environment, such as the Republic of South Africa. We are breeding cultivars with short growth seasons, and by adding extra light in the late autumn, we are able to create three generations year. Nonetheless, it would be desirable to create doubled haploids if resources were not limited or while working with intermediate or winter wheat. In Fig. 1, this possibility is also shown. The large number of lines that are eventually eliminated on the basis of highly heritable, basic features, such as illness susceptibility, is a general issue related with the creation of doubled haploids from heterogeneous genotypes. So, it would make sense to grow the male fertile F1 as a population that is space-planted in the field and to choose individual plants based on their disease and agronomic phenotypes to be utilized for doubled haploid production in the third year. Seedling screening of F2 segregates in a greenhouse is an option once again.

A field-planted doubled haploid nursery may be developed and examined for agronomic, infectious disease, and quality traits in the fourth year. The selection of male parents and genotypes for further testing will then be based on this group. While genotypic variation for wide crossability or androgenetic response may initially make the use of doubled haploids in recurrent selection challenging, the frequency of genes that promote haploid production should increase over time in the recurrent mass selection population as a result of its indirect selection, facilitating doubled haploid production. It is feasible to develop each of the F4 and F6 populations in several locations under various environmental conditions in order to promote selection for wide adaptability. In a four-year cycle, it is even conceivable to include up to four locales. The recurring population should eventually become enriched with beneficial alleles, at which point it could be advantageous. extending the selection cycle to five or six years would allow for more accurate multiple locale testing of inbred/doubled haploid lines, which would enhance the selection of quantitative features.

Effective Population Size

The material processed during a four-year period determines the actual size of the base population since the selection cycle lasts four years. The inclusion of comparably large numbers of genotypes further mitigates the potential genetic impact of highly rigorous selection on the base population. It is advised that very severe selection should be balanced by an increase in the size of the chosen population since the recurrent mass selection method may rapidly create a high number of offspring.

Recurrent Mass Selection to Increase Allele Frequencies

Recurrent selection may be particularly successful in increasing the frequency of single main genes with high heritability, such as those for resistance to wheat stem, leaf, and stripe rust, as well as genes for which highly specific markers are available. The effectiveness of lowering the frequency of a bad gene will be the same. Assuming dominance and an initial allele frequency of 5%, the impact on allele frequency when the F1 alone, the F6 exclusively, or both the F1 and the F6 are chosen. The graph clearly shows that when selection is present in the F1, allele frequency gradually changes over the course of four cycles before abruptly rising when selection is also present in the male parent. The efficiency of F6 selection in increasing gene frequencies is much greater. In comparison to five and ten cycles of F1 selection, one and two cycles of F6 selection are projected to increase gene frequencies to greater levels. The majority of the resistant plants chosen in the F6 are homozygotes, predominantly passing on gametes with the desired allele to the next generation if the male population is inbred for five generations. Much more successful, but more expensive, is combined F1 and F6 selection[8].

It is obvious that severe selection of the male father should only be carried out in situations where gene frequencies are high enough to avoid bottlenecks or when huge populations can be screened to assure the preservation of genetic diversity for other characteristics. After single-seed descent inbreeding begins, phenotypic or marker-assisted selection may be used to increase the frequency of the desired genotypes in the F6 field population[9], [10]. This prevents the loss of variability that can occur when using small male populations.Usage of Markers in Combination with Repeated Mass Selection to Find Genes Resistant to Pyramid RustMarais and Botes computed the proportion of F6 inbred lines that may be predicted to have the target alleles for different numbers of genes and gene frequencies to be used in the recurrent mass selection scheme of Fig. 1. For instance, 2.6% of inbred lines will have all ten of the targeted genes when the target allele frequencies are 0.7 for ten genes. Around 0.4% of the F6 is predicted to contain all 15 of the targeted genes. Around 1% of the inbred plants should have all of the desirable alleles if the frequency of each desired allele at each of the 20 loci is 0.80. Other inbred lines with other combinations of less beneficial target genes will undoubtedly exist. As a result, with proper management, the recurrent population will eventually develop into a reliable supply of varied pyramided genotypes[11], [12].

CONCLUSION

Recurrent mass selection is incredibly effective when handled correctly. Molecular marker-assisted selection for rust resistance was not used in our program until 2005. Previous to it, only the resistance phenotype was used for selection. We train strong phenotypic selection for adult plant leaf, stem, and stripe rust field resistance together with low occurrence of susceptible pustules, and saw a quick shift in the base population's average resistance levels.

It is simple to carry out the recurring mass selection technique on a big scale and on a tight budget. The approach is surprisingly less expensive than traditional wheat breeding methods like pedigree, bulk, and twofold haploid, in our perspective. In a medium-sized pedigree breeding operation, the work needed to produce 60,000–70,000 F1 hybrid seeds is about similar to performing 150–200 planned hand crossings. The number of Formula One cars manufactured was consistently far more than the quantity we could use in a season. With this approach, inbred lines are simply numbered sequentially in the F6 and there are no pedigrees to maintain. As a result of the significant focus on early generation selection, lines with evident flaws are removed early, allowing for the carrying of larger starting populations. The selection response for adaptability, quality, and yield will be reduced since only the male parents are field-tested; however, a large portion of this impact will be countered by the inbreeding phases.

The method's use is quite flexible; for instance, it may be employed as a breeding strategy on its own, using either one base population or a number of base populations. Inbred lines or land race cultivars may be derived from such populations. On the other hand, it might be used as an addition to a traditional pedigree breeding program with the goal of maximizing the utilization and pyramiding of advantageous genes within a select few well-adapted elite lines. Recur- rent mass selection applications may vary depending on how the base population is made up.

The base population may be made up of varied and not necessarily suited germplasm and exhibit considerable genotypic variability. When a new breeding program is being started and the breeder wants to explore with a larger spectrum of variety, this would often be the situation.

Yet, by mixing near-isogenic lines with a variety of varied resistance genes in a genetic background with acceptable processing quality and agrotype, it may be feasible to generate the base population in a manner that makes it uniform in certain qualities and variable for others. Such a population eliminates the need for quality and agrotype screening, allowing the breeder to concentrate entirely on creating lines with complex resistance.

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CHAPTER 7

AN IMPORTANT COMPONENT IN SEMIARID CLIMATES FOR SUSTAINABLE CROP PRODUCTION

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ABSTRACT:

In semi-arid areas of the globe, the idea of "fallow" has been a popular management strategy, allowing farmers to make up for insufficient precipitation. Yet fallow periods result in the deterioration of the soil. In the semiarid steppe of the United States, for instance, winter wheat-fallow with tillage has been utilized for decades; organic matter levels in soils have decreased by about 60%. As a result, farmers in this area are worried about the long-term viability of this rotation. Yet, no-till techniques enhance the flow of water, allowing for the addition of extra crops to the winter wheat-fallow cycle. Because of the shift in cropping patterns, farmers are looking for cropping systems that are not only economically feasible but also enhance soil health, increase resource efficiency, and need less external inputs like pesticides and fertilizers. Continuous cropping with no-till may achieve these four objectives, according to long-term rotation experiments conducted on the steppe. Yet, since water availability is often constrained, rotation design is essential for the effectiveness of continuous cropping.

KEYWORDS:

Agriculture, Crop diversity, Resource, Soil restoration, Weed management.

INTRODUCTION

As compared to traditional systems, designing rotations in a cycle of four with a variety of crops enhances net returns by a factor of four while cutting the cost of weed control by half. The top 5 cm of soil were subjected to continuous cropping for 12 years, which boosted soil organic carbon by 37% and nitrogen by 20% while also enhancing soil porosity and aggregate stability. Because of this, soil production has doubled. Also, the cycle-of-four design gives legumes a crop niche in this semiarid environment, which improves soil function.

Certain crops increase the subsequent crops' water usage efficiency by 20–35%, reducing the effects of low precipitation. Constant no-till cultivation has sparked a cycle of soil regeneration. The main crop farmed in the central steppe region of the United States, which includes parts of eastern Colorado and Wyoming and western Kansas, Nebraska, and South Dakota, is winter wheat. To compensate for the low precipitation, which varies from 350 to 450 mm and mostly occurs from April through August, it is planted in a winter wheat-fallow rotation. During the fallow period, neither crops nor weeds are permitted to grow, so precipitation is stored in the soil. Water added to the soil during fallow periods lowers crop loss and production variability brought on by drought stress[1].

However substantial soil deterioration has resulted from winter wheat-fallow. Over 60% of the original organic content in the soil has been destroyed, and fallow times are when it is most vulnerable to wind erosion. The ineffectiveness of winter wheat-fallow un utilising precipitation for crop development is another factor. Winter wheat only uses about half of the precipitation that it receives over the course of two years; the remainder is lost to evaporation, runoff, or leaching below the crop rooting zone.

No-till farming techniques keep crop waste on the soil's surface and enhance water flow, enabling farmers to increase the number of crops in the winter wheat-fallow cycle. In place of winter wheat and fallow fields, corn, proso millet, sunflower, and dry pea are now cultivated in succession. Producers have been prompted to consider their long-term objectives with regard to agricultural systems by this shift in cropping patterns. While the economics of more varied rotations have proven positive, farmers also desire to restore the soil damage done by winter wheat-fallow. Sustainable crop-ping systems have been on scientists' and farmers' minds lately. While defining sustainability has been challenging, steppe farmers have four main objectives: commercially feasible rotations that restore soil health, increase resource efficiency and decrease reliance on outside sources. In order to optimize nutrient cycling, soil aggregation, precipitation infiltration, water storage, and soil microbiological activity, one objective of soil health is to increase the amount of organic matter. Organic matter levels in the soil have been closely correlated with soil production. In this semi-arid area where water is scarce, farmers would want to increase the water-use efficiency of their crops. Also, they favor cropping practices that rely less on agrochemicals[2].

In the last 20 years, the steppe has seen the establishment of many long-term rotation studies, which have measured patterns in yield, economics, and soil changes over time. These patterns could provide guidance for reaching these four objectives. Yet, we find philosophical debates about sustainability to be fascinating. Hill and MacRae advised revamping farming systems based on ecological principles rather than adjusting current systems in response to a particular problem after studying several approaches to sustainable systems. Brummer urged scientists to put sustainability at the forefront of their work before concentrating on agricultural yield within that framework. This strategy contrasts with the past perspective that prioritized crop yield without taking into account rotation design. As a result, while assessing trends in these rotation studies, we also take rotation design into account. Our analysis may provide guidance for the creation of sustainable systems not only in the American steppe but also in other semiarid parts of the globe.

Changes in Biology Associated with No-Till Cropping Systems

In three locations in Colorado and two sites in South Dakota, long-term rotation experiments on the central American steppe were initiated in the 1980s. The rotations with continuous cropping did not contain a 12- to 14-month fallow phase.

These studies investigated different combinations of crops, from winter wheat-fallow to continuous cropping. Crops from both the cool- and warm-season rotations were used. Winter wheat, spring wheat, and dry pea are examples of cool-season crops that are sown in late March or late September. Corn, proso millet, sunflower, chickpea, and soybean were warm-season crops that were sown in May or June . The investigations were conducted in the grass steppe's Mollisol soils. Each research covered every stage of each rotation. We looked at yield, soil changes, and insect populations after multiple years of these research to determine production options that support sustainability with semiarid cropping systems.

Economic Activity and Land Productivity

When summer crops like maize are added to winter wheat-fallow, land productivity rises. For instance, using certain methods, annualized production per land area might almost quadruple. By summing the yields of all the crops in a rotation for a certain year and dividing by the number of years in the rotation, the annualized yield is derived. The investment of fallow periods in agricultural production is reflected in this value. The production of winter wheat-corn-fallow, winter wheat-corn-proso millet-fallow, or winter wheat-corn-proso millet, was two times larger than winter wheat-fallow in a rotation study near Akron, Colorado. The yearly yield of W-F, for instance, was 970 kg/ha, whereas W-C-M-F produced 1,910 kg/ha—an increase of 97%. A fascinating finding was that continuous cropping, or W-C-M, also produced twice as much as W-F. Similar outcomes were shown in the other steppe trials, when crop rotations doubled the productivity of the area. The economy is also improved through agricultural rotations with more crops and less fallow time. In the central steppe, net returns for varied rotations were 25% greater than for W-F. Crop diversification in rotations decreased monetary risk as well[3].

Resource-Use-Efficiency

Water

No-till techniques increase the effectiveness of precipitation-storage during fallow periods. Tilled systems have PSE of less than 30%, whereas no-till systems have PSE of 40% or more thanks to crop residue preservation on the soil surface. The storage efficiency of PSE in no-till fallow fields also tends to be highest in the winter and lowest in the summer. PSE during the shorter fallow periods is improved by over 50% when warm-season crops like maize are included.No-till and diversified crop rotations enhance the amount of precipitation turned into agricultural production in addition to enhancing PSE during fallow times. 40 to 45 percent of the precipitation that fell throughout the two years of this rotation is converted into grain by winter wheat-fallow. In comparison, continuous cropping converts 75% of precipitation into grain, compared to rotations like W-C-M-60% F's conversion. Constant cropping reduces the inefficiency of fallow times, increasing conversion rate[4].

DISCUSSION

Nitrogen and phosphorus

Continuous cropping raises soil organic N levels over time, as was discovered with SOC. According to Bowman et al. and Sherrold et al., continuous cropping raised SON by 15-20% when compared to W-F. However, even with rotations made up of three crops and one fallow season, both study teams discovered that a 12- to 14-month fallow period negated this improvement in SON. Higher SON soils in the steppe increase the efficiency of crop N consumption. In a long-term crop residue research, Maskina et al. discovered that maize produced 10% more under a high SON treatment compared to a low SON treatment, even with enough N fertilizer.

The 10% yield differential persisted independent of the amounts of N fertilizer utilized, suggesting that the high SON treatment boosted the growth efficiency of the maize crop. Nitrates have been leached from the soil profile as a result of W-F. According to research by West-Fall et al., rotations with shorter fallow periods result in lower nitrate levels in the soil; the amount of nitrate in the top 2 meters of soil was 42% lower in W-C-M-F compared to W-F. Continuous cropping further lowered the amount of nitrate in the soil in the Akron, Colorado research; in contrast, all rotations with fallow periods encouraged nitrate buildup and leaching in the soil profile. Similar findings were reported by Zentner et al., who found that continuous cropping decreased nitrate leaching in soil when compared to rotations with fallow intervals in the semiarid steppe of Canada. They concluded that increased synchronization between N release by mineralization and crop absorption resulted in reduced leaching in continuous cropping.

Weed Control

Cool- and warm-season crops should be rotated because the differing planting and harvest dates provide chances to stop weeds from establishing new plants or producing seeds. This tactic has a positive effect on weed seed germination in soil. Less than 5% of the seeds from annual weeds are still viable after two years, compared to around 20% of their seeds after one year. By preventing new seeds from being introduced to the soil, growers may encourage the natural loss of weed seeds over time by rotating crops with various life cycles[5].

Rotation studies in the steppe, however, reveal an unexpected pattern. When rotations consist of two cool-season crops followed by two warm-season crops, weed density gradually decreases. In contrast, weed density rises when crop rotations, like W-M, alternate one cool-season crop with one warm-season crop. Weed density was six times higher in two-crop rotations than in rotations made up of two cool-season crops followed by two warm-season crops, according to patterns across three rotation studies. As comparison to four-crop rotations, weed density was also greater in three-crop rotations. The necessity for crops to vary within a seasonal interval of four-year rotations is a second tendency shown by these investigations. For instance, the density of winter annual grasses like downy brome increased quickly if two winter wheat harvests were cultivated successively during a cool-season hiatus. According to one research, compared to rotations with a sequence of dry pea and winter wheat, downy brome density was forty times greater in four-year rotations with two years of winter wheat. By the planting of dry pea in late March, downy brome's wintertime emergence may be managed. Crop diversification is also advantageous during the warm-season period[6].

Sustainability and Rotation Design

One of our aims in conducting this study was to take producers' sustainability aspirations into account when considering cycle design. Continuous cropping, such as W-M or W-C-M, is beneficial for resource efficiency and soil restoration. These rotations do, however, have significant drawbacks, particularly in terms of crop productivity, residue generation, and insect control.

Winter wheat yields after proso millet are sometimes less than half of those following fallow periods. In this semiarid environment, it is challenging to convert more than 75% of precipitation into crop growth, which is one reason for poor yields. Average yields with W-M and W-C-M would need 85% of precipitation to be turned into crop growth. The poor crop residue output of winter wheat, which lowers corn yield the following year, is another drawback of W-C-M. Due to worse water interactions and lower residue levels on the soil surface, corn yields are 15% lower in W-C-M than W-C-M-F. Moreover, when weed densities grow with W-M and W-C-M, management costs rise.

Planning rotations in a cycle of four, like W-C-M-F, is beneficial for managing pests and increasing land production. Most crops provide their best grain yields when cultivated every four years, whereas W-F land productivity is twice as high. With the cycle-of-four design, weed density decreases, allowing farmers to spend less on weed control. We propose that four-crop rotations may be the most advantageous for attaining our four sustainability objectives based on these patterns, but only if crop sequencing can be created for continuous cropping. By eliminating the advantages of continuous cropping with SOC, SON, phosphorus absorption, aggregate stability, and soil porosity, the 12- to 14-month fallow interval is harmful for soil restoration. Moreover, fallow periods cause soil to lose nitrates. We doubt if any rotation that includes fallow periods will be able to accomplish soil regeneration and sustainability in this area[7], [8].

In this Semiarid Environment, Can We Substitute Fallow Time with a Crop?

Water supply is a problem with continuous farming and doing away with the 12- to 14-month fallow period. Winter wheat, for instance, may be sown two years in a row. Yet, owing to root infections and insufficient water, the grain yield and residue output of both winter wheat harvests are 25–50% lower than wheat after fallow. The sequence also causes the weed density in winter wheat to increase quickly. Legumes provide a better alternative, particularly for restoring soil. Through their symbiotic production, legumes provide nitrogen, which is particularly useful on the American steppe where grains make up the majority of the crops. Drinkwater and Snapp noticed that in cereal-based rotations, legumes help the soil accumulate SOC and SON; the greater level of SON enhances the absorption of N by succeeding crops and lowers the requirement for fertilizers[9]–[11].

CONCLUSION

The semiarid steppe's agricultural output has changed as a result of no-tillage techniques and residue management, which have increased land productivity and decreased the requirement for fallow periods. Also being restored is the health of the soil. Lal observed that the removal of agricultural leftovers from the farming system triggers a chain reaction that degrades the soil. The U.S. steppe's no-tillage agricultural methods have stopped this cycle and are regenerating soil health. Increased crop yields from no-tillage and four-crop rotations also increase agricultural residue production, which then enhances water relations to boost crop yields even more in later years.

As a result, the system for soil restoration is self-sustaining. By lessening the effects of limited water availability, we may be able to further emphasize this cycle of soil regeneration as we learn more about positive relationships between crops and enhanced soil functioning. The design of rotations will be important, particularly if new crop sequences that work well together to maximize resource efficiency can be found. Producers in the semi-arid steppe of the United States may profit greatly by planning rotations in a cycle of four. We think that researchers and farmers in other arid locations of the globe may be able to reap a similar set of advantages by using no-tillage techniques and crop rotations made up of a variety of diverse crops.

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CHAPTER 8

LOCATION OF THE HOST PLANT AND THE CHEMICAL ECOLOGY OF GERMINATION AS TARGETS FOR SUSTAINABLE CONTROL

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ABSTRACT:

One of the most troublesome pests of agricultural crops across the globe is parasitic plants. The intimate physiological relationship between the established parasite and host plant makes it difficult to effectively manage the parasite using conventional ways, which contributes to the overall lack of effective control approaches. Prior to host attachment, seed germination and host location are crucial early development phases that provide intriguing targets for ecologically sound control of parasitic weeds. The development of innovative management strategies should be aided by knowledge of parasite-host interactions, especially chemical signals that trigger parasite seed germination and influence host location. We examine studies on the primary parasitic weeds that target agricultural crops' seed germination and host distribution, and we address the significance of current results for the creation of sustainable and efficient management measures.

KEYWORDS:

Striga Orobanche, Cuscuta Strigolactones, Volatiles, Plant-plant communication.

INTRODUCTION

The presence of chemical stimulants emitted by plant roots is known to be necessary for seed germination in parasitic plants that connect to host roots, such as Striga and Orobanche species. The recent discovery that these substances encourage the colonization of helpful fungus might have significant ramifications for the management of parasitic plants. The early stages of parasitic plants, such as Cuscuta spp., that adhere above-ground to host shoots, are far less well understood. It was only recently discovered that foraging C. pentagona seedlings need airborne signals to seek and choose among hosts since the seeds of these parasites lack germination stimulants.

Almost 4,500 species of flowering plants are parasitic, relying entirely or partially on other plants for their water and nutrients. In many regions of the globe, a tiny number of these parasitic species infest crops and pose major issues for farmers. There aren't many effective and cost-effective strategies for eliminating parasitic plant species, in part because most herbicides aren't effective against them due of their physiological ties to their hosts. Due of the high amount of long-lasting seeds that parasitic weeds frequently generate, they might be challenging to eliminate. Consider the approximately 200,000 dust-like seeds that one Orobanche sp. plant may generate and which are viable for 8–10 years. Moreover, agricultural plants may suffer significant harm from parasitic plants that attack host roots before emerging from the soil, making it difficult to identify infestations before monetary losses arise[1].

A potentially cost-effective method of managing parasitic plants is to breed for host-plant resistance. Breeding operations, with a few notable exceptions like cow-pea resistance to Striga, have not led to effective control measures and are difficult because plant resistance features are often poorly characterized, genetically complicated, and of low heritability. Some of these challenges may be solved through genetic engineering, but social objections to genetically modified technologies may hinder their widespread use.

A deeper understanding of the intricate ecological and physiological relationships between parasitic plants and their hosts will aid in the quest for better or alternative methods of managing parasite plants in agriculture.

The most harmful parasitic weeds are obligate parasites that rely on the sparse reserves included in seeds to swiftly seek appropriate hosts. Host location is an essential component of their life cycle. So, the host site appears like a good target for control techniques. With a focus on the chemical ecology of seed germination and host location, we cover the most significant plant parasites of agricultural crops in this work and address the possibility of modifying these processes to manage these significant weeds.

The Main Agriculture-Related Parasitic Plants

Over the development of angiosperms, parasitism appeared on its own multiple times, and different species of parasitic plants exhibit quite different lifestyles. Although some species are obligatory parasites that are unable to grow independently, others are facultative parasites that may live without hosts.

It is possible to distinguish between hemiparasitic plants, which have chlorophyll and can produce some of the nutrients they need through photosynthesis, and holoparasitic plants, which have no chlorophyll and are totally reliant on host resources. However, this distinction is not always paper to make. It is possible to distinguish more clearly between parasitic plants that cling to host plant roots below ground and those that cling to host plant shoots above ground. Witchweeds, Striga spp., broomrapes, Orobanche spp., and dodders, Cuscuta spp., which create above-ground attachments on host shoots, are the categories of plant parasites that are most significant commercially[2].

Striga spp., which infest almost two-thirds of the grains and legumes in sub-Saharan Africa and cause yearly agricultural losses estimated at US$7 billion annually, are obligate root hemiparasites that significantly impact the lives of more than 300 million people. Striga species vary, but S. hermonthica and S. asiatica are the most pervasive and devastating, attacking the principal grain crops in Africa. Broadleaf plant parasite Striga gesnerioides poses a severe danger to the cultivation of cowpeas in many regions of Africa. S. asiatica was found to be parasitizing maize in the southern United States in the 1950s, but an aggressive eradication operation has stopped its expansion there.

Orobanche spp. are obligate root holoparasites that mostly affect the Mediterranean, the Middle East, and northern Africa and limit the growth of several crops. O. ramosa and O. aegyptiaca, two of the six Orobanche species that are regarded as major pests, have the broadest host ranges and cause significant crop damage, especially to tomato, potato, eggplant, faba bean, lentil, peanut, chickpea, cucumber, cabbage, and sunflower.

Chemical Cues Used by Parasitic Plants to Find Hosts

Most parasitic plants have a little amount of energy stores in their seeds that allow for limited development. As a result, seedlings are only able to live a short time after germination before adhering to a host. Rapid host discovery is probably a significant evolutionary selection pressure that favors the emergence of effective host-location systems. This is accomplished via the use of chemical signals generated by host plants by both root and shoot parasite plants[3].

DISCUSSION

Germination stimulants for root parasitic plants

Only in the presence of chemical substances secreted by host roots can the seeds of Striga and Orobanche species begin to sprout. These germination stimulants, commonly known as strigolactones, exist in concentrations adequate to stimulate germination only within a few millimeters of host roots because they are fragile and breakdown quickly in the soil. The directed development of the parasite radicle toward the host root may also be facilitated by concentration gradients of strigolactones. The conditioning time under warm, humid circumstances and concurrent production of gibberellins in seed tissue determine the susceptibility of parasite seeds to these germination stimulants.

From the root exudates of both host and non-host plants, numerous germination stimulants have been isolated and identified to date. The first germination stimulant for Striga lutea was found in the non-host cotton's root exudates. Since then, it has been discovered that real hosts like maize and millet's roots emit strigol. Sorgolactone from sorghum, orobanchol and alectrol from red clover, as well as 5-deoxy- strigol from Lotus japonicus, are other strigolactone germination stimulants that have been discovered. In contrast to what was previously believed, strigolactones have recently been shown to be apocarotenoids generated by plants via the carotenoid route. While several processes have been suggested, the specifics of how strigolactones induce germination remain unknown. Striga and Orobanche spp. seeds may germinate when ethylene is applied, indicating that strigolactones may work by promoting ethylene production. Strigolactones have recently been shown to be crucial cues for plant-beneficial arbuscular mycorrhizal fungus, which raises the possibility that parasitic plants have adopted these signals to identify and find host roots[4].

Plant Volatiles from Shoot Parasitic Plants

Cuscuta spp. seeds do not need stimulants from a host plant to germinate, in contrast to root parasitic plants. Seedlings must instead hunt to find nearby possible hosts. We recently demonstrated that C. pentagona seedlings employ volatiles from the host plant to direct host location and selection. Cuscuta spp. seedlings may forage randomly or focus their development on different light signals related to the presence of host plants, according to prior theories. Although there is a chance that light cues contribute to host location, we discovered that C. pentagona seedlings showed directed development in the direction of tomato volatiles that were produced experimentally even in the absence of any other plant-derived signals. Moreover, seedlings "choosed" tomatoes, a favored host, versus nonhost wheat via volatile signals. Certain tomato volatile mix components such as -pinene, -myrcene, and -phellandrene were appealing to C. pentagona seedlings, but -hexenyl acetate, a component of the wheat volatile blend, was repulsive. After our initial findings, we were able to confirm that C. pentagona seedlings react to volatiles from a variety of host plants, including Impatiens, wheat, and alfalfa. These results provide a reasonable method to account for earlier accounts of selective foraging by Cuscuta spp. [5]While they are unrelated, the very similar shoot-parasitic plants of the genus Cassytha and maybe climbing it’s possible that vines in general employ volatile signals to find their hosts, but this possibility hasn't been rigorously tested.

Control Techniques

There has been a lot of study done on the potential use of germination stimulants to manage Striga and Orobanche. Among the control measures are "suicidal germination," germination inhibition, and a decrease in the amount of germination stimulants produced by crop plants. Also, the recently discovered function of strigolactones in the recruitment of symbiotic AMF has created new opportunities for manipulating the host plants' ability to produce germination stimulants. As Cuscuta species lack germination stimulants, we are not aware of any research examining the potential for affecting host location by utilizing these species. Nevertheless, the discovery of various attracting and repellent molecules, as well as the newly confirmed involvement of volatiles in host localization by C. pentagona, imply that such techniques may be feasible[6].

Suicide Germination

Inducing Striga and Orobanche spp. seeds to germinate in the absence of a suitable host plant causes "suicidal germination," which reduces the amount of parasitic plant seeds in the soil. The capacity of both man-made and natural substances to promote germination has been studied. Analogs of strigol have been created, and they are effective in inducing germination in both Striga and Orobanche species. Nevertheless, they have not yet been used in agriculture due to their instability in soil and high cost of production for significant quantities of these compounds. Ethylene, which causes 90% germination when sprayed into the soil, has been an important part of the Striga asiatica eradication effort in the United States. Nevertheless, ethylene soil fumigation is likely to have a deleterious impact on AMF and other unintended soil microorganisms. A greater knowledge of the relationships between bacteria, ethylene, and crops is required before this technique can be used in agriculture. It has been suggested that ethylene-producing non-pathogenic bacteria might be employed to promote suicidal germination of Striga. While it has been shown that other natural substances, such as methyl jasmonate and fungal toxins, may promote the germination of Striga and Orobanche spp. seeds, nothing is known about how these substances could be used in agriculture. The best method for controlling Striga at the moment may be to plant nonhost trap crops that cause suicidal germination. Studies done recently in this field have mostly focused on finding and evaluating the efficacy of possible trap crops and the potential for breeding for higherstimulation of germination by production [7].

The additional advantage of using nitrogen-fixing legumes as trap crops is that they improve soil fertility, which may further help reduce Striga as it thrives in depleted soils. Inoculating crops with additional nitrogen-fixing rhizobia together with ethylene-producing bacteria might possibly boost the effectiveness of legume rotations by promoting suicidal germination and soil fertility at the same time. Legumes have also shown their value in a cutting-edge "push-pull" pest control strategy that highlights the value of greater plant variety by concurrently lowering infestations of lepidopteran stemborers and the Striga bacterium. Desmodium spp. is a leguminous trap crop that may be interplanted with maize or sorghum to reduce parasitism by Striga spp. and discourage ovipositing stemborers, which then go toward the grasses surrounding the field. Desmodium inhibit Striga by releasing compounds that interfere with the growth of haustoria in addition to a germination stimulator.

Preventing the Growth of Parasitic Plants

Since the formation of gibberellin during seed conditioning is positively correlated with the susceptibility of Orobanche spp. seeds to germination stimulants, gibberellin biosynthesis inhibitors may prevent germination in these seeds. The performance of sunflowers was greatly improved by adding the gibberellin inhibitor uniconazole to the soil surrounding them. O. cernua-resistant sunflower types secrete coumarins, which prevent germination and are poisonous to freshly sprouted seedlings. Most recently, when intercropped with legumes, unknown allelochemicals from oats seemed to decrease O. crenata seed development and diminish parasitism. Certain amino acids, which have recently been demonstrated to have significant impacts on the growth of O. ramosa, may also affect seed germination. Exogenous methionone, for instance, decreased the number of growing Orobanche spp. tubercles on tomato roots and nearly totally suppressed seed germination, suggesting that soil applications of amino acids or amino acid-producing bacteria may be utilized to control parasitic weeds[8].

Agricultural Plants Should Produce Less Germination Stimulants

The mechanism of crop resistance to parasitic plants that has been most thoroughly studied is decreased production of germination stimulants. This approach has been effectively used in sorghum breeding to provide certain sorghum cultivars with resistance to Striga. It seems there is resistance. Missing in several agricultural plants, such as maize and cowpea, however significant heterogeneity has been documented across tomato and Arabidopsis genotypes. Current research suggests that crop interactions with advantageous AMF may be negatively impacted by selecting for lower germination stimulant production. Knowing that strigolactones that cause parasitic plant seeds to sprout also attract AMF, which provides nutrients, raises the possibility that controlling mycorrhizal colonization may be utilized to control parasite plants. According to recent studies, nutritional deficiencies might cause prospective host plants to produce more strigolactone, which is sometimes counteracted by AMF. Moreover, AMF colonization of host plants may inhibit the synthesis of germination stimulants, suggesting that increasing AMF colonization of crop seedlings in fields might lower strigolactone synthesis and perhaps lower the amount of parasite plant seeds that germinate.

Cuscuta spp. disruption of volatile host location

The revelation that Cuscuta spp. employ chemical signals to identify hosts, much like root-parasitic plants, may result in management techniques intended to disrupt host localization similar to those reported for root-parasitic plants. Even more than strigolactones, plant volatiles are sensitive to environmental factors and may be altered to lessen the attractiveness of Cuscuta spp[9]seedlings. Moreover, the ability to produce plant volatiles is a heritable feature that may be used in a plant-breeding program to increase Cuscuta resistance. Moreover, a "push-pull" strategy similar to that utilized for the management of African stemborers may be used to manage Cuscuta spp. since at least one repellent component has been found. Nevertheless, very little to no research has explored the viability of such strategies to far, and further investigation is required to understand how Cuscuta spp. perceive and react to plant volatiles[10], [11].

CONCLUSION

Despite much study, effective methods of managing parasitic plants are still elusive, and these weeds continue to pose a danger to agricultural products all over the globe. Early-stage parasitic plant interactions with their hosts are mostly controlled chemically, which may be used to reduce infestation. Current developments in this field point to a variety of potentially successful strategies, including the possibility of controlling both parasitic weeds and beneficial symbionts at the same time. Using AMF-friendly cultural techniques, such as lowering tillage and fungicide treatment, might, for instance, boost crop growth and drought tolerance while also possibly reducing Striga infections.

Understanding the mechanisms underpinning strigolactone sensing and responses in both parasitic plants and AMF requires more study. Another promising strategy that calls for continuing research into finding viable trap crops and enhancing their effectiveness is intercropping with nonhost plants that cause "suicidal germination" and/or are allelopathic to root parasites. Further research is required in this area, but recent work on the function of volatiles in host location by C. pentagona implies that control tactics meant to disrupt host localization may be utilized against parasites that form above-ground attachments. Any one technique by itself is unlikely to provide parasitic weeds long-term control. An integrated strategy that combines one or more techniques to attack the chemistry employed in host locations by parasitic weeds is more likely to provide long-lasting tactics that will reduce crop losses.

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CHAPTER 9

RICE SEED INVIGORATION

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ABSTRACT:

For individuals in South Asia, Southeast Asia, and Latin America, rice accounts for 55–80% of all calories. It stands for a valuable commodities crop elsewhere. In many Asian nations during the last 20 years, direct seeding has replaced the traditional manual transplanting of seedlings as the preferred technique of agricultural establishment due to increased production costs, particularly for personnel and water. The term "seed invigoration" refers to advantageous treatments that are given to seeds after harvest but before planting in order to enhance germination, promote seedling development, or make it easier to transfer seeds and other materials needed at the time of sowing. In order to enhance seedling establishment in both stress-free and demanding circumstances, several seed invigoration treatments are used in a variety of field crops, including rice. Hydropriming, seed hardening, on-farm priming, osmohardening, humidification, matripriming, priming with plant growth regulators, polyamines, ascorbate, salicylate, ethanol, osmolytes, coating technologies, and more recently presowing dry heat treatments are some of the treatments used to energize rice seed.

KEYWORDS:

Agriculture, Hydropriming, Rice Seed, Seed Priming, Stress Tolerance.

INTRODUCTION

Direct seeding technologies in rice cropping systems are the subject of intense research worldwide and provide an alluring alternative to conventional rice production systems in light of the daily rising cost of labor and water limitation. In this respect, practical methods for establishing optimal stand establishment in the new rice culture include seed invigoration procedures. In both ideal and unfavorable soil conditions, they support breaking seedling dormancy and enhancing seedling density per unit area. The claimed foundation for the enhanced performance employing these procedures is the induction and de novo production of hydrolases, such as amylases, lipases, and proteases; and antioxidants, such as catalases, superoxide dismutase, and peroxidases. Simple soaking in water, a solution of salts, hormones, osmoprotectants, matric strain-producing materials, and other unconventional methods may all be used to prime rice seeds. Rice seed invigoration has proved beneficial in raising rice production and quality despite several limitations, such as water potential, oxygen, and temperature. Therefore, in-depth research is necessary to comprehend the physiological and molecular underpinnings of rice seed priming[1].

More over 50% of the world's population eats rice as a staple meal, and in South Asia, Southeast Asia, and Latin America, rice accounts for 55–80% of the calories consumed. It stands for a crop with a high worth as a commodity across the rest of the globe. Growing food consumption and decreasing water supply are threats to global food security. In this situation, both farmers and academics are coming up with methods for producing crops in a way that conserves water without sacrificing productivity. Researchers' tireless efforts have resulted in a novel method of growing rice that uses less water than the traditional production technique. This newly developed technique strives for good yields while growing rice on aerobic soils with extra watering like other cereals.

While aerobic rice is a viable alternative to the conventional rice production method, its widespread adoption is hindered by poor stand establishment and significant weed infestation. Weed management is one of the main benefits of a conventional trans-planting technique, since it would need extra attention in an aerobic rice crop. The improvement of germination and subsequent growth in this crop has been the subject of several recent research. One of the key factors affecting seedling establishment in trans-planted rice is the age of nursery seedlings. Most of the world's nurseries have historically grown plants from seeds, which has led to inconsistent and subpar seedling development. Younger nursery seedlings than in a standard transplanting system are transplanted in a rice intensification method. Seed priming may also enhance the development of rice nursery seedlings and, as a result, their performance in transplanted culture. According to reports, seed priming increases root proliferation, which improves nutrient and water absorption. By boosting the activities of antioxidants such glutathione reductase, catalase, and superoxide dismutase, it increases resistance to low temperatures, salt, and drought. Also, priming decreased plasma membrane permeability and the concentrations of active oxygen species. While past evaluations have addressed seed revitalization in a variety of crop species, there isn't a single study available on rice. This paper summarizes the recent advancements made in rice seed vigoration[2].

Two Techniques for Activating Seeds

Techniques known as "seed invigoration" are value-added processes used on a specific seed batch to enhance its field performance. This phrase is often used synonymously with seed priming. It is an umbrella phrase, nevertheless, that includes a variety of presowing methods. "Post-harvest treatments to boost germination and seedling development or to expedite the transportation of seeds and other supplies necessary at the time of planting" are known as "seed invigoration" or "seed improvements".

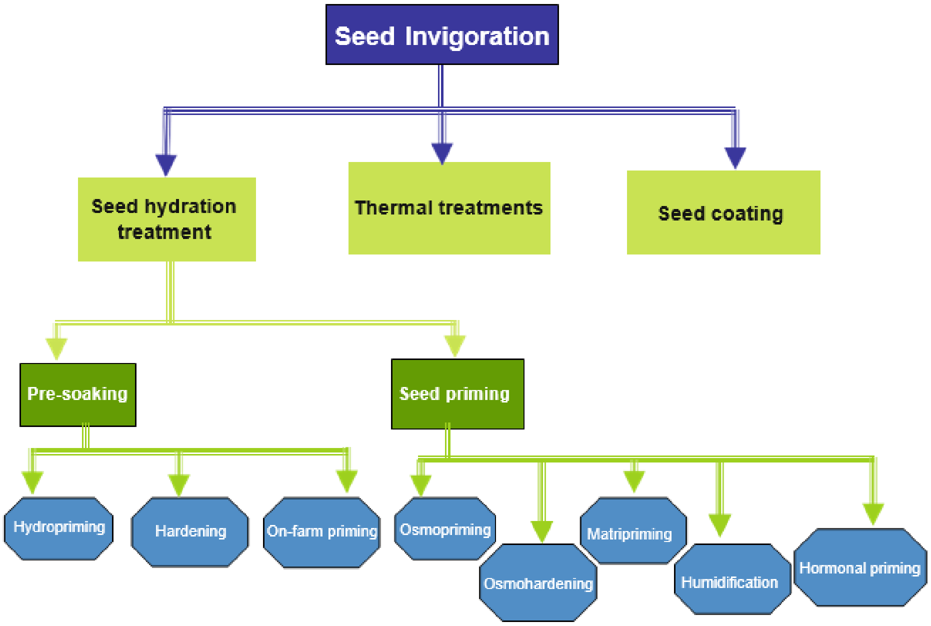

Figure 1: Techniques for seed vigor are categorized. Generally speaking, hydration, coating, and thermal treatments may be further broken down into chilling therapy and drought treatment.

Presowing hydration therapies, low molecular weight osmoprotectant seed treatments, coating technologies, and, more recently, presowing dry heat treatment are all included in this classification. Figure 1, showing In general, cooling therapy and drought treatment may be used to further categorize hydration, coating, and thermal therapies.These methods concentrate on speeding up seedling emergence and shielding the seeds from biotic and abiotic factors.

Seed Hydration Methodologies

For seed to germinate, it needs water, oxygen, and the right temperature. Taking in water has a triphasic rhythm. Imbibition, the first stage, starts when seeds, whether living or dead, physically take in water. Because of how much the dried seeds' water potential vary from water, it often happens extremely quickly. Little metabolic activity takes place in living seeds at this stage. In actuality, dead seeds will absorb water at a rate equal to that of living ones. The lag phase is phase II. While there is significant metabolic activity during this phase, there is minimal water intake and no change in fresh weight as a result. The seed transforms reserves kept in reserve into the substances required for germination. Radicle protrusion is phase three. This stage is characterized by a time of fast water intake and often occurs during radicle emergence. Throughout Phases I and II, seeds may tolerate desiccation; but, during Phase III, this tolerance is typically lost. Depending on whether water intake is uncontrolled or managed, pre-sowing hydration methods may be divided into two types[3].

DISCUSSION

Pre-Soaking

Presoaking refers to techniques that make water readily accessible to seedlings and ensure that their absorption is not constrained by the surrounding environment. The seed tissues' attraction for water controls the water absorption. Such methods include soaking seeds in water or ingesting them on moistened blotters. In the subsections that follow, crucial presoaking techniques used to prime rice seed are described.

Hydropriming

Before planting, hydropriming involves soaking and drying the seeds. With or without aeration, seeds may be soaked by being submerged in water. Non-dormant seeds would easily sprout if there was sufficient water, oxygen, and a climate that was conducive for germination. This method is harmless for the environment since it doesn't include any chemicals. The fact that the seed hydration might be inconsistent using this method, leading to non-uniform germination, is probably a drawback.

The length of hydropriming is crucial for reviving seeds. According to what we know, just one research was done on hydropriming rice for seed vigora-tion. Except for seeds hydroprimed for 60 hours, coarse and fine rice seeds hydroprimed in aerated tap water for 12, 24, 36, 48, and 60 hours showed enhanced vigor in both rice kinds. In both varieties of rice, the seeds hydroprimed for 48 hours showed the greatest gain in vigor, followed by those hydroprimed for 36 hours. Hydropriming has the ability to enhance germination and early seedling development in both coarse and fine rice, as shown by the grain yield, which is ultimately influenced by improved germination and seedling establishment. In a field research, hydropriming for 48 hours increased direct-seeded coarse and fine rice cultivars' emergence, seedling establishment, growth, and yield. Another research found that nursery seedling development, as well as the subsequent growth, yield, and quality of both coarse and fine rice in trans-planted cultures, were all enhanced by hydropriming for 48 hours. In essence, hydropriming may be used to enhance the performance of direct-seeded and transplanted rice. For both varieties of rice, 48 hours was the optimal priming period[4].

Hardening

Hardening is the process of repeatedly soaking in water and drying, also known as wetting and drying or hydration-dehydration. The cycle of hydration and dehydration might happen twice, three times, or more. The advantages of seed hardening mostly relate to the pre-enlargement of the embryo, biochemical changes such as enzyme activation, and enhancement of germination rate, especially in older seeds. The quantity of cycles and, more importantly, the intervals between the cycles during seed hardening are crucial for enhancing vigor. Two alternate soaking and drying cycles are helpful for rice seedlings. The greatest way to increase the vitality of both coarse and fine rice was to harden it for 24 hours. Except for the seeds hardened for 24 h, which acted as the control, seeds hardened for one or two cycles of 12 and 18 and 24 h increased vigor in both coarse and fine rice kinds. Seeds hardened for 24 hours showed the greatest vigor improvement, which was comparable to seed hardening for 12 hours.

Rice seed germination and seedling stand establishment have been reported to be significantly improved by seed hardening treatments. Rice seeds that were normal and naturally aged benefited more from seed hardening than rice seeds that had been osmoconditioned. During a series of lab and field tests, Mathew et al. determined that the seed hardening technique was superior in enhancing the numerous properties, such as speed of germination, germination percentage, and seedling vigor that aided crop establishment in the field with low soil moisture. With treatments including hardening, there was less seedling mortality and a greater seedling density. The growth, yield, and quality of direct-seeded coarse and fine rice varieties were similarly enhanced by seed hardening over 24 hours. The development of nursery seedlings as well as the subsequent growth, yield, and quality of both coarse and fine rice in transplanted culture were all enhanced in a separate trial by seed hardening for 24 hours. This shows that seed hardening, when utilized up to one cycle of 24 hours each, is a key strategy for enhancing seed germination, stand establishment, and ultimately seed production[5].

Priming of seeds on-site

Recent studies have shown that "on-farm priming," which involves soaking in water for a while, followed by surface drying before planting, may produce high-yield harvests in a variety of crop species by promoting quicker germination, early emergence, and rapid seedling development. On-farm seed priming is an paper, inexpensive, and safe way to encourage seedling establishment as well as robust and quick seedling development. The amount of time that each crop cultivar should be submerged is crucial, and it should never exceed the safe limit. Premature germination might harm seeds or seedlings if the priming period is longer. The idea of a "safe limit" distinguishes pregermination from on-farm seed priming. Primed seeds won't sprout until they're put on a damp surface or until moisture becomes accessible later. But, seeds that have been soaked for a longer period of time than is safe will continue to even without an external moisture supply, begin to germinate. Pregerminated seed has inherent dangers, while primed seed acts like dry seed in the event of delayed planting or unfavorable seedbed conditions.

Rice may be successfully soaked overnight. For farmers, it generates a better stand, the crop develops sooner, and it offers bigger yields for minimal expense. A broad variety of phenological and yield-related advantages result from rice seed that has been primed for germination and seedlings that emerge more quickly, evenly, and aggressively. With direct-seeded rice, on-farm seed priming leads to greater emergence, earlier blooming, higher plants, longer panicles, and larger numbers of panicles per plant. For instance, in their study, Harris and Jones examined how 11 kinds of upland rice, including traditional and improved O. sativa and O. glaberrima varieties, as well as novel interspecific hybrids, responded to seed priming. While seed priming with water for 24 hours decreased germination time in all kinds from 46 to 32 hours, it had no effect on the ultimate germination percentage. This is consistent with the time that was actually saved. In conclusion, on-farm priming is a straightforward method for enhancing rice phenology and production even under unfavorable soil conditions. The best course of action in this case is an overnight soak.

Prime the Seed

When seeds are slightly moistened, germination-related metabolic activities start to take place without radicle emergence. This process is known as seed priming. In this procedure, seedlings are submerged in high osmotic potential solutions. As a result, the seeds are unable to hydrate enough to reach Phase III. By confining the seed inside the lag phase, this actually causes Phase II to be extended. The seeds are metabolically active during this time and transform saved energy for use during germination, when membrane and genetic repair is superior to regular imbibition. After being taken out of the priming solution, the seeds are dried and then washed with water. When these seeds are sown, they germinate more quickly than unprimed ones[6].

Increased germination rate, germination uniformity, and sometimes higher overall germination percentage are typical characteristics of primed seeds. These alterations have been linked to germination-promoting metabolite accumulation, metabolic repair after ingestion, and osmotic adjustment. Yet, a simple shortening of the imbibition lag time occurs for seeds that are not redried following treatment. As explained in the next subsections, there are many ways to prime seeds.

Osmopriming

Improving germination and stand establishment is the main goal of using seed osmopriming. To limit water absorption and inhibit radicle protrusion, seeds are soaked in aerated low-water potential solutions, a process known as osmoconditioning, osmopriming, or halo-priming. Many vegetable seeds have been shown to germinate better after receiving such treatments, particularly when they are exposed to unfavorable environments. Osmoconditioned seedlings are really less susceptible to changes in temperature and lack of oxygen. Proline, mannitol, polyethylene glycol, and other inorganic salts stand out among the several osmotica used as priming agents[7].

Rice germination was given a boost by osmopriming with calcium chloride, potassium nitrate, sodium chloride, and polyethylene glycol-8000, which also decreased mean germination time. The germination of both coarse and fine rice was increased by priming with polyethylene glycol-8000. Rice seedling vigor index, seedling and stand establishment, and osmopriming with calcium chloride alone and mixed with sodium chloride were all enhanced in a greenhouse research. As compared to the combination of salts in solution alone, the addition of gibberellic acid to a solution containing a mixture of calcium chloride and sodium chloride did not significantly speed up emergence or stand establishment. Rice seeds were primed with 4% potassium chloride before to planting in a field experiment, and 50 ppm paraquat was sprayed during the tillering or booting phases. Plant moisture content, leaf-area index, chlorophyll content, and nitrate reductase activity all rose as a result of seed priming. When paraquat was treated during tillering, plant moisture content and the leaf area index were at their highest, whereas chlorophyll content and nitrate reductase activity were at their highest when paraquat was applied at booting. The germination of rice seeds may also be sped up by priming with lanthanum nitrate solutions, which also greatly boosts seedling vigor in terms of root development.

To increase the effectiveness of seed priming, researchers are experimenting with various fertilizers. Another topic of significant interest in this regard is nutripriming, which involves using fertilizers to enhance the performance of direct-seeded rice. According to Kalita et al., nutripriming with 4% monoammonium phos- phate produced the most successful tillers and the largest grain production in direct-sown summer rice. Contrary to what was said above, micronutrient priming did not increase rice grain production or grain micronutrient content in a series of field studies. A total failure of germination and emergence was seen in a laboratory investigation using fine and coarse rice seeds primed with urea, nitrophos, di-ammonium phosphate, and potassium sulphate. This was brought on by the fact that these fertilizers caused more membrane damage. This indicates that before carrying out nutripriming, a certain amount of each fertilizer should be preoptimized.

Salt concentration and priming time are negatively correlated and of critical relevance. Reduced and unequal germination and stand establishment may be the outcome of priming seeds in salt solutions with increasing concentrations for prolonged periods of time. The environment during priming affects how well primed seeds function. For instance, Lee et al. came to the conclusion that priming rice seeds in distilled water for 4 days at 15°C and 1 day at 25°C behaved similarly, however 4 days was the ideal amount of time in polyethylene glycol solution independent of the temperature during priming. In a different time-course investigation, seeds soaked in aerated polyethylene glycol solutions for 48 hours or less produced fine and coarse rice that behaved similarly to or worse than untreated seeds, probably as a result of the lengthier priming times[8].

Many studies have shown enhanced germination and seedling stand establishment as a result of various osmopriming procedures. In both fine and coarse rice, osmoconditioning for 24 hours increased germination and early seedling development.

After osmopriming with calcium chloride alone and in conjunction with sodium chloride, Ruan et al. found that germination energy was greatly increased and mean germination time decreased. Similar results were obtained by Lee et al. who discovered that osmopriming with -0.6 MPa polyethylene glycol solution at 25°C for four days reduced the time it took to reach 50% germination by up to three days and increased the rate and ultimate germination percentage compared to untreated seeds. The priming of rice seeds may be a valuable strategy for enhanced seedling establishment under challenging soil conditions in addition to under ideal climatic circumstances. Under low temperature and salt conditions, osmoprimed rice seedlings exhibited significantly higher and faster germination.

Osmopriming has a yield improvement as its main benefit. In a research on adoption in five states of Nigeria, 83 farmers out of the 300 who took part in the knowledge transfer for priming upland rice seeds between 2000 and 2002 realized a 33–84% yield increase over nonprimed seeds.

The majority of these farmers spread the technique to other farms because of the increase in output. This demonstrated a broad use of rice seed priming technology in the covered regions. In conclusion, a variety of inorganic salts at the right quantities may be employed to enhance rice germination. The solution's reduced osmotic potential seems to be important for seed priming. Up to 48 hours may be spent priming, but any longer might result in subpar germination and seedling stands.

Osmohardening

Recent developments in rice seed invigoration have resulted in the effective integration of both seed hardening and osmoconditioning, known as an osmohardening. With this method, increasing the seed vigor depends on both the quantity and length of cycles. Finding the best salts to utilize as priming agents for rice seed invigoration is crucial since this is a relatively new technology.

The information at hand indicates that both coarse and fine rice were osmohardened using a range of salts. Both coarse and fine rice seeds were hardened and osmohardened in a laboratory experiment such that the osmotic potential of each solution was -1.25 MPa. Hardening and osmohardening with potassium chloride were the next best treatments for both kinds of rice, followed by osmohardening for 48 hours with calcium chloride[9].

The best method for enhancing the development of rice nursery seedlings and stand establishment in direct-seeded coarse and fine rice was osmohardening with calcium chloride. Osmohardening using calcium chloride in fine rice resulted in 2.96 t ha-1 of kernel production, 10.13 t ha-1 of straw yield, and a harvest index of 22.61%. On the other hand, for coarse rice, calcium chloride hardening followed osmo-hardening with potassium chloride in terms of harvest index and yield of kernels and straw. The quantity of viable tillers and 1,000 kernel weight were the main contributors to the increased yield. In a different study, osmohardening with calcium chloride increased the vigor of the young seedlings and enhanced growth, yield, and quality of transplanted fine rice. Improvements in yield included a 3.75 t ha-1 increase in kernel production, a 11.40 t ha-1 increase in straw production, and a 24.57% increase in harvest index. The growth in the number of fertile tillers was blamed for the increased yield.

In essence, osmohardening is a very useful technique for improving rice that has been transplanted or directly sown in terms of emergence, seedling stand establishment, growth, yield, and quality.

In both cultivation techniques, osmohardening using potassium chloride for coarse rice and calcium chloride for fine rice was more successful. The foundation for improvements in seedling density and economic yield in rice will come from further research.

Matripriming

Matripriming entails carefully regulating seed hydration, just how the plant medium naturally absorbs moisture. Seeds are combined with wet solid carriers, such vermiculite or granulated clay. These substances' surfaces provide matrix forces that retain water to speed up the seed's sluggish absorption. The seed is then removed from the solid carrier after treatment and left to dry.

Just a limited number of research have been done on tiny seeded crops like rice since matripriming is a more efficient vigor improvement strategy employed in bold-seeded crops. Sand has been used as a priming solid matrix in the development of a matripriming technique for rice more recently. the four rice seeds types were combined with 3.8% water-containing sands and stored in plastic boxes for 72 hours at 18°C.

As a result, direct-sown rice had better emergence and seedling density in the lab. Also, compared to the non-primed controls, the seedling height, root length, number, and dry weight of the root were all considerably higher. In comparison to soaking seeds without priming, field tests revealed that the seed establishment and yield of matriprimed seeds were enhanced by 20-23% and 10-31%, respectively.

Using hormones and other biological sources to prime

Plant growth regulators, polyamines, and a few other organic sources have been added to various vegetable and field crops, including rice, during priming and other presowing treatments to improve seed performance. Gibberel-lic acid, one of the phytohormones, is widely recognized for activating -amylase to break down starch contained in seeds so that developing embryos may use it during germination. After germination, gibberellic acid and ethylene both promote the elongation of the mesocotyle, coleoptile, and internodes in rice seedlings. Moreover, abscisic acid encourages the mesocotyle of rice seedlings to elongate. Depending on the concentrations of gibberellic acid, gibberellic acid treatment without seed priming speeds up the time it takes for seedlings to emerge in rice by one to two days. In a research on kinetin and gibberellins, both of these hormones enhanced rice germination when administered to dehusked seeds of indica and japonica rice under aerobic circumstances. Yet, in anaerobic conditions, gibberellins had a favorable impact whereas kinetin had a negative one[10].

Research on the effects of gibberellic acid, urea, naph- thaleneacetic acid, etc. on hybrid rice have shown that the use of 200 g of naphthaleneacetic acid per hectare per year produced the highest percentage of pan- icles at the lowest cost. The highest paddy yield was achieved with this treatment, followed by 50 g gibberellic acid + 50 g naphthaleneacetic acid ha-1 and 100 g gibberellic acid ha-1. Naphthaleneacetic acid has been shown to be a practical substitute for gibberellic acid for the production of hybrid rice seeds based on its cost-effectiveness. Four different rice cultivars' seeds were soaked in gibberellic acid by Chen et al., who found that several cultivars dramatically boosted their seedling emergence and dry matter as a result.

Plant growth and development have been shown to be significantly impacted by polyamines. As polyamines are cations, they may interact with anionic membrane components like phospholipids to stabilize the bilayer surface and slow membrane breakdown under stressful situations. There is solid evidence that polyamine buildup aids in plants' defense against a variety of environmental stressors. Lower polyamine concentrations in the soaking solution for fine rice seeds accelerated, synchronized, and improved germination. Improvement in seedling fresh and dry weight, root and leaf weight, and shoot and root length

Score was further noted. For the majority of the investigated qualities, seed treatment with a 10 ppm putrescine solution was quite successful. Salicylate is an organic phenolic endogenous growth regulator that participates in the control of physiological processes in plants. Effects on ion uptake, membrane permeability, and other things are among them. Salicylate also interacts with other signaling pathways, such as those controlled by ethylene and jasmonic acid. By activating glutathione reductase and guaiacol peroxidase, it also increases the tolerance of seedlings to osmotic stress, low or high temperature. As compared to the control group, studies on coarse rice seed priming with salicylicate showed a larger vigor enhancement. Nevertheless, seeds primed with 10 ppm ascorbate solution showed the quickest and most consistent germination and emergence. In a research, presowing seed treatments with 10, 20, and 30 ppm salicylicate caused the germination to occur sooner, more synchronously, and with greater potency. While 30 ppm concentration was the most beneficial, improvements in root length, leaf score, and seedling fresh and dry weight were also seen with these treatments.

One of the most significant antioxidants is ascorbate. Several studies have shown how ascorbate, when used in small amounts, may enhance the germination of cereals including wheat, barley, and rice. The germination and early seedling development of both coarse and fine rice varieties were increased by priming with ascorbate at different concentrations, according to a laboratory research, while priming with 10 ppm was the most successful. The growth, yield, and quality of direct-seeded coarse and fine rice were likewise enhanced by ascorbate priming. Another research on transplanted rice found that ascorbate priming increased production and quality of both coarse and fine rice varieties in addition to nursery seedling development.

Butenolides are a class of lactones with a four-carbon heterocyclic ring structure that are among other organic sources. Ascorbate is the most prevalent and significant example of a butenolide. Certain plants produce butenolide derivatives in response to high temperatures; these substances may cause seed germination in plants whose reproduction is fire-dependent. Low butenolide concentrations significantly increased seedling root and shoot length as well as the number of lateral roots in a recent research. Rice seeds treated with smoke, water, and butenolide had significantly higher vigor indices than untreated seeds.

It has also been investigated if imidacloprid works well as a priming agent to increase yield. In a research where rice seeds were primed with imidacloprid, sodium chloride, potassium chloride, and Azospirillum, imidacloprid significantly outperformed the other treatments in terms of seedling density and yield performance. Several plant species' seeds have been found to germinate more quickly when exposed to ethanol. At concentrations of 10 and 15 percent ethanol, none of the seeds could sprout, however at concentrations of 1 and 5 percent, seedling emergence was more evenly distributed and was followed by a greater number of leaves per plant. In another investigation, 0.5–5% ethanol was employed to alleviate the germination inhibition brought on by de-husking japonica rice. In summary, priming with plant growth regulators and several other organic sources at comparatively lower concentrations has the potential to further improve the consistency of germination, stand establishment, growth, and harvestable yield.

Low-Molecular-Weight Priming Osmolytes

Osmolytes support the structure and activities of certain macromolecules, sustain cyptoplasmic turgor pressure under water stress, and ultimately promote plant development in challenging environments. It is widely known that seed treatment and foliar application of these solutes may have some benefits since they increase plants' capacity for tolerance.

The predominance of low temperatures during planting causes poor rice seed germination, seedling establishment, and vigor in various temperate rice-growing areas across the globe. Four different rice cultivars' seeds were immersed in various glycinebetaine mixtures for two days in Petri plates in a low-temperature glasshouse. According to the mean emerging time after this soaking period, cold-tolerant cultivar HSC-55 showed quicker seedling emergence than the other three cultivars, suggesting that glycinebetaine was ineffective on those cultivars. Research showed significant variations across genotypes in how seedling emergence and vigor were affected by the application of gibberellic acid and glycinebetaine at low temperatures.

Humidification

Pre-sowing controlled hydration known as humidification involves equilibrating seeds in an environment with a high humidity level. With this method, seeds come into touch with water vapor directly. To our knowledge, just one research has been done to look at the viability of this method of reviving rice seeds. When temperatures and soil conditions were ideal, the germination of typically germinating rice seeds was not sped up by humidification, but it was. Older seeds humidified at 60% relative humidity did not affect the rate of germination or the time it took for germination to reach 50%. Nevertheless, 80% relative humidity increased the time to 50% germination and decreased the germination percentage.

More Techniques for Reviving Seeds

In order to get the best seedling density and final output per unit area, rice seed has been successfully revitalized using a number of unconventional methods.

Thermal Procedures

The dry-heat treatment of seeds is used for two purposes: to break the dormancy of seeds and to reduce external and internal seed-borne diseases, such as fungus, bacteria, viruses, and nematodes. Yet, the ideal temperature for breaking dormancy encourages rice seed germination and seedling emergence. High temperature in dry heat treatment often affects seed viability and seedling vigor. In a research on coarse and fine rice seeds, dry-heat treatment at 40°C for 72 hours sped up germination by 50% and enhanced fine rice's germination index, radicle and plumule length, root length, root/shoot ratio, fresh and dry root weight, and radicle and plumule growth rate. None of these treatments enhanced seedling vigor or germination in coarse rice. Both coarse and fine rice seeds were subjected to thermal hardening in a laboratory research. The heating-chilling-heating cycle was the most effective for treating fine rice, while the chilling-heating-chilling cycle was the most effective for treating coarse rice.

Seed Coating

The size, shape, and color of seeds vary widely. As little seeds are often used, precise placement and singularization are frequently problematic. Moreover, a variety of pests that prey on germination-stage seeds or seedlings should be kept away from seeds. In both scenarios, seed-coating treatments may be used; they help mechanical sowing achieve regular plant spacing and can be applied in target zones with little impact on the soil ecology and environment. According to Ross et al., when seeds were covered with a single super phosphate, mono ammonium phosphate, or potassium phosphate, rice seedling emergence was reduced by 40–60%. On the other hand, seed coating with rock phosphate did not impair seedling emergence in the end, albeit delaying it by 2-3 days. Coatings boosted the shoot dry weight but lowered the root dry weight of seedlings 20 days after sowing. Up to 40 days after planting, coating treatments continued to have an impact on plant development, which at this point had grown by 400–870% in terms of root length, dry weight, and shoot dry weight. For low P soils, coating rice seeds with rock phosphate may be more effective in promoting early rice development. According to Song et al., film wrapping rice seeds may enhance the performance of rice seeded directly.

In order to encourage the sprouting of direct-seeded rice seedlings in wet soil, Japan has long been covering rice with a source of oxygen. Due to their lower specific gravity and tendency to be weakly anchored, seeds that are dispersed in standing water will continue to float or get stuck.

According to Yamauchi, iron coating may improve the specific gravity of rice seeds, which promotes seed germination and, in turn, stand establishment.

Three elements that impact seed priming

The physiology of seed performance is impacted by a variety of environmental factors in the priming regimens. Yet, according to Corbineau and Come, the oxygen, temperature, and water potential of the priming media are the most crucial elements that impact seed priming.

Oxygen

One of the key factors influencing how successful seed priming is has been found as oxygen. To the best of our knowledge, not much is known about how aeration affects the priming of rice seeds and their subsequent performance. Osmopriming in a polyethylene glycol solution with an aerated solution and an osmotic potential of -1.25 MPa increased germination and early seedling development. In both transplanted and direct-sown rice, osmohardening in aerated calcium chloride and potassium chloride solutions, each having an osmotic potential of -1.25 MPa, increased germination, stand establishment, growth, and yield.

Temperature

Low temperatures may alter the performance of the seed during priming. Despite the seed properly absorbing water, this may delay the physiological germination processes. Moreover, lower temperatures lessen the chance of microbial contamination during priming. Rice seeds were germinated at 17°C, 20°C, or 25°C after being primed at 15°C and 25°C by Lee et al. In terms of germination rate, four days at 15°C and one day at 25°C were the ideal priming times in water. The efficiency of seed priming was unaffected by priming in a -0.6 MPa polyethylene glycol solution at a low temperature, however. Whether low, high, or optimal temperatures play any particular roles in promoting improved germination in response to seed priming, further research is required to determine this.

Water Capacity

When a seed's water potential reaches a certain point, it begins to germinate. This varies across plant species and within them, but generally speaking it happens when the seed environment is between 0 and -2 MPa. Excep- tions happen when seeds have hard seed coats or have compounds in them that must be eliminated before germination may take place. Three separate stages of germination typically occur for seeds with permeable seed coats: imbi- bition occurs when the water content of the seed environment is higher than that of the seed, allowing water molecules to pass through the seed epidermis and into the embryo. This results in the activation phase, during which hormones and enzymes stored in the seed stimulate physiological processes.

Development that results in the radical's growth, putting an end to the germination stage. Typically, dormant seeds have a very low water potential, between -350 and -50 MPa. Even at these low water potentials, some metabolism takes place. During the imbibition phase, water moves quickly into dry seed at first but then slowly slows when the environment's water potential is reached by the seeds. Rapid ingestion often results in injury to hydrated cells.

Wide-range water potentials have been attributed by several researches to better germination and seedling stand establishment. In both coarse and fine rice, osmoconditioning with KNO3 and water potential at -1.1 MPa increased germination and early seedling development. The pace and ultimate percentage of germination were both increased by osmopriming with -0.6 MPa polyethylene glycol, according to Lee et al. Rice seeds primed in this solution at 25°C for four days required less time from planting to 50% germination than untreated seeds did.

Managing Dormancy and Seed Priming

The germination of dormant seeds is halted, and a number of priming treatments have shown their efficacy in reversing this physiological process. It is possible to prime with salts, hormones, or other chemicals to break the dormancy. The hull removal, use of salts, hydrogen peroxide, and temperature regimes were some of the dormancy-breaking procedures used in the seed-germination experiments of 18 accessions representing 16 rice species. These results showed that removal of the seed hull was very effective in removing seeds from their dormant state, that species responded differently to different temperature regimes, and that no single regime consistently worked to remove seeds from their dormant state in all species, and that some species responded to specific chemical treatments well when temperatures were at their most favorable levels. The greatest outcomes for breaking seed dormancy came from a proper mix of seed hull removal, dry heat, or chemical treatments, and germination under the ideal temperature regimes for each unique rice species.

Gibberellins, a class of plant hormones, are widely recognized for helping resistant seeds germinate and bringing dormant seeds out of their dormancy. The highly dormant rice cultivar Urucuia was subjected to predrying in a forced air circulation chamber for seven days or soaking in 60 mg of gibberellic acid L-1 concentrations at 30°C for 2, 24, or 36 hours. Evaluation of the effectiveness of gibberellic acid in breaking seed dormancy showed that all the treatments significantly reduced seed dormancy, which was closely linked to an increase in -amylase activity and seed germination. This further suggested that -amylase activity is a useful marker to investigate rice seed dormancy. In essence, a variety of seed treatments may be used to break the dormancy of rice seeds. Nevertheless, heat treatments, inorganic salt priming, and gibberellic acid priming are more efficient. In rice, further research including new growth-promoting compounds is essential.

Priming of Rice Seeds and Stress Tolerance

As a result, compared to other crops, rice has an unusual range of stress tolerances and susceptibilities. It tolerates submersion at levels that would kill other crops and thrives in soggy soil. While rice responds to stress better than other crops, it is only moderately tolerant to salt and acidity in the soil. In contrast, it is very susceptible to drought and cold. Certain rice-growing situations, however, need for even more tolerance than what is present in the enhanced germplasm. Like to other crops, rice is impacted by a variety of environmental factors. This is a survey of the relevant literature:

Drought

While it is often avoided in irrigated rice farming systems, the 63.5 Mha of rainfed rice that is planted each year, the majority of which is in tropical Asia, Africa, and South America, is characterized by persistent drought. The frequency and severity of droughts may greatly rise in the newly implemented aerobic rice crop. When Du and Tuong tested the efficacy of various osmotica to enhance the performance of direct-seeded rice, they discovered that osmopriming with saturated calcium phosphate solution and 14% potassium chloride solution was effective in enhancing seedling emergence, stand establishment, and yield under water-scarce conditions. According to Harris et al., primed rice seeds germinated effectively in drought-prone locations and sprouted seedlings more quickly and evenly, increasing production. In water-strapped circumstances, a germination study of 11 varieties of upland rice demonstrated early and synchronized emergence caused by seed priming.

In conclusion, priming rice seeds may help improve seedling establishment in soils with low water availability.

Salinity

A significant problem for grain production globally is salt stress. While rice is a salt-sensitive crop, it is the only grain that has been suggested as a desalinization crop due to its capacity to thrive in flood-prone environments. This is so that the salt content of the topsoil in rice fields may be lowered to a level suitable for succeeding harvests. Rice's tolerance to salt varied widely, despite the fact that it is very sensitive to it. The impact of salt on the germination of rice seed and growing seedlings may be minimized by using a variety of techniques. For instance, adding putrescine to a NaCl solution will improve water absorption while reducing net salt and chloride ion buildup in seeds. This shows that putrescine may lessen sodium chloride salinity's negative effects on rice seed germination and early seedling development. According to Kim et alresearch, .'s indole acetic acid was more efficient than gibberellic acid in increasing the salt tolerance of dehulled rice seeds. Inducing stress tolerance is another use for brassinosteroids. For instance, treating rice seeds with brassinosteroids may make salinity's negative impact on germination and seedling development ineffective. The salinity tolerance of rice was also increased by osmopriming with mixed salts. The evidence presented above suggests that rice may be improved for salt tolerance using a number of priming strategies.

Low Temperature

In many temperate rice-growing nations, the frequent low temperatures during planting lead to poor rice seed germination, seedling establishment, and vigor. To defeat the enemy of low temperature, a variety of tactics might be used. For instance, in a lab experiment, proline, betaine, putrescine, spermidine, and spermine were added to rice seeds to boost germination and vigor at low temperatures. As compared to cultivating the seedlings in water alone, these chemicals enhanced shoot development by around 9 to 27%. Also, for proline, betaine, putrescine, spermidine, and spermine, the amounts that increased shoot growth the greatest were 0.5, 2, 0.5, 0.05, and 0.05 mM, respectively. According to Sasaki et al., treatment with hydrogen peroxide at a low temperature in a greenhouse encouraged development. Rice may be made to tolerate low temperatures by soaking its seeds in different solutions of indole acetic acid and glycine betaine. Also, the performance of rice seeds improved more from the application of both than from either strategy used alone. Sand priming was shown to increase the cold tolerance of direct-seeded rice in another investigation. Osmoprimed rice seeds had much greater and quicker germination. According to this, osmoprotectants may be applied to seeds to induce low-temperature resistance during germination more effectively.

Water logging and Submergence

In all regions that produce rice using rainwater, including South Asia, Southeast Asia, and tropical Africa, excess water is a regular problem. Around 15 Mha of Asia's 40 Mha of rain-fed lowlands-grown crops are regularly affected by submergence. Due to heavy rainfall and/or blocked drainage, submergence stress may also harm crops in irrigation-gated regions, especially early in the growing season. Around 80 kg ha-1 of yield is thought to be lost on average each year as a result of submersion. Due to its ability to form aerenchyma, rice is tolerant to wet conditions, although total submersion may be fatal. By osmopriming with calcium and sodium salts, Ruan et al. demonstrated increased seedling vigor index, seedling emergence, and stand establishment in wet soil. According to a different research, treating rice seeds with hydrogen peroxide may successfully increase their resistance to submersion and floods.

The use of commercial fertilizers as seed coating and priming agents merits further study. It is important to evaluate the performance of revitalized seeds in a variety of field environments. To increase resistance to biotic and abiotic stressors, these tactics should be used. It is important to thoroughly research thermal treatments that alternate between low and high temperature cycles. Another important issue in the technology transfer and commercialization of primed rice and other crops' seeds may be the protracted storage of hardened and primed seeds. Thus, further research should be done to determine how well primed seeds store. It is important to do research on the integration of potential revitalization strategies. It is important to identify the mechanisms of rice seed priming, especially those connected to enzymatic processes. Also, it could be necessary to look at how calcium and potassium ions influence -amylase during the priming process. The ability to handle stress during germination is crucial. Thus, it is important to look into the anti-oxidant biosynthesis pathway. Research into the functional genomics of seed priming might provide significant rewards. While baseline data is available, functional investigations of specific genes and proteins linked to the enhanced seed priming efficiency are becoming more crucial.

CONCLUSION

In conclusion, seed priming with optimal concentrations of inorganic salts, polyamines, osmoprotectants, plant growth regulators, and hydrogen peroxide may be utilized to increase tolerance against a variety of challenges, including salinity, low temperature, and waterlogging/submersion. Therefore, a deeper comprehension of the processes involved in drought and high-temperature tolerance during seedling growth is essential to acclimatize the direct seedling rice without puddling.

In a variety of field circumstances, seed invigoration methods have a tremendous potential to enhance emergence and stand establishment. Osmopriming, osmohardening, hormonal priming, and the use of extremely soluble and low molecular weight compounds are some of the strategies that need particular attention. These methods may be used successfully to improve crop production in salty, submerged, and dry environments. Rice performance in direct-seeded cultures may also be improved by using seed invigoration procedures. The reactions of different rice species, kinds, genotypes, and types to different priming treatments vary greatly, indicating that more effort has to be done to understand the unique behavior of the rice material. A variety of salts, plant growth regulators, jasmonates, and osmolytes should be used at various concentrations and for various lengths of time in order to create more accurate invigoration strategies. Also, it is important to look at the ideal water potential, temperature range, and oxygenation demand. To evaluate the seed priming-based invigoration, it is very essential to know how the genes and proteins are regulated and expressed.

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CHAPTER 10

SOIL MANAGEMENT FOR DISEASE CONTROL IN SUSTAINABLE CROPS

ABSTRACT:

The over use of agrochemicals in traditional crop management has led to significant issues with the environment and human health, including the extinction of species and mental diseases. Many chemical biocides have intricate long-term consequences, including as modifications to the immunological and endocrine systems. During the last fifty years, there has been a significant growth in the use of various chemical biocides on plants and soil. From 1950 to 2000, the total amount of chemical fertilizers used globally grew by a factor of 10. This holds true for chemical biocides as well, which we now utilize on an annual basis and cost us $30 billion.

A major contribution to agricultural ecological sustainability and quality may be made by managing and using soil environmental conditions as part of an integrated control approach. By boosting competition for resources, the use of organic materials and techniques that boost soil microbial activity may improve the overall suppression of diseases.

KEYWORDS:

Biodiversity, Compost, Cropping system, Diseases, Organic farming, Organic matter · Microbial biomass, Nitrate, Soil fertility, Sustainability.

INTRODUCTION

A population reduction results from the selection of crops in a rotation with plants that are less vulnerable to certain infections owing to natural mortality and the antagonistic actions of coexisting root zone microorganisms. Compared to soils with little biological variety, plants growing in soil that inhibits illness have far superior disease resistance. The objectives of this literature study were to identify the best crop management practices to prevent, avoid, escape, and control illnesses as well as to comprehend the impact of soil environmental variables on plant disease incidence. This paper discusses several crop management techniques that lower the frequency of plant diseases. It covers the primary subjects of soil fertility associated with N-P-K and other macro- and micronutrients, as well as soil pH, structure and texture, organic matter, and microbial reserves[1].

Plant diseases pose serious risks to the economy and pose difficult difficulties in agricultural ecosystems. There is evidence that large losses from pests and illnesses still occur in agricultural production despite the widespread use of chemical biocides. According to estimates, 10% of crops are lost worldwide to weeds, and the global industry for chemical biocides is worth roughly $30 billion annually. When a vulnerable host and a disease-causing pathogen come together in a favorable environment, plant diseases may develop. There won't be any sickness if any one of these three requirements is not satisfied. Several methods of disease management, such as the use of fungicides and fumigants, concentrate on controlling pathogens after the onset of disease symptoms, which is often too late to be helpful. Focusing on the time before disease infection occurs and fostering circumstances that are beneficial to the plant but unfavorable to the pathogen is a more dependable strategy. In order to reduce pathogen growth in soil and reduce disease susceptibility in host plants, this paper underlines the need of doing so.

In all production methods, soil is the essential medium for crop development. Each system's performance is greatly influenced by the soil's properties, such as its nutrient content and structural elements that influence roots. Yet, the prevalence and severity of plant diseases may be influenced by the soil conditions for plant development. Controlling and taking use of the suppressive effects of the soil environment as part of an integrated management plan may significantly improve the sustainability of agriculture and the environment.

If pathogens may establish themselves in a soil but cannot cause illness, if they can establish themselves but do not, or if they become established, they briefly generate illness before fading away.

The physical characteristics of the soil, its fertility, its biodiversity and population of soil organisms, and its management all affect the amount of suppression. In addition to providing water and nutrients directly, the soil environment also indirectly effects crop growth by promoting the development of weeds, pests, and diseases. Although the fundamental principles are postulated, little is known about the specific soil elements and ambient circumstances that affect how severe plant diseases are. This is necessary to make managing plant diseases easier. The objective of this review paper was to identify the most effective agrochemical-free crop disease control practices.

Fertility of Soil

Using the nutrients present in host tissues effectively is necessary for infections to successfully colonize plants. If excessive fertilizer treatments result in rapid development of foliar and other portions, they may make a plant more susceptible to diseases. Conflicting findings have been made on the influence of soil fertility on the emergence of illness in various pathogens and plants. According to Portela et al., if there are limitations on root extension brought on by poor soil fertility, low aeration, and high-soil compaction as a consequence of occasional soil disturbance by tillage, chestnut recovery from ink disease is poor. According to Maynard et al., carrots with hollow spots have low calcium levels in both their roots and petioles. Subsequently, it was discovered that excessive soil potassium levels may cause plants to accumulate potassium, which inhibits calcium absorption and, in turn, causes cavity spot to form[2].

Nitrogen

In terms of plant diseases, nitrogen is the nutritional element in soil that has been investigated the most. An abundance of nitrogen promotes succulent growth, a protracted vegetative stage, and delayed plant maturity, all of which prolong the plant's susceptibility to diseases. Inadequate plants are weaker, develop more slowly, and are more vulnerable to diseases. It is challenging to distinguish between a nitrogen supply's direct and indirect impacts on the host-pathogen interaction due to the pathogen's influence on crop development, crop physiology, and crop microclimate dynamics. While they have been proposed, direct alterations in host susceptibility to infection with increased amounts of nitrogen are still debatable. Several plants and pathogens have shown reactions to high nitrogen levels in terms of growth and illness. the impact of soil nitrogen content on the emergence of disease in various agricultural crops.

DISCUSSION

The type of ammonium or nitrate in the nitrogen may have an impact on the occurrence of plant diseases in addition to the quantity of nitrogen accessible to the host or pathogen. Although the nitrate form of nitrogen caused more plant deaths, the ammoniacal form of nitrogen lessened the severity of the Phymatotrichum omnivorum in cotton. The Fusarium wilt of tomatoes was inhibited by nitrogen fertilizer in the nitrate form, but the severity of the illness was exacerbated by ammonia. Fusarium spp., Plasmodiophora brassica, Sclerotium rolfsii, and Pyrenochaeta lycopersici all produced more severe illness when an ammonium fertilizer was employed.

The pH of the soil may have a role in how nitrogen behaves. Ammonium ions are taken up by the roots via exchange with H+ ions, which are then released into the environment and lower the pH of the soil. The root zone is less acidic when nitrate is present. Fundamentally, by utilizing acidifying ammonium nitrogen, the advantages of high pH are lost. As a result, using fertilizers containing ammonium, such ammonium sulphate, can lower soil pH and encourage the growth of diseases that are encouraged by low pH. On the other side, illnesses that are encouraged by neutral to alkaline pHs will be more severe using nitrate fertilizers. Studies employing the nitrogen compounds nitrate and ammonium against the Fusarium wilt of tomatoes, for instance, have demonstrated that adding nitrate to soil that has previously[3].

High pH helps reduce wilt. While there are many different ways that infections and their hosts interact, Huber and Watson found that more often than not, the kind of nitrogen that is accessible to the host or pathogen determines how severe the illness is or how resistant it is. Both ammonium and nitrate forms of nitrogen, together with very minute quantities of organically bound nitrogen, are digested by plants. Although nitrate may be preserved, the ammonium form is swiftly transformed to amino acids. The primary source of nutrition for infections is the nitrate form.

Phosphorus

As a reactant and effector chemical, phosphate is essential to plant cell metabolism. Phosphorus is the least available macronutrient in many habitats, which often inhibits plant development. Phosphorus in the soil may have a crucial role in the development of diseases. Phos- phites, which are excellent sources of phosphorus for plant nutrition or as agricultural fungicides, are alkali metal salts of phosphoric acid 2. According to published research, phosphite effectively controls a variety of crop diseases brought on by different kinds of pathogenic fungus that belong to the genus Phytophthora. There are several findings linking the development of crop diseases with the amount of phosphorus in the soil that is readily available. While it should be calculated, the ideal amount for each crop will vary depending on the disease and the soil. Thus, as part of a comprehensive plan for managing crop diseases, careful monitoring and control of the available phosphorus and its balance with other nutrients might be taken into account[4].

Potassium

The development of diseases is also connected to potassium fertility. Spraying aqueous potassium phosphate dibasic, potassium oxalate, or potassium tribasic solutions on cucumber plants, for instance, caused systemic resistance to Collectorichum lagenarium, Cladosporium cucumerium, Dydimella bryoniae, Sphaerotheca fuliginea, Pseudomonas lachrymosa, Erwinia tracheiphila, tobacco necrosis virus, and cucumber mosaic virus. Field mustard's black spot disease was less severe after potassium application because more phenolics were being produced by the plants, which prevent conidial germination and lessen A. brassicae sporulation. In order to control crop disease, it is vital to take into account potassium's rate, shape, and balance with other soil nutrients. The ideal balance for a variety of circumstances has to be established.

Additional Macronutrients and Micronutrients

Similar correlations between their levels in the soil and the susceptibility or resistance to certain illnesses have been shown in studies involving additional elements such as calcium, magnesium, iron, zinc, and other micronutrients. In regard to controlling Pythium damping off in wheat, sugarbeet, soybeans, peanut, peas, peppers, beans, tomatoes, and onions, calcium had a significant role. Zea mays, Cucumis melo, Brassica napus, Vigna sinensis, Brassica juncea, Solanum esculentum, as well as root-knot nematode damage brought on by Meloidogyne incognita, all seem to be affected by the /K ratio. The levels of nutrients in the panicle tissues were correlated with the severity of panicle blast in four genotypes of rice. Although potassium and calcium were inversely connected with the intensity of rice panicle blasts, the levels of nitrogen, phosphorus, and magnesium in panicle tissue were favorably correlated. High K and Zn tissue contents and low N, P, and Mg tissue concentrations were linked to the enhanced cultivar Guarani's reduced disease severities. According to Matocha and Hopper and Matocha and Vacek, there is a correlation between the severity of Phymatotrichum omnivorum occurrence on cotton and the degree of iron deficiency chlorosis. Analysis of soil samples revealed that when this disease grew to extreme levels, at least two plant nutrients, Fe and Mg, were often in inadequate supply. Wheat plants that received chloride fertilizer had less powdery mildew and leaf rust. Duffy et al. demonstrated that soil pH and accessible phosphorus were negatively connected with the biocontrol efficacy of Trichoderma koningii for preventing take-all disease in wheat, whereas soil iron, nitrate-nitrogen, boron, copper, soluble magnesium, and % clay were favorably correlated. According to Lee et al., silicon soil amendments reduced the severity of the blast disease in rice grown on a number of silicon-deficient soils[5].

Organic Matter in Soil

By providing nutrients or by creating favorable or unfavorable settings for both plants and pathogens, soil organic matter, soil microorganisms, and pesticides have an influence on the growth and development of plant pathogens. Increased microbial activity, decreased pathogen aggression and infestation, greater virus resistance, and a decrease in soil fatigue or toxicity are all factors that contribute to the function of organic matter in crop protection. Additionally, the uptake of phenols, phenolic acids, and other compounds like salicylic acid, which have an antibi- otic effect and also directly attack pathogens, increases the individual plant's resistance as a result of the addition of organic matter. This increases the vigor of the plant due to the physical and chemical improvement of the soil. The antiphytopathogenic potential of soils is directly influenced by the application of organic manures.

This is crucial when it comes to diseases like Rhizoctonia, Fusarium, and Pythium that cause fungal damping-off. The antiphytopathogenic potential of the soil is thought to be influenced by a number of different compounds in the soil. As organic manures decompose, carbon dioxide is released, which may be harmful to certain pathogens in high quantities. Toxins found in crop waste, commonly known as allelo-chemicals, which are created against other biological agents like weeds, may also work against plant diseases. Most studies have shown that many plants become disease resistant when mature organic matter, like compost, is added to the soil. Usually, the amount of overall soil microbiological activity was correlated with the extent of disease suppression.

In several instances, adding organic matter to the soil demonstrated beneficial substitutes for chemical plant disease treatment. For instance, mature calf dung and sugarcane husks have been shown by Viana et al. to be effective alternatives for controlling bean damping-off. Groundnut plants exposed to 5 t/ha of farmyard manure once every three years saw a 32% reduction in dry root rot. According to Ceuster and Hoitink, composted bark may be added to container medium to help reduce Pythium and Phytophthora root rots. Yet, there have been claims that utilizing organic fertilizers accelerated the spread of illness. For instance, Chauhan et al. discovered that increasing the amount of farmyard manure applied—from 25 to 75 t/ha—increased the severity of the cauliflower stem rot disease. Composting might enhance soil microbial populations. The ability of the soil's active microbial biomass to use carbon, nutrients, and energy grows, making the resources available to soil-borne diseases much more scarce. The helpful microbes that create antibiotics, antagonists that compete with plant pathogens, and creatures that feed on and parasitize diseases all find food and refuge in compost. The level of decomposition in compost greatly influences disease suppression; as compost ages, it typically gets more suppressive. Rhizoctonia and Pythium were nonetheless repressed by easily accessible carbon compounds present in poor-quality juvenile compost. Compost may be increased in suppression by either curing it for four months or more before use, or by putting it into the field soil many months before to planting and inoculating it with certain biocontrol agents. Trichoderma and Flavobacterium strains, which are introduced to potatoes to inhibit the growth of Rhizoctonia solani, are two examples of advantageous organisms employed as inoculants. Trichoderma harzianum produces antifungal exudates that are effective against a variety of soil-borne fungal crop diseases, including R. solani.

Depending on the duration of the soaking period known as the "extrac- tion time," application of compost extracts or compost "teas," which are filtered combinations of compost components and water, exhibited potential crop protection benefits. Compost extracts' mechanisms of action are unknown, however they seem to rely on the host/pathogen interaction and the method of administration. According to Goldstein, composts and compost[6]. Plants' genes for disease resistance are activated by extracts. These are the genes that ordinarily become active when a pathogen is present. The pathogen invasion is met by chemical defenses being mobilized. It's possible that plants growing in compost already have these disease-prevention mechanisms engaged.

As previously established, nutritional impacts may affect how severe infections are, thus it is important to consider the contribution of compost to nitrogen fertility. Examples of diseases that become more severe as a consequence of increased nitrogen fertility put into container medium using composted biosolids are Phytophthora die back of Rhododendron and Fusarium wilt of Cyclamen. Nevertheless, when composts are made from materials with a high carbon-to-nitrogen ratio, such wood waste, this effect may not be present. Most composts with a high C/N ratio immobilize nitrogen. Consequently, plants grown in such materials experience chronic nitrogen deficit, which stunts development and makes them more vulnerable to infections or insects that cause stress. With lower C/N ratio composts, Fusarium wilts may worsen due to the excess nitrogen, which promotes Fusarium. High C/N ratio tree bark compost may inhibit Fusarium wilts.

The spectrum of organisms that live in the completed compost depends on the moisture level once the compost has reached its peak heating stage. Pythium illness will be reduced in compost that has at least 40 to 50 percent moisture content because both bacteria and fungi will colonize it. The density of pathogens in soil may be indirectly increased by certain biocides. Herbicide-treated weeds and other plants' roots are considerably more easily colonized by diseases like Pythium, Rhizoctonia, and Fusarium than living plants are. This is so that infections may feed on the sugars and other carbon compounds that decaying roots release. After 21 days following treatment, Pythium levels in the soil rose in bean areas treated with glyphosate or paraquat.

As a result, adding mature organic matter to the soil enhances plant health and increases many plants' resilience to disease. Nevertheless, several features of organic additions, including as compost and the quality of organic manure, must be managed to produce consistent outcomes due to their variable nature, as Ceuster and Hoitink recommended. The compost itself must be stable and of a constant quality if you want more consistent outcomes. It is important to carefully analyze the composition of the organic matter used to make the compost, the composting procedure, the stability or maturity of the completed product, the amount of plant nutrients it supplies, as well as the timing of application. When using organic fertilizer, farmers should be aware of the C/N and N/P ratios. This will help them create a comprehensive disease control plan. They should be able to keep a close eye on the availability, rate, form, and balances of N-P-K.

Microbial Soil Biomass

Eukaryotes such fungus, yeasts, protozoa, and algae, as well as prokaryotes like eubacteria, actinomycetes, and archaea, make up the majority of the soil's microbial biomassand distinct microbes in each soil. Being a relatively labile source of plant nutrients including nitrogen, phosphorus, and sulphur, they play a crucial part in the cycling of nutrients and in encouraging soil aggregation.

Yet, the kind and quantity of organic elements that enter the soil ecosystem play a key role in determining the microbiological status of the soil. With the exception of phototrophic bacteria and algae in surface soils and chemolithotrophic prokaryotes like nitrifying bacteria, the overwhelming majority of soil microorganisms are heterotrophic. Both carbon and energy must come from biological materials. So, it is possible to anticipate that management techniques that entail varying inputs of organic materials into soils would alter the microbial communities there. The biological processes of nutrient transformation, the soil food web, and the activity of soil microbes are specifically affected by the quality and amount of organic inputs [7].

Many data suggest that soil-dwelling organisms may act as plant diseases' enemies. Several fungi are hyperparasites of other fungi, and over 100 different kinds of fungus capture and feed on nematodes. For instance, Trichoderma species that emit lytic enzymes are active against fungal cell walls; Talaromyces flavus may target Sclerotinia sclerotiorum sclerotia; and Verticillium dahlae and Sporidesmium sclerotiorum can combat five significant plant pathogens' sclerotia. According to Sullivan, there is a clear relationship between overall microbial activity, microbial biomass, and the level of Pythium suppression.

The breakdown of organic materials is impacted by nematodes and protozoa because they feed on microbial populations. It's probable that such feeding eventually liberates resources trapped in microbial cells or lessens competition amongst bacteria, accelerating mineralization. These actions not only affect the overall nutrition, health, and vigor of higher plants, but they also affect how root-infecting fungus and their microbial adversaries compete with one another.

Common soil bacteria known as streptomycetes are efficient, tenacious soil saprophytes and often found in close proximity to plant roots. They are well-known manufacturers of extracellular hydrolytic enzymes and antibiotics. According to Samac et al., because of their capacity to colonize plants and lessen damage from a wide variety of infections, streptomycetes have the potential to substantially contribute to an integrated disease management system that encompasses alfalfa and other crops like potato, maize, and soybeans.

The activities of soil microorganisms are influenced by a number of variables, including soil moisture, temperature, soil organic matter, and agronomic practices including irrigation and pesticide usage. Field management strategies and agricultural practices have an impact on the populations of soil microorganisms and plant diseases. By boosting the competition for nutrients, the application of organic matter and any other treatments that boost soil microbial activity may help decrease diseases more broadly due to natural mortality and the antagonistic actions of coexisting root-zone microorganisms, the population declines when crops in a rotation are chosen with plants that are less vulnerable to certain infections.

Crop rotation may also alter the microbial community in ways that go beyond those often connected to saprophytic survival and the host range of pathogens. Rotation is the most effective method for reducing the impact of diseases with poor saprophytic survival potential or biotrophic pathogens that need live host tissues. It is least effective in preventing sickness brought on by viruses that may infect a variety of hosts or that have long-lasting survival mechanisms like sclerotia or oospores. The severity of the Rhizoctonia disease has also been demonstrated to be influenced by seed source, perhaps as a result of different levels of microbial antagonists. Production of antibiotics, siderophore synthesis, nutrition competition, niche exclusion, and development of systemic acquired host resistance are just a few of the ways endo-phytes might function as biocontrol agents. Hence, bacterial endophytes may contribute to pathogen control, and complementing crop sequences may promote advantageous allelopathy. The symbiotic mycorrhizal networks aid in nutrient uptake by plant roots. In a number of other ways, mycorrhizal fungi shield plant roots against illnesses. They include creating a physical barrier to stop the pathogen's invasion, secreting chemicals that are hostile to it, engaging it in competition, enhancing plant roots' capacity to absorb nutrients, and altering the quantity and nature of their root exudates[8].

pH of the soil

Indirectly, via the availability of soil nutrients to the plant host, and directly through impacts on the populations of soil-borne pathogens and microorganisms, soil pH affects plant disease infection and development. For instance, pH levels less than 4.0 decreased sporangium production, zoospore discharge, and the mortality of zoospores of Phytophthora cinnamomi. While the disease did manifest in soil pHs of 8.7 and 9.8, the proportion of peanut stems infected by Sclerotium rolfsii was higher at soil pH 5.6 than in more alkaline soil.

Holmes et al. used Pythium oligandrum as an antagonist to examine the impact of pH levels ranging from 4.5 to 8.0 on the biocontrol of sugar beet damping-off. They demonstrated that this species could regulate sugar beet damping-off before and after emergence, but only at pH 7.0 and 7.5. A pH of 5.2 to 8.0 or higher might cause severe cases of potato common scab. According to Sullivan, this disease is often inhibited at lower pH levels but is more severe in soils with pH values over 5.2. The soil becomes acidic due to sulphur and ammonium sources of nitrogen, which additionally the prevalence and severity of potato scab. Liming, on the other hand, makes the illness worse.

Although increasing soil pH or calcium levels may be helpful for disease management in many other crops, reducing pH is an efficient method for controlling potato scab. There are correlations between disease incidence and pH values, cation exchange capacity, sodium in solution, and iron, according to studies on the impact of soil factors on Fusar-ium wilts in banana plants. According to Blank and Murray, Cephalosporium gramineum conidia did not significantly differ in their ability to germinate in soil with a pH range of 4.7 to 7.5.

In terms of soil fertility and nutrient availability, soil pH is crucial. The occurrence and severity of several illnesses may be influenced by the host's weakened nutritional state brought on by soil acidity. For instance, certain plants benefit from improved manganese absorption and appropriate manganese-stimulated disease resistance in an acidic environment.

For a variety of crops, including tomato, cotton, and melons, a clear association between sufficient calcium levels and/or higher pH and declining levels of Fusarium incidence has been shown. Applying lime to the soil improves its pH and lessens the likelihood of carrots developing cavity spots. Amendments with lime and gypsum may alter the availability of nutrients, the acidity of the soil, and the severity of diseases.

Soil Structure and Texture

Due to their impact on root development, water-holding capacity, nutritional status, and gas exchange, soil texture and structure may have an impact on plant diseases. For instance, clay soils have a lower incidence of stem rot in cauliflower than sandy soils do. Sand had a faster rate of radial spread of the wheat root rot pathogen than loamy sand, which in turn had a faster rate of radial spread than sandy clay loam soil. The sandiest soil, according to Bolanos and Belalcazar, was where Erwinia chrysan- themi impacted plants the most. Whereas Rotylenchulus reniformis reproduction was highest in loamy sand, Meloidogyne incognita reproduction was larger in coarse-textured soils than in fine-textured soils. In this research, silt and clay percentages were shown to have an adverse effect on the population densities of M. incognita, but R. reniformis was favored by moderate levels of clay plus silt of around 28 wt%. In many illnesses, the interaction between tillage and soil texture is crucial. Tillage did not have an impact on the severity of early season damping-off, although it did interact with texture. In silt loam and loam soils, it was found more often after conservation tillage than during conventional tillage. While the frequency was much higher in sandy loam, compared to conservation tillage, conventional tillage. There was no tillage-texture interaction overall, but tillage and soil texture had a substantial impact on the population densities of Heterodera glycines. In no-till fields that were left unaffected from harvest to planting, there was an inverse association between the population densities of Heterodera glycines nematodes and the percentage of clay, while in tilled fields, there was little to no change[9].

The likelihood of a severe infection with several plant pathogens increases significantly under adverse soil structural conditions brought on by soil compaction or inadequate drainage. In wheat take-all, a low concentration of the illness was tolerated in dense soil with no impact on crop production. Yet, the same degree of illness was much more detrimental when compaction led to delayed drainage. Cavity spot disease in carrots was linked to low soil aeration brought on by unfavorable soil type, soil structure, or water logging. Compaction, temperature, and soil moisture are known to have an impact on the pea root rot complex. Chang demonstrated that root rot greatly enhanced the frequency and severity of the illness when soil bulk density rose as a result of compaction. The disease also significantly decreased the fresh weight of pea plants. Root rot pathogens often cause less severity and damage to many plants, including beans, when tillage measures that improve drainage, decrease soil compaction, and raise soil temperature are applied. Due to increased root penetration and development, breaking hard pans and subsoiling following seedbed preparation were observed to minimize Fusarium root rot damage in beans. Several findings suggest that adding organic matter enhances soil structure. The structure of the soil food web, which is important for the turnover of the microbial biomass and macronutrients, may be significantly impacted by the usage of organic materials as mulches.

Cropping systems and agricultural methods number seven

Several researchers have hypothesized that the use of agrochemicals and other changes in cropping systems and agricultural practices after World War II are to blame for the increased pest and disease pressure in agroecosystems. Rotation, fertilization, and the use of pesticides are examples of cultural practices and cropping systems that may have an impact on soil properties and plant disease development. The ways in which conventional and organic agriculture methods address soil fertility and insect control are two key contrasts. According to Brown et alexperiments's and on-farm surveys, organic farm management is linked to improved soil physical, chemical, and biological features. The four essential elements nitrogen, phosphorous, potassium, and calciumare often supplied as synthetic fertilizers in quite strong amounts that go beyond crop requirements in traditional systems. Both an increase and decrease in the availability of certain nutrients necessary for crop development and a change in the pH of the soil, as well as a short-term increase in productivity, may result in soil imbalances. On the other hand, if certain other necessary components are not restored in time to fulfill crop need, deficits may develop over a longer period of time. In contrast, organic systems employ organic manures that include both moderate levels of the core components and minor and trace elements. Organic farms benefit from balanced fertility, which reduces disease control challenges.

In traditional agriculture, regular applications of easily soluble fertilizers contribute directly to the supply of immediately usable nutrients and, to some degree, cut out soil processes. In organic systems, organic or slow-release sources of nutrients are often introduced to the system. A larger emphasis is put on chemical and biological processes to release nutrients in plant-available forms in soil solution since the majority of materials absorbed into the soil in organic systems do not contain easily soluble nutrients.

According to some sources, soil on organically managed farms is more fertile than soil in conventional systems, having higher levels of total N, total P, humic acid, exchangeable nutrient cations, water-holding capacity, and microbial biomass. It also typically contains an average and balanced level of nutrients that are good for managing disease. Nine farms were examined, and seven had greater levels of N, six had higher levels of P, and three had higher levels of K in the organic portion of the farm than in the conventional portion. The soil was discovered by Derrick and Dumaresq on an organic farm compared to traditional farms, contained lower quantities of exchangeable Mn and greater concentrations of exchangeable potassium, calcium, and sodium. The concentrations of total Mg, Na, N, Mn, and K, as well as the exchangeable Mg and organic carbon content, did not vary significantly between organic and conventional farms.

According to Joo et al., the accessible phosphorus levels in organic and conventional agricultural soils were 986 mg/kg and 935 mg/kg, respectively. The average total phosphorus levels were 1830 mg/kg in conventional farm fields and 2973 mg/kg in organic farm fields. According to Oehl et al., a balanced amount of accessible phosphorus was maintained after 21 years of organic management. The availability of phosphorus is kept constant via an equilibrated input-output budget. According to Wells et al., accessible phosphorus rose on the organically managed field more than on conventional farms after three and a half years of vegetable cultivation. In comparison to traditional systems, organic and low input systems had considerably greater levels of substrate-induced respiration, mineralized nitrogen, extractable carbon and nitrogen, and arginine synthesis.

A handful of sources, nevertheless, provide the opposite findings. Derrick and Dumaresq noted that the soil of organic farms had noticeably lower quantities of phosphorus that could be extracted. In the organic cropping systems, there was a negative nutritional balance for potassium, according to Loes, Ogaard, and Haraldsen et al. According to the research mentioned above, farms that are maintained organically have better soil nutrient balances, which contributes to a reduction in long-term illness issues.

Many organic amendments and residue management techniques help to control plant diseases, however our knowledge of the underlying processes is still restricted. Under organic farming methods as opposed to conventional farming systems, soil organic matter content and biological activity are often greater. According to Joo et al., the organically managed farm had an average organic matter content that was 44 g/kg as compared to 24 g/kg, which was substantially higher. Yet, other studies indicate that there aren't any significant differences between organic and conventional systems in terms of the overall organic matter concentration.

According to published research, applying certain organic manures raises the total phosphorus levels in the soil, which in turn promotes the growth of several plant diseases. A high quantity of total phosphorus may result from the recurrent application of composted manure with a low N/P ratio. Shepherd et al. came to the conclusion that ephemeral stabil- ity through fungal hyphae, extracellular polysaccharides, and regular input of new organic matter is essential for strengthening soil structure. As compared to chemical fumigants or fungicides, the advantages of using organic amendments for disease management are gradual and often slower acting, but they may also persist longer and have cumulative effects. Organically cultivated soils often include practices that incorporate organic elements.

Agricultural methods that alter the soil environment have a significant impact on the microbial communities that live in the soil. According to Peacock et al., soil management techniques that result in variable carbon inputs also have an effect on the biomass size and community structure of the soil. Using cover crops and organic amendments to improve the carbon availability to microorganisms is one such technique. Gunapala and Scow studied the dynamics of microbial communities over the course of two growing seasons in soils beneath tomatoes grown using conventional techniques with 2- and 4-year rotations, minimal input, or organic approaches. In the conventional system, microbial composition strongly connected negatively with the levels of soil mineral N, but in the organic system, they favorably correlated with mineral N.

Microbial activity and biomass were shown to be greater under the organic management technique, according to Bolton et al. Another research revealed that although the ratio of active-to-total bacterial biomass was greatest in organic field soils, total bacterial biomass was higher in conventional field soils. According to Schjonning et al., microbial biomass C in dairy farm soils was greater following long-term organic management of more than 40 years. Increased soil microbial activity enhances the possibility of competition effects in the soil by releasing carbon from crop leftovers.

The pathogen's capacity to live may be reduced if the residue is placed in soil and causes it to be ejected from its preferred environment. As a result of converting to organic land management, soil microbial biomass changes, and plant pathogen populations vary between organic and conventional systems. Moreover, the variety and presence of helpful species like insect pathogenic fungus are positively impacted by the lack of synthetic pesticides in organically cultivated soil. Traditional agricultural practices are often linked to issues including the degradation of soil structure. According to Brown et al., organic farms had the greatest mean humic acid content, air capacity, and accessible water capacity, whereas conventional farms had the lowest values for aggregate stability and cation exchange capacity.

Traditional farming practices sometimes entail repetitive plowing, constant exposure of bare soil to rain, and a heavy reliance on pesticides and fertilizers. Such practices may seriously harm soil structure, cause soil erosion, lower soil fertility, lose fertilizers and other chemicals due to increased run-off and leaching, and ultimately create an environment that is less conducive to plant development and more conducive to the occurrence of plant diseases. Compaction and erosion occurred on the traditional farm as well. When the soil resource degrades over time, these consequences may result in decreased production and profitability. Gerhardt came to the conclusion that an organic farm had considerably improved soil structure over a conventional farm, with greater A-horizon depth, organic matter content, porosity, number and activity of earthworms, and better-developed aggregates[10].

Long-term soil structure maintenance and improvement are possible using organic management techniques. According to Wells et al., organically managed fields' cation exchange capacity rose after three and a half years of vegetable cultivation. The organic farms' soil qualities have shown to have a better, more pronounced on-site sustainability benefit over conventional systems. Many secondary plant metabolites have a role in plant insect defense. For instance, phenolic compounds, which are often found in fruits and vegetables, serve as a barrier against insect and mammal herbivory. Traditional farming methods use quantities of pesticides and fertilizers that may prevent a plant from naturally producing phenolic compounds. There is a wealth of research that suggests secondary plant metabolites are important for both plant and human health. Due to their strong antioxidant activity and a variety of pharmacological characteristics, including as anticancer, antioxidant, and aggregation inhibitory action, plant-based phenolic metabolites are particularly significant. There is increasing concern that certain phenolic levels in foods produced using standard agricultural methods may be below what is best for human health. It is possible that organically cultivated food may be healthier for plant and human health than similar conventionally grown product due to differences in the concentration of secondary plant metabolites in organic and conventionally produced fruits and vegetables.

Among the most crucial elements of integrated soil management and crop disease suppression are the soil environment, notably balanced fertilization. There is evidence that links the availability of various plant nutrients with the prevalence of certain illnesses in both a good and a negative way. High nutrient concentrations have been shown to generally increase the incidence of illness. Hence, it would seem that maintaining balanced soil fertility, which is often accomplished by applying the right quantity of organic matter, might be an effective method of preventing crop diseases. Plant diseases grow and spread as a result of variables including soil moisture and temperature. The advantages of the aforementioned elements are mostly to blame for this. It has been shown that solarization, which involves applying high temperatures, harms microorganisms. Yet, the interaction between these elements has a significant role in the survival and occurrence of diseases.

It has been discovered that high soil microbial biomass, a measure of soil biodiversity, influences disease incidence by having a greater antagonistic effect on plant pathogens. By using effective crop management techniques, such as the right crop rotation, tillage method, mulch application, etc., this might be improved. The prevalence of illness has also been observed to be positively or adversely impacted by soil pH. According to research, soil-borne diseases are especially affected by this directly or indirectly through affecting the soil's capacity to hold onto nutrients. It has been discovered that the degree of soil compaction, drainage, and soil temperature are all influenced by the physical characteristics of the soil, including temperature, moisture, and structure.

CONCLUSION

In order to control crop diseases in all cropping systems, a range of organic resources, including compost and manure, may be utilized to enhance soil structure, food webs, and the mineralization of nutrients in the root zone. Nearly all crop production practices have an impact on the populations of plant pathogens and the severity of diseases, as well as the good soil microflora and fauna. The requirement to restore organic matter to the soil after harvesting ought to be a top priority for current agricultural techniques. Those findings provide intriguing evidence in favor of the hypothesis that long-term management of soil organic matter might improve plant tolerance to pests and diseases. To address the many soil and environmental quality problems brought on by the widespread adoption of agricultural techniques, a concentrated research effort is needed. To better understand the biological, physical, and chemical features of soil and their effects on plant diseases, and to create a contemporary integrated pest control program, a comparative research of field soils from conventional and organic farms is required. The advancement of agroecological crop production systems that incorporate agroecological techniques to maximize soil organic fertilization, crop diversity management, and more natural systems of pest regulation without suffering significant yield penalties should be encouraged by growing knowledge about the relationships between soil fertility and pests or diseases.

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CHAPTER 11

PROTECTING THE LAND WITH ORGANIC AGRICULTURE

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ABSTRACT:

In Europe, erosion affects around 17% of the continent's total land surface, and 45% of the continent's soils are thought to have little organic matter. Agri-culture takes up the biggest amount of the land, hence agricultural management is crucial for soil quality and conservation. Here we analyze, on the basis of published studies, whether or not organic farming could be a means to preserve and improve soil quality. Studies of real farms and results of field tests all agree that with time, differences between organic and conventional farming techniques become more obvious. Soil organic matter often accumulates or is preserved better with organic farming practices. With two research showing no discernible differences and two studies with extremely old organic farms demonstrating 50–70% more soil organic C than their conventional neighbors, soil organic carbon was 6-34% higher under organic management than under conventional management.

KEYWORDS:

Aggregate stability, Erosion, Nitrogen, Phosphorus, Potassium, Soil organic matter,Water infiltration, Water holding capacity.

INTRODUCTION

This coincides with an up to 21% rise in soil total nitrogen concentration, yet it has been shown that nitrogen-conserving techniques employed in organic farming prevent increasing nitrogen losses to groundwater. When comparing "organic" management to conventional management, there doesn't seem to be any overall trend in the "plant available" soil concentrations of phosphate and potassium. Organic agricultural methods often have a favorable impact on soil structure. Infiltration rates were up to twice as high and macroaggregate stability increased by up to 70% in organic farming compared to conventional management. In the experiments studied, soil water content rose by 5-72%, and it was estimated that this increase in soil water content was responsible for the organic systems' 30% greater yields during the very dry years encountered during the Rodale Farming Systems Trial. Erosion was decreased under organic management, as determined by measuring topsoil thickness, resulting in topsoils that were 2–16 cm thicker. Between 15% and 30% less erosion was seen under organic management when the universal soil loss equation approach was applied to simulate erosion[1].

In conclusion, the study's analysis demonstrates that organic management preserves and enhances soil quality. Larger inputs of organic matter, more varied crop rotations, including cover crops and green manures, and prolonged soil cover were identified as the key drivers of these advantages. These advantages of organic farming may be depended upon since it is the only farming system that is legally defined and regulated, notwithstanding some variation within organic farming due to varying farm types and production intensities. Several crucial tasks for both the environment and man are carried out by soils. Water, air, organic matter, and mineral cycles are regulated by soils under both natural and anthropogenic conditions. They store, transform, buffer, filter, and buffer data. Microorganisms, plants, animals, and people all rely on soils as their primary source of food and shelter. And last but not least, soils are the foundation of forestry and agriculture. In light of this, it is concerning that soils are coming under increased strain from landslides, salinization, erosion, pollution, sealing, loss of organic content, and other factors. 17% of Europe's total land surface is affected by erosion, and 45% of its soils are thought to have little organic matter. Particularly in the new EU member states, soil compaction is seen as a significant threat to soil fertility. The costs of off-site effects on the nearby civil public infrastructure, such as the destruction of roads and siltation of dams, reach about EUR 32/ha, according to estimates from the European Environment Agency. Economic losses due to soil degradation in agricultural areas of Europe are estimated to be around EUR 53/ha per year.

Only after storms, floods, and marsh slides does soil degradation come to the attention of the general public; otherwise, it happens quietly and without being recognized. As agriculture takes up the majority of land, agricultural management is essential for maintaining the quality and quantity of the soil. Pesticide contamination, one of the most prevalent issues with conventional agriculture, is completely avoided with organic farming since pesticides are not utilized. As many of the early proponents of organic farming, including Eve Balfour, Albert Howard, Newman Turner, Friend Sykes, and Hans Peter Rusch have stressed, the fertility of the soil is perceived to not only have implications for soil degradation but also for the health of the crops, animals, and people who derive their sustenance from it. This is why soil quality and health play such an important role in organic farming.

"Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them, and help sustain them," and "Organic agriculture should sustain and enhance the health of soil, plant, animal, human, and planet as one and indivisible" are among the principles of organic farming, according to the International Federation of Organic Agriculture Movements. The cornerstone of organic farming is said to be the live, healthy soil, which serves as the foundation for healthy plants, healthy animals, and healthy goods. The maintenance of soil structure, earthworms, microbes, and bigger insects is crucial to the operation of an organic system since organic farming is entirely reliant upon maintaining ecological balance and growing biological processes to their maximum potential. Hence, protecting the environment and the soil is a basic "must" for the organic farmer and cannot be added on later if revenues permit. The objective of the current analysis is to assess whether organic farming can live up to its promises to preserve the soil and sustain soil quality in comparison to conventional farming approaches based on published research findings[2].

Organic Matter in Soil

Climate, soil texture, and soil drainage quality are the main factors influencing the concentration of organic matter in soils. Crop management and rotation often have a smaller but still significant influence. Since it is regarded as the foundation of soil fertility in organic farming, preserving and growing soil organic matter is given high priority. For instance, the Bio Austria Association's guiding principles state that "Organic farming aspires for a focused humus management. Hence, the long-term losses from decomposition must at least be offset by the intake of organic matter. Increased soil life activity is the goal of fertilization.

Several field studies in the United States and Europe compared the effects of organic vs conventional management on changes in soil organic matter and soil organic carbon, respectively. In the Sustainable Agricultural Farming Systems experiment, cover crops, organic fertilization using composted and aged manure, and an eight-year crop rotation experiment on silty soil were all used. The organic treatment used a four-year crop rotation, while the conventional treatment used a straightforward two-crop cycle with no cover crops and mineral fertilizer. The soil total carbon content, as measured by combustion analysis, had considerably risen in the organic treatment after eight years, going from 9.11 g kg-1 to 10.21 g kg-1, whereas it had stayed constant in the conventional treatment. In other studies, both the organic and conventional treatments used the same crop rotation.

In the Rodale Institute Farming Systems study, conventional management with a straightforward maize-soybean rotation was compared to organic management with legumes, both with and without cow manure. After 21 years, the soil had considerably more total carbon than the conventional treatment, as measured by combustion analysis, at 25 and 24 g kg-1 in the organic treatments with and without manure, respectively.In the Swiss DOK experiment, biodynamic management using composted cow manure and biodynamic preparations as well as organic management using rotted cow manure were compared to conventional management, both with and without cow manure, as well as to a control group that didn't receive any fertilizer. In the biodynamic treatment, soil organic carbon, as determined by K2Cr2O7 digestion, had grown by 1% after 21 years, but the soils in the organic treatment and the conventional manure treatment had lost, respectively, 9% and 7% of their Corg. 15% of soil Corg was lost with mineral fertilizer, while 22% was lost without treatment[3]. There are, however, a few studies that found no significant differences between conventional and organic farming in terms of the humus concentration. At the Koln-Aachener Bucht, two paired farms with loess soil and very high natural fertility that had been managed differently for more than 10 years were examined by Konig et al. In general, there were no differences between conventional and organic farms in the amount of soil organic matter as measured by dry combustion. The impacts of manure treatments and the usage of lucerne-grass on organic farms were overshadowed by the increased plant and root biomass with mineral fertilization.

Just a trend toward greater soil Corg concentrations with organic management was seen in a research comparing 256 paired plots on nearby conventional and organic farms across Germany. Yet, there was a noticeable increase in soil microbial biomass under organic management. The site circumstances and variations in humus reproduction within organic and conventional farms, respectively, were blamed for the absence of changes in soil Corg.

In conclusion, increased soil organic matter content under organic management is often seen in comparisons of identical farms with similar soil and climatic conditions, with differences becoming more noticeable over time. In addition to these impacts on the overall amount of organic matter in the soil, numerous authors have demonstrated that ongoing additions of organic matter, along with varied crop rotations, low nutrient input, and giving up pesticide use, typically increase the size of the micro-biome and promote enzyme activity. The addition of organic matter to soils has also been demonstrated to significantly enhance earthworm populations by providing an extra food source. When the proportion of the most stable humin grows, the composition of humus likewise changes.

In conclusion, the results of field experiments and studies on real farms consistently demonstrate that, while the amount of soil organic matter varies greatly depending on the site conditions and farm type, differences between organic farming and conventional farming practices are typically better at increasing or conserving soil organic matter over time. Larger organic inputs such manure, manure compost, and biowaste compost as well as more varied crop rotations that often include cover crops are to blame for the rise in soil organic matter.

DISCUSSION

Increased soil nitrogen mineralization results from higher total nitrogen levels. In organic farming, this is desirable and required to feed crop plants from the resources of the soil, but it may also carry the danger of increased nitrogen leaching into the groundwater. Organic farmers aim to lose as little nitrogen from their soils as possible for ecological, but more importantly for economic, reasons due to the prohibition on synthetic nitrogen fertilizers and stringent regulation of imported organic fertilizers. Studies comparing the nitrogen balances of organic and conventional farms show that organic farms are more effective at using nitrogen. Several research examined the nitrogen-leaching capacity of organic vs conventional farming methods based on nitrogen concentration in the unsaturated zone, nitrogen leaching, and residual N in the soil profile in the fall.

These studies shown that organic management generally results in lower nitrogen losses; however, they also demonstrated that certain organic agricultural management approaches, particularly those that include plow- ing in cover crops of legumes, may be problematic in this regard. Using green manure at the right time is essential to prevent nitrogen leaching losses. To adapt the nitrogen supply to crop demand in time and place, organic farmers use a variety of methods.

Particularly in the second year after the incorporation of green manure, cover crops are a crucial strategy in the context of decreasing N losses. The process of decomposition and N mineralization of green manure plant material may be influenced by variations in the chemical makeup of plant species and varieties, i.e., various clover/grass mixes. Annual plants with deep roots that were seeded in the fall and had a strong root system by spring might access nitrate before it dropped below the maximum rooting depth. Deep-rooted plants like sunflower and safflower as well as green manure legumes like lucerne may be useful for recovering minerals that have been deeply leached. Moreover, intercropping grains and legumes has the potential to enhance nitrogen usage[4]. The overall soil nitrogen concentration often rises under organic management, according to the findings of both field tests and investigations on actual farms. Nevertheless, owing to several nitrogen-conserving techniques utilized in organic farming, which result in an overall greater nitrogen efficiency of organic farms, this increase does not cause an increase in nitrogen losses in the groundwater.

Potassium and Phosphorus

Inorganic phosphates make up the majority of the phosphates in soil, either as distinct phosphate compounds or films of phosphate retained on top of organic ppapers. Adsorbed phosphorus diffuses over time into the soil matrix, rendering it temporarily inaccessible for absorption. P may shift from weak to strong and from strong to weak bonding sites, despite the fact that it was formerly believed that P was permanently fixed in soils.The phosphate supply to a plant is greatly influenced by the size of the root system, the density of its root hairs, the intensity of its ramifications, and the level of mycorrhization because of the sluggish rate of diffusion of phosphate. Even in calcareous soils, plants, especially legumes, may mobilize soil phosphates via proton excretion and acidification of the rhizosphere. Consequently, growing a variety of crops together with green manures encourages the availability of P. Lindenthal looked at phosphorus absorption and availability in prolonged fertilization studies. He claimed that treatments without P fertilization resulted in a significant and long-lasting mobilization of soil P stores.

The flux of phosphorus between the matrix and the soil solution, as determined by the 32P isotopic exchange kinetic method, was found to be highest with biodynamic management in the DOK experiment, where biodynamic management and organic management were compared with conventional management, both with and without cattle manure, and with an unfertilized control group.

Soil Organization

In terms of agronomy, a "good" soil structure is one that demonstrates the qualities of optimal soil strength, aggregate stability, optimal bulk density, optimal water-holding capacity, and optimal rate of water infiltration. These qualities provide resistance to structural degradation, such as capping/crusting, slaking, and erosion. The water stability of aggregates is dependent on organic components, as shown by Tisdall and Oades. Organomineral complexes and humic acids are examples of persistent organic binding agents that are categorized as transiently effective compounds, momentarily effective compounds, and temporarily effective compounds based on their stability. The first two types of compounds are what have an impact on cover crops and green manures. Living roots from cover crops or green manuring provide significant numbers of dead cells, exsudates, and secretions to the soil, which provide soil microbes with a food source.

In addition to producing polysaccharides, microbes that break down organic materials also make clover, grass, and fungal hyphae, which enmesh aggregates and stabilize them. Arbuscular mycorrhizal fungus use the glycoproteinaceous compound glomalin to maintain soil aggregates. Even more than trash and agricultural leftovers, dead roots serve as a substrate for slowly developing microorganisms, notably fungus. Due to the short to medium duration of these organic binding agents' effects, regular addition is necessary[5]. Since the organic matter in this scenario is rich in humic acids, which constitute rather persistent binding agents, the addition of decomposed or composted materials, such as manure or compost, results in a more gradual but long-lasting increase of aggregate stability. Consequently, a blend of green manures with composted or decomposed materials yields the best results.

There is often a strong association between the amount of organic matter in the soil and the stability of its aggregates since organic matter is so crucial to the production of stable aggregates. There is a lot of data to suggest that organic farming and fertilizer increase the stability of soil aggregates. Since 1956, the treatments of bare fallow, no-N, green manure, farmyard manure, and peat have been contrasted in the long-term soil organic matter experiment at Ultuna. On the basis of equal quantities of ash-free organic materials, the organic fertilizers are applied. The stability of the soil aggregate responded clearly to soil management. It increased from bare fallow to no-N to green manure to peat to farmyard manure in the following sequence. Except in the peat treatments, where the unfavorable high C/N ratio was present, increasing Corg concentrations generally increased aggregation ratio and the diminutive size of the microbial biomass resulted in a noticeably diminished impact of the soil organic matter.

Since 1978, biodynamic management, organic management, conventional management, both with and without cow manure, and an unfertilized control group have all been contrasted in the DOK experiment. Two approaches were used to determine aggregate stability. The stability of aggregates derived from the biodynamic farming method was greatest when assessed using a rainfall simulator. In both organic farming systems, aggregate stability in percolating water was consistently greater than in conventional agricultural systems. On three different dates, it varied from 533 to 881 ml 10 min-1 for the biodynamic treatment and from 408 to 937 ml 10 min-1 for the organic treatment, as opposed to 301 to 745 ml 10 min-1 for the conventional treatment using manure and 167 to 630 ml 10 min-1 for the conventional treatment using mineral fertilizer alone.

Enhancement in soil aggregation has been shown in both organic treatments after the production of legume hay and cover crops in the Rodale Institute Farming Systems study, which compared organic management with legumes and with and without cow dung to conventional management.Maidl et al. evaluated 10 pairs of fields in Bavaria that were managed organically vs conventionally. The aggregate stability was greater in the organic fields in eight of the pairings. In the organic fields, the overall stability of all pairings was, on average, 4% greater.

The larger proportion of grass-clover leys in the crop rotation and the shallower soil cultivation on organic farms were also factors in the better aggregate stability under organic management. Water stable macroaggregation was 75% under organic farming and 44% under conventional farming in a paired farm research conducted in the Netherlands using two farms that had been managed differently for 70 years[6].

Yet, two studies comparing matched farms found little variations in aggregate stability. The distribution of organic matter in the soil profile and the threshold value for organic matter in soils, past which there is no further rise in stability, may both have a role in this. Other chemicals, such as CaCO3, may also have stabilizing effects. Due to a diluting effect brought on by the mixing of the new organic material with the denser mineral portion of the soil, soil bulk density may decrease in organic farming as a consequence of the addition of organic matter. Soil bulk density was an average of 1.26 t m-3 in the organic fields as opposed to 1.36 t m-3 in the conventional fields in a study of five farm pairs in Nebraska and North Dakota where the organic farms had been organic for 9-29 years. In contrast, when the soil settles from lack of soil cultivation, increasing growth of grass and clover may lead to an increase in soil bulk density. soil compacting due to traffic and agricultural practices heavy equipment usage and cultivation of wet soils both have a detrimental impact on soil structure and water penetration.

Field passes are not necessary while farming organically for the application of pesticides and herbicides. To manage weeds mechanically, additional field passes are required. The more varied crop rotations used in organic farming reduce the risk that the soil is cultivated improperly in wet conditions, which may be unavoidable if a significant portion of the farm is growing the same crop, as is the case in many conventional farms, and cultivation must be finished in a specific amount of time. Certain inorganic fertilizers, such ammonium sulphate, cause the disaggregation of soil clods, which has a negative impact on soil structure. A soil with higher biological stability may respond to pressure more quickly, become less compressed, or recover from a short-term compression more readily than a soil with less biological stabilization.

In numerous ways, soil organic matter affects the water regime in soils. Secondly, organic matter improves the soil's ability to store plant-available water, which is measured as the difference between the amount of water stored at the permanent wilting point and that at field capacity. It achieves this by directly absorbing water as well as by promoting the development and stability of aggregates with plenty of holes that can store water under mild pressure. Hudson evaluated the impact of soil organic matter on the amount of water that was accessible in three different textural categories of surface soils. The amount of water maintained at field capacity grew considerably more quickly within each group as organic matter increased than it did at the permanent wilting threshold. As a consequence, extremely substantial positive correlations between the amount of organic matter and the amount of water that is accessible were discovered. The available water holding capacity of the soil more than doubled as the organic matter level rose from 0.5 to 3%.

Total porosity and pore size distribution, on the one hand, impact soil water infiltration and the soil's ability to store water, which may protect crops from water stress during dry seasons.

Even during periods of heavy rainfall, water will permeate the soil in soils with high infiltration rates, but in soils with low infiltration rates, some of the rain will be lost as surface run-off, reducing crop water availability and accelerating erosion.

Long-term organic management also results in improved soil water-holding capacity. In California's Sustainable Agriculture Farming Systems experiment, cover crops, composted and aged manure, and a four-year crop rotation were used in the organic treatment whereas mineral fertilizer and no cover crops were used in the conventional treatments. With the low-input approach, cover crops were employed instead of as many herbicides and fertilizers. After ten years, the organic system had a greater measured soil water content than the conventional systems. In the Rodale Farming Systems study, soil water content was measured for the organic legume and conventional systems over the growth seasons of 1995, 1996, 1998, and 1999[7].

Water infiltration capacity is influenced by soil porosity and soil structure, especially near the soil surface. Organic matter affects infiltration rate by enhancing soil structure and porosity. The increased porosity in organically managed soils is mostly due to earthworms, which are commonly said to be more prevalent in organic farming. Earthworms produce a significant number of macropores via their burrowing activities. Organically managed fields may have infiltration rates that are twice as high as conventionally managed fields, particularly due to the ideal circumstances for biopores. After 10 years, soil water infiltration in the Sustainable Agriculture Farming Systems experiment in California was 0.028 m3 m-1 for the conventional, 0.062 m3 m-1 and 0.065 m3 m-1 for the low-input and organic, respectively systems, correspondingly. After 10 years, the penetration rate was also assessed in the Rodale Farming Systems study and fell in the following order: organic management with legumes and with cow dung, organic management with legumes alone, and conventional management.

In general, organic farming techniques such organic fertilization, cover crops, and green manuring often have a favorable impact on soil structure as evaluated by soil aggregate stability, water-holding capacity, and water infiltration capacity. More water may be absorbed by the soil after heavy rain thanks to higher infiltration rates, which may lessen how severe floods are. A characteristic that may become even more crucial in light of the anticipated climatic changes is increased soil water-holding capacity, which has been demonstrated to significantly boost production during very dry years. This trait improves the water supply for the plants during dry seasons.

Erosion

The soil's ability to absorb water is another important factor in erosion vulnerability. Rainfall that is unable to permeate the soil will instead run off at the surface, triggering erosion. While a site's susceptibility to erosion is mostly determined by its terrain and climate, the kind of land use has a significant impact on how quickly erosion begins and progresses, how much soil is lost, and how much damage is done.

For example, crop rotations with a high proportion of forage crops and a low proportion of row crops, the use of cover crops and undersown crops, which keep the soil covered all year long, and the addition of organic matter with all its beneficial effects on soil structure are just a few of the cultivation techniques used in organic farming that can reduce erosion.

Yet, frequent soil disturbance caused by mechanical cultivation, which is important for organic farming's weed management, may raise the danger of erosion as well as the crops' slower early growth and early demise from disease. Organic gardening requires bigger cultivation areas than conventional farming because of poorer yields. Since it is often believed that they necessitate the use of herbicides, direct seed cropping and no-till farming, which are very successful at reducing erosion, are seldom encountered in organic farming in Europe. Yet, research from Brazilian farm studies suggests that using cover crops and rotating crops with legumes may make no-till farming without pesticides both technically and financially possible. Many field tests were conducted in Germany, Switzerland, and France to evaluate reduced tillage methods utilizing the chisel plow rather than the mouldboard plow. While not always, decreased tillage techniques enhanced soil aggregate stability, aeration, and water penetration capability and raised soil humus levels. Nevertheless, the decreased tillage treatments showed a propensity for poorer yields, which became substantial when there were serious weed issues. Reduced tillage in organic farming is conceivable, according to actual farmer experiences, but it requires a high level of knowledge and commitment on the part of the farmer as well as customization to specific farm circumstances[8].In the research studied, the increase in soil organic matter under organic management results in an increase in soil total nitrogen content of up to 21%. Due to several nitrogen-conserving techniques utilized in organic farming, which result in an overall greater nitrogen efficiency of organic farms, it was shown that this increase would not cause an increase in nitrogen losses to the groundwater.

Comparing organic farming to conventional farming, there doesn't seem to be any overall trend in the "plant accessible" soil concentrations of phosphate and potassium. Nevertheless, the utility of soil analysis data is restricted since the amount of P and K that plants get is mostly dependent on the size, density, and mycorrhization of their roots. It has been shown that organic farming increases the availability of P through increasing soil biological activity. It is important to consider K's supply from the "nonexchangeable" pool.

Organic farming methods often have a favorable impact on soil structure as evaluated by soil aggregate stability, water-holding capacity, and water infiltration capacity. The physical enmeshing of aggregates by roots and hyphae, as well as the presence of organic substances like polysaccharides and humic acids, all of which are given by organic fertilization, cover crops, and green manuring, are necessary for aggregates to be water-stable. The impacts of organic farming in the research examined varied from having no effect to producing macroaggregates that were more stable by more than 70%.

Soil structure, especially at the soil surface, and soil porosity have an impact on soil water penetration. According to data from the Sustainable Agriculture Farming Systems project, organically managed fields may have infiltration rates twice as high as conventional fields, particularly due to the ideal circumstances for earthworms and the macropores they produce. More water may be absorbed by the soil after heavy rain thanks to higher infiltration rates, which may lessen how severe floods are. By directly absorbing water from the soil and stabilizing aggregates with plenty of pores, organic matter increases the soil's ability to store plant-available water. The studies studied showed an increase in soil water content of 5-72%, and it was suggested that this increase was responsible for the organic systems' 30% better yields during the trial's very dry years. According to one research, the available water-holding capacity was 19% greater in the organic fields there. Enhancing plant water availability during dry seasons is a trait that might become even more crucial in light of anticipated climate changes.

Measurements of topsoil thickness were used in various studies to evaluate erosion. There were 2–16 cm more topsoil remaining in the organically farmed soils, indicating that there had been less topsoil lost to erosion. Several studies that employed the USLE approach to estimate erosion found that organic management resulted in between 15 and 30% reduced erosion. Both approaches demonstrated that in organic farming, growth strategies that lessen soil erosion clearly exceed those bringing a greater erosion risk. As a result, soils grown organically suffer from erosion less often[9].In conclusion, the study's analysis demonstrates that organic management preserves and enhances soil quality. While there are certain differences between organic farming and conventional farming, the advantages of organic farming highlighted in this papercannot be solely depended upon various farm kinds and productivity levels. Yet, the only kind of farming that is governed by law and in which adherence to the rules by the farmers is carefully monitored is organic farming. As a result, there is a chance that the advantages of organic farming may materialize[10].

CONCLUSION

Although the amount of soil organic matter greatly depends on the site conditions and farm type, field experiments and studies on actual farms consistently demonstrate that increases in soil organic matter with organic farming practices are more pronounced than increases with conventional farming practices over time. The increase in soil organic carbon under organic management in the research reviewed varied from 6 to 34%, with two studies finding no obvious differences and two studies with very old organic farms showing 50–70% more Corg than their conventional counterparts. Larger organic inputs like manure, manure compost, and biowaste compost as well as more varied crop rotations that often use cover crops and green manuring are to blame for the rise in soil organic matter.

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CHAPTER 12

SURFACTANTS IN AGRICULTURAL SOILS MODIFIED BY SEWAGE

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ABSTRACT:

One of the most common and significant families of organic chemicals is the family of surfactants, which is present in many detergent compositions. Due to their extraordinary ability to change the surface tension of water and solubilize xenobiotic substances, surfactants have the potential to contaminate the environment. Domestic wastewater often contains detergents, which may be dumped in bodies of water without being treated, posing health dangers to those who consume the water. Although though a wide range of goods fall under the general category of "surfactants," just 10 different kinds of compounds account for 80% of their demand. The annual volume of the worldwide significant market exceeds 18 million tons.

KEYWORDS:

Agriculture, Bioavailability, Degradation, Environment, Sewage sludge, Soap, Soil, Surfactants.

INTRODUCTION

Continuously released into the environment in large amounts, surfactants build up in sediments and soils where, depending on their structural makeup, they may be destroyed or cannot. Most people use linear alkylbenzenesulfonate as a surfactant. In aerobic circumstances, LAS can be broken down, but under anaerobic conditions, it may remain in the environment. There are a number of ways that surfactants may infiltrate the terrestrial ecosystem, but using sewage sludge as fertilizer on agricultural land is by far the most significant one. The biota may be impacted by high surfactant concentrations and their breakdown products. Surfactants, on the other hand, may interact with both inorganic and organic pollutants owing to their amphiphilic nature, which may impact their bioavailability. The use, types, and consumption of surfactants, the analysis of surfactants in environmental matrices, the presence of surfactants in soil amended with sludge, the biodegradation of surfactants, the transport and fate of surfactants in wastewater treatment plants, the fate of surfactants in waters and soils, and the interactions of surfactants with soil contaminants are all covered in this review paper [1].

Surfactants, also known as "surface-active agents," are the primary ingredient in soap shampoo. They are also used in the composition of detergents together with auxiliary chemicals, boosters, and builders such as tripolyphos- phate. This kind of formulation is mostly used to remove fatty substances from various surfaces, including the human body, hair, clothing, and dishes. Although there was a time a few years ago when the increased use of builders also presented environmental issues, until the introduction of restrictive legislation, the focus of concern in terms of environmental issues is largely on the effects of surfactants from detergent formulations in ecosys- tems.

A crucial physical characteristic of surfactants is the presence of both hydrophobic and hydrophilic groups in each molecule, which enables these substances to form micelles in solution. Surfactants' detergency and solubilization capabilities result from the production of micelles in solution. The critical micelle concentration is the amount of surfactants in water at which surfactant molecules cluster together.

The switch from soap-based detergents to synthetic surfactants historically came as a result of the possible environmental contamination caused by surfactants. The transition era roughly spanned 1940 to 1970, during which time the usage of synthetics increased by three orders of magnitude while that of soap decreased by more than half. At this period, residential detergent usage also partially switched from solid to liquid form. Up until 1960, propylene tetramer benzene sulphonate was the main surfactant utilized in detergency.

During this period, sewage treatment issues started to crop up, and rivers and wastewater treatment facilities both had foaming issues. The discharge of propylene tetramer benzene sulphonate into water systems was shown to be resistant tobacterial biodegradation brought on by the branched alkyl chain. The use of this nonbiodegradable surfactant was outlawed, forcing the transition to more biodegradable straight-chain alkyl surfactants; as a result, linear alkylbenzene sulphonate has become the main anionic surfactant in use today [2].

Large amounts of detergents and their components are discharged into terrestrial and aquatic habitats after usage. LAS may infiltrate the terrestrial ecosystem via a number of different channels, mostly through the addition of sewage and the use of pesticides. It should be noted that, like detergent formulations, pesticide formulations for crop protection also comprise surfactants. The dominating input for soils, however, throughout the last several decades has been the use of sewage sludge as fertilizer on agricultural land. LAS concentrations in sewage sludge may reach more than 10 g/kg dry weight, which is a significant burden.

Soil modified with sludge may contain significant quantities of LAS and its metabolites. Nonetheless, it has been predicted that just 5% of the LAS produced in the United States makes it to the aquatic environment, where concentrations at g/L levels have been discovered. This is mostly because wastewater treatment effluents are discharged into surface waterways. The growing use of sludge as a pesticide and organic soil amendment highlights the need of researching how surface-active substances behave in agricultural soils. An analysis of the research on the properties of surfactants, their movement and alteration in wastewater treatment facilities, and their eventual destiny in the terrestrial environment is given.

Surfactant Usage and Consumption

One of the most often used families of organic compounds is the surfactant family, which is utilized in a variety of formulations in many different sectors including food, agrochemicals, home goods, paint, coating, textiles, dyes, and oils. The capacity of surfactants to produce micelles in solution is a crucial characteristic. Each surfactant molecule has both hydrophobic and hydrophilic groups, which contribute to this feature. Surfactants have the capacity to solubilize more hydrophobic organic molecules than would be dissolved in water alone at concentrations above the critical micelle concentration limit[3].

Surfactant Types

Surface-active substances have a distinctive molecular structure made up of a structural group called a hydrophobic group, which has very little attraction to water, and a group called a hydrophilic group, which has considerable attraction to water. A structure like this is referred to be amphiphilic. The hydrophilic group is often an ionic or highly polar molecule, whereas the hydrophobic group is typically a long-chain hydrocarbon.

Surfactant Applications

One of the most common and significant groups of chemical compounds is the surfactant family. In actuality, unique types of surfactants are found in the membranes of all living cells, making life on earth possible. Surfactants are utilized in a variety of formulations in a wide range of sectors, including the production of cosmetics, personal care products, home goods, paints, coatings, textiles, dyes, polymers, foods, agrochemical supply, oils, and wastewater treatment. Table 3 provides a short overview of the history of surfactants, beginning with soap, whose production was first documented by the Sumerians around 2500 BC.Because of its two key characteristics their ability to lower surface or interfacial tension and their capability to dissolve substances that are insoluble in water surfactants are frequently employed. Nowadays, a wide range of surface-active agents are referred to as "surfactants" in general. However just a few of products primarily LAS, lauryl ether sulfate, and alcohol ethoxylates can meet 80% of their demand; soap continues to be the surfactant used most often in the world[4].

The oldest and most commonly used surfactants are anionics, which are also widely employed in many technological and scientific disciplines in addition to being used as detergents. They are often regarded as the "workhorse" of the emergency sector. They have been effectively used to increase the effectiveness of the active substances in a variety of industrial processes, including cosmetics, biotechnological compounds, pharmaceutical and agricultural formulations, and cosmetics. The environmentally dubious branched alkylbenzene sulfonates are still in use in several nations, notably in the Asia-Pacific area and South America. Yet given their poor biodegradability, it won't be long until the already-dominant linear form takes their place.

The main causes of lauryl ether sulfate's 4.5% annual growth rate include the rising usage of dishwashing products, shampoos, and bath preparations with surfactants. Fatty alcohol sulphates will undoubtedly gain in significance as synthetic surfactants with improved performance replace conventional soap. Nonionic surfactants often combine with ionic surfactants because they are less sensitive to water hardness and pH and produce positive interactions. Alcohol ethoxylates' 4% annual growth rate is mostly due to the replacement of environmentally dubious alkylphenol ethoxylates, which are still utilized in certain regions of the globe[5].

Surfactant Analysis in Environmental Matrix

Throughout the last several years, the repeatability, selectivity, and sensitivity of the analytical techniques used to identify surfactants in environmental mixtures have all been progressively improved. The fundamental issue with surfactant analysis is that, because of their amphiphilic nature, surfactants often concentrate near surfaces. As a result, surfactant losses from aqueous solutions happen as a result of their adsorption onto testing equipment or suspended papersin particular for matrices like the quantitative recovery of the analytes develops into a significant issue when working with biological samples, sediments, and sewage sludge. Monitoring the levels of surfactants in soil modified with sewage sludge is necessary as a consequence of the fertilization of agricultural land with sewage sludge. Typically, samples are taken using a stainless steel corer from the top 5 cm of the soil, dried at 60°C, ground, and kept in the dark at 4–8°C.

Solid-liquid extraction is the preferred technique for removing surfactants from sewage sludge, sediments, and soils. Prior to quantitative determination, however, further purification of the extracts is often required. LAS are removed from sewage sludge by two different processes: a noncontinuous extraction into chloroform as ion pairs with methylene blue, or a continuous extraction using a Soxhlet apparatus with solid NaOH added to the dried sludge to improve extraction efficiency. LAS may also be extracted from sludge or sediment samples with recoveries of 85% by heating the samples in methanol under reflux for 2 hours.

Surfactant concentrations in environmental samples are often below the analytical method's limit. Preconcentration is thus required before analysis. Before the surfactants can be quantified, interfering elements from the matrix must be eliminated in a separate prepurification phase. Reversed-phase materials made of graphitized carbon black or silica gel modified with alkyl groups of various chain lengths are effective in concentrating anionic surfactants. Via the use of C2-, C8-, or C18-silica gels, LAS has been extracted[6]. A technique for the simultaneous measurement of LAS, nonylphenol ethoxylates, and their respective metabolites, sulfophenyl carboxylates and nonylphenoxy carboxylates, in water was developed by Marcomini et al. Samples of river or wastewater are brought to pH 2 with HCl and then run through C18 cartridges. With methanol, the adsorbed analytes are eluted.

The initial analyses of environmental surfactants used general analytical techniques like colorimetry and titrimetry. This technologies' principal drawback is that, in addition to surfactants, other problematic organic chemicals from the ambient matrix are also detected, leading to systematic mistakes. Yet, due to their ease of use and minimal requirements for equipment, colorimetric and titrimetric techniques are still often employed to determine anionic, nonionic, and cationic surfactants. Methylene blue is used to identify anionic surfactants. The method is based on the creation of ion pairs between anionic surfactants that may be extracted using chloroform and the cationic dye methylene blue. When the organic phase has been separated, the amounts of anionic surfactants are measured colorimetrically at 650 nm. With methylene blue, other anionic organic compounds also combine to create extractable complexes, which raises the value of the substance that makes methylene blue active. On the other hand, the prior approach has the issue that due of the presence of cationic chemicals, where ion pairs with anionic surfactants result in low results.

The measurement of individual compounds, isolated from all of their isomers and/or homologues, is the ultimate objective of the environmental study of detergents. When it comes to separation effectiveness and sensitivity, chromatographic techniques like high-performance liquid chromatography, gas chromatography, or supercritical fluid chromatography are among the most potent analytical tools. Surfactants are not very volatile, hence HPLC is employed much more often than GC. Liquid chromatography-mass spectroscopy coupling has been more popular with the introduction of atmospheric pressure ionization interfaces for the determination of surfactants.

The bulk of HPLC applications for determining anionic surfactants solely focus on the study of LAS, the surfactant that is now utilized the most in detergent compositions. In reversed-phase columns with a mobile phase modified with NaClO4, individual homologues of LAS are commonly separated using UV or fluorescence detection. The separation of the LAS homologues and their isomers is accomplished by using C18 columns with gradient elution. The isomers of every single LAS homologue, however, were eluted as a single peak by long-chain C18 phases with isocratic elution or short-chain alkyl-bonded reversed phases like C8 and C1 columns. Since there are a lot less peaks, chromatogram interpretation is made simpler as a result.

Lower detection limits are achieved using fluorescence detection because it is more sensitive and selective than UV detection. For the measurement of LAS by HPLC, detection limits of 2 g/L for water using fluorescence detection and 10 g/L for water using UV detection have been reported.

By combining an electrospray ionization interface with LC-MS, it was possible to determine LAS and their primary metabolites simultaneously. The use of a suppressor between the LC column and the mass spectrometer has solved issues with large salt loading of the mobile phase caused by the ion pair reagent[7]. Popenoe et al. devised an LC-MS technique for the measurement of fatty alcohol sulphates and lauryl ether sulfate. Ion spray LC-MS is used to identify the analytes after separation on a C8 column. The resulting mass chromatograms provide data on the distribution of the oligomeric ethoxylates as well as the distribution of the alkyl homologues.

As previously mentioned, alcohol ethoxylates, alkylphenol ethoxylates, and alkylpoly glycosides are the principal nonionic surfactants. Alkylphenol ethoxylates often feature branched-chain octyl- or nonylphenol, whereas n-alkanols with chain lengths of 8 to 20 make up the hydrophobic portion of alcohol ethoxylates and alkylpolyglycosides typically have alkyl groups with chain lengths of 8 to 18. The amounts to which alcohol's polyethoxylate chains have been polymerized ethoxylates and alkylphenol ethoxylates range in ethoxy unit count from 3 to 40, while alkylpolyglycosides polymerize on average with 1.3–1.7 moles of glucose per mole of fatty alcohol.

Alkylphenol ethoxylates were determined using a reversed-phase HPLC technique by Giger et al. on a C8 column with isocratic water/methanol elution and UV detection at 277 nm. The homologous alkylphenol ethoxylates series compounds are split into two peaks under these circumstances. The main use of normal phase HPLC is to gather data on the distribution of alkylphenol ethoxylate chains. Alkylphenol ethoxylates' individual oligomers may be identified using aminosilica columns with gradient elution and UV detection.

By using reversed-phase HPLC and gradient elution, fluorescence detection is also employed to simultaneously determine LAS, alkylphenol ethoxylates, and their associated metabolites, sulfophenyl carboxylates and nonylphenoxy carboxylates, respectively. Alkylpolyglycosides have also been subjected to HPLC analysis using C8 or C18 columns using a refractive index detector or a conductivity detector after the eluate had been treated with 0.3 mol/L NaOH in a postcolumn reactor.

Alkylphenol ethoxylates and alcohol ethoxylates have been analyzed utilizing a number of LC-MS techniques using an electrospray ionization interface. Alkylphe- nol ethoxylates and alcohol ethoxylates surfactants are effectively formed as ions during the electrospray process when crown ether-type complexes between the ethoxylate chain and cations like NH4+ or Na+ are formed. Nonylphenoxy carboxylates and alcohol ethoxylates are separated using a C18 HPLC column based on the length of their aliphatic chains. Coeluting ethoxylate homologues are separately discovered in the following mass analysis due to their variations in mass by 44 mass units.

Surfactants in Soils Amended by Sludge

Almost every chemical business uses surfactants, including those in personal care, housekeeping, agrochemicals, paints, mining, petroleum, and paper. The majority of household goods with surfactants in them are by far the laundry detergents, cleaning supplies, and personal care items. They are mostly discharged into municipal wastewater after usage, which then goes to sewage treatment facilities. Contrarily, agricultural pesticides must be prepared with surfactants to disperse the active ingredients into a hydrophilic system. Part of the time, they are discharged directly into the soil or eventually reach it via irrigation or rainwater. There, biodegradation or adsorption halt, alter, or abolish the various detergent composition constituents. As a result, in the instance ofwithout adequate biological degradability, they might pollute the environment.

Surfactant Biodegradation

Surfactants may be broken down primarily in aerobic environments. Some of them, like LAS, are persistent in anaerobic environments. Nonyl and octyl phenols, which are stable and have demonstrated estrogenic effect to species like fish, are produced when alkylphenol ethoxylates are partly decomposed under anaerobic circumstances. The biota may be impacted by surfactant concentrations that are high and the byproducts of their breakdown. On the basis of a comparison between the projected environmental concentration and the predicted no-effect concentration, the environmental risk presented by surfactants and the byproducts of their degradation may be evaluated in terms of toxicity. Therefore, additional toxicity data are required to determine the risks of surfactants and the products of their degradation on land. The common consensus is that LAS are biodegradable surfactants. It should be mentioned that certain wastewater treatment facilities using aerobic methods have detected extremely high levels of biodegradation. Alkylphenol ethoxylates, on the other hand, are less biodegradable. The linear alkyl chain, the sulphonate group, and eventually the benzene ring all degrade in LAS' breakdown mechanism[8].

Surfactant Transfer and Fate in Wastewater Treatment Facilities

The most significant anionic surfactants, LAS, will almost entirely reach the municipal WWTP. Many research on the fate of LAS during wastewater treatment have shown that physical, chemical, and biological mechanisms may effectively eliminate them. Apart from precipitation and adsorp- tion onto suspended solids, which can account for between 30 and 70% of the initial contents, microbial degradation typically accounts for the main elimination route and typically accounts for around 80% of the LAS load in activated sludge systems, resulting in a reduction of 95-99.5%. Yet, via treatment plant outputs, some residues of the intact surfactant as well as its intermediates of aerobic breakdown, sulfophenyl carboxylates, permeate the receiving waters. Notwithstanding the massive volumes of LAS that have been utilized, concentrations in surface waters are in the lower g/L level.

In contrast, the amounts of surfactants in water might be much greater if residential wastewater is released directly into natural water streams due to inadequate treatment facilities. While most homes in Western Europe and the United States are linked to treatment facilities, the practice of discharging untreated sewage into rivers is nevertheless common in many nations.This is especially concerning since, under these conditions, aquatic organisms are exposed to large quantities of surfactants, which have relatively significant toxicity. The kind of LAS homologue present is the most important consideration when determining the degree of LAS adsorption on particulate matter in wastewater. More hydrophobicity is conferred by the longer alkyl chains, enhancing adsorptive propensity. The Ka for LAS was found to rise by two to three times for each carbon atom added to the alkyl chain. The adsorption of LAS may be significantly impacted by the chemical makeup of the effluent. The partition coefficients of LAS in untreated wastewater might be dramatically changed by water hardness. Whereas comparatively soft water produced only 10–20% of the LAS concentration of the raw sewage, waters with high Ca concentrations produced sludge from main settling tanks that contained 30–35% of that amount. In raw wastewater, a significant fraction of LAS binds to ppaper debris. With concentrations ranging from 5–15 g/L, main settling tank sediment is relatively rich in LAS.

Depending on the sort of treatment the sludge receives, there may be substantial quantities of LAS in sewage sludge exiting the treatment facility. As previously mentioned, LAS are easily broken down in an aerobic environment because molecular oxygen is required for the alkyl chain oxidation at the terminal methyl group[9].

The results of pilot surfactant monitoring experiments using LAS as the reference chemical were published at activated sludge treatment facilities in five European nations. During aerobic wastewater treatment, a very high average LAS removal from water of 99.2% has been discovered. Hence, only very low levels of LAS well below the levels thought to have no effect—were released into the receiving waters. Low levels of LAS were also detected on sediments at river sample locations below the effluent discharges, with amounts ranging from 0.49 to 5.3 g/g. In Fig. 4, the transport of surfactants in treatment facilities is shown as an example. The numbers may change depending on the plant. LAS concentrations in anaerobically processed sewage sludge range from 100 to 500 mg/kg dry weight, whereas those in aerobically digested sewage sludge are much lower. As a result, the kind of treatment facility and the sludge digestion technique used have a significant impact on the level of LAS contamination of sewage sludge.

To examine the impact of LAS homologues on the anaerobic digestion process of sewage sludge, batch anaerobic biodegradation studies at laboratory scale with various LAS at increasing concentrations were conducted. When LAS homologues were added to anaerobic digesters, the generation of biogas rose at surfactant concentrations of 5–10 g/kg dry sludge, and at higher surfactant loading, the methanogenic activity was partially or completely inhibited. Consequently, no negative impacts on the anaerobic digesters in a WWTP may be anticipated at the typical LAS concentration ranges in sewage sludge.

Surfactant Fate in Soils and Waters

Pesticide use, the use of surfactants, the dumping of sludge on land, and other activities may release surfactants into the environment. Once in the environment, they go through processes including disintegration and sorption onto soil or water ppapers. Understanding these surfactants' activity in the environment requires a knowledge of the mechanisms that lead to their dispersion throughout ecological compartments. Surfactant sorption on a sediment or soil is influenced by a variety of variables, including the type of the sediment or soil, its physicochemical qualities, and environmental circumstances. The order of sorption for surfactants on sludge, sediment, and soils is cationic > non-ionic > anionic, and it is pretty high. Positively charged cationic surfactants have a great attraction for the surface of the mostly negatively charged sewage sludge ppapers.

Sulfophenyl carboxylates and LAS concentrations were monitored at several locations along a river's course to determine if they were present. The river is northeast of the city of Niteroi. This river had significant concentrations of LAS, ranging from 12 to 155 g/L, as well as its metabolite sulfophenyl carboxylates, ranging from 1.7 to 12 g/L, coming from various settlements with a combined population of around 20,000 people. The results demonstrate that there are enough microbial populations in the river to oxidize LAS and produce long-chain sulfophenyl carboxylates. In order to discover nonionic surfactants and their metabolites, the effects of raw wastewater discharges from municipal and industrial sources on surface water were tested in a river in Taiwan. Surfactant concentrations varied from 11.7 to 135 g/L, whereas breakdown products were discovered at concentrations of 0.3 to 3.1 g/L[10].

In receiving waterways in the United States upstream and downstream of domestic treatment facilities, Trehy et al. reported on levels of LAS and sulfophenyl carboxylates. Whereas the mean concentration of sul-fophenyl carboxylates was 9.3 and 31 g/L for LAS, respectively, the values for LAS averaged 16 and 35 g/L. Two severely contaminated riverine sites were tested upstream and downstream of a treatment facility as part of an Italian monitoring program. Although sulfophenyl carboxylate levels varied from 368 to 420 g/L, the average concentration ofLAS increased somewhat from 177 to 187 g/L. The ratio of LAS to sulfophenyl carboxylates may be an indication of the treated wastewater that was released based on this data representing various wastewater disposal scenarios. A low ratio value, like those observed in the American and Italian studies, may be a sign that wastewater has been treated. Increased readings between 270 and 6.7 in the Taiwanese research, as well as between 13 and 1.6 in the Brazilian rivers, may be a sign that a significant portion of the wastewater is untreated 1.5 km downstream from the discharge point in the Brazilian river, LAS concentrations in the water have been shown to drop quickly. The drop in concentration is caused by biodegradation as well as the loss of surfactants as a result of adsorption on river sediments and suspended ppapers in the raw sewage.

The concentration of surfactants in the water may be lowered through sorption onto riverine sediments as well as by biodegradation via endogenous bacterial populations existing in the stream, with slower kinetics than treatment plant. Since LAS and their even more polar metabo- lites are very soluble in water, convectional transport of these materials over comparatively large distances is possible. In the end, contaminated river mouths into estuaries, then into the sea, contribute to the pollution of coastal waterways.

In contrast to the terrestrial environment, which has received far less attention, the fate and consequences of LAS have been extensively researched in the aquatic environment. Surfactants are a substantial source of exposure for soil, and even at low concentrations, they seem to have a significant impact on soil biology, chemistry, and physics, with sorption processes predominating. The study of LAS is significantly favored in the literature on the fate of surfactants in wastewater sludge-amended soil, with other surfactants getting less or no consideration.

Sludge-amended soils in a Spanish grapevine farm and a vegetable farm were tested for LAS. Initial soil concentrations of 16 and 53 mg/kg, respectively, from rather high sludge application concentrations of 7,000–30,200 mg/kg dry weight, were noted. The soil concentrations of LAS were 0.3 mg/kg at 90 and 170 day intervals. During an initial period of LAS removal, soil concentrations seemed to level off and did not drop any further, indicating that LAS may have been mixed in with the soil ppapers or may have been linked to the organic matter in the soil. The microorganisms in charge of the surfactant's biodegradation are thus rendered inaccessible by this circumstance.

Less than 1 mg LAS/kg and no more than 5 mg LAS/kg of surfactants are often present in soils that have not recently received sludge. This is lower than the LAS concentration at which experimental effects have been seen. The laboratory results are consistent with LAS aqueous solution field experiments.

Observations on the ecological effects of applying sewage sludge or LAS spiked into sludge, however, show that LAS is less harmful when delivered through sludge. Jensen came to the conclusion that while LAS may be detected in sewage sludge in large quantities, it is unlikely to pose a long-term hazard to terrestrial ecosystems due to its relatively quick aerobiological breakdown and decreased bioavailability when delivered through sludge.Aerobic microorganisms start to break down these surfactants as soon as LAS is removed from the anaerobic environment of sludge digestion and/or storage.

LAS half-lives are generally brief because to rapid metabolism. There is minimal probability of LAS accumulating in soil because of their relatively high biodegradability in an aerobic environment, according to the majority of writers who have monitored their presence in sludge-amended soils[11].

Surfactant-Soil Contaminant Interaction

As previously mentioned, each surfactant molecule has both hydrophobic and hydrophilic groups, which allows surfactants to form micelles in solution. Organic pollutants may be partitioned into the organic pseudophase that is created by the organic interior of micelles. If surfactants are present, this behavior may significantly increase the overall concentration of the pollutant in solution beyond its aqueous solubility limit. In fact, it has been discovered that a hydrophobic solute's solubility in surfactant micelles is many orders of magnitude greater than its solubility in aqueous solution in the absence of surfactants. The octanol-water partition coefficient of a solute may be used to determine how much of it will concentrate in a micelle. In general, a solute has a stronger propensity to concentrate within the micelle the bigger its Kow. Surfactants may interact with organic substances in soil in two different ways. Contaminants are solubilized in surfactant micelles in the first and most significant process. The second mechanism involves moving pollutants out of the soil, and it relies on surfactants' propensity to lessen the capillary and interfacial forces that keep the contaminant trapped in the soil. These interactions have an impact on how bioavailable soil contaminants are, making them useful for soil bioremediation.

It is generally known that surfactants may be used to clean up soil and cleanse underground water supplies. Both anionic and nonionic surfactants have also been employed to clean up oil and hydrocarbon-contaminated land. The remediation of soil contaminated with oils, hydrocarbons, and several other organic pollutants has been accomplished using both anionic and nonionic surfactants. An novel method for reducing the interfacial tension between the nonaqueous phase of the soil and water and for improving aqueous-phase solubility has been surfactant addition. With the integration of pollutant molecules into surfactant micelles, the NAP contaminants may be made soluble. It is not advised to use water to effectively remove contaminants from a polluted environment.

In soil cleaning methods, organic surfactants should be used instead of dirt

For soil decontamination, Triton X-100 and sodium dodecyl sulfate, two synthetic surfactants, were combined with a solution of humic acid-HA, a natural surfactant. In contrast to soil B, which had a higher concentration of thiophenes, soil A was richer in polycyclic aromatic hydrocarbons. The mixture of synthetic surfactants that was utilized was able to lower the contamination levels in both soils by 80 to more than 90%. Same quantities of pollutants were removed from a contaminated soil by natural, nontoxic surfactants like HA as they were by synthetic surfactants. Yet, because of their toxicity, synthetic surfactants that are effective at washing away dirt might pose new environmental issues. In order to prevent additional environmental issues, a natural surfactant such a humic acid solution may be used to wash a polluted soil with the same effectiveness and less toxicity than synthetic surfactants.

Investigations have also been done on the possible impact of certain surfactants on the biodegradation of chlorinated hydrocarbons in wastewater. The addition of mineral fertilizers and surfactants significantly improved the biodegradation of a genuine waste that included a wide range of hazardous chemicals. Hexachlorobenzene, trichloroethylene, halogenated organic solvents, tetrachloroethane, volatile aromatic hydrocarbons such as benzene and toluene, and polynuclear aromatic hydrocarbons were among the contaminants. When wastewater and surfactants were combined, the amount of pollutants was reduced by 49% more. Both sodium dodecylsulphate and a non-ionic surfactant have been tested[12].

It is typical to find soils that are polluted with both hydrophobic organic contaminants and heavy metals. For the remediation of soils polluted with Pb and/or marine diesel fuel, improved washing using sodium dodecyl sulphate and ethylenediaminetetraacetic acid was investigated. Using batch tests, it was thoroughly explored whether ethylenediamine-tetraacetic acid and sodium dodecylsulphate could be recovered and used again, as well as the physicochemical interactions between the chemical agents, pollutants, and soils. The best washing order was then identified. The experimental findings demonstrated that EDTA could be recovered and reused four times without suffering a major loss in its chelating capacity, but SDS's ability to extract was considerably diminished after each cycle of reuse.

The sorbed Pb on soils was physically segregated by the free phase of marine diesel fuel, which reduced the need for ethylenediaminetetraacetic acid to remove it. It was shown that the addition of sodium dodecylsulphate, either alone or in combination with low concentrations of ethylenediaminetetraacetic acid, increased Pb removal. This was likely accomplished by electrostatic interaction and the dissolving of soil organic matter. In addition to their ability to clean the soil, certain surfactants have been shown to speed up the biodegradation of several xenobiotics in soil, even at extremely low concentrations. The partitioning of xenobiotics into surfactant micelles, however, has been found to cause degradation to be delayed at higher surfactant concentrations. In soil, surfactant-pollutant interactions are very complicated and largely reliant on a variety of factors, such as the surfactant concentration in soil-water relative to CMC, the surfactant and pollutant's adsorption properties, the pollutant's solubility, and the type of soil.

The surfactant CMC is the most crucial factor when determining a surfactant's capacity to mobilize hydrophobic xenobiotics in contaminated soil. Surfactant levels in soil-water below the CMC often have little to no impact on the solubilization of hydrophobic compounds. Significant desorption of such contaminants from soil surfaces only takes place when micelles are present. The inclusion of surfactant, on the other hand, may promote the adsorption of hydrophobic xenobiotics to soil ppapers in specific circumstances and typically at concentrations much below the CMC. This phenomenon has been explained by the xenobiotic's partitioning into surfactant hemimicelles that were generated on the soil surface. Adsorption of surfactants to surfaces in environments like soils and sediments makes it essential to accomplish micellization in porewater at significantly greater total surfactant concentrations than in clean water systems. As a result, far greater surfactant concentrations are needed than what may be anticipated to significantly alter xenobiotic activity. Very high amounts are unusual for sludge-amended soil.

CONCLUSION

Detergents are extensively utilized not just domestically but also in a variety of sectors, including food, agrochemical supplies, oil, paint, coatings, textiles, dyes, and home goods. All different kinds of surfactants anionic, cationic, nonionic, and amphoteric are included in the formulations, but LAS, an anionic surfactant, is by far the most often used. Surfactants may enter agricultural soils in a variety of ways, but the two most important ones are pesticide applications to crops and soil amendment using sewage sludge. Several sorts of metabolites may be produced depending on the type of surfactant being broken down, whether it happens under aerobic or anaerobic settings. LAS, cationic surfactants, and alkylphenol ethoxylates are all quite resistant to degradation in anaerobic environments, according to the published data. Consequently, if sludge digestion has been carried out anaerobically, the application of sludge to agricultural soils might be a significant source of surfactants. Nevertheless, the compounds are quickly broken down when they are reintroduced into an aerobic environment, like soil. To assess the possible toxicity of cationic surfactants in the environment owing to their ability to suppress microorganisms, further research on their degradation is required.

Due to surfactants' potential to impact the bioavailability of contaminants like heavy metals and organic compounds, surfactants may be employed in the bioremediation of soils, making the interaction between surfactants and pollutants a significant area of research today. Last but not least, surfactant input in agricultural soils is not minimal and is rising globally. To assess their behavior in agricultural regions under the rising use of organic amendments and agrochemicals, information on their introduction channel, interactions with polar and nonpolar pollutants, and destiny and persistence in the environment is thus necessary.

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CHAPTER 13

THE LEGUME-RHIZOBIA NITROGEN FIXING SYMBIOSIS'S MINERAL NUTRITION

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ABSTRACT:

Crop output significantly increased as a result of modern agriculture's development and intensification beginning in the middle of the 20th century. Yet, increased productivity has resulted in a remarkable simplicity of agricultural systems and an increased dependence on outside inputs. The widespread use of fertilizers and pesticides contributes to widespread health issues and environmental damage. Such data have sparked discussion on the viability of the present intensive agriculture methods. Organic farming is emerging as a solution to the drawbacks of traditional farming since it attempts to provide wholesome food while respecting the environment. Chemical fertilizer will be used less in the context of sustainable organic agriculture if biological nitrogen fixation is used successfully without reducing production. To do this, it is critical to have prior knowledge of the mineral nutrients needed to maximize symbiotic nitrogen fixation and the growth of legume crops. Here, we first go over the fundamentals of mineral nutrition and the significance of these minerals in particular for the biological nitrogen fixation in the symbiotic relationship between legumes and rhizobia.

KEYWORDS:

Calcium, Cobalt, Iron, Legume-symbiosis, Mineral nutrition, Molybdenum.

INTRODUCTION

Second, the main focus of this paper will be an overview of the activities of boron and calcium in plants, with a focus on their crucial roles in nitrogen fixation and the symbiotic relationship between legumes and rhizobia. The demand for some nutrients is higher for legume nodule development and function than for non-nodulated legumes, and corrections of nutrient deficiencies are occasionally required to ensure crop success. Symbiotic nitrogen fixation is the best alternative to reducing the application of chemical N-fertilizer. Because to the phosphate required for nodulation and the relatively energy-intensive nitrogen fixation process, phosphorus is a frequent nutrient that limits the development of nodulated legumes. An economical and environmentally friendly strategy to address P constraint is to increase the association of nodulated-legumes with vesicular-arbuscular mycorhizas, enhancing phosphorus absorption. While a K+ supplement for osmoadaptation must be taken into consideration for development in salty soils, sulphur and potassium are not typically limiting nutrients for nodulated legumes.

Similarly, while there is a larger requirement for cobalt or nickel in nodulated legumes than in non-nodulated legumes, it is uncertain how much of these micronutrients may be found in the soil[1]. The anaerobic and acidic environment within the nodule, however, reduces the availability of these micronutrients, making iron and molybdenum restrictions for nodulated legumes frequent, even in soil with adequate Fe and Mo. Thus, the use of Fe and Mo fertilizer in sustainable agriculture based on nodulated legumes cannot be disregarded. B and Ca are without a doubt the minerals that have the most impact on the symbiosis of legumes. B and Ca2+ are both required for nodulation and nitrogen fixation, with calcium being more important for early symbiotic processes and B for nodule development. On boron-deficient soils, an early modest calcium supplement minimizes the effects of B limitation during nodulation since boron shortage is quite prevalent and there is a danger of toxicity after B fertilization because it emerges at amounts near to sufficiency. In order to effectively rectify boron deficit and increase crop output, B-Ca feeding should be done correctly. Overall, mycorhizal interactions and improved symbiotic nitrogen fixation in legumes provide a natural fertilizing alternative to conventional chemical fertilizers. Yet, to address nutrient shortages, boost crop output, and meet the rising demand for agriculturally generated food, a modest and restricted use of conventional farming methods must be taken into account[2].

DISCUSSION

Agriculture output is rising exponentially as a result of the requirement to meet the nutritional needs of the world's present population. Because to the increasing demand, there has been widespread and perhaps indiscriminate use of the only human reaction to the dearth of nitrogen available for plants in cultivable soils is the use of pesticides and nitrogen fertilizers. The usage of chemical fertilizers across the globe has rapidly expanded since the middle of the 20th century. In 2000, 136 million tons of fertilizer were consumed worldwide. In densely populated nations like India and the US, fertilizer consumption has stabilized. With more than 40 million tons used in 2004, China is now the largest user of chemical fertilizers. According to data from the European Union, active pesticides are used and excessive nitrogen fertilization is practiced. Excessive applications of fertilizers and pesticides harm rural communities as well as farmers and contaminate the ecosystems that support agriculture.

There is now a push for sustainable agriculture based on organic ecological farming, which yields nutritious food, as a result of serious issues resulting from these techniques. The high costs of increasing fertilizer production for this practice are unquestionably a problem from an economic standpoint, and increased production has also resulted in another serious obstacle to human survival as well as the survival of the biosphere: the nitrate contamination of surrounding waters by raising nitrate contents to toxic levels, which leads to the eutrophication of lakes and rivers as a result. For instance, the recommended use of pesticides in the United States is estimated to cost \$10 billion in environmental and health care costs annually; excessive fertilizer use costs \$2.5 billion in wasted fertilizer inputs; and the costs of public and environmental health issues related to soil erosion by conventional modern agriculture exceed \$45 billion annually[3].

Massive land expansions throughout the globe have been degraded by the use of N as fertilizer, and biological nitrogen fixation is now needed to replace tons of artificial fertilizers. The ability of certain soil microbes to fix atmospheric N2 and convert it into ammonium, which may be utilised by the plant when the fixing microorganism develops a symbiotic connection with it, accounts for this natural method of delivering nitrogen to plants. Agronomic interest in biological nitrogen fixation is high. Rhizobial symbiosis with more than 100 agriculturally significant legumes is thought to be responsible for at least half of the yearly nitrogen fixation in soil ecosystems. In comparison to nitrogen fertilizer, this plant-microorganism symbiosis has a number of benefits, including high nitrogen uptake by plants—often close to 100%—minimal nitrogen leaking into the soil, and less soil and water pollution.

As no homogeneous taxonomic group unites all living N2-fixers, its sole shared trait is the existence of the nitrogenase enzyme complex. They consist of phototrophic organisms such as bacteria from the families Rhodospirillaceae, Chlorobiaceae, and Cyanobacteriae;

chemoautotrophs such as Thiobacillus, Xanthobacter, and Desulfovibrio; heterotrophs such as Azotobacter, Enterobacter, Klebsiella, and Clostridium; and bacteria from the families Frankiaceae and Rhizobiaceae. These creatures have the ability to fix nitrogen either as free-living forms or by forming symbiotic connections with other living things. The N2-fixing symbioses between higher plants that are created between rhizobia and legumes and between Frankia and actinorhizal plants are the longest. On ruined soils, Actinorhiza pioneers plants, and Frankia symbioses gain significant environmental significance for the restoration of eroded soils. Rhizobia-legume symbioses, on the other hand, have a huge potential to create food for people or animals, to replenish cultivable soils via the use of culture rotation, and undoubtedly to minimize the usage of artificial fertilizers.

The relationship between rhizobia and legumes has been extensively researched since the seminal investigations of Hellriegel and Wilfarth, which conclusively showed that microorganisms within the root nodules enabled legumes to acquire N from the air. Nevertheless, several features of this interaction remain unexplained. One of them is the impact of different nutrients that the system needs to start or develop the symbiosis and to cause nodule organogenesis[4].

Legume-Rhizobia Nitrogen Fixing Symbiosis: Mineral Nutrition

Following more than a century of study, a wealth of information has been accumulated about the molecular features of the interaction between legumes and rhizobia. Until we completely comprehend the symbiotic process, however, there are still a number of murky elements of physiological, environmental, and nutritional themes that impact one or both symbiotic partners, or more precisely their interaction. In general, a variety of genetic and environmental factors affect how plants grow. The most crucial elements for a plant's development in a concrete environment are light, water, CO2, and nutrients. Around 90–95% of the dry weight of the plant is made up of the C, O, and H that atmospheric CO2 and soil water provide. The mineral fraction is the remaining 5–10%. All of these mineral nutrients are vitally necessary for activities linked to plant growth and development, including plant-microbe interactions like those that lead to legume-rhizobia symbiosis, despite their modest or even very low quantitative presence. For instance, Mo is 0.1 ppm is all that is necessary for it to be present, yet it is absolutely necessary. While certain plants are able to withstand and collect heavy metals at concentrations that are extraordinarily high, these plants do not need heavy metals as a nutrition. It must be made apparent that neither the existence nor the concentration of a mineral element are reliable indicators of essentiality. Only the inability of a plant to complete its life cycle in the absence of a certain mineral may classify it as an important nutrient. Marschner, Epstein, and Bloom are three good monographs to read if you want to understand more about plant mineral nutrition.

It is crucial to stress that nutrient deficits may have an impact on rhizobia soil populations in addition to plants. Nutritional effects on bacteria are mostly unknown due to the significant variety in response across genera, species, and strains. Moreover, nutritional deficits in rhizobia, particularly of those nutrients with limited availability in many soils, such phosphorus or iron, might decrease the nodulation capacity. This is because plants and soil microbes compete with one another for resources. Certain nutrients may directly play a specialized role in various phases of the formation of the symbiosis, in addition to their effects on both symbiotic partners. Lastly, nutritional balance may alter how other mineral nutrients are absorbed and accumulated, impacting how both symbionts develop and how the interaction's regulatory genes are expressed. Consequently, to completely comprehend nutritional stressors in the legume-rhizobia symbiosis, integrative techniques incorporating plant physiology, microbiology, and molecular biology studies are needed. Instead of focusing on the development of free-living bacteria and plants, this review will instead concentrate on mineral nutrients that have a significant impact on the symbiotic process.

While each of the 17 nutrients mentioned above that are considered essential for all plants are also necessary for the symbiotic relationship between legumes and rhizobia, several of them have specific functions. As the ingredient that must be repaired from atmospheric N2 by bacterial nitrogenase, N must, of course, be emphasized.

In addition, various mineral nutrients that have a more focused impact on the interaction are briefly covered below. They include substances like Co or Ni that are either essential for the microsimbiont or just for the N2-fixing event.

Moreover, B and Ca are two nutrients that are said to be in high demand for nodulated plants. Both of them have a significant impact on nodulation and nitrogen fixation, and it has long been known that B and Ca are involved in a variety of physiological plant processes. Consequently, a more thorough explanation of the functions of both mineral nutrients in symbiotic nitrogen fixation will be provided[5].

As was already mentioned, deficits of the nutrients discussed here, particularly B and Ca, have an impact on the symbiotic process and consequently crop productivity. The symbiotic relationship between legumes and rhizobia is a tightly controlled process of organogenesis, and various mineral nutrients have a significant impact on various phases of the symbiotic interaction's growth and/or on the nitrogen fixation process itself. Understanding the functions of mineral minerals may help choose the best nutrient supplements to boost crop bean output without compromising environmentally friendly farming methods.

Macronutrients

Nitrogen

It's not necessary for soil rhizobia and legumes to coexist. Both bacteria and plants may stay unassociated for the whole of their life cycles in soils with sufficient available nitrogen. Yet, only when N levels are low does the interaction take place. Symbiosis can only successfully grow into a nodule where molecular N2 is decreased if N conditions are maintained.

Depending on when it is applied, combined nitrogen lowers nodulation by preventing bacteria from adhering to the roots or by lessening infection. It also suppresses the production of leghemoglobin and nitrogenase, which speeds up nodule senescence. A sufficient nodulation of the legume is necessary for maximum N2-fixation, hence reducing fertilizer-N input is necessary to maximize rhizobial infection in a sustainable agricultural environment[6].

Potassium, Sulfur, and Phosphorus

P is a typical limiting nutrient of N2-fixing legume crop yield in many places, along with calcium, among macronutrients. Nitrogen fixation and nodulation are affected by phosphate. N2-fixing legumes will need more P than those provided with mixed nitrogen because nitrogen fixation is a very costly process, requiring more than 16–18 mol ATP per mol N2 fixed. Vesicular-arbuscular mycorhiza infection may significantly increase phosphorus absorption to meet the high requirement of nodulating legumes, particularly in soils with low P supply.

While symbiotic systems have been said to be more susceptible to low K than the legumes themselves, the impacts of sulphur and potassium are often less striking. Nevertheless, K+ becomes very important as an osmolyte for adaption in saline soils. A K+ supplement must be taken into consideration in order to effectively grow symbiotic legumes in salty soils, since roughly 50% of the world's irrigated land is classified as having potential salinity concerns.

Micronutrients

Molybdenum and iron

For nodules, these two nutrients are extremely important. The MoFe protein makes up component I of the nitrogenase enzyme system, while the Fe protein makes up component II. A lot of additional proteins, including heme-containing ones like the oxygen transporter leghemoglobin and cytochromes or Fe-S proteins like ferredoxin, are also present within the nodules and are necessary for symbiotic N2 fixation. As a result, legume nodules have a very high Fe demand, and reduced iron availability in soils will have an impact on more nodulated than combined N-fed legumes.

Moreover, the anaerobiosis necessary for N2-fixation may hinder the conversion of Fe3+ to Fe2+, worsening a potential Fe restriction. Similar to this, it is necessary to boost the supply of Mo to soils with low levels of this micronutrientdevelopment of legumes that fix nitrogen [7]. Certain naturally acidic, inadequately buffered soils have molybdenum restriction. The production of crop legumes may be hampered by the acidifying impact of nitrogenase activity. Hence, a danger of iron or molybdenum deficits in symbiotic legumes must be taken into account once the nodule develops and the nitrogen fixation process starts, notwithstanding the benefits of increased biological nitrogen fixation for sustainable agriculture.

Cobalt

Several stages of nodule formation and function are impacted by cobalt deficiency. Ahmed and Evans reported that Co was needed by N2-fixing nodules.

Further experiments proved the dependency on Co, the cobalamin coenzyme B12 level, leghemoglobin, and N2-fixation. For enzymes like methionine synthase, ribonucleotide reductase, involved in bacteroid development, methylmalonil-coenzyme A mutase, involved in the creation of heme groups, and leghemoglobin or bacterial cytochromes, cobalamin, which contains co as the metal component, is necessary. As a result, Co is a micronutrient that has a significant impact on both nodule function and development.

Nickel

To completely meet plant needs, 200 g of Ni are required, which forms complexes with several enzymes. There is thus no concrete proof of a Ni deficit in soils, even if it has been documented that providing Ni to plants fed urea in calcareous soil has positive benefits. Plant and rhizobial ureases are both enzymes that need Ni to function. Ureaides are the primary means of transporting fixed nitrogen from growing determinate nodules to shoots in legumes like bean and soybean.

Urease is required to break down urea, an intermediary in the metabolism of nitrogen and ureides. Otherwise, urea buildup will result in leaf necrosis. Rhizobial hydrogenase also needs Ni, in addition to urease. These enzymes increase the efficiency of the nitrogen fixation process by recycling hydrogen produced by nitro-genase enzymes. Hydrogenase activity is constrained by agricultural soils' low Ni concentration.

The Role of Calcium and Boron in Legume Symbiosis

Research on the mineral nutrition of plants often examines the relationship between B and Ca. The amount of one nutrient affects how it is distributed and how much of the other is needed for optimum plant development. Plants need the element boron at micromolar quantities, but it has been linked to a number of physiological functions, including phenolics metabolism, reproduction, nitrogen fixation, cell wall formation, and membrane structure and related reactions. A lack of this vitamin has pleiotropic effects on plant growth owing to the variety of plant activities that B influences. While the fundamental function of B in plants is unclear, it has been demonstrated that any activity of B is based on the ability of borate anions to create stable covalent bonds with cis-diols of carbohydrate moieties of molecules.

Moreover, calcium is involved in several physiological processes in plants. Recent studies have concentrated on cytosolic free Ca2+ as one of the most significant messengers engaged in signal-response coupling, despite the fact that the traditional roles of calcium in plants also pertain to cell wall formation and membrane structure and function. Maintaining a modest quantity of cytosolic free Ca2+ is crucial because various physiological events are followed by variations in cytoplasmic calcium concentration, even if the majority of plant Ca is attached to the cell wall and membrane. Moreover, a variety of environmental conditions alter cytosolic Ca2+, which serves as a second messenger in the communication between environmental factors and plant responses. Our earlier research in cyanobacteria showed that calcium is important for heterocyst envelope integrity and, as a result, for protecting nitrogenase function under stress. Furthermore, calcium may have a role in heterocyst differentiation as well as early signaling in cyanobacteria in response to temperature shocks, salinity, and osmotic stress. Finding the fundamental sensors that detect stressors and initiate Ca2+ signaling will therefore be a big problem for future study. Cellular targets of Ca2+ signals for cell differentiation will also be a major task[8].

Despite the fact that the majority of studies on the B-Ca connection have been on the structure and function of the cell wall, evidence of a physiological B-Ca interaction has been identified for transport processes across the cell membrane. In this regard, Kobayashi et al. demonstrated that Ca2+ facilitated the in vitro production of dimers of borate-rhamnogalacturan II and postulated that Ca2+ stabilizes the cell wall's pectin polysaccharides via ionic and coordination bonding in the polygalacturonic acid region. B may be responsible for the cytosolic Ca2+ being released via the cyclic-ADP ribose pathway, which controls, among other things, ABA signaling, at the signal transduction level. Our team demonstrated a nutritional link between B and Ca in cyanobacteria, which is relevant to species that fix nitrogen. B is necessary for these microbes to keep the specialized N2-fixing heterocysts' envelopes intact. Heterocyst structure and nitrogenase activity were restored by adding more Ca to cultures developing in the absence of B or by adding B to Ca-deficient treatments. In the rhizobia-legume Carpena et alinvestigations .'s on nodulated pea plants show a particular B-Ca interaction; they explained how low B affects Ca concentration and how B is moved from old to new growth tissues in B-deficient plants via the use of Ca.

Rhizobia and legume symbioses that fix nitrogen and boron

Legume N2-fixing symbioses include the growth of a new plant organ called a nodule, which is often found in the root. It need fresh wall and membrane material to form a nodule, and various rhizobia and plant macromolecules with cis-diol-rich glycosil-moieties are thought to be involved in interactions between the cell surfaces of plants and bacteria. B is thus a key component in the development and maintenance of these symbioses.

Brenchley and Thornton first proposed the need for B for symbiotic N2 fixation in legumes in Vicia faba, and nodulated Pisum sativum and Phaseolus vulgaris plants around the turn of the 20th century verified their hypothesis. B deficiency significantly reduced nodules and nitrogenase activity in nodulated legumes. A high need for B and the characteristic symptoms of B-deficiency in the structure of nodules grown without B may be explained by rearrangements and changes in cell wall structure during nodule growth in addition to the massive synthesis of new membranes and walls. Investigations at the molecular level have shown that pectin polysaccharides and hydroxyproline/proline-rich glycoproteins are improperly assembled, resulting in aberrant nodule cell walls.

Rhizobia are now referred to as bacteroids and are surrounded by a membrane formed from plants after acquiring the cytosol compartment. As biological nitrogen fixation occurs, they expand, split, and transform into distinct symbiosomes. Each infected cell contains several thousand symbiosomes, and the peribacteroid membrane contains a differentiated glycocalyx made of glycoproteins and glycolipids that codifferentiate with bacteroids. As a result, extensive membrane synthesis and differentiation occur at rates that are 30- to 50-fold higher than in other tissues. New proteins are sent to the symbiosome compartment during symbiosome development to form a peribacteroid fluid. A nodule-specific lectin-like glycoprotein with two isoforms seems to play a role in bacteroid development. It has been shown that these glycoproteins' glycosyl-moiety interacts with both the symbiosomal membrane and the surface of bacteroid. As a result, this connection seems to be directly related to the establishment of symbiosomes as N2-fixing bacteroids do not arise in pea mutants missing the symbiosomal form of PsNLEC 1 or in cell surface deficient rhizobia that do not physically engage with PsNLEC 1. PsNLEC-1's sugar groups were found by particular antibodies, proving that the carbohydrate-moiety was present[9].

This protein was altered when B was not present. PsNLEC-1 glycoprotein localization in ultra-thin pea nodule sections revealed that they were collected in cytoplasmic or Golgi-derived vesicles rather than symbiosomes in B-deficient nodules. This shows that in B-deficient nodules, Ps-NLEC glycoproteins were not successfully targeted to the peribacteroid fluid of symbiosomes. Recently, several glycoproteins that may be borate ligands and that seem connected with the glycocalyx of the peribacteroid membrane of proliferating symbiosomes have been linked to aberrant bacteroid development in the absence of B. Since they share antigenicity with rhamnogalacturonan II pectin polysaccharide, they are known as RGII-glycoproteins. These glycoproteins were never seen in B-deficient cells, indicating that they are stabilized on the glycocalyx by borate bridges and that RGII-glycoproteins are responsible for the connection of the carbohydrate moiety of PsNLEC-1 with the peribacteroid membrane. Overall research shows that boron has unquestionably increased in demand as a micronutrient for symbiotic legumes. While B is extensively dispersed in both the lithosphere and the hydrosphere, plants often only have access to soluble B, making boron insufficiency the most prevalent plant micronutrient shortage globally. Consequently, boron shortage is a barrier to sustainable agriculture based on the symbiosis between legumes and rhizobia; nevertheless, both boron sufficiency and toxicity are in a restricted range of concentrations, therefore boron administration after diagnosis of boron deficiency needs to be highly cautious[10]–[12].

Biological Nitrogen Fixation and the B-Ca Connection

In our research on the functions of boron in nitrogen fixation, we established a connection between the micronutrient and calcium in cyanobacteria as well as nodulated legumes. B and Ca2+ have a significant impact on the rhizobia-legume symbiosis at various stages of nodule formation and organogenesis. The recovery impact of B deficiency by addition of Ca2+, which is translated to a plant's, mostly its root, growth, is very significant. Pea, bean, and alfalfa plants exhibit varying numbers of nodules and nitrogen-fixing activity when grown in medium with varying concentrations of B and Ca2+ and infected with their host rhizobia. This indicates that the connection between B and Ca can be precisely described.

CONCLUSION

In a setting of sustainable agriculture, it is essential to understand the nutritional needs, the function of various mineral nutrients at each stage of the growth of a legume-rhizobia symbiosis, as well as the influence of mineral nutrients on the process of nitrogen fixation. The availability of phosphorus, potassium, iron, and molybdenum is a particularly significant aspect for optimizing symbiotic N2-fixation depending on the soil characteristics. The "triple symbiosis" of legume-rhizobia-mycorhiza will result in less need for N- and P-chemical fertilizers since vesicular-arbuscular mycorhiza infection enhances phosphorus absorption. Nonetheless, in order to maximize crop output without endangering the environment, sustainable agriculture must use a few of the traditional agricultural methods in a controlled manner. This is true for potassium fertilization in salty soils, the application of micronutrients like iron or molybdenum that have a lower availability due to the nodule environment or the nitrogen fixation process, or the application of micronutrients like cobalt or nickel that have a higher requirement for the development of symbiosis or the nitrogenase function. Our research over the last two decades has shown that boron is unquestionably the element whose deficit has the greatest effect on the growth of nodules and the ability of legume symbioses to fix nitrogen. Since boron deficit is so widespread across the globe, it is crucial to determine B availability before growing nodulated legumes. Our research also demonstrates a connection between calcium and boron during legume nodulation and symbiotic nitrogen fixation, both in physiological and stressful situations. B and Ca2+ are necessary for nodulation and nitrogen fixation in legume-Rhizobium symbioses. B was necessary for nod gene expression, curling of the root hairs, and bacterial adsorption to the root surface during the early stages of nodulation, while Ca2+ addition might counteract the inhibitory effects of B shortage and reduced nodule quantity. High Ca2+ concentrations also helped Rhizobium invade cells and tissues, which were severely hindered by B deprivation, while Ca2+ was unable to repair nodule structure. Small calcium supplements can be used to correct boron deficiency without a heavy application of B- fertilizer, especially in the early stages of nodule development when Ca2+ can partially prevent B-deficiency, given that boron concentrations leading to either sufficiency or toxicity are quite precise. A good B and Ca diet may help people tolerate salt, according to research on symbiosis under salt stress. Hence, in order to determine the ideal nutritional circumstances for each species of legume and assure the success of symbiosis, plant growth, and crop production in salty soils, such research should be conducted alongside genetic techniques looking for tolerant cultivars.

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CHAPTER 14

UNUSUAL HEAVY METALS, METALLOIDS, AND PLANT TOXICOLOGY

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ABSTRACT:

A category of hazardous contaminants that receives special attention is heavy metals. Many heavy metals, including zinc, nickel, and copper, are necessary as key components of pigments and enzymes. Yet, due to their ability to interfere with enzyme processes, replace necessary metals in pigments, or produce reactive oxygen species, all metals are poisonous in large amounts, particularly cadmium, lead, mercury, and copper. Thorium, arsenic, chromium, antimony, selenium, and bismuth are among less common heavy metals and metalloids whose toxicity has been studied.

KEYWORDS:

Agriculture, Environment, Heavy Metals, Metalloids, Phytoremediation.

INTRODUCTION

Heavy metal toxicity and other characteristics, as well as their destiny in the environment, are still hot topics. According to the number of papers where the phrase "plants and heavy metal" has been discovered in titles, abstracts, and keywords, this fact is well-documented. The curiosity is possibly a result of worries about having enough food. Moreover, technologies that can clean up a heavy metal-polluted environment have been evolving. Phytormediation technologies are those that employ plants to achieve this goal. Many elements have an impact on the plants. A simplified diagram of how a plant interacts with its surroundings. Heavy metals are one class of substances that have an impact on plants. A heavy metal is one of a broad category of elements that have metallic characteristics. This category mostly consists of transition metals, certain metalloids, lanthanides, and actinides. They are extensively dispersed across the crust of the Earth.

Rocks of volcanic, sedimentary, or metamorphic origin that contain certain elements may be mined for heavy metals. In soils, rivers, lakes, saltwater, and seafloor sediments, dissolved or particulate, are heavy metals that have weathered from naturally existing rock formations. Heavy metals are also released into the atmosphere by volcanoes, as shown in Figure 1. Higher concentrations of heavy metals may be found, nevertheless, in locations with a high concentration of industrial and agricultural activities. Heavy metal stress and metalloid contamination from Zn, Pb, Cr, Mn, Fe, Tl, In, or As are particularly harmful to soils around heavy metal mining. Heavy metals in chemical form are still being researched to determine their potential mobility, bioavailability, and toxicity in habitations. Heavy metals and metalloids that are mostly reducible pose significant dangers to human health, particularly given that they are soluble in aquatic settings[1].

Plant Uptake of Heavy Metals and Metalloids and their Bioavailability

There are few plants that are able to absorb metals from the air, thus soil and water content play a crucial role in the bioavailability of metals and metalloids. The real form of the heavy metal in the soil or water that corresponds to the actual circumstances, such as pH, oxygen content, and the presence or absence of other inorganic or organic chemicals, is the following crucial element. There is no consistent relationship between the amount of a metal in the soil and the amount of that metal in plant tissues. Since certain heavy metals are soluble insoluble and interact with soil papers, they are virtually completely inaccessible to plants. The best example is lead, which is abundant in exposed places yet almost inaccessible to plants due to its poor solubility and strong interactions with soil papers. A crucial role is played by metals and metaloids' capacity to combine with substances found in soil and water to produce complexes that boost their bioavailability and absorption. Plants may absorb heavy metals and metalloids via various metal transporters as well as up-take mechanisms for necessary cations. Low molecular-weight substances that are actively released by plant roots and function as chelators play another crucial role in enabling the uptake of heavy metals and metalloid ions[2].

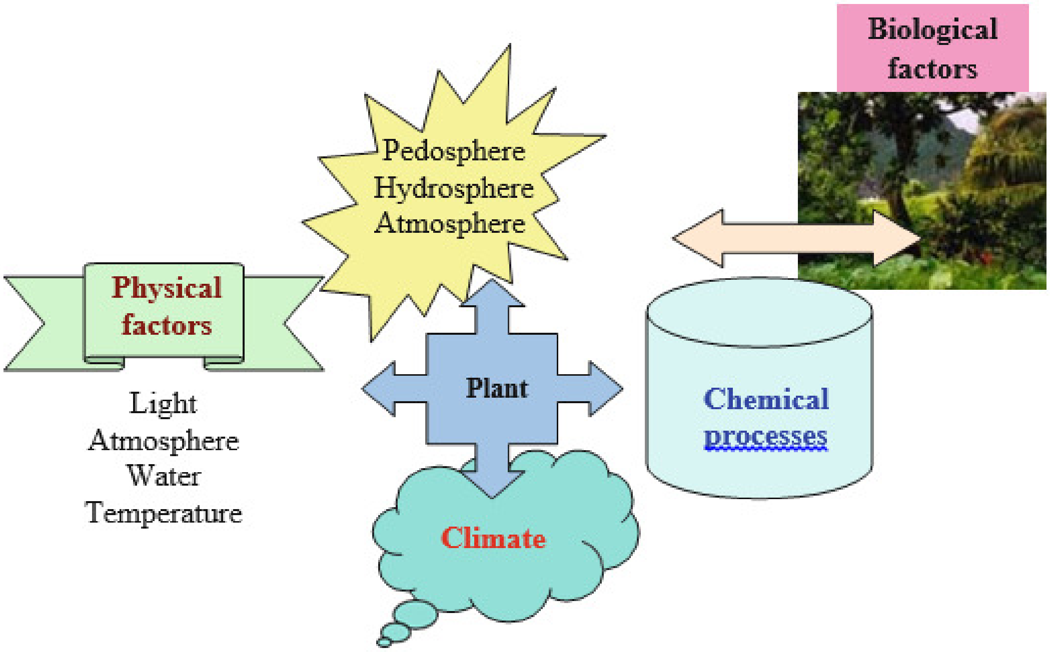

Figure 1: the impact of physical, chemical, and biological variables on a plant.

Heavy Metal and Metalloid Transport in Plants

It's common for heavy metals and metalloids to accumulate in one or more plant organs but not in others; this phenomenon is often species-specific. How heavy metals are transported to the xylem portion of vascular bundles by radial transport, which involves radial passage across rhizodermis and endodermis with Casparian strips and their "efflux" from xylem parenchyma cells, is still a mystery. Vertical transport then occurs to the aerial parts, which refers to the vegetative as well as generative plant organs. Many heavy metals/metalloids are transported attached to both low- and high-molecular-weight ligands, particularly sulfur ligands and perhaps organic acids, according to certain research, as seen in Fig. 4. Heavy metals and metalloids with low molecular weight may be stored in the vacuoles of root parenchymatic cells, where they are transferred by specialized transporters. But, how are heavy metals and metallicoids moved through xylem? According to several studies, metal and metalloid ions are transported through the cytosol of parenchyma cells and into vascular cells by p-type ATPases even when they are linked to oxygen or nitrogen ligands[3].

DISCUSSION

Metals/Metalloids Tolerance and Toxicity

The most extensively researched heavy metal is cadmium, and the symptoms of metal/metalloid poisoning are comparable. The following are the main impacts of heavy metals and metallicoids:

1. Oxidative stress because many heavy metals and metalloids have oxidative-redox characteristics.
2. Because they resemble necessary metals, heavy metals and metalloids bind to the structures of proteins and other bioactive compounds.

In reaction to the presence of heavy metal/metalloid ions, plants synthesize phytochelatines, which are thiol compounds found in plants. Metallophytes are plants that exhibit hyperaccumulation of one or more metals or metalloids as well as tolerance to heavy metals or metalloids. Two significant commercial opportunities for these plants are phytoremediation and phytotomining. The many methods of phytoremediation include:

Rhizofiltration is the decontamination of polluted waters and sewage by adsorbing or up-taking the roots of plants. Phytoextraction is the accumulation of heavy metals from soils in plant organs that can be harvested. Phytodegradation is the use of some plants' ability to decompose pollutants. Phytostabilization is the storage of heavy metals or other pollutants in plant tissues in the form of complexes with limited solubility.

Phytovolatilization is the process through which plants that may create volatile molecules purify soil.While the exact processes causing hypertolerance are yet understood, several genes, particularly those related to stress and metal homeostasis, have been shown to be involved. Environmental issues may be treated using phytoremediation technology. One of the key benefits is that phytoremediation is less expensive both in situ and ex situ than conventional procedures. They may deteriorate during the cleanup of organic compound-polluted settings. Moreover, the prospect of recovering and using priceless metals is also a possibility[4].

Thallium

Sir William Crookes discovered the heavy metalloid thallium in 1861. It is a soft, bluish-gray substance that is malleable. It is ten times more common than silver, hence it is not an uncommon element. In clays, soils, and granites, this metalloid primarily co-occurs with potassium minerals like sylvite and pollucite. Although though thorium minerals are uncommon, a few of them, including crookesite, lorandite, christite, avicennite, ellisite, or sicherite, are widely recognized. They are made up of complexes with antimony, arsenic, copper, lead, and silver and include between 16 and 60 percent thallium as sulfides or selenides.

In the 1970s, several thallium compounds, including thallium sulphate, were used as insecticides and rat poisons. Certain substances continue to be used, particularly in electronic gadgets, infrared light detectors, and medical imaging equipment. This metalloid is also created as a by-product of the nonferrous metals, zinc, and cement industries.

While thallium is only partly soluble in water, when it is present in significant quantities in soils, it may spread via groundwater. Thallium may also spread by sludge adsorption. There is evidence that thallium is rather mobile in soils. It does not degrade once it is in the environment; instead, plants absorb it. It then moves up the food chain, where it may build up in fish and other animals and exhibit toxicity[5].

Antimony

A metalloid called antimony may have one of two distinct chemical forms: either metallic or nonmetallic. Natural occurrences of antimony exist in the environment, however human activity also allows it to infiltrate the living environment. There are more than 100 well-known minerals that include the metalloid antimony, which is extensively distributed in nature. While antimony is a fairly uncommon element in and of itself, it is far more prevalent in sulfides and sulphur salts. Stibnite is the main mineral, whereas aurostibite, kermesite, or valentinite are other significant minerals. Antimony is mostly present in environmental samples as Sb and Sb.

Human activities are the only ones that emit antimony into living spaces. Antimony trioxide, a byproduct of burning coal or smelting antimony-containing ore, is the most significant antimony form that is released into the atmosphere. Due to its close neighbor on the periodic table, arsenic and antimony exhibit highly similar chemical behaviors. Less soluble antimony species are adsorbed onto soil ppapers; they are mostly associated to iron and aluminum. The soluble antimony forms are extremely mobile in water.

The most significant causes of antimony pollution in metropolitan areas are the emission of antimony in vehicle exhaust and antimony abrasion from brakes, tires, and street surfaces. Antimony's toxicity is unknown, however Sb species are often more poisonous than Sb species, and antimony has similarities with arsenic and bismuth in terms of its biochemical activity. It is likely that plants and algae with a high capacity for accumulating As and Bi can also do so for antimony. Several studies are focused on how antimony affects microorganisms. Chlorella vulgaris is an intriguing species that shows superior growth characteristics in a medium supplemented with potassium tartrate as compared to a media deficient in antimony.

Its capacity to bioaccumulate antimony—12 mg Sb to 1 g of dry matter—is also intriguing. According to these findings, harmful antimony is changed in live cells into far less toxic antimony, which is then coupled to low molecular weight proteins and maybe stored in vacuoles. Sb has a very low bioavailability due to the element's very poor bioavailability. There are no thorough research focused on antimony's harmful effect's absorption, transport, or mechanisms. We may infer that the processes of antimony metabolism are comparable to those of other heavy metals: upon uptake, the harmful Sb form is transformed to the Sb less-toxic form, which is then complexed with proteins or carbohydrate molecules and stored in the vacuoles of plant cells. Organic, methylantimony compounds as well as inorganic forms of antimony were identified in plant extracts from regions polluted by mining operations that removed antimony. Cyanobacteria and plants that bioaccumulate antimony from contaminated waters due to their capacity to grow partially submerged at least, such as Ceratophyllum ssp., were identified as potent Sb bioaccumulators, along with Dittrichia viscosa, Digitalis purpurea, Erica umbellata, Calluna vulgaris, and Cistus ladanifer.

Selenium

A nonmetallic chemical element called selenium resembles tellurium and sulphur in its chemical activity. Many allotropic forms of this metalloid are present. Selenium is a fairly uncommon element on the surface of the planet. Selenium is very uncommon and often occurs alongside sulfides and metals like copper, zinc, and lead. Selenides, selenates, selenites, and elemental Se are the most significant selenium inorganic forms. Selenium is a naturally occurring element that is emitted by both natural and human processes in living environments. The most significant selenium form that is released into the atmosphere is selenium dioxide, which is produced during the burning of coal and oil. This material may be adsorbed on dust ppapers and transformed into other selenium forms, such as methyl derivates or selenium acid. Selenium tends to wind up in the soil of disposal regions from both the air and garbage. The interactions between selenium and other substances as well as the environment have a significant impact on how the metal behaves in soils and water. In soil, selenium is immobile, but when oxygen and acidity levels rise, more mobile selenium is formed[6].

More Exotic Heavy Metals and Metaloids

A metalloid called tellurium is a semiconductor that is often utilized in the manufacturing of thin films, rechargeable batteries, and charge transfer devices. Human health is expressly impacted by tellurium. Tellurium residue may be discovered in milk samples, as well as in water, sediment, soil, and plants. While the uptake, trans- port, and metabolism of tellurium are yet unclear, they are likely related to sulphur or selenium.

Germanium, a metalloid found in tiny amounts in the Earth's crust, is poisonous to humans and plants at high concentrations. It has chemical characteristics akin to silicon. Reciprocal ratio Ge/Si is used to evaluate weathering processes in subtropical and tropical ecosystems as well as to track silicon sources in marine sediments.

Although the function of silicon in plants is well understood, little is known about the function and metabolism of germanium. Sil- icon is absorbed by plants as undissociated monisilic acid – through passive as well as active transports and precipitates in cell walls, intercellular gaps, and sio2, an amorphous opal, in the cells. Moreover, silicon interaction with proteins was shown. A relatively limited amount of data on germanium uptake and transport is compared to silicon, although it is clear that there are parallels to Si metabolism. The capacity of Ge to form complexes with various ligands is a crucial characteristic[7], [8].

Gallium is an extremely uncommon element that is utilized in industry and as a semiconductor. It may be found in nature in traces in bauxite, coal, or sphalerite. Gallium salts, including gallium maltolate, are being researched as possible anticancer medications. Certain salts, such gallium citrate or gallium nitrate, are employed as radiopharmaceutical agents used in scintigraphy. Gallium was also shown to have antibacterial effects via disrupting Fe uptake. Ga shown less harmful effects than aluminum in a research on the algae Chara corallina. In addition, scandium was compared, which showed the highest hazardous effects when compared to Ga and Al. In a research, Wheeler et al. validated the significant gallium uptake by roots. Since plants exposed to gallium had iron deficiencies, disturbances and interactions with aluminum uptake were not known to be the mechanism of gallium's cytotoxic impact.

As compared to conditions without Sc supplementation and prior experiments, wheat seedlings that had Scandium bioaccumulation exhibited improved growth metrics. Sc levels in aerial sections of seedlings moved from Sc-enriched to conventional culture conditions decreased, although Sc concentration in roots remained high. Gold may be absorbed by plants from the soil. These findings were supported by a research on alfalfa plants by Lasat that showed the plants' capacity to absorb gold from medium. There are restrictions on the uptake of gold since it is a rare element and has a relatively poor solubility in natural conditions. The addition of Au-chelating chemicals to medium dramatically boosts the uptake of Au by plants[9]–[11].

CONCLUSION

From maize, a rare earth element-binding protein that is not likely phytochella-tine was identified. It is made up of two subunits and has a molecular weight of 183.000. This protein is high in glycine, alanine, leucine, glutamine/glutamic acid, asparagine/aspartic acid, and glutamine/glutamic acid. It also has 8.0% covalently bound carbs. In vascular plants, the concentration of REEs is often greatest in the roots compared to the stems and leaves, and the lowest concentration was found in the fruits and seeds. A greater REE content was also found in plant tops.

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CHAPTER 15

RHIZOBACTERIA THAT PROMOTE PLANT GROWTH: THEIR FUNCTION IN THE REHABILITATION OF METAL-CONTAMINATED SOILS

ABSTRACT:

With the start of the industrial revolution, the danger of toxic metal pollution of the biosphere has grown significantly. Industrial processes including mining, smelting, forging metal, burning fossil fuels, and applying sewage sludge to agricultural techniques are the main sources of metal contamination. The soil's microbial population density and physico-chemical characteristics are negatively impacted by the metals emitted from these sources, which in turn reduces soil fertility and crops' yields. The majority of the time, heavy metals cannot be naturally broken down into less hazardous byproducts, therefore they remain in the environment. Traditional techniques for metal detoxification are efficient and yield huge amounts of harmful byproducts. With the development of bioremediation, there is now an alternative to traditional techniques for cleaning up metal-contaminated soils.

KEYWORDS:

Bioremediation, Heavy Metals,Plant Growth, Rhizobacteria, Symbiotic Nitrogen, Phytoremediation, Rhizoremediation.

INTRODUCTION

In contrast to traditional agriculture, where a larger use of agrochemicals reduces their relevance, metal-tolerant plant growth promoting rhizobacteria play a natural function in maintaining soil fertility in metal-contaminated soils. Rhizobacteria play a crucial part in the detoxification and removal of metals, but they also stimulate plant growth via the production of siderophores and other growth-promoting compounds. Another cutting-edge, low-cost in situ method for cleaning up contaminated soils is phytoremediation. The cautious and meticulous application of suitable heavy metal-tolerant, plant growth-promoting rhizobacteria, including symbiotic nitrogen-fixing organisms, may increase the effectiveness of phytoremediation. In order to restore contaminated soils and subsequently increase crop productivity in metal-polluted soils around the world, this review presents the results of studies on the most recent advancements in the utilization of plant growth-promoting rhizobacteria for direct application in soils contaminated with heavy metals under a wide range of agroecological conditions[1].

The ecosystem of the soil is seriously threatened by the emission of heavy metals from numerous industrial sources, agrochemicals, and sewage sludge. In general, heavy metals are not naturally destroyed and remain in the environment forever. As toxic metals build up in soils, they have an impact on the metabolic processes of microbial communities, particularly rhizobacteria that aid in plant development. Additionally, the increased levels of metals in soils and plants' uptake of those metals have a negative impact on crop growth, symbiosis, and yield by disrupting cell organelles and membranes, acting as a genotoxic substance, interfering with physiological processes like photosynthesis, or by impairing respiration, protein synthesis, and carbohydrate metabolism. As a result, it is critical to clean up metal-contaminated soils since they often cover sizable regions that are no longer suitable for sustainable cultivation.

Agronomically significant microorganisms have developed a variety of methods to withstand the absorption of heavy metal ions in order to avoid the metal stress. The influx of metal ions from outside the cell, their accumulation and sequestration within the cell, the conversion of hazardous metals into less toxic forms. These characteristics have led to a significant decrease in the toxicity of metals when PGPR, including nitrogen fixers used as seed inoculants, are applied to soil that has either been intentionally treated with metals or is already contaminated. This has improved the overall growth and yield of chickpea, greengram, and pea. The PGPR are widely recognized for their involvement in improving soil fertility and raising agricultural production by supplying necessary nutrients and growth regulators, in addition to their role in shielding plants from metal toxicity. They also help plants develop by producing 1-aminocyclopropane-1-carboxylate deaminase, which reduces the stress brought on by the ethylene-mediated influence on plants. The use of these microorganisms, which have numerous metal resistance capabilities and the capacity to stimulate plant growth through a variety of pathways in soils polluted with metals, makes them one of the most attractive options for bioremediation investigations[2].The revolutionary method known as phytoremediation is the second alternative method utilized to purge the polluted soils utilizing plants. In order to remove, transfer, or stabilize pollutants from soils, this method uses metal-accumulating plants, however the process is time-consuming. Nevertheless, the activity of rhizosphere microorganisms, the speciation, and concentration of metals deposited into the soil have an impact on how effective the phytoremediation process is. For instance, it has been shown that using PGPR Pseudomonad and Acinetobacter increases the growth and biomass of nonhyperaccumulating maize plants, improving their capacity for phytoremediation. Moreover, plants that are growing in metal-stressed soils may defend themselves against metal toxicity by producing antioxidizing enzymes that neutralize the toxicity of reactive oxygen species produced by plants and associated bacteria under metal stress.

Rhizobacteria that Promote Plant Development

Plant growth-promoting rhizobacteria are rhizosphere bacteria that may aggressively colonize plant roots and promote plant development. According to their interaction with the host plants, PGPR may be broadly separated into two groups: symbiotic rhizobacteria and free-living rhizobacteria that can infiltrate the interior of cells and either live within or outside the plant cells. These organisms have three separate effects on plant growth: they synthesize and provide certain chemicals to the plants, they facilitate the absorption of specific nutrients from the environment, and they produce specific compounds themselves and guarding plants against certain illnesses. Generally speaking, rhizobacteria enhance plant development by producing precursors to phytohormones, vitamins, enzymes, siderophores, antibi- otics, and preventing the production of ethylene. Moreover, the rhizobacterial strains may solubilize inorganic phosphorus, mineralize organic phosphorus, and boost plants' ability to withstand environmental stresses such salt, dehydration, and metal toxicity. This results in greater plant development.

DISCUSSION

Metals' Biological Availability in Soil

Heavy industrial processes including smelting, mining, metal forging, making alkaline storage batteries, and burning fossil fuels emit heavy metals like lead, arsenic, cadmium, copper, zinc, nickel, and mercury. A large quantity of metals are also added to the soil by agricultural practices including the use of sewage sludge and the use of agrochemicals. Two factors—the metallic element that precipitates as positively charged ions and the element that makes up the negatively charged component of salt determine whether these metals are bioavailable or nonbioavailable.

Metal availability in soils is determined by the physicochemical characteristics of soils, including cation exchange capacity, organic matter, clay minerals, hydrous metal oxides, pH and buffering capacity, redox potential and extent of aeration, water content, temperature, and root exudates and microbial activities. Even at high total metal concentrations, the toxic-ity of metals in soils with high CEC is often modest. Metals are often found in soluble cationic forms in oxidized and aerobic environments, whereas they typically precipitate as sulphide or carbonate in reduced or anaerobic environments. Due to the development of insoluble metal minerals like phosphate and carbonate in high-pH soil, metal bioavailability reduces. In low-pH soil, however, it rises owing to the metal's free ionic species. Some metals in soils are often mobile and bioavailable in the following order: Zn > Cu > Cd > Ni. Yet, there are significant differences in the levels of heavy metals in each element of the ecosystem[3].

Metals' coexistence and persistence in soils as different contaminants make it easier for these pollutants to enter food chains and eventually make their way into human diets. Environmentalists are paying a lot of attention to the heavy metal contamination of agronomic soils since it has now become a worldwide danger to the viability of agro-ecosystems. In order to evaluate the effects of metals on beneficial rhizospheric microbes and crops grown in metal stressed soils, as well as to predict the application of bioremediation technologies that could be used to clean up metals from the polluted soils, it is necessary to assess the bioavailability of heavy metals and the uptake of metals by plants. Thus, it is crucial to address the remediation of such soils as soon as possible to ensure the sustainability of crops and, in turn, global food security[4].

Rhizobacteria that Promote Plant Growth Fight Heavy Metal Stress

An increasing environmental problem is the buildup of heavy metals in the soil environment and its uptake by both PGPR and plants. Heavy metals are difficult to remove from polluted settings, in contrast to many other pollutants, which may go through biodegradation and create less hazardous, less mobile, and less bioavailable compounds. While the speciation and bioavailability of certain metals may fluctuate with variations in environmental conditions, they cannot be biologically destroyed and are ultimately indestructible. Certain metals, including zinc, copper, nickel, and chromium, are necessary or advantageous micronutrients for plants, animals, and microbes, whereas others are unknown to have any biological or physiological roles. The increasing concentration of these metals, however, has significant consequences on the microbial communities in soils in a variety of ways, including by reducing overall microbial biomass, reducing the numbers of certain populations, or altering the structure of the microbial community. Hence, at high concentrations, metal ions may either totally block the microbial population by preventing their different metabolic processes from occurring, or organisms can adapt to the high metal concentrations and acquire resistance to them.

Several rhizospheric microorganisms, particularly symbiotic N2-fixing bacteria, have the capacity to flourish even in high metal concentration. This property may be the consequence of inherent or induced processes. While resistance is the ability of microbes to endure in higher concentrations of toxic metals through detoxification mechanisms, which are activated in direct response to the presence of heavy metals, tolerance may be defined as the capacity to cope with metal toxicity through intrinsic properties of the microorganisms.

These procedures can have limited uses because of financial or technical limitations. Thus, it is necessary to look for alternative techniques that may restore damaged soils in an affordable, labor-saving, secure, and environmentally responsible way. Bioremediation is one such alternative strategy, which is described as the use of microorganisms or other biological processes to degrade or change environmental contaminants into harmless forms or to levels below regulatory authority-set concentration limits. It is possible to apply bioremediation ex situ to soil at the site that has been excavated away without first removing and transporting any contaminated soils or disturbing the soil matrix. Thus, controlling microbial populations in the rhizosphere by utilizing micro- bial inoculum made up of a group of PGPR and symbiotic nitrogen fixers as associated colonizers and biofertilizers might provide plants advantages essential for ecosystem restoration on abandoned lands. These microbes may be naturally occurring in polluted areas or they may be isolated from other locations and then introduced to contaminated regions. Functioning rhizosphere organisms and favorable environmental conditions are prerequisites for bioremediation. New or enhanced metal bioremediation techniques have been developed as a result of improvements in our knowledge of how microorganisms function in these processes and our capacity to control their actions using molecular biology methods[5].

Benefits and Drawbacks of Bioremediation

The option of harnessing natural biological activity to breakdown or make certain toxins harmless is known as bioremediation. As a result, it is an affordable, low-tech approach that may be continuously used on polluted sites, typically with a high level of public acceptability and often without impacting the fertility of soils or the metabolic activities of microorganisms. Its remedial property aids in preventing the off-site transportation of waste and, as a result, the possible risks to human health and the environment that might develop during transport. Moreover, bioremediation may be helpful for the remediation of several toxins, resulting in their total elimination. As contaminants are changed, their toxicity decreases. Technologies for bioremediation also have certain drawbacks, such as the possibility that the biodegradation's byproducts would be more hazardous or persistent than the original chemical. Since biological processes are often specialized, they need active, specialized microbial communities whose effectiveness is influenced by the soil's nutritional status and the quantities of pollutants at the places that need to be cleaned up. That takes a lot of effort, and field success doesn't always translate well from laboratory results. Since bioremediation seems to be a good method Research in this area is expanding quickly as an alternative to traditional clean-up technology. Yet, molecular engineering of microorganisms is still urgently needed in order to control them for improved performance and broader applica- tion under various agroclimatic conditions[6].

Rhizobacteria-Assisted Plant Growth-Promoting Heavy Metal Remediation

In comparison to nonrhizosphere soils, rhizosphere soils have a higher concentration of nutrients released by the roots, which attracts more microorganisms. This phytobacteria system has been shown to be more successful in reducing the bioavailability and biotoxicity of heavy metals. These bacteria, especially PGPR, help the plant flourish in turn. The PGPR, however, has mostly been used in agricultural activities as a growth-promoting agent; significant attention is being put on them in order to fully utilize their bioremediation potential. By artificially introducing viable populations to polluted locations, stimulating a viable native microbial population, and using biotransformation, bioreduction, bioaccumulation, and biosorption, metals from contaminated soils may be removed via PGPR. Recent studies have successfully used both dead and live microbial biomass to investigate novel metal treatments and recovery methods based on biosorption.

Prokaryotic bacteria often assemble metals by passively attaching them as cations to the cell surface. In this respect, substantial research has been done on the PGPR strains' ability to biosorb metals. As an example, Hernandez et al. discovered three enterobacteriaceae species of bacteria that could accumulate nickel and vanadium. Ion exchange and micro-precipitation are two further possible substitute methods now in use that involve surface complexation for metal removal.

According to a research, Streptococcus faecalis, Streptococcus aureus, Bacillus subtilis, Bacillus licheniformis, Pseudomonas aeruginosa, Proteus vulgaris, and Serratia marsce- cens, in mixes of Gram positive and Gram negative bacteria, biosorbed cadmium, copper, selenium, and zinc. Surface complexation often takes place between metal pollutants and organic P groups in teichoic acid on the surface of Gram-positive bacteria. For instance, among all the uranium solid phases, uranium phos- phate solids are the least soluble. Gram-negative bacteria, on the other hand, don't have these organic P groups on their cell surfaces, which may explain why they seem to be less able to sorb uranium. The S-layer is a crystalline proteinaceous surface layer that is one of the most prevalent surface structures in both bacteria and archaea. It reduces the sorption capacity of Gram-positive bacteria[7].

Also, since heavy metals in general cannot be metabolized by living things, they remain in the environment. Yet, a broad range of multivalent metals that pose serious risks to the environment may be transformed by microbes. Several PGPR strains with the capacity to reduce metal have been found in this area. Hexavalent chromium, for instance, is more hazardous and carcinogenic than other forms of chromium because of its high solubility in water, quick permeation through biological membranes, and subsequent interaction with intracellular macromolecules. The remediation of chromium-contaminated soil settings is thought to benefit from the reduction of harmful hexavalent chromium to a trivalent form of chromium. Microbes may reduce/detoxify hexavalent chromium in a cost-effective and ecologically friendly manner, offering a workable solution for safeguarding the soil environment against chromium toxicity.

Symbiotic nitrogen-fixing organisms and rhizoremediation

Since it offers an environmentally responsible and secure way for restoring and remediating damaged soils, the use of plants for rehabilitation of heavy metal-contaminated soil is an emerging topic of study. Despite the fact that many plant species are capable of hyperaccumulating heavy metals, technology is insufficient for reclaiming contaminated lands. Combining the benefits of microbe-plant symbiosis inside the plant rhizosphere with an efficient cleaning method might be a significant answer. Rhizobiologists have long researched the relationship between plants and their symbionts, particularly in the case of legumes. The region around a plant's root system, known as the rhizosphere, is distinguished by higher biomass production. Plant roots secrete nutrients, which results in a nutrient-rich environment that fosters an increase in microbial activity. Rhizosphere bacteria consume nutrients that are secreted by roots, such as organic acids, enzymes, amino acids, and complex polysaccharides. Moreover, rhizosphere microorganisms get nutrients from the mucigel released by root cells, lost root cap cells, or the degradation of whole roots. In exchange, the bacteria transform nutrients into forms of minerals that plants can readily absorb.

For instance, it has been shown that chickpea infected with phosphate-solubilizing bacteria and Mesorhizobium ciceri had higher growth, symbiosis, and yield due to improved phosphate solubilization and availability of appropriate amounts of N to the bean. Moreover, the root tips provide a stable redox environment and a platform for bacterial colonization. Rhizoremediation methods have taken use of this symbiotic interaction by researchers. Rhizoremediation, which combines bioaugmentation with phytoremediation, may be able to address some of the issues with abandoned land that arise when using both treatments alone. In this procedure, the root exudates of diverse plants encourage the development and metabolism of nodule bacteria, which in turn remove contaminants from contaminated regions extremely efficiently. While there is little known about rhizobia's molecular and cellular tolerance to metals, it has been decisively shown via a variety of research that they develop resistance when cultivated in soils that are extensively contaminated with metals. However, due to the fact that rhizobia affect the solubility, bioavailability, and mobility of metals in both the rhizosphere and within their legume host, as well as help maintain the N pool of soils and legumes, interest in rhizobia for their role in remediating heavy metals has significantly increased recently[8].

Rhizobia develop slowly in soil over extended periods of time, but if they successfully infect appropriate legume hosts, they may expand quickly, and a single bacterium's successful infection can result in the production of a nitrogen-fixing nodule on the root of legumes. Moreover, after symbiosis has been established, metals may begin to build up in nodules. This would be a different, more affordable way to remove metals from the soil. Because the symbiotic relationship between leguminous plants and rhizobia could be used to improve plant abilities by introducing genetically modified rhizo- bia to plant roots, the use of Rhizobium legume symbiotic interaction has been suggested as a tool for rhizoremediation of metals in defunct soils. Recombinant rhizobia are useful for the production of foreign genes that aid in sequestering metals in polluted soil, and they may be found in each nodule on a legume root. For instance, the N2-fixing bacteria Mesorhizobium huakuii subsp. rengei strain B3 has a symbiotic association with the legume Astragalus sinicus, which has been employed as green manure in rice fields in China and Japan and creates nitrogen-fixing root nodules. It would be helpful if this plant could be utilized to boost N levels while also removing metals from the soil.

In other research, M. huakuii subsp. Rengei strain B3 was modified to produce the gene encoding the metal-binding protein, tetrameric metallothionein, or arabidopsis phytochelatin synthase, which was under the control of a bacteroid-specific promoter, nifH or nolB. The buildup of cadmium in free-living cells was increased by the recombinant strains that were produced. Leguminous plants like alfalfa are suited for rhizoremediation, according to a different research on the subject. They may house a lot of germs on their root systems, which is presumably why. Rhizoremediation, on the other hand, is dependent on a number of variables, including primary and secondary metabolites, colonization, the creation of rhizobial communities, survival, and ecological interactions with other rhizosphere-dwelling species.

Another research found that green gram plants injected with metal-tolerant Bradyrhizobium greatly improved plant growth and symbiosis while reducing the absorption of nickel and zinc by plant organs when cultivated in sandy clay loam soils exposed to various amounts of nickel and zinc.

Thus, it was hypothesized that the overall rise in inoculated green gram plants in metal-contaminated soils was caused by either a decrease in metal toxicity or by the plants' adequate availability of N and phytohormones produced by the inoculants strain.

Phytoremediation

The ecologically acceptable and aesthetically pleasing process of phytoremediation uses plants to remove toxins from damaged soil environments. Plant species and genotypes have a big impact on how sensitive or tolerant plants are to metals. In general, plants may be divided into three categories: accumulators, indicators, and excluders. Whereas indicators have weak control over metal absorption and transport pathways and react accordingly to soil metal concentrations, excluder groups' plants are sensitive to metals across a broad range of soil concentrations and survive via limitation mechanisms. Grasses are included in the excluder and indicator categories, as well as grain and cereal crops. Since they cannot stop metals from getting into their roots, plants in the accumulator group have developed unique detoxification systems for the large levels of metal that have built up in their cells. Tobacco, mustard, and plants from the composite family are examples of common plants included in this category. Some plants among these accumulators, known as hyper-accumulators, have a very high capacity for gathering metals, which enables them to endure and even flourish in highly polluted soils[9].

How Plants Aid Soil Restoration

In contaminated soils, plants' roots are the first organs to come into touch with heavy metals, and once the roots have absorbed the metals, the metals are transferred to other parts of the plant. As shown in Fig. 10, plants in soils with high levels of metal contamination experience a variety of injuries that eventually result in their mortality, including the inactivation of photosynthesis, the synthesis of proteins and DNA, stomatal activity, and the production of free radicals.

Yet in order to live in the metal-contaminated soils, plants might build up, sequester, or create metal-binding complexes, which are simply -glutamyl peptides that develop in response to the stress of heavy metals and are among the few really adaptive stress responses seen in plants. Typically, plants will use one or a combination of the following defenses against metal toxicity. These processes include phytoextraction, a low-cost method of removing or concentrating metal into plant parts, which results in a mass of plants and contaminants that can be transported for disposal or recycling, phytodegradation, also known as rhizodegradation, or rhizofiltration, in which metal is absorbed by plant roots, and phytostabilization, a method of immobilizing metals.

Rhizobacteria that Promote Plant Growth and Influence Phytoremediation

Since helpful bacteria have been lost, contaminated soils are often nutrient low or sometimes nutrient deficient. The PGPR would not only provide the vital nutrients to the plants growing in the contaminated sites, but would also play a significant role in detoxifying heavy metals, assisting plants that can remediate heavy metals. However, such soils can be made nutrient rich by applying metal-tolerant microbes, especially the PGPR. For instance, PGPR Kluyvera ascorbata SUD165, isolated from metal-contaminated wetlands in Sudbury in Ontario, Canada, has demonstrated to improve the growth of canola while safeguarding the plants from nickel toxicity when applied to soils altered with nickel, zinc, lead, and chromate. When cultivated in soils enriched with nickel, lead, and zinc, nickel resistant Kluyvera ascorbata shielded tomatoes, Indian mustard, and canola plants. The growth-promoting rhizobacteria Variovorax paradoxus, Rhodococcus sp., and Flavobacterium sp. also encouraged root elongation in Indian mustard seedlings whether toxic cadmium was present or not, suggesting that these bacterial strains could be developed as inoculants to enhance the growth of the metal-accumulating Indian mustard in the presence of toxic cadmium concentrations, as well as for the development of plant inoculant Similar to how the Enterobacter cloacae-inoculated canola plants grew substantially more than nontransformed canola plants when cultivated in the presence of arsenates[10].

In other research, Ochrobacterium intermedium and Bacillus cereus shielded green gram plants against chromium toxicity, while Ochrobacterium intermedium inoculation enhanced sunflower growth when cultivated in soils with metal amendments. Several investigations have shown the significant protection against metal toxicity provided by metal-tolerant, growth-promoting rhizobacteria. As a result, plant growth, symbiosis, and seed output have all increased. The ability of metal-tolerant rhizobacterial strains to reduce the toxic effects of metals using the mechanisms discussed earlier in addition to providing plants with adequate amounts of growth-promoting substances was attributed to the increase in the growth of agronomically significant crops grown in metal-stressed soils. To boost plant biomass, stabilize, revegetate, and restore/remediate heavy metal-polluted soils, inoculate plants with these rhizobacterial microorganisms[11], [12].

CONCLUSION

An emerging field of study that has made significant in-situ progress in remediating metal-polluted soils has to be further solidified by field tests in various agroclimatic regions of the globe.

To more accurately model the full impact of phytoremediation in the restoration of abandoned lands, it will be necessary to comprehend the mechanistic underpinnings of the physical, chemical, and biological rhizosphere processes as well as the interactions between hyper-accumulators and nonaccumulators and PGPR. Rhizobacteria can be mass grown simply and cheaply, making its use in the remediation of heavy metal-contaminated areas an intriguing field of study. To increase the effectiveness of growth-promoting rhizobacteria mediated or plant-based remediation of polluted soils, both microbes and plants might be molecularly engineered to include desirable genes.

Nevertheless, some of the issues must be seriously addressed in order for bioremediation to be a viable alternative for the remediation of polluted soils. Research is required to investigate various aspects of metal accumulation by plant organs, and we also need to understand the mechanisms involved in mobilization and transfer of metals to develop new strategies and optimize existing ones. These problems include: why PGPR fail to perform in comparably extreme environments; how rhizobacteria colonize plant roots and interact selectively with other indigenous microflora; how the remediation effects will change under field conditions. Before the promise of bioremediation in cleaning up metal-polluted soils can be understood, scientists must give these issues their immediate attention.

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CHAPTER 16

USING PHOSPHATES TO IMMOBILIZE LEAD IN SOILS

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ABSTRACT:

Lead is a harmful metal that occurs in water and soil, mostly as a consequence of human activity, in its soluble ionic forms. To lessen their toxicity, lead ions may be complexed with a variety of substances to reduce their bioavailability. Phosphate addition is a frequently used method for chemically immobilizing Pb from polluted soils and aqueous solutions. As various P amendments are applied, Pb in soils changes from forms that are most available to those that are most tightly bound.

KEYWORDS:

Agriculture, Environment, Pyromorphite, Remediation.

INTRODUCTION

The development of pyromorphite Pb53X, where X F, Cl, Br, OH, and the most stable environmental Pb compounds across a broad range of pH and Eh natural circumstances, causes a rise in Pb in the residual or insoluble fraction. Since pyromorphite is insoluble in the digestive system, accidental pyromorphite consumption does not result in bioavailable lead. A wide variety of organic and inorganic phosphate substances, including apatite and hydroxyapatite, biological apatite, rock phosphate, soluble phosphate fertilizers like monoammonium phosphate and diammonium phosphate, phosphoric acid, biosolids rich in phosphate, phosphatic clay, and mixtures, have been used to immobilize lead. Different nondestructive methods, including x-ray diffraction, scanning electron microscopy coupled with energy dispersive X-ray spectroscopy, x-ray absorption fine structure, transmission electron microscopy, and electron microprobe analysis, have been used to identify pyromorphite in phosphate-amended soils. Sequential extraction, the toxicity leaching process, and a physiologically-based extraction procedure imitating metal intake and gastrointestinal bioavailability to humans have all been used to assess the efficiency of in situ Pb immobilization.

In order to effectively immobilize Pb via P amendments, it is necessary to induce acid conditions to increase the solubility of both the phosphate phase and the Pb species phase. While the addition of phosphorus seems to be quite successful, excess P in soil and its possible impact on the eutrophication of surface water as well as the risk of arsenic increased leaching remain a worry. Combining therapies may be a good idea to increase their potency in lowering lead phyto- and bioavailability[1]. By pedogenic and anthropogenic activities, lead enters the soil environment. The main cause of lead contamination of soils is human activity, namely industrial operations, manufacturing, and the disposal of household and industrial waste. Without taking into account its chemical speciation and mineral form, it is impossible to evaluate the existence of lead and its compounds in the environment, as well as their potential toxicity to the eco-system and to the human population. Understanding lead speciation is essential for forecasting lead's mobility and bioavailability as well as assessing the danger that it poses to living things since insoluble forms of lead are difficult for biota to absorb.

The bioavailability of the Pb is a crucial factor in the danger from soil Pb. The bioavailability of Pb in soil is directly influenced by soil characteristics and Pb form. The main cause of worry for people is Pb consumption. Consuming soil ppapers that contain Pb often results in this. Before the Pb can be taken into the body, it must first be released as Pb2+ in the digestive juices. Hettiarachchi and Pierzynski provide an overview of in vivo research on Pb consumption. Waterborne ppapers or dissolved lead may both be transported in it. The majority of this lead is subsequently precipitated as a solid and gets integrated in the sediments at the base of the watercourse or ocean, however few lead compounds easily dissolve in water. The majority of the time, lead in soil is comparatively insoluble and is not very mobile. As a result, lead-contaminated soils maintain high levels of lead for hundreds or even thousands of years. According to estimates, lead's half-life in soil is 740–5,900 years. Acidic conditions, which might be present in mine wastes or landfill leachate, make lead compounds more mobile.

Three main mechanisms have an impact on the amount of lead in soils: precipitation as a barely soluble mineral phase; adsorption on clay fraction; Fe and Mn oxides; alkaline earth carbonates and silicate lattices; and formation of relatively stable complexes by interaction with soil organic matter. Many variables affect lead mobility, including Pb speciation, total Pb concentration, soil type, pH, moisture content, and water penetration from precipitation or other drainage. Pb2+ is the main dissolved specie and exhibits relatively low aqueous phase concentrations in soils[2].

While solubility is often used to describe a Pb mineral's stability, it is really a thermodynamic quantity that is only specified at system equilibrium. Most of the time, rather than being instantaneous equilibria, the mechanisms of soil contaminant retention and release are time-dependent processes. The kinetics of mineral dissolution must be taken into consideration in a system as dynamic as soil. There is a small danger of soil Pb migration into groundwater as a consequence of slow rates of Pb dissolution from certain minerals. So, while assessing the stability of a Pb compound, the dissolution rate must also be taken into consideration in addition to solubility. Pb phosphates are not very soluble; in comparison to similar carbonates and sulphates, they are many orders of magnitude less soluble. Metal-contaminated soil disposal and remediation are both exceedingly costly and labor-intensive processes. In situ chemical immobilization offers a long-term remediation option via the development of stable metal minerals and/or precipitates and is an affordable alternative to excavation and land-filling. The probability of heavy metal transmission from polluted soils to groundwater and surface water is decreased by the reduction in metal solubility.

Geochemistry of Pb in P-Modified Soils

Pb in soils changed from forms with high availability exchangeable, carbonate, Fe-Mn oxide, and organic-matter bound to the most firmly bound Pb fractions sulphide or residual after the application of various P amendments. The development of pyromorphite is the cause of the rise in Pb in the residual fraction. Cao et al. and Melamed et al. showed that the residual fraction rose by up to 60% while the carbonate-bound Pb soil fraction decreased by up to 40% and the Fe Mn oxide bound fraction by 10%. More quantities of Pb should be transferred from the nonresidual to the residual portion by the more efficient treatments. According to some reports, some Pb transition from nonresidual to residual forms took place during the extraction process, but the fact that the residual Pb soil percentage grows with time clearly suggests that this process truly happens in the field. Less phytotoxicity was the outcome of this redistribution of Pb, as seen by increased plant growth and decreased metal concentration in plant tissue. Pb migration and fixation in water, soils, and wastes are important buffer mechanisms controlled by the interaction of Pb and P via the production of pyromorphite, lowering Pb solubility as well as bioavailability. As accidental pyromorphite consumption does not produce bioavailable lead, phosphorus amendment might be a useful method of immobilizing lead in drinking water or sewage.

Even at low pH levels, pyromorphite is very stable and does not significantly disintegrate in the human digestive system. Pyromorphites have very low solubility products, which are 1071.6, 1076.8, 1078.1, and 1084.4 for fluoro-, hydroxyl-, bromo-, and chloropryromorphites, respectively. Due to the prevalence of chloride in nature, chloropyromorphite is the predominant type of pyromorphites despite being many orders of magnitude less soluble than hydroxyl-, bromo-, and fluoropyromorphytes. Chloropyro-chemical morphite's and physical characteristics showed that its persistence would withstand the majority of environmental conditions, making Pb immobilization through phosphorus an appropriate remediation method. Thermodynamics predicts that other solid phases would be changed to pyromorphite by a dissolution-precipitation process because pyromorphites are the most stable Pb phosphate minerals under normal environmental circumstances. The rate-limiting phase in the transformation of numerous Pb compounds, including cerrusite, anglesite, galena, and lead in contaminated soils, to chloropyromorphite is the dissolution/oxidation of Pb in the bearing solid, according to experimental evidence. Nevertheless, to effectively immobilize Pb via P additions, metal solubility must be increased by creating acidic conditions[3].

DISCUSSION

Mixed Phosphate Amendments

Hettierachchi et al. investigated several P additions on Pb-contaminated soils, including triple superphosphate, phosphate rock, acetic acid and triple superphosphate, and H3PO4 in various concentrations. Phosphate rock, the most efficient in the stomach phase, and triple superphosphate, the most successful in the intestinal phase, were produced as a consequence of a considerable decrease in bioavailable Pb, as evaluated by PBET. Similar findings were reported by Cao et al., who found that a combination of H3PO4 and phosphate rock was the most effective at immobilizing Pb while having less of an effect on the pH of the soil and less of a tendency to leach soluble and PR immobilized Pb, Cd, and Zn from contaminated soil, creating a more potent soluble source for reducing Pb bioavailability. With Cd2+ and Zn2+, there were no clear-cut findings. To determine whether P amendments phosphate rock, triple superphosphate, and H3PO4 could minimize the availability of Pb in situ, an international interlaboratory research was conducted. The best results were obtained when P was given as triple superphosphate or H3PO4, as seen by the enhanced plant growth, decreased metal concentration in plant tissue, decreased soil solution and extractable Pb, and decreased soil Pb bioavailability. In vitro assays to examine the effects of adding various P amendments on the bioaccessibility of Pb in soils to people. According to these researchers, solitary superphosphate performed the best at reducing Pb bioaccessibility in the stomach phase and hydroxyapatite in the small intestine phase[4], [5].

Moreover, Zhu et al. investigated the impact of various P additions in an alkaline Pb-polluted soil. By using consecutive extractions and plant absorption, the Pb bioavailability was calculated. Pb was successfully converted from nonresidual fractions to residual form by hydroxapatite, which decreased Pb bioavailability in soil and Pb buildup in vegetable crops. The alkalinity of the soil was the cause of the phosphate rock's poor performance. In order to reduce the bioavailability of lead in contaminated soils, Chen et al. evaluated the effectiveness of various phosphorus amendments, including natural hydroxyapatite, phosphate rock, triple superphosphate, and diammo- nium phosphate. They came to the conclusion that phosphate rock and hydroxyapatite were most effective because they caused the formation of pyromorphite in the soil and roots. Diammonium phosphate was effective in immobilizing Pb, but it also lowered soil pH, which led to heavy metal leakage from the soil. Plant uptake, SEM-EDX, and SE measurements were used to estimate the immobilization and bioavailability of Pb[6].

It was discovered that a combination of Cotter-Howells and Caporn's mix treatment the formation of pyromorphite by amendment of contaminated Pb soil with soluble phosphate Na2HPO4 and by the biochemical action of the roots of Agrostis capillaris was more environmentally friendly than the addition of large amounts of soluble phosphate. A shooting range soil's bioavailability of lead was also studied in relation to the impacts of mixing two microbial amendments with three distinct types of apatite[7], [8].

Given that pH, the solubility of the phosphate phase, and the solubility of the Pb species are all kinetically regulated by the production of pyromorphite as a solubility-controlling phase, soluble or acidic phosphate supplies are required for in situ effective treatment. Pyromorphite development is reduced when lime is used to restore the pH of the soil. Due to its simplicity of delivery and better capacity to dissolve Pb2+ from existing minerals and turn it into pyromorphites, phosphoric acid was thought to be the most efficient amendment. While adding phosphorus seems to be quite successful, there is still worry about the excess P in soil and how it may affect the eutrophication of surface waters. While the use of combination therapies may increase their efficiency in lowering lead absorption and bioavailability, it is difficult to determine how efficient they are because to testing irregularities. The kind of soil, the character, and the degree of the contamination all affect how effective the P amendment is in Pb-contaminated soil. It is important to thoroughly research the kind, dosage, and application management of the P source to be employed in the soil amendment. Furthermore of significant concern are the risks of primary P leaching, eutrophication of surface water sources, and the potential for as increased leaching[9]–[11].

CONCLUSION

While total metal content is not greatly lowered by amendment addition, the fundamental objective of in situ soil remediation procedures is to minimize mobility, bioavailability, and toxicity of the metal contamination. The findings of these investigations show that the interaction between Pb in contaminated soil and various phosphorus sources might result in the development of pyromorphite, improving the geochemical stability of soil Pb. Less bioavailability and reduced phytotoxicity were the results of the shift of lead from more chemically labile forms to residual phases, as shown by increased plant growth and lower metal concentrations in the plant tissue. Pb immobilization by phosphorous amendments is a very effective remediation technique because accidental pyromorphite ingestion does not result in bioavailable lead because pyromorphite is insoluble in the intestinal tract. This is due to the chemical stability of pyromorphite under various environmental conditions.

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CHAPTER 17

RESPONSES, MECHANISMS AND MITIGATION STRATEGIES

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ABSTRACT:

Cadmium contamination of soils is a significant element influencing soil characteristics and plant development. Most plants are poisonous to cadmium in low quantities, however other plants have different growth tendencies when exposed to high levels of cadmium. Some plants have cell walls that may bind the cadmium they have received. Due to their direct exposure, roots usually acquire more cadmium than shoots. Plant stunting, leaf rolling, chlorosis, and necrosis are just a few of the above-ground parts of a plant's symptoms of cadmium toxicity. Other symptoms include hormonal imbalance, decreased stomatal conductance and gas exchange, disturbed leaf water and nutrient status, production of oxidative stress, and increased peroxidation of membrane lipids. The creation of metal chelating proteins, expression of enzymatic and nonenzymatic antioxidants, organic acids, and plant root-mycorrhizal interaction are only a few of the strategies used by plants to deal with cadmium. The exogenous use of metal chelators, as well as organic and inorganic sources, may reduce the toxicity of cadmium. Discovering ways to bind cadmium in soil systems and having a greater knowledge of species diversity for cadmium tolerance, cadmium-responsive genes, and the molecular basis of cadmium tolerance may be crucial methods for dealing with this issue, which is becoming worse all the time.

KEYWORDS:

Agriculture, Cadmium, Chelation, Heavy metal, Nutrients.

INTRODUCTION

Heavy metal contamination is a growing global problem. Variable amounts of heavy metals, such as cadmium, mercury, copper, and zinc, build up in soils and plants and cause a variety of problems for both agriculture and human health. Pesticide and fertilizer usage, the dumping of solid waste and sludge, and operations including electroplating, batteries, welding, smelting, and pigment production are among the major contributors of soil pollution. Wastewater is often utilized for irrigation, which is a major factor in the buildup of even necessary micronutrients to phytotoxic levels in soils in many nations. In order to reduce the negative effects of toxic metals on plants, it is essential to pretreat wastewater and soils before using them. Cadmium has a lengthy biological half-life and is a significant toxin that affects plant production. Heavy metals have accumulated in higher soil layers as a result of the uninterrupted use of industrial wastewaters for irrigation over the last several decades. This is phytotoxic and decreases the bioavailability of vital metals. Cadmium is a non-essential element that is emitted into the environment by a number of different sectors, including metal manufacturing, power plants, heating systems, and urban transportation. Its widespread usage in several industries makes it a valuable supply. It never occurs alone in natural settings; rather, it is often discovered with lead and zinc as a guest metal[1].

Cadmium toxicity in plants is seen at the cellular and molecular levels as well as across the whole plant. The most significant effects include disruption of metabolic processes including photosynthesis, energy transduction, protein synthesis, and nutritional issues. Plants have built-in defenses against these harmful effects, such as the production of antioxidants, osmoprotectants, and proteins that bind to and chelate metals. Moreover, breeding and selection techniques, functional genomics methods, exogenous use of organic and inorganic compounds, and mem- brane stabilizers may all be used to reduce the negative effects of cadmium. This review focuses on significant consequences, processes, and some mitigating techniques used to counteract cadmium's negative effects on plants.

The Soil System and Cadmium

The phytoavailability of cadmium is significantly influenced by the physico-chemical characteristics of soil and soil solution. Unfortunately, there is a dearth of information on how additional cadmium affects the characteristics of soil. This is most likely because cadmium is hazardous to plants at very low concentrations, and plants cannot grow in soils with high concentrations of cadmium, which might change their physiological characteristics. The research that is now accessible demonstrates the significance of soil qualities such as chemical form and speciation, valence state, solubility characteristics, interactions with vital metals, presence of cadmium-chalators, ascorbate, metallothionein, and cadmium-complex formation.

It has been shown that oxygen consumption stimulation on soil incubated with 0.01 and 10 mg of cadmium per kilogram of soil may decouple respiratory phosphorylation. Growing crops on heavy-metal dredging sediments has been demonstrated to alter their physico-chemical state by reducing pH, increasing redox potential via mechanical action of the root, producing soluble organic molecules, and encouraging microbial activity. These activities increase the mobility and bioavailability of heavy metals that are already present, which might pose a serious hazard to the ecosystem and future vegetation[2].

A significant buildup of nitrite nitrogen at greater cadmium concentrations shows that cadmium is harmful to soil nitrification. Once nitrogen and proton separate, ammonium nitrogen decreases the pH of the soil and increases cadmium's bioavailability. The concentration of cadmium in solution as well as its sorption and desorption in soil are controlled by a variety of soil properties, including cation exchange capacity, organic matter, and pH, according to other research. The pH of the soil is the most crucial of them since alkaline pH decreases phytoavailability while acidic pH increases it. On the other hand, chelating substances in organic matter may chelate cadmium and promote the growth of the soil microflora. In addition to chelating agents, the addition of phosphate as KH2PO4 raises the pH of the soil, adds a negative charge to it, aids in soil adsorption, increases the amount of soluble and exchangeable cadmium in the soil, and decreases the physical availability of the metal.

Phytotoxicity Reactions to Cadmium

Cadmium does not play any physiologically advantageous roles in plants, but when it is accumulated, it has an impact on every element of growth and development. The most often seen consequences of cadmium-phytotoxicity include a reduction in biomass production, a reduction in photosynthetic activity, a suppression of root elongation, and even plant death. It has a high level of phytotoxicity and causes a wide range of morpho-anatomical, physiological, and biochemical alterations. These effects are highly influenced by the stage of plant development, the amount of cadmium used, and the physico-chemical makeup of the medium used for plant growth.

Reactions in Morphology, Growth, and Yield

One of the most dangerous and movable metallic elements in soil is cadmium. It has the potential to contaminate the ecosystem and the soil. Since cadmium is extremely mobile in its ionic state within the phloem and its salts are very water-soluble, it may quickly move to other areas of the plant. Due to its characteristics, including a high affinity and interaction with the sulphydryl group of amino acids and certain proteins in the sieve tube, cadmium has a high mobility in the phloem. Plants' ability to produce dry matter and lengthen their shoots and roots is reduced, mostly as a result of reduced photosynthetic activity. Cotton, pea, lupin, salix, mungbean, Avena strigosa, Crotalaria juncea, and many more plant species are among those whose genotypes and species vary in their capacity to absorb, transport, and accumulate cadmium[3].

The severity of the current stress is directly indicated by the symptoms present on plant sections. Leaf rolling, chlorosis of the leaf and stem, necrosis, tip-burning, plant-stunting, browning of the roots and yellowing of the leaves are some of the visible symptoms of cadmium toxicity on plants. Due to higher tissue concentrations of cadmium, these symptoms also cause impaired growth and a decrease in yield. Deficits in iron and phosphorus or impaired manganese transport are thought to be the cause of these consequences. Within 48 hours of exposure, poisoning symptoms might be seen. Cadmium quickly absorbs from the substrate and accumulates in plants. The major causes of plant stunting brought on by cadmium stress are decreased water absorption and decreased leaf gas exchange. These impacts may greatly aid in the identification of stress-related symptoms, the adoption of effective stress-reduction techniques, and, ultimately, the selection of promising germline material.

For cadmium accumulation and tolerance, species and cultivars show significant variances. Physiological changes including a decrease in the generation of reactive oxygen species and an increase in antioxidative defense make these distinctions clear. Several development stages of certain crops have shown intra- and interspecific differences in cadmium concentration. Because of differences in zinc homeostasis and root development, a comparison of two Nicotiana species showed that Nicotiana rustica was more tolerant to cadmium than Nicotiana tabacum. Although the roots of both these plants shown higher sensitivity to cadmium than the shoots, seed germination in maize and soybeans did not seem to be a reliable measure of cadmium toxicity. Postgermination mortality in mungbean was regarded as a significant cadmium-phytotoxicity impact.

DISCUSSION

Developmental and Anatomical Reactions

As a starting point, roots exhibit a variety of reactions to cadmium excesses. Cadmium deposits have been found in the vacuoles of the exodermal cells of Phragmites australis during histolocalization tests using transmission electron microscopy. This demonstrates that roots store cadmium in the vacuole as a tolerance mechanism to shield the cytoplasm from its harmful effects. Cadmium kills cells in the elongation zone of Arabidopsis roots, according to Suzuki. The roots were exposed for two weeks to a sublethal concentration of cadmium, which caused the cells to distort and have irregularly thickened walls. The endodermis, pericycle, and cambium of these cells revealed the buildup of some chemical. It seemed that cadmium inhibited the root cells' ability to undergo mitosis, albeit the precise mechanism generating these alterations could not be determined. Cadmium influences the developmental phenomenon at the cellular and tissue levels in addition to generating morphological alterations. It promoted premature root growth, accelerated xylogenesis, and eventually resulted in the creation of shorter roots. This was mostly due to increased hydrogen peroxide generation and peroxidase activity in the early metaxylem and vascular bundles[4].

Cadmium has been found to have negative effects on cellular ultrastructures. The chloroplast ultrastructure became disorganized as a result of applied cadmium, which also caused an increase in plastoglobuli and the production of vesicles in the vacuole. It triggered a metabolic switch from peroxisomes to glyoxysomes and caused the senescence of peroxisomes.In summary, greater cadmium levels have a significant impact on the morphological and developmental alterations that cells and tissues experience, including the disruption of organelle structure.

Localization of Cells and Tissues

Cadmium accumulates there and harms the plant after being absorbed by the root and transported to numerous cells and tissues. More labeled cadmium concentration in the roost than the leaves, with the most of it being kept in the distal section as a tolerance strategy, was shown by cadmium-tolerant tobacco species. Research using energy-dispersive x-ray microanalysis, x-ray spectromicroscopy, and analytical electron microscopy showed that cadmium was located in vascular bundles and connected to the S-ligands and pericycle cell walls in the root of Arabidopsis thaliana. Yet, the primary sites of cadmium accumulation were found in leaf trichomes.

Despite the fact that a high dosage of cadmium did not cause any ultrastructural alterations in the roots of Phragmites australis, histochemical localization showed that cadmium had been deposited in the parenchyma cells underneath the exodermis. Nevertheless, cadmium was shown to deposit with phosphorus in the apoplast and sulfur in the symplast in a research on the ultrastructure of Ara- bidopsis thaliana roots using energy-dispersive x-ray microanalysis, indicating its precipitation with phytochelatins.

Cadmium was hidden in the endodermis as tiny granular deposits in the cytoplasm. The passage cells seemed to be involved in the transfer of cadmium from the pericycle to the stele before it was reabsorbed into the apoplast. Cadmium was found in the tracheids but not in the mesophyll cells of the leaves.

This suggested that cadmium had moved back from the shoot to the root. Major cadmium deposition occurred in the veins of the willow, where it induced tannin-plugging and necrosis in the leaf margins surrounding the mesophyll and upper epidermis, hastened the senescence of the mesophyll cells, and caused a layer of collenchyma cell walls rich in pectin to form. Several studies demonstrate that roots acquire more cadmium because they are directly exposed to it. Greater cadmium accumulation in the root of Phaseolus vulgaris showed no discernible impact on the plastid ultrastructure. Younger leaves exhibited a larger disruption of chloroplast structure and function than did main leaves. It was concluded from this that when cadmium is transferred to the shoot, photosynthetic cells are more vulnerable to cadmium toxicity where it is deposited, leading to oxidative damage and speeding up senescence. In conclusion, calcium builds up and is deposited in both shoot and root tissues, interfering with physiological processes and upsetting cellular architecture[5].

Biochemical and Physiological Reactions

The inactivation of macromolecules and cellular structures as well as the development of oxidative stress are cadmium's two main impacts on plant systems. Reduced photosynthetic rate is one cause of the decreased growth and yield associated with high amounts of cadmium in growth medium. Yet, as will be shown in the next sections, there is still much to learn about the processes behind cadmium toxicity.

Photosynthesis

It has been claimed that cadmium excesses are sensitive to all facets of photosynthesis, including light and dark reaction and assimilate partitioning. By hindering chlorophyll manufacture, accelerating its heme-level breakdown, or impairing photochemical and carboxylation reactions by interfering with the activities of chloroplastic enzymes, it affects the chloroplast metabolism. All photosynthetic enzymes are impacted, but the enzymes involved in light reactions are particularly impacted. Applied cadmium has a noticeable and immediate impact on photosystem-II activity over short exposure times in Thlaspi caerulescence, and both photosystem-I and II over lengthy exposure times in peas. More reactive oxygen species production and decreased antioxidant activities were related to a higher arrest in photosystem-II activity compared to photosystem-I in Riccia. Nonetheless, oxidative damage caused the photosystem-II activity in two maize cultivars to diminish but not halt, despite a significant drop in the quantities of carotenoids and chlorophylls[6].

While lower levels of cadmium boosted carotenoid content, higher levels decreased carbonic anhydrase activity and photosynthetic pigments in the leaves and nitrate reductase activity and carbohydrate content in the root and leaves. The principal effect of cadmium on photosynthesis in sun-flowers is oxidative damage to chloroplastic membranes, which reduces photochemical and nonphotochemical quenching as well as the quantum efficiency of photosystem-II and CO2 assimilation. Stomatal conductance and its indices, transpiration, and net photosynthetic rate are among the gas-exchange metrics that are significantly impacted by cadmium. Stomatal closure may be the cause of the cadmium-treated plants' decreased transpiration rate. Although while cadmium decreases stomatal conductivity, there may be a positive side effect from this impact, such as limiting cadmium transfer with decreased transpirational flow. In conclusion, cadmium has an impact on every facet of photosynthesis. Cadmium toxicity specifically targets the enzymes involved in the dark reactions and photosystem-II functioning.

Water and nutrient relationships

As a consequence of cadmium's impacts on root structure and functions, plants' access to water and nutrients suffers right away. Existing data indicate that Cadmium affects the interaction between cells and water by entering the cytosol via calcium channels on the plasmalemma. As they make up either structural or functional components of cells, acquiring vital nutrients in the right proportions is crucial for plant development. The intake and distribution of various macro- and micronutrients in different plant portions have been shown to be negatively correlated with elevated cadmium levels, which have a significant impact on the mineral nutrition of plants. Due to cadmium's antagonistic action on the absorption of iron, phosphorus, manganese, zinc, and copper, deficits in these nutrients, especially in cadmium-sensitive cultivars, result in cadmium-induced leaf chlorosis. It seems that cadmium is transported by the same metal transporters as other metal ions. The initial targets of cadmium poisoning are root membrane transporters involved in the absorption of potassium, calcium, and magnesium. Low levels of cadmium promoted potassium absorption in the cadmium-tolerant but non-hyperaccumulator Matricaria chamomilla plant, but higher levels induced potassium leakage from the root. This suggested that changing root structure and functions are largely responsible for alterations in both water and nutrient connections[7].

Antioxidants and Other Enzyme Activities

Enzymes are essential for metabolic processes in cells because they act as biochemical catalysts. Cadmium has a distinct inhibitory impact on the activity of enzymes, similar to other metals. Leucine-aminopeptidase and endopeptidase isozymes, which showed signs of senescence on the leaves, as well as glyoxylate cycle enzymes in the pea leaf peroxysomes are all enhanced by applied cadmium. It inhibits the ATPase activity of the plasma membrane of roots, which hinders the processes of transfer and transport at the root surface. Cadmium totally inhibited the -aminolevunic acid dehydratase activity in the root, nodules, and leaves of soybeans, causing a buildup of -aminolevunic acid levels in these areas. As a result of increased arginine and ornithine decarboxylase activity brought on by cadmium exposure, putrescine and spermine levels increased while spermine and proline contents decreased in sunflower plants. While S-adenosyl-L-methionine had a protective function against -aminolevunic acid caused oxidative damage, this buildup led to the elevated thiobarbituric acid reac- tive substances and reduced expression and activity of antioxidants. By changing the lipid content of membranes and increasing their permeability to solute leakage, cadmium causes changes in how well they function. According to studies, cadmium-induced oxidative damage to the membrane lipids causes these alterations[8].

The oxidative damage has also been linked to the senescence seen in soybean nodules treated with cadmium. oxidative stress is thought to be caused by cadmium, either directly or indirectly by the generation of free radicals. Reactive oxygen species are produced in plants with higher levels of cadmium in the cytosol. The interaction of several reactive oxygen species-producing and -scavenging processes produces a balance between the steady-state levels of distinct reactive oxygen species. In this sense, it is crucial to consider the plant's physiological state as well as the integration of many environmental, developmental, and biochemical inputs. Antioxidant induction is a defense mechanism against oxidative damage. The perox- iredoxin family of proteins includes many antioxidants such as superoxide dismutase, catalase, ascorbate peroxidase, glutathione reductase, and thioredoxin. Intracellular ascorbate and glutathione are two nonprotein scavengers that are added to these protein antioxidants. To remove the reactive oxygen species, such as hydrogen peroxide and superoxide, that increase membrane permeability. The quantity of glutathione fluctuates in Bacopa monnieri and potato tubers as a result of decreased glutathione reductase activity or superoxide dismutase activity in Brassica juncea. In maize, on the other hand, there was no change in the superoxide dismutase, ascorbate peroxidases, or glu- tathione reductase activities, but there was an increase in peroxidase activity under cadmium stress.

Mechanisms of Cadmium Tolerance and Detoxification

Cadmium is inevitably taken up by the roots and affects a variety of plant organs and tissues when it is present in soil at supraoptimal levels. The soil's ability to bind metals chemically and biologically may limit the absorption of cadmium. Many metabolites, such as phytochelatins, met-allothioneins, and organic acids, which may bind to and inactivate cadmium, are produced by plants. Unfortunately, their induction and synthesis need some time to complete, and in the meanwhile, the plant is still suffering from metal toxicity. Hence, the creation of complexes with the chelating metabolites cannot be the exclusive explanation for plants' resistance to metal toxicity. In the adaptation of plants to metal toxicity, phytohormones are also thought to be crucial. In light of this, cellular, physiological, and biochemical pathways found in soils and whole plants may be linked to cadmium tolerance in plants[9].

Mechanisms in Soils

The detoxification of cadmium in soil may happen in a number of ways. Cadmium migration into the groundwater may be stopped by cadium immobilization, which entails fixing by solidification or stability by physical, chemical, or biological mechanisms. Another effective method is soil washing, which includes transferring heavy metals into a wash solution either by desorption or solubilization. Cadmium and other heavy metals in the soil may be bound and chelated by organic ligands such as organic acids and amino acids, rendering them inaccessible to soil microorganisms or root uptake. Even in low pH or low organic matter soils, heavy metal ions may often bind to soil ppapers in substantial proportions. The flow of cations into the xylem of vascular plants is likewise constrained by the binding affinity of cations. Chelation, which is typically regarded as the process of cation binding to a compound, may be used as an universal solution to this issue since it creates neutrally-charged complexes that can move more easily across a range of substrates.

The rhizosphere's role in bioremediation may be a crucial one in the fight against metal poisoning. The soil's microflora and high levels of organic carbon promote the degradation of organic compounds in the soil. According to the available data, arbuscular mycorrhizal fungi help beans and maize absorb cadmium up to 41% more efficiently, albeit this depends on the pH and amount of cadmium in the soil. In a research, Heggo et al. discovered that when the soil's cadmium content was high, arbuscular mycorrhizal fungus enhanced the amount of cadmium that soybeans absorbed. Despite the lack of clear explanations for these events, arbuscular mycorrhizal fungi seem to hold promise for phytoextraction.

Mechanisms throughout the Entire Plant

Many grains, potatoes, vegetables, and fruits have accumulated cadmium. Consequently, the capacity of crops to absorb and accumulate cadmium in specific sections may be connected to their tolerance to cadmium toxicity. Due to the low cadmium-accumulating isoline's reduced ability to transmit nutrients from the root to the shoot, two nearly isogenic lines of durum wheat accumulated grain differently. Moreover, none of the isolines' shoot cadmium accumulations were impacted by root phytochelatin production. Higher cadmium applications caused stomatal opening and closing alterations as well as wax accumulation on both leaf surfaces.

Cell Wall Binding

The optimum detoxifying method would theoretically include plant cell walls preventing cadmium ions from entering the cytosol. Root cell walls may serve as a first line of defense against cadmium stress by immobilizing cadmium excesses. The data we have shows that cadmium binds to the middle lamellae and secondary wall of maize roots. In contrast, cadmium was mostly linked to pectic sites and hystidyl groups of the cell wall in the roots and leaves of the bush bean. In white lupin, it was discovered that the cell wall retained up to 47% of the cadmium that was absorbed in the leaves, 51% in the stems, and 42% in the roots. This accumulation was strongly associated with increased phytochelatin production, especially in the roots. This suggested that a key detoxifying mechanism is cell-wall binding[10].

Constrained Transport

Transporters are used to move cations across cell membranes, albeit their exact role is yet unknown. The copper, zinc, and iron transporters from Arabidopsis thaliana were cloned as a result of molecular research. Increasing a plant's tolerance to heavy metals may be possible by blocking the transcription of the gene encoding for transporters. Metal sequestration inside root cells, symplastic transport into the stele, and release into the xylem are all factors that control the transfer of metals from roots into the xylem after they have been absorbed by the root symplasm. Cadmium is transported to phloem during transit and quickly dispersed throughout the plant. The most significant ATP-binding cassette transporter family reported from bacteria, yeast, plants, and animals transports a broad range of molecules across cellular membranes and is one of the transporters implicated in heavy metal resistance. Escherichia coli's ZntA, a p-type pump, and two yeast ATP-binding cassette transporters produce complexes of cadmium with phytochelatins and transport them into the vacuole. Only AtMRP3 and AtATM3 of the plant ATP-binding cassette transporters have been shown to sequester cadmium into the vacuole.

After cadmium treatment in Arabidopsis thaliana, Bovet et al. found a higher synthesis of four putative sequences coding for ATMRPs genes. Moreover, the gene expression of these transporters was associated with the presence of phytochelatins, glutathionein, and oxidative stress. AtPDR8, another ATP-binding cassette transporter, provided cadmium resistance when overexpressed in transgenic Arabidopsis thaliana plants. The use of radioactive cadmium demonstrated that AtPDR8 functioned as a cadmium efflux pump at the plasmalemma of Arabidopsis thaliana.

Involved Physiological Mechanisms

Several metabolic processes in plants are influenced by heavy metal buildup. Yet, as shown in the next section, plants have certain adaptive physiological processes for cadmium tolerance.

Transfer of Water and Nutrients

It has been shown that cadmium obstructs water transport as well as the intake and distribution of a number of macro- and micronutrients in plant roots. According to some data, cadmium may interfere with cell water status when increased transpiration rates cause it to infiltrate the cytosol via calcium channels on the plasmalemma. According to data, cadmium may affect how well plants can absorb minerals by limiting their availability in the soil or by diminishing the number of soil microorganisms.

It has been shown that cadmium obstructs the movement and distribution of a number of macro- and micronutrients in plant roots. Phragmites australis roots were shown by Ederli et al. to be able to withstand greater cadmium concentrations by accumulating in parenchymatous cells below the endodermis. Due to the application of cadmium, nodules were discovered in legumes that showed an increase in nitrate reductase activity, nitrogen fixation, and primary ammonia assimilation. The use of radioisotopes revealed that cadmium and zinc used the same transporter in the cadmium-hyperaccumulator Arabidopsis halleri, but that cad- mium detoxification did not follow the zinc-detoxification pathway.

Assimilation and Photosynthesis Partitioning

In plants, photosynthesis is a crucial metabolic route for the creation of organic molecules with high energy content. An even distribution of reducing capabilities is necessary for the absorption of these high-energy molecules in development phenomena. In order to control electron transport, photosystem-II maintenance and activity are crucial. A growing body of research indicates that photosystem-II is very vulnerable to adverse circumstances, including cadmium toxicity.

Nevertheless, the particular processes by which cadmium poisoning affects different components of photosynthesis are still poorly understood. Cadmium had a significant impact on the synthesis, degradation, and assembly of the D1 protein, according to pulse-chase labeling tests using [35S]methionine. This effect seemed to be caused by an unidentified main action of cadmium on the photosystem-II apparatus. When exposed to cadmium stress, wheat's effective sulfur absorption and antioxidative system protected the plant's capacity to photosynthesize and preserved its high-yield potential[11].

Membrane harm and antioxidant defense

The generation of reactive oxygen species, which results in the peroxidation of membrane lipids and interferes with normal membrane activities, is one of the most noticeable symptoms of cad- mium poisoning, as was previously mentioned. Due to its relative longer life compared to other reactive oxygen species, hydrogen peroxide production is more destructive. The enzyme NADP-oxidase, which is located on the tonoplast of the bundle sheath and plasma membrane of mesophyll cells and is involved in the production of activated oxygen and hydrogen peroxide, catalyzes the production of hydrogen peroxide in the mitochondria and peroxisomes of mesophyll and guard cells. As a result of exposure to cadmium chloride, repeated waves of reactive oxygen species production that varied in their nature and subcellular localisation accompanied the death of tobacco cells. They included a wave of reactive oxygen species made up of fatty acid hydroperoxide that occurred concurrently with cell death, buildup of activated oxygen in mitochondria, and NADPH-oxidase dependent accumulation of hydrogen peroxide. This was shown by the fact that the cell line gp3's decreased NADPH-oxidase activity prevented hydrogen peroxide from building up. Yet, it seemed that cadmium toxicity caused the cell death thereby, preventing the

The amount of NADP-oxidase may be decreased by NADP-oxidase activity. Detachable rice leaves were treated with diphenyleneiodonium chloride and imidazole, inhibitors of NADP-oxidase, to stop the production of hydrogen peroxide, which suggests that hydrogen peroxide production was the main cause of cadmium chloride toxicity. The key antioxidant enzyme glutathione reductase, which may exist in several isoforms and is expressed in different tissues, protects plants against oxidative damage when they are exposed to a range of stressors, including cadmium poisoning. While the expression of mRNA and proteins did not alter in wheat roots, posttranslational modification was clearly present. As a defense against oxidative stress, these modifications up-regulated the GR activity and produced different isoforms.

Modification of Hormonal Levels

Hormones are crucial in helping plants adapt to challenging situations. Cell senescence is brought on by cadmium via several mechanisms. Nitric oxide production may decrease and ethylene and reactive oxygen species production may increase, both of which are factors in cellular senescence. The production of jasmonic acid and salicylic acid may control how the body's cells react to calcium damage. In plants exposed to hazardous metals, abscisic acid accumulation and cytokinin reduction have both been observed. Shanti and Kumar made the observation that seed germination and seedling growth of abscisic acid-deficient and abscisic acid-insensitive mutants of Arabidopsis thaliana were comparable to wild-type plants in an effort to clarify the role of abscisic acid in cadmium tolerance. This suggested that abscisic acid did not play a mediatory role in cadmium tolerance.

Reducing the Consequences of Cadmium Toxicity

Cadmium has hazardous effects that are both immediate and long-lasting. It is critical that measures be taken to lessen the effects of cadmium toxicity for sustainable crop production. There have been various research initiatives in this area, which are listed in Table 2 and briefly discussed in the part after. It has been shown that the synthetic chelator ethylene diamine tetra acetic acid significantly reduces soil's ability to exchange cations. Since the 1950s, it has been used often to treat iron deficiency and enhance phytoextraction of metal pollutants like lead from soil. Plants may always die if there is a rapid increase in bioavailable metals when ethylene diamine tetraacetic acid is used. Ethylene diamine tetraacetic acid may be added after plants have reached an advanced stage, hence overcoming this. By doing this, the metal becomes more accessible and is absorbed by the plant in huge amounts for a brief period of time before the plant perishes.

CONCLUSION

Over the world, cadmium poses a serious danger to plant development, soil processes, and production. Cadmium poisoning causes plant reactions at the morphological, physical, and biochemical levels. Stunted development, alterations in the composition and operation of organelles, reduced photosynthesis, negative effects on membrane transporters, manipulation of metabolic pathways, and changed gene expression are a few of these. The most significant defenses used by plants against cadmium's harmful effects include reduced uptake from the soil, binding of the absorbed metal to cell walls, storage within cellular compartments, and detoxification using substances that chelate and complex metals, such as organic acids, phytochelatins, and metallothioneins.

Metal chelators may be used in the soil to reduce the bioavailability of cadmium to plants, hence lowering its toxicity. Among the crucial methods for reducing cadmium toxicity on plants are the breeding and selection of plants that exhibit a decreased capacity for cadmium accumulation in the cells and tissues, as well as its effective binding, complexation, and compartmentation; seed and foliar application of osmoprotectants; mineral nutrients; and plant growth regulators.

It would be ideal to focus research efforts on identifying new chemicals with the capacity to bind and inactivate cadmium, as well as plant species that can efficiently bind or exclude metal at root levels due to their decreased propensity to transit to shoots and partition to grain. This will help these plant species be used more economically and produce sustainably on soils with low cadmium contamination.

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CHAPTER 18

IMPACTS OF ORGANIC FARMING ON SOIL ENVIRONMENT QUALITY AND FERTILITY IN GREENHOUSES

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ABSTRACT:

The use of organic farming methods has been seen as a crucial component of global sustainable agriculture. It is still unknown if organic farming may lessen agriculture's harmful environmental effects, particularly in greenhouses. This research aims to examine the long-term effects of conventional, low-input, and organic farming in greenhouses on soil fertility and environmental quality after 15 years of cultivation. We discovered that the OC treatment's soil organic carbon content was 1.7 times higher than CC's and 1.2 times higher than LC's. The OC treatment had a much larger output of vegetables and had more alkali nitrogen, accessible phosphorus, and available potassium than the LC and CC treatments did. A higher concentration of heavy metals was found in the OC treatment as a result of the significant intake of organic fertilizers. Moreover, tetracycline antibiotics and pesticide residues accumulated significantly in the soil as a consequence of organic farming. According to an ecological risk evaluation of soil contaminants, organic farming gets the greatest ecological risk score. Nowadays, low-input farming or partial organic replacement may be a viable strategy for the advancement of sustainable agriculture.

KEYWORDS:

Heavy Metals, Pollution, Organic Fertilizers, Organic Farming, Sustainable Agriculture.

INTRODUCTION

Industrialized agriculture has been used to feed the expanding global population, but it has also had significant negative effects on the environment and human health, including soil quality degradation, water eutrophication, and groundwater pollution, the buildup of heavy metals, greenhouse gas emissions, and biodiversity losses. Many studies have shown that the use of chemical fertilizers and pesticides decreased soil pH and increased the amount of reactive nitrogen in the soil. In addition, nitrogen fertilizer production produces nitrogen oxides that may harm the ozone layer in the atmosphere[1].

One of the key components of sustainable agriculture, which may provide high-quality food while preserving the environment, has been thought to be organic farming. It maintains a sustainable agricultural system by enhancing soil fertility via crop rotation, the planting of legumes, and the use of organic fertilizers while forbidding the use of any synthetic pesticides and fertilizers. Long-term studies on organic farming have shown that the soil quality was enhanced. The amount of soil organic carbon is much larger than in typical systems, and the amount of nutrients was also increased. Because of its capacity to sequester SOC, organic farming has also been recognized as a significant step in the effort to decrease greenhouse emissions. By using organic fertilizers instead of synthetic ones and pesticides, organic farming also dramatically enhanced soil microbial diversity. This protected the soil against pathogen infestation and assisted in the degradation of outside contaminants.

Because of the high cropping index, substantial pesticide input, and enclosed environment, greenhouses cause the soil quality to decrease. Globally, agricultural production in greenhouses has gained popularity because it creates a favorable environment for plant development via artificially adjusting temperature, humidity, and light, which increases crop yields. In 2014, 700 Mt of vegetables were produced in China on 20 million hectares of land, with greenhouses accounting for 35% of the area and 20 million hectares of the agricultural output. The sustainability of greenhouse production has been significantly hampered by soil acidification and salinization, loss of soil organic matter, buildup of heavy metals, and pesticide usage, which also pose a danger to the natural environment and public health. According to Jiao et al., applying chemical fertilizers, metal-containing insecticides, and fungicides repeatedly over an extended period of time would progressively raise the amounts of these substances in agricultural soils. According to several research, the mean concentration of heavy metals in greenhouse soils in eastern China is greater than that of nearby agricultural soils and background values. To lessen the risks to the ecological environment posed by conventional growing in greenhouses, low-input chemical and pesticide agriculture as well as organic farming that forbids the use of any chemicals or pesticides have evolved[2].

There has not yet been a thorough investigation of the integrated effects on soil fertility and environmental quality in CC, LC, and OC systems. This research assessed the effects of CC, LC, and OC treatments on crop output, soil fertility, soil environmental quality, and ecological hazards over the course of a 15-year greenhouse experiment. In order to improve the soil environmental quality of organic vegetables and support the sustainable growth of organic vegetable production in greenhouses, we are evaluating the overall effects of various agricultural systems on soil fertility and soil environmental quality in greenhouses.

DISCUSSION

Organic farming increases crop output and soil fertility

It is hotly debated how organic farming affects agricultural production. According to many meta-analyses, crop yields under organic management are typically 19%–25% lower than those under traditional management. Moreover, commercial crop yields in the United States revealed an average yield difference of 20% between organic and conventional management. Since the environment is tightly regulated in a greenhouse, crop production there is substantially different from that in an open field. For instance, increasing greenhouse temperatures have greatly increased crop biomass, which has raised the soil's need for nutrients. A superior environment for crop development is also created by the greater control of water management, air humidity, and light in greenhouses as opposed to open air. High nutrient requirements and quick growth cycles are characteristics of organic vegetable cultivation in greenhouses[3].

As a result, it seems that in greenhouses, the organic fertilizer used in organic horticulture is more quickly turned into soil organic matter and readily accessible nutrients. Legume crop rotation, which is the primary source of external N, is seldom employed in greenhouses because of its expensive cost. To improve vegetable output, growers of such organic greenhouse farms choose to use copious quantities of animal dung and compost. Our research revealed that conventional and low-input greenhouse farming both provide lower vegetable yields than organic management. Large amounts of organic fertilizer were used in greenhouse organic farming, which enhanced the amount of accessible nutrients and organic matter in the soil while simultaneously increasing vegetable production and yield stability.

Increasing SOC content, which enhances soil structure and fertility, is one of the main advantages of organic farming. The balance between the entry of organic material and the outflow of organic material through decomposition determines the content of SOM. With increasing input of organic fertilizer into an organic system, soil organic carbon content rose. Our findings supported this assertion. SOC content was 1.2 and 1.7 times greater in organic farming than it was in low-input and conventional systems, respectively. Low SOM concentration in surface soil in greenhouses is the consequence of the degradation of SOM being accelerated by high temperatures and humidity, which also impact microbial and enzyme activity. This could have something to do with how much organic fertilizer was used in the greenhouse. The amount of SOM in greenhouses will decrease when the intake of organic materials is smaller than the production of organic materials. The substantial input of organic fertilizer into an organic system increased soil fertility and vegetable output by supplying a significant quantity of organic matter to the soil as well as encouraging the mineralization of organic matter. The effects of organic farming on the environmental quality of the soil. The following background includes a detailed discussion of the accumulations of heavy metals, antibiotics, and pesticide residues in soil as key soil environmental features[4].

Heavy metal buildup in the soil

Heavy metal buildup in soils may result from fertilizer application, irrigation water use, or air depositions. Because every single greenhouse was made of plastic, air deposition could be disregarded. Groundwater served as the source of irrigation, and since heavy metals are so highly stable in soil, it only sometimes contained any. Thus, fertilizer inputs were the main source of heavy metals. According to Huang & Jin, the North China Plain surface soil has significant concentrations of Cd, Cu, and Zn as a result of the use of chemical fertilizers and organic manures. In eastern China, greenhouse vegetable soils had greater average Pb, Cu, and Zn concentrations than open field soils. Our findings demonstrated that after 15 years, all heavy metals accumulated in conventional, low-input, and organic greenhouse horticulture. Heavy metal buildup is heavy and moderate in organic agriculture, while it is moderate and mild in low-input and conventional farming, demonstrating a positive association between the quantity of organic fertilizer used and the levels of heavy metals that accumulate.

Manure and the compost that is made from it served as the input fertilizers in organic and low-input farming. Inorganic manure included 31.49 mg kg-1 of Cu, 209.59 mg kg-1 of Zn, 8.13 mg kg-1 of Pb, 16.21 mg kg-1 of Cd, and 5.10 mg kg-1 of As, respectively. The amounts of these heavy metals in manures are within the HJ 333-2006 Environmental quality assessment standard for farmland of greenhouse vegetables production standard range, however owing to long-term repetitive application, their concentrations in the soil continue to rise. The greatest soil heavy metal accumulation index and potential ecological risk index were found in organic farming, suggesting the most severe levels of heavy metal contamination. A significant quantity of metal is used in animal feeding operations all over the globe in the livestock production business to cure animal ailments and enhance animal development, and this metal may end up in the feces.

Due to their comparable qualities to antibiotics and antibacterials to stimulate animal development, several feeding additives were mostly to blame for the relatively high quantities of heavy metals in animal manures. According to Zhang et al., the concentrations of Cu, Zn, Cr, and As in the manures of cattle and poultry from typical farms in seven Chinese provinces or municipalities ranged from 1017 to 1591, 7113 to 8710, 0 to 688, and 0.01 to 65.4 mg kg-1, respectively. According to Ondoua, the co-digested pig and cow manure's digestates had a high copper and zinc concentration. Heavy metals accumulate in soils and cannot be degraded because of their persistence. The ecotoxic response of heavy metals, which is affected by soil physical and chemical characteristics and speciation, is a key indicator for assessing heavy metal contamination. The addition of organic waste and pig manure may also increase the amount of accessible heavy metals in the soil, which may harm human health when ingested via food.

Reducing antibiotic residues may be accomplished by managing the organic fertilizer's supply and composting procedure. According to the composting procedure may remove 17–100% of antibiotic residues from sludge and manure. Even after a high-temperature composting procedure, antibiotic traces were found in the organic fertilizer. Tetracycline, doxycycline, oxytetracycline, and chlortertracycline were all present in organic fertilizer at concentrations of 0.80 mg kg-1, 3.34 mg kg-1, 0.05 mg kg-1, and 0.05 mg kg-1, respectively. The major reason why the concentration of oxytetracycline in organic fertilizers was substantially lower than that in soil was because the samples were kept too long, which caused the antibiotics to degrade. The structure of the soil's microbial population will change if organic fertilizers containing antibiotic residues are applied repeatedly. According to Kahle & Stamm, prolonged application of cattle manure may result in a 70% rise in antibiotic-resistant bacteria, which is harmful to the biological ecology of the soil as well as human health[5].

Pesticide buildup in the soil

The majority of the substrates for the organic amendments employed in traditional farming came from crop waste and animal manure. Hence, it is feasible for pesticide residues to build up in soils used for organic farming. The number of OPPs that remained and the ecological danger that OPPs posed in organic agriculture soils were the greatest in the current research. Once again, it was mostly due to the extensive use of organic fertilizer in organic farming. The organic additions were animal manure, the pesticide residues might have originated from the silage the animals had eaten, and the manure produced by the animals after they had digested the silage would have included pesticides that hadn't yet dissolved. According to Zhao et al., the residues of organochlorine pesticides in manure and fodder were 25.3565.62 ng g-1 and 33.4690.89 ng g-1, respectively. This finding suggests that feeding is a significant route by which pesticides infiltrate manure[6].

The degradation of organophosphorus pesticide residues involves composting. While the concentration of pesticides in anaerobic digestates of organic fertilizer is below acceptable limits, long-term use might nevertheless pose environmental concerns to the soil. However, certain organic pesticides, according to studies, might be more dangerous than synthetic pesticides. Organic insecticides often have minimal levels of toxicity and environmental persistence. While having reduced toxicity, certain organic pesticides, including sulfur and rotenone, need higher dosages and more frequent application, which has a greater environmental effect. It is clear that the kinds and concentrations of pesticides used in organic fertilizer for organic agriculture need to be rigorously regulated. However, there are currently no effective laws to prevent pesticide residues in organic fertilizers[7].

Consequences and advice

Organic farming was seen as a double-edged sword that could both increase soil quality and put soil's health at danger. Throughout the composting process, it was challenging to thoroughly disintegrate the persistent organic insecticides. Due to residue buildup from compost, sludge, and organic manure being applied over an extended period of time, several studies have indicated that organic farming may introduce considerable amounts of contaminants to the soil. The amount and quality of the organic fertilizer used determines the effect of organic farming on the soil. It is required to establish tight quality control for composting materials and modern, environmentally friendly organic composting technology in order to increase the quality of organic fertilizer. We still have a lot of work to do to create high-quality organic fertilizer. It demands active adjustment of agricultural output, human lifestyle, and animal husbandry in the period of fast global growth. Nowadays, low input farming or partial organic replacement might be a potential strategy for the growth of sustainable agriculture[8], [9].

CONCLUSION

In comparison to the other two agricultural methods, organic farming produced much more vegetables and improved soil fertility. Organic farming raised SOC, alkali-hydrolyzed nitrogen, accessible phosphorus, and potassium by 72.25%, 26.88%, 22.25%, and 4.37%, respectively, in comparison to conventional farming. When used in conjunction with ecological risk assessments, organic fertilizer has a contradictory impact on soil properties, improving soil fertility but also promoting the buildup of heavy metal, antibiotic, and pesticide residues in soils under organic agricultural techniques. Especially, Zn, Cd, and Cr contents rose by 199.80%, 312.50%, and 253.74%, respectively, after 15 years of organic farming. Moreover, organic farming results in the greatest levels of TCs and dimethoate. Optimizing management tactics for organic farming will benefit from taking into account both processes for increasing soil fertility and those for detrimental residue buildup. Before using a broad scale of organic farming, quantitative controls on the quantity and make up of the organic fertilizers need to be conducted with prudence.

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CHAPTER 19

BIOREMEDIATION OF ORGANIC POLLUTANT-CONTAMINATED AGRICULTURAL SOIL

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ABSTRACT:

Natural resources, particularly soil and water, are at risk from pipeline accidents and crude oil contamination of the environment. Once the local gas condensate pipeline ruptured, samples of agricultural soils polluted with total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs) were obtained. Five treatments—I, control (clean soil), II, 100% contaminated soil plus organic absorbent plus nitrogen, III, 100% contaminated soil plus organic absorbent, IV, and V—50% clean soil plus 50% contaminated soil plus organic absorbent—were used in triplicate for the experiment. The soil's pH, organic matter content, carbon and nitrogen content and ratio, and variations in the concentration of TPHs and specific PAHs—potential organic contaminants were all examined. The results showed that, after six months, the organic absorbent and nitrogen combination effectively absorbed organic contaminants from the contaminated soil. For the decomposition of hydrocarbons, however, Spill-Sorb alone was more efficient. The concentration of organic contaminants and the application of nitrogen affected how well the absorbent worked.

KEYWORDS:

Agriculture, Bioremediation, Nitrogen, Hydrocarbons, Organic Absorbent.

INTRODUCTION

Environmentally risky interventions and procedures are used throughout every stage of the exploration and production of crude oil and gas, including drilling operations, the construction of subterranean pipeline canals, transportation, refining, and storage. There is a significant danger of leak even if oil is produced, transported, and consumed. While all areas of the petroleum business utilize acceptable materials and advanced technical solutions to achieve a high degree of safety, regrettable occurrences do sometimes occur. Natural resources, particularly soil and water, are at risk from accidents that result in pipeline leaks and environmental degradation from crude oil, rendering them, for example, unfit for agricultural cultivation. Oil and petroleum products may harm ecosystems when they enter the environment by drastically altering soil pH and aeration. One of the most crucial tasks of soil cleanup following such accidents should be to swiftly eliminate the effects of oil spills. The techniques for cleaning up soil after oil spills are always being improved for this reason. Bioremediation is one of the most often used methods for removing organic contaminants from soil[1].

The key driver of a quicker rate of breakdown of various hydrocarbons in this applied approach is the growth of soil microorganisms. Due to its influence on the reduction of soil contamination, sorbent utilization is now seen as being of utmost importance. On the market, there are around 200 different sorbents for soil cleaning. The kind and quantity of contamination, the location (in situ or ex situ), the agro-environmental circumstances and the soil type are the primary factors to consider when selecting a remediation strategy for polluted soils. On the whole, bioremediation, soil mixing, or natural attenuation will be preferred by researchers who want to conserve healthy soil. These techniques are referred described as "green" and "cost-effective" technologies together because even after remediation, the soil retains its live soil characteristics and edaphone (soil flora and fauna). A recently developed technology called bioremediation enhances the breakdown of organic contaminants while minimizing the detrimental effects on soil. Also, compared to other ways, using this technology is quite inexpensive. Nevertheless, other writers assert that since bioremediation is a lengthy procedure that needs time for the optimum results, it will ultimately cost more money. The use of nitrogen fertilizer to polluted soils is another widely used technique. By acting as an initiator for microorganisms that break down oil, nitrogen increases the efficiency of organic pollutant degradation. As a necessary nutrient, nitrogen keeps the soil's microbial community healthy, which accelerates the breakdown of hydrocarbons. Petroleum and crude oil are manifested as soil pollutants when they unintentionally touch the surface[2].

They include a variety of hydrocarbons, ranging from light, flammable, short-chain to heavy, long-chain, branching elements. The usage of land may be restricted by soil holding these hydrocarbons, and petroleum leftovers may bind to soil for many years. Total petroleum hydrocarbon (TPH) and polycyclic aromatic hydrocarbon (PAH) pollution of soil from crude oil is a growing issue since it may contaminate soil and groundwater. Unfortunately, it is not practical to completely remove PAHs and TPHs from soils. TPH is a combination of dozens of different hydrocarbon molecules, mostly alkanes, cycloalkanes, and aromatic hydrocarbons with significant amounts of nitrogen and sulfur compounds. Vegetation growth and reproduction may be impacted by TPHs. A class of polycyclic hydrocarbons with one or more benzene rings are known as PAHs.

Many organic substances that include two or more fused aromatic rings of carbon and hydrogen atoms may also be categorized as PAHs. Their presence in the natural environment is quite little. Nonetheless, their composition may quickly rise as a result of numerous human activity. The United States Environmental Protection Agency (US EPA) has designated 16 kinds of PAHs as significant pollutants due to their potential for toxicity. PAHs are considered as the most important of all petroleum products. The photodegradation of PAHs, which entails either exposing contaminated soil to natural radiation or degradation by microorganisms, is the most successful bioremediation technique. To lessen soil pollution, remediation solutions based on various strategies still need to be taken into account and investigated[3], [4]. The goal of this research is to look at the impacts of adding ecologically friendly absorbents and nitrogen to soils that have been polluted by TPHs and PAHs as a result of a local oil pipeline leak. According to the study, biological absorbers would clean up the polluted soil, and the addition of nitrogen would speed up how quickly the organic pollutants (TPHs and PAHs) in the soil degrade.

DISCUSSION

Hydrocarbons with a Polycyclic Aroma (PAHs)

The variations in each of the 12 PAHs under investigation as well as their total. PAHs have been classified as priority pollutants by the US EPA. Since their baseline concentrations were less than 0.001 mg kg1 soil, the following four PAHs—Benzo(a)pyrene, Indeno (1,2,3-cd) pyrene, Dibenz(a,h)anthracene, and Benzo(g,h,i)perylene—are not included in this table. There are four or more benzene rings in these PAHs. All experimental treatments had higher fluranthene and phenanthrene2 concentrations at the start of the study (2 days later) (except the control). Fluoranthene still exceeds the tolerance threshold in the treatment with 100% nitrogen-contaminated soil, despite the fact that their concentration was greatly decreased in the subsequent assessment (10 days). Phenanthrene's content was elevated over the tolerable value in all treatments (apart from control). The total PAHs in all treatments combined in this measurement are higher than the acceptable level. The concentration of fluoranthene on the treatment with 100% contaminated soil with nitrogen was only still greater than the permissible value in the subsequent measurement taken after 50 days. The total amount of individual PAHs on the treatment with 100% contaminated soil with nitrogen and 50 + 50 + N was still over the permissible tolerance range. At the most recent assessment (153 days), 100% of the soil was found to be polluted with nitrogen, however the quantity of phenanthrene was higher than expected. Only fluoranthenes and phenanthrenes were discovered in the polluted soil after 153 days, although their concentrations were below the maximum permitted levels [5], [6].

In this work, we showed how nitrogen and Spill-Sorb affected the rate of total petroleum and polycyclic aromatic hydrocarbon degradation in condensate-polluted soil. Based on related research, the link between contaminated soil, nitrogen, and Spill-Sorb was determined. A well-known technique for the biological rehabilitation of hydrocarbon-contaminated soil uses nitrogen. In our work, the variations in soil pH in the experimental treatments provide as a clear illustration of the impacts of applied nitrogen. Under the 100 N treatment, the pH of the soil was the lowest. No discernible variations in soil pH were found between the control, 100 + N, 50 + 50 + N, and 50 + 50 N during the course of the research. This is to be anticipated since soil pH rises as a result of ammonium formation after nitrogen fertilizer. Also, the soils with hydrocarbon contamination enhanced nitrogen buildup in the soil microbial mass while decreasing nitrogen absorption by plants.

There is a wealth of research stating that high levels of petroleum hydrocarbons, which have a high carbon content (80%), may cause an abrupt drop in the amount of inorganic elements, such nitrogen, in the soil. In parallel, nitrogen levels fall as a result of an increase in microbial activity. Then, nitrogen starts to act as a limiting factor for microbial breakdown. Nitrogen depression is the term used to describe this occurrence. This effect, which was seen in our research in nitrogen-supplemented treatments (100 + N and 50 + 50 + N), can only be reduced by supplying nitrogen as a food source for soil microorganisms. Nitrogen is a crucial component of several molecules, including proteins, nucleic acids, and others, that are necessary for the development of plants. The findings show that TN was remained high in treatments with nitrogen addition in the latest assessment[7], [8].

Moreover, it was anticipated that the high hydrocarbon content in the soil (caused by the pipeline rupture and spill) would affect the C/N ratio, causing large quantities of organic matter and carbon to be found. Yet, owing to the addition of nitrogen (KAN) and Spill-Sorb, SOM concentration rises in all subsequent measurements compared to the control. It is noteworthy to note that the 100 + N had a much greater SOM content than the other treatments at the time of the first sample (2 days). This is explained by the fact that the soil sampled for analysis was contaminated soil that has undergone both bioremediation processes, which significantly raise the soils' organic matter contents. Only Spill-Sorb (100

N) substantially increases the SOM content in polluted soil as compared to the control and the 100 + N treatment at the measurements after 10, 50, and the final 153 days. Due to the rise in microbial activity and mineralization of organic matter, this behavior makes Spill-function Sorb's in growing SOM without nitrogen application more advanced.

After 153 days, the nitrogen addition did in fact result in soil acidification. The largest challenge in applying nitrogen, according to Chaillan et al. and River-Espinoza, Dendooven is determining the ideal quantity and kind of nitrogen in order to prevent adverse effects. The soil bioremediation process won't provide adequate results if the recommended dosage isn't used. Regarding the TC content, the SOM content has a significant influence on the patterns. As anticipated, the measurements at 2 and 10 days showed that the control had a much lower carbon content. The typical organic matter content in the native soils in this region of Europe is 50–54 percent carbon and 4–6 percent nitrogen, which suggests that the ideal C/N ratio is 10:1. Only at the suggested ideal C/N ratio can soil organic matter decompose quickly and with excellent quality. According to several other writers, the ideal C/N ratio falls between the ratios of 100:10 and 100:1. Similar C/N levels were discovered in this investigation depending on the treatments investigated[9].

It is crucial to stress that all of the nitrogen generated during this stage of organic matter breakdown is used by microorganisms up to a certain point, which happened at 153 days in 100 N treatments. The soil becomes much more microbially active when there is an increase in carbon content brought on by the presence of crude oil. The C/N ratio determines the direction in which these activities take place and whether bacteria (good, harmful, or neutral microbes) prevail in the soil. For instance, the synthesis and mineralization of organic materials depend heavily on soil bacteria. The pH of neutral and alkaline soils decreases as a result of the decomposition of organic matter, whereas the pH of acidic soils rises as a result of the release of organic acids and CO2. Yet, only in treatments without nitrogen inputs did the pH of the soil throughout the research period alter considerably in our experiment. Our findings verified the need for additional nitrogen to counteract nitrogen depression's harmful consequences. Nitrogen concentrations between 0.5 and 1.5% have been suggested to boost the quantity of hydrocarbons. As higher carbon concentrations are introduced and the C/N ratio rises over 30:1, nitrogen becomes immobilized. If the C/N ratio is less than 20:1, mineral nitrogen normally releases right away at the start of the hydrocarbon breakdown process, and immobilization of mineral nitrogen release may not happen at ratios of 30 to 20:1.

In general, any kind of nitrogen is beneficial, however calcium-containing nitrogen fertilizers should be favored when used on acidic soils because calcium neutralizes the acids created by the breakdown of hydrocarbons. Our findings were reinforced by the fact that applying more nitrogen fertilizer causes soil organic matter and other organic molecules containing nitrogen to mineralize more quickly. KAN was selected for this investigation above other individual nitrogen fertilizers primarily because of its reduced propensity to leak and pollute groundwater. The key factor contributing to UREA's decreased application efficiency is ammonium loss via evaporation. The conversion of amide to the nitrate form of nitrogen from UREA results in a 20% loss of this element, which is a significant nitrogen loss and increases environmental danger. It is clear from the data that during the first measurement, the concentration of hydrocarbons in the treatments 100 + N and 100 N, respectively, exceeded the maximum allowable limits (2 days later). Based on the study of the entirely polluted soil, this is assumed. The hydrocarbon content is already below the allowable level for all further tests and treatments. Even when compared to treatments where 50% of the soil was clean, the addition of Spill-Sorb (100 N) alone resulted in the most successful bioremediation. Due to pipeline leaks, the calculated total of 12 PAHs in the case of PAHs exceeded the permitted amount at the first measurement (2 days following), as is predicted.

The levels of fluoranthene and phenanthree were the highest among the various PAHs. The total of the 11 PAHs discovered in the following measurement is higher than the limits allowed for all treatments (except the control). Nevertheless, the impact on bioremediation was greatest in the treatments with simply Spill-Sorb additions (100 N and 50 + 50 N). The maximum allowable values in the 100 + N and 50 + 50 + N treatments were exceeded in December 2018 (50 days following), when the concentrations of five PAHs were found to be greater than 0.001 mg kg1. The most successful soil bioremediation treatments in this assessment included solely Spill-Sorb inputs. Just two separate PAHs (fluoranthene and phenanthrene) were found at the time of the most recent assessment (153 days), and their combined concentration was below the limits allowed for all treatments. The Spill-Sorb bioremediation substance utilized is the cause of this. It should be noted that applying nitrogen was less effective than using Spill-Sorb by itself. Conclusion: Compared to adding Spill-Sorb alone, nitrogen deficit in the soil accelerates PAH breakdown.

If nitrogen is administered in the wrong amount, organic contaminants may be degraded inappropriately. The soil microbial community that is responsible for degrading organic pollutants may be reduced or increased by an extra nitrogen dosage. One of the most successful natural resources for making inexpensive and ecologically beneficial sorbents is peat moss, which is used in bioremediation treatments like Spill-Sorb. By itself, Spill-breakdown Sorb's process increased the microbial population in the soil and enhanced their metabolic activity. Moreover, the physical structure and chemical makeup of this kind of sorbent are very porous, creating a vast surface area for the adsorption of contaminants. In fact, Spill-impact Sorb's in our investigation was most successful at breaking down hydrocarbons, mostly because of its high adsorption rate. During this case study, it was believed that the nitrogen dosage in the treatments with KAN was too high, demonstrating the effectiveness of the Spill-Sorb therapy. A high nitrogen dosage, according to another author, might restrict or perhaps totally halt the breakdown of hydrocarbons in the soil. It is crucial to stress that bioremediation processes should also occur in aerobic settings, at ideal temperatures, and with the ideal level of soil moisture[10], [11].

CONCLUSION

In order to clean up a region that has been polluted by organic pollutants as a result of a pipeline spill, this research presents an overview of two bioremediation techniques (nitrogen and Spill-Sorb). The major findings show that the breakdown of TPHs and PAHs was enhanced by the presence of nitrogen and Spill-Sorb in the soil. The research shows that the use of the adsorbent Spill-Sorb alone was more successful than the application of the nitrogen fertilizer KAN (calcium ammonium nitrate). The concentration of organic contaminants and the application of nitrogen affected how well the absorbent worked. The idea that adding nitrogen would increase effectiveness is disproved. With the growth in the population of decomposing soil microbes, it can be said that the application of Spill-Sorb alone has a greater impact on the breakdown of organic pollutants. In fact, it has been shown that the nitrogen dosage outperforms KAN's capacity for bioremediation. Consequently, Spill-Sorb is an ecologically benign technology, and we advise using it in future work on organic soil contamination. Further studies are necessary to better understand the impacts of nitrogen concentrations on the breakdown of TPHs and PAHs in contaminated soils, as well as their effects on the microbial communities in the soil.

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CHAPTER 20

BIODEGRADATION TECHNOLOGY FOR ORGANIC AND INORGANIC POLLUTANTS

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ABSTRACT:

The principal hazardous features of soil's persistent organic pollutants (POPs) pose a threat to all of humanity. They may also be a complex combination of heavy metals, microorganisms, and organic compounds derived from animal waste, septic systems, and other sources of organic inputs. A developing method called phytoremediation may be used to clean up soil from organic contaminants. This chapter attempts to address the origins of organic pollutants, variables influencing how plants absorb organic pollutants, various mechanisms causing organic pollutants, phytoremediation of organic pollutants, and its benefits and drawbacks.

KEYWORDS:

Phytoremediation, Beneficial soil bacteria, Persistent Organic Pollutants (POPs).

INTRODUCTION

The two fundamental natural resources on which agriculture can be sustained and civilization can continue to exist are land and water. Regrettably, both have suffered severe degradation as a result of a variety of natural processes (leaching, mineralization, volcanic eruption, etc.) as well as human activity (industrial waste, chemical farming, smelting, mining). Of of all the factors that contribute to soil deterioration, organic pollution (OP) in the soil is regarded as a significant factor that endangers human health as well as the environment. In general, organic contaminants remain in the soil for a very long time and accumulate in extremely low quantities. Even if they are constantly rising, the low levels of organic pollutants in the impacted soil make it challenging to conduct a time-constrained toxicological investigation. These organic pollutants are lipophilic and hydrophobic by nature and may be deposited in the soil in any region of the world by human activities or by naturally occurring events such as forest fires, volcanic eruptions, etc. Via various plant mechanisms, these organic contaminants penetrated the plant system. While some of the organic material in the wastes may biodegrade, heavy metals and metalloids pose a new concern because of how persistent they are in the environment. The impact of organic pollutants on the environment might be somewhat mitigated by using a phytoremediation procedure[1].

Sources of organic contaminants in soil and their impact on the environment

Organic contaminants come from spontaneous processes that don't entail human intervention. Organic contaminants in the soil may come via spontaneous air sedimentation after forest fires, in addition to the erosion of soil elements. One of the main sources of organic pollutants in soil are forest fires that take place in densely vegetated regions. Polycyclic aromatic hydrocarbons are a common organic contaminant that are thought to be dangerous to people and carcinogenic in nature. They are liberated after the burning of plants or other biomass and either sink into the soil's top layer or become mobile as a result of rainwater seeping through the ground [8, 9]. Similar spontaneous sources, such as volcanic eruptions and other geogenic processes, may result in the formation of many additional organo-halogen compounds in the soil as a result of the burning of flora and animals.

There are various ways that anthropogenic sources of organic pollutants might be created. Due to pollution from various point sources or dispersed sources, agricultural operations may be an anthropogenic source of organic pollutants. The direct inputs in an agricultural field, such as fertilizer or insecticides, are where point source organic pollutants come from. Diffused organic pollutants are those introduced to the soil indirectly by atmospheric deposition and floods. Fertilizers and insecticides have existed from the beginning of conscious agriculture to lessen and avoid crop loss and to boost yield. The need for food is rising along with the world population, but since there is a shortage of fresh agricultural land, agricultural output must be intensified[2].

With individuals growing more concerned about their health and nutrition, organic fertilizers have completely changed the way that agriculture is produced. These organic fertilizers are a fantastic way to grow organic food while also enhancing the soil's general health by adding organic carbon and nutrients that release slowly. Compost, animal waste, municipal wastes, sewage, and waste water may all be used to make organic fertilizers. The disposal and recycling options for these materials seem to be more environmentally beneficial. On the other hand, we could discover over time that the administration of organic fertilizers also has certain flaws.

Increased amounts of copper and zinc, which are supplied to animal feed and then seen in the feces of the animals, may be found in organic manures made from animal waste. When these components are present in excess in the soil, they operate as pollutants and pose threats to agricultural output. Because organic manures are the source of antimicrobials in the soil after incomplete digestion in the animal or human body, concerns about organic pollutants from such manures increase. Many resistant strains may form and build in the soils after treatment with organic manures, which is then recycled to the human/animal body and poses a serious health concern to people everywhere[3].

By fermenting and composting biological wastes including wastewater, municipal solid waste, green waste, and food waste from homes, organic fertilizers may be produced. Recent research, however, indicates that this kind of fertilizer may include difficult-to-remove biosolids and microplastic ppapers. According to tests, bio-solids are suitable for use as fertilizer because they include large concentrations of organic matter and biogenic chemicals, particularly nitrogen and phosphorus, which are essential for plant development. Yet, one of the most significant soil donors of trace elements in soils is bio-solids when applied to land and contaminated with lipophilic trace elements. Another source of nano- and micro-plastics is bio-solids. The bio-solids are thought to comprise 95 percent of all the micro-plastics that are processed at the wastewater treatment facility. Besides trace elements, wastewater sludge and bio-solids can be contaminated with POPs including polychlorinated dibenzo-p-dioxins and dibenzo furans (PCDD/F), poly chlorinated biphenyls (PCBs), chlorinated paraffin (CPs) and perfluorinated alkylated substances (PFASs) likeperfluoro octane sulfonate (PFOS) or perfluorooctanoic acid (PFOA), which has resulted in the pollution of agricultural soils.

Inorganic substances including compounds of nitrogen, sulfur, copper, mercury, and arsenic served as the basis for the earliest insecticides. But, the inorganic pesticides were replaced by the organic chemicals in the middle of the 20th century, when the globe saw a significant change in agriculture with the start of the green revolution. Since that time, these natural insecticides have been widely employed in agriculture and sold on the international market.

Rainfall or irrigation will wash organic pesticides off sprayed plants or seeds and deposit them in the soil. Accidental chemical discharges from leaky containers regularly harm agricultural soils. Pollution may also be caused by improperly disposing of unused or outdated pesticides, pesticide containers, and cleaning application equipment. Although being organic in nature, the majority of pesticides do not breakdown and remain in the soil because of their lengthy half-lives. These organic pesticides and their leftovers may accumulate in soils and may have long-term negative impacts on both people and animals. Certain volatile substances might travel long distances and end up in a non-native soil[4].

DISCUSSION

Factors influencing how organic contaminants are absorbed by plants

Heavy metal deposition in soil environments has grown widespread around the world. In this regard, phytoremediation has shown to be highly successful. Plants must be grown in order to remove toxins from the soil without obstructing that growth and development's normal course. According to research cited by a number of academics, the lithosphere may be cleared of organic pollutants by using the mechanisms of phytostabilization, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatilization. Plants' ability to absorb organic contaminants depends on a number of factors. Enhancing the crop physiology's capacity for uptake requires a knowledge of these aspects.

Types of plants

A number of intricate events take place during the plant's absorption of an organic pollutant. Several characteristics of the plant as well as the element's qualities have an impact on how effectively a compound is absorbed. The plant species should have a quick rate of development, a large amount of biomass, a deep root system, and resistance to high levels of harmful metals. An essential pre-requisite for the intake of organic compounds from a severely degraded environment is the identification of plant species that are suitable for heavy metal accretion into their systems, combined with successful growth and development with the normal management approaches. After harvest, the crop is burned to generate energy and recycle the metal in the ash, removing it from the soil system in the process[5].

Leersiaoryzoides, a species of terrestrial plant, was shown to be able to sustain the high arsenic absorption up to 6 weeks of research in its system and provide a decent output in a green house. Studying the test crop Alternantheraphyloxeroides for lead absorption into its physiology, Cho-Ruk and his colleagues discovered that the distinctive stolons and enormous fibrous root structure gave increased surface area for improved assimilation of the metal. From 30 to 80 percent of the technique was found to be effective. By generating root exudates that form complexes with these metals and lessen their mobility in the environment, the Brassica species also have an effective mechanism for uptaking cadmium and lead from the soil solution.

Medium Properties

Crops' ability to absorb contaminants is also influenced by the medium. The pollutants are present in the media's air, water, and soil ppapers in an adynamic condition. According to reports, the presence of electrolytes, pH, and redox potential of the medium are all crucial factors in determining how bioavailable organic chemicals are in the soil solution and how paper it is for plant roots to absorb them. Another important environmental element influencing the roots' ability to absorb non-ionic organic chemicals from soil is the amount of organic matter present in the soil. Crop practices and packaging are created in accordance with the need to speed up phyto-extraction and phyto-stabilization processes. In a study done it was discovered that treating damaged soils with compost decreased the availability of heavy metals in the medium by 80%. According to Traunfeld and Clement [54], the quantity of lead absorbed by the plant significantly decreased after the application of lime, which raised the soil pH to 6.5-7.0[6].

Chemistry of the Rhizosphere

The amount of soluble cations in the area of the soil that is affected by root secretions and microorganisms is controlled by the rhizosphere's chemistry. The amount of ions that are present for potential plant uptake also has an impact. Pollutants may be absorbed by the root ecosystem and stored or moved about within the plant tissue. Either either the apoplastic route or the symplastic pathway, organic substances reach the root cell. Rhizo filtration prevents heavy metals from leaking into freshwater bodies of water and the groundwater table. By releasing specific enzymes, the varied microbial population found in the rhizosphere contributes to the breakdown of complex organic molecules into simpler ones. They aid in the rhizo-degradation of the pollutants, together with the root exudates released by the plant system. It has been discovered that sunflower and Indian mustard have large fibrous root systems, which makes them good candidates for metal removal by rhizo filtration in terrestrial systems.

Integration of changes

The application of chelating chemicals, natural zeolites, lime, and other amendments may also significantly increase the rate at which heavy metals are absorbed by plants. They enhance the amount of pollutants that are absorbed by the crop by making them more soluble in the solution. It is difficult for the chemicals to be absorbed since they often stay sorbed to the clay mineral lattice. As a result, an abrupt change in the quality of the soil environment causes groundwater pollution. In order to release the organic contaminants into the system for absorption by plants, the ligand group of the chelating compounds engages in ion exchange and forms complexes at the exchange sites of the soil minerals. According to a laboratory research by Roy et al. [57], exposing plants to EDTA for a prolonged length of time improves the phyto-extraction process by strengthening metal translocation in plant architecture.

Contaminant Characteristics

The physicochemical characteristics of each element, such as their aversion to water, solubility in water, and vapor pressure, influence how easily organic chemicals may enter the plant body. The amount of time that metals may be kept in the medium, as well as how they interact with other elements and chemicals inside, have a significant impact on the solubility of contaminants in water. Because to their hydrophobic nature, the majority of pollutants may collect in plants' aerial plants. Brassica napus and B. juncea have shown outstanding results for phytovolatilization of soils contaminated with selenium. The phytovolatilization occurs at very low concentrations, keeping the air pollution-free.

Environmental Circumstances

Temperature, humidity, stress levels, and rainfall are abiotic elements that can have an impact on how plants absorb organic contaminants. For instance, found that the impermeability of the root in dry soil under drought stress conditions caused an increase in root diameter and a decrease in root length. Because of this, plants are less able to absorb heavy metals, leaving them more susceptible to runoff and soil erosion[7].

Via their stomata and cuticles, leaves absorb various organic pollutants from the surrounding environment. The leaf's stomata are numerous on the abaxial side and have a larger role in absorbing organic molecules than the adaxial side's thicker cuticular layer. The leaf's stomata facilitate the simple passage of gases and liquid organic pollutants. The number of stomata on a leaf and their quantity on the surface of the leaf influence the permeability of gaseous organic pollutants. Nevertheless, the permeability of liquid organic pollutants via stomata is determined by moisture on the leaf surface, surface tension of the liquid contaminants (such as pesticides, herbicides, liquid aerosol, etc.), and stomata shape. Gas molecules enter via the opening and are then carried by the phloem to other plant components.

While roots play a crucial role in the absorption of organic contaminants from soil, plants may absorb organic pollutants from either the air or the soil. As organic contaminants often have low volatility, plants come into touch with them in polluted soil or water via their root tissues. Some lipophillic organic pollutants are passively adsorbed to the lignin of the cell wall of the plant surface or root that come into contact with the contaminant, which helps to phytostabilize the pollutants and stop their leaching into the groundwater, volatilization into the air, or entry into the food chain. Likewise, unlike the cuticular layer of leaves, these contaminants are readily transported through the cuticle-free, non-suberized cell walls of root hairs. Organic pollutants are absorbed by plant roots in two stages: first, they take in the pollutants from the soil and water around them, and then they spread out and collect in various areas of the plant. Organic contaminants are passively diffused across plant cell membranes by plant roots in the first phase. Pollutant transport to the root is controlled by the root concentration factor, or the ratio of pollutant concentration in plant roots to that in an external solution.

One of the elements influencing the organic pollutant's absorption is its hydrophobicity. Organic contaminants are translocated to several plant sections after absorption. In higher plants, there are two different types of transport pathways: intracellular and intercellular short-distance transport, and long-distance transport (conducting tissue transport). After absorption by the root, organic pollutants are found to reach the root xylem transport tissues by free intercellular space (apoplast) or cell to cell movement through plasma desmata (symplastic route), according to investigations on the mechanism of organic pollutant uptake. Compounds that travel through the apoplast of the root cortex need active transportation, or symplast, to get to the xylem, where further chemical translocation takes place. Organic pollutants must be translocated if they are to be transported over long distances, such as to the plant's leaves.

The simple diffusion mechanism, which is akin to uptake, is how organic contaminants that travel in a symplastic manner (cell to cell) in the root enter the root xylem. The translocation of an organic chemical is determined by the transpiration stream concentration factor, which is the ratio of a compound's concentration in the xylem sap to that of an external solution. The transpiration pull, which is more pronounced at high air temperature, low relative humidity, moderate wind speed, and excellent quantity of light, affects the movement of compound and water from root to shoot.

In general, organic pollutants are less hazardous to plants because they are less reactive and become conjugated, stored, or destroyed enzymatically after entering the cell. Depending on the characteristics of the organic pollutants, they may either be absorbed by the plant or destroyed there before going through processes like volatilization, sequestration, and volatilization. According to the "green liver idea," plants absorb organic contaminants or xenobiotics in a manner similar to how mammals do. Chemical modification, conjugation, and compartmentation are the three stages that organic contaminants go through. Enzyme-catalyzed reactions are involved in the detoxification process (oxidation, reduction, hydrolysis, conjugation etc.). Functionalization, or the first change of a chemical, comprises processes such enzymatic oxidation, reduction, hydrolysis, etc. To become polar, an ahydrophobic organic pollutant is given a hydrophilic functional group, such as a carboxyl, amino, or hydroxyl group, which increases the reactivity and enzyme affinity of the hazardous compounds for further transformation and conjugation[8].

The process of coupling toxicants with intracellular endogenous substances such amino acids, proteins, organic acids, various carbohydrate molecules, lignin, etc. is known as conjugation, and it often involves a significant portion of organic toxicants. Initial transformation intermediates or initial pollutants with a function group are susceptible to conjugation with many cellular substances. For instance, the cytochrome P450 monooxygenases enzyme catalyzes the oxidative transformation of organic herbicides like atrazine by forming a hydroxyl side group.

The development of such a side group facilitates conjugation, and the resulting conjugates are much less hazardous than their parent molecules. Conjugation, followed by compartmentation of conjugates in the vacuole (soluble conjugates that couple with sugar, amino acids, peptides, etc.), and sequestration on cell wall (insoluble conjugates that couple with lignin, cellulose, pectin, starch, etc.), are all methods used for the immediate temporary detoxification of organic pollutants.

Plants rely on active transport of these conjugate complexes to vacuole and cell wall employing ATP dependent glutathione pump since they lack any particular excretion mechanism to keep pollutants away from critical cell components and activities. In the conjugation and sequestration of organic toxicants, glutathione is crucial. Vacuole deposition of 2,4-D following hydroxylation and conjugation with glucose and malonyl residues is one example of functionalization followed by conjugation and compartmentalization. Organic substances migrate from the xylem to the symplast of the shoot, then to the leaf, through simple diffusion. Pollutant compartmentation takes place in leaf cells similarly to root cells. If these pollutants or their conjugates are retained or aggregated at tissue levels in leaves, they do so in the epidermis and trichomes.

One of the crucial steps in the transformation of organic pollutants and phytoremediation is the degradation or breakdown of organic pollutants both in root and (or) shoot tissue. The process of degradation is catalyzed by enzymes. Either the whole organic pollutant is mineralized to CO2, water, and other simple molecules as a consequence, or just a portion of it is degraded to a more stable intermediate (for conjugation and sequestration) that may be further stored in the plant. Dehalogenases, peroxidases, phenoloxidases, ascorbate peroxidase, catalase, carboxylesterases, peroxygenases, nitrilases, esterases, phosphatases, mono- and dioxygenases, nitroreductases, etc. are enzymes that directly contribute to the breakdown of organic contaminants. Monooxygenases that comprise cytochrome P450, glutathione-S-transferases, malonyl-O-transferases, glucosyl-O-transferases, and other enzymes catalyze conjugation.

Plant Selection and Plant Density

Plants are chosen based on the kind of contamination, the qualities of the soil, and the local meteorological conditions. Plants with high biomass (> 3 tons/acre) are often preferred. Deep-rooted trees like willow, cottonwood, and poplar are planted in rows perpendicular to the flow of water when groundwater is the intended location for restoration. Throughout the neighborhood, there are a few monitoring wells.

Soil Amendment and Irrigation Techniques

Flooding promotes pollutant dissolution and raises net evapotranspiration. Moreover, the pH of the soil may change simultaneously, requiring further modifications. By utilizing chelating agents, phytoextraction efficiency may be improved. Heavy metals and radionuclides are kept in solution by chelate complexes that ethylenediaminetetraacetic acid (EDTA) produces with them. This facilitates quick uptake by plants[9].

Agricultural methods

Organic modifications

In a test, Vamerali and his colleagues hypothesized that cement would function by enclosing contaminants, lime would raise pH, and iron sulphate would immobilize As. Lime and cement, when used at low rates (1%), did decrease Pb, Cu, and Zn mobility, but not Cd mobility. They came to the conclusion that cement and lime may be administered inexpensively and widely, with some consideration for lime, which enhances pH and As mobilization. There was a plant-specific response of fertilizers to phytoextraction of heavy metals[10], [11].

CONCLUSION

It has several limitations, such as the fact that it takes a long time (3–4 years) to reach the clean-up objectives and that government bodies must see more on-field outcomes before accepting phytoremediation technology as a standard method for remediation of contaminated soils.

Waste biomass must be treated properly since it poses a biohazard. Some prominent drawbacks of this technique are incorrect handling and high post-harvest handling expenses.Chelating compounds like EDTA and EDGA may aid in enhancing phytoremediation. Significant benefits, however, have only been obtained when greater amounts of chelating agents were used, raising severe concerns about the possibility of chelate increased metal leaching and groundwater pollution. It has been shown that EDTA may enhance metal shoot: root ratio while decreasing net root and shoot biomass production. Instead of using chemical assisted phytoremediation, a biodegradable chelating agent like EDDS in hot solution (90°C) may be employed to lessen chemical leaching.

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CHAPTER 21

HARVESTED PLANTS FROM SOIL THAT HAS BEEN TREATED WITH ORGANIC FERTILIZERS AND USED AS A SOURCE OF SOIL NUTRIENTS

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ABSTRACT:

It is commonly known that using organic resources as soil fertilizers may increase agricultural output. These organic substances may, however, include hazardous contaminants that might build up in plant tissues and ultimately be eaten by people. Sludge, urine, human waste, and urban garbage are examples of organic materials that are used in agriculture and organic farming, although there is a misunderstanding regarding their utilization. The review effort looked at the sources and applications of organic material used in agriculture in developing nations as well as the risks associated with using contaminated organic material in agriculture.

The study looked at the literature on the availability and absorption of contaminants in crops grown under organic farming practices. The assessment determined that processed waste materials used for farming might potentially absorb contaminants. It has been shown that certain pollutants may be bio-accumulated by plants when grown in soil that contains these pollutants. The review's conclusion established the need of raising knowledge about the potential health concerns connected to the usage of organic materials, particularly if such materials are contaminated. The evaluation also emphasized how crucial it is to inform peasant farmers about the risks involved in collecting garbage from untreated sources.

KEYWORDS:

Harvested Plants, Organic Fertilizers, Soil Fertilizers,Soil Nutrients.

INTRODUCTION

It is extensively established in the literature that organic materials (compost, waste, urine, human waste, wastewater, and bio solids) are used in farming. The objective is to increase soil fertility and crop nutrient delivery. The cumulative loading of these toxic pollutants in agricultural soil, however, may represent a serious danger to the ecological functions of soils, plant development, and human health. This is because certain organic components have been shown to contain harmful pollutants. Organic farming should not be confused with the use of organic resources in farming.

The first published policy on organic farming, the European Union (EU) policy, defined organic farming as a production method that employs agricultural inputs that were once generated from organic farming. To boost the fertility of the soil, which may increase crop yield, this requires the use of non-synthetic materials and forbids the use of any goods made from plant, animal, or human leftovers that do not come from organic farming. Yet, when using organic materials in agriculture, this is often not the case. Peasant farmers, in particular, gather organic elements from a variety of sources and apply them directly to the soil for agricultural reasons[1].

Different nations' sources and use for organic resources in agriculture.

There are few, if any, written regulations on the operation of organic farming and the use of organic materials in agriculture in several regions of Asia and Africa. Without understanding the origin and effects of home trash on agriculture, people, particularly impoverished farmers, depended on it. Street garbage, biosolids (human and animal waste), processed and untreated sludge, and other kinds of organic waste are often collected for use in farming. Municipal solid wastes are often obtained from municipal dump sites, marketplaces, or street bins in India and sold off-the-record to peri-urban farmers. In this instance, the wastes are put to farms without being separated with the express purpose of boosting production. It is made up of ash, manure, domestic garbage, and street sweepings. From the same region, discarded and unused materials from tanneries and abattoirs have also been used, and since these contain materials that are swept on the streets, they may also contain an unknown amount of toxic materials like trace metals and other pollutants like polycyclic aromatic hydrocarbons (PAHs) and (PCBs).

In general, farmers in Africa continue to depend on organic waste in the form of compost, either manually collected from the farmers' own residences or derived from household wastes that have been dumped in landfills. Additionally, some farmers who have farms near streams or rivers benefit directly from using the waste water in the form of effluents as a form of irrigation in an effort to lower the cost of providing water to their farms. This is typical in areas where there is a constant experience of drought due to low annual rainfall. Urinary diverting toilets were recently introduced in South Africa, favoring the use of human urine in agriculture. Because of different contaminations that may result from bacteria, research on the use of human feces as a source of organic amendments is currently under progress[2].

This kind of farming does not adhere to the rules that defined organic farming. Only "safe organic waste" is allowed to be used for agriculture, according to the regulations for using organic waste in agriculture. The usage of sludge for agricultural purposes should be reassessed, according to research, which may need far stronger limitations on the levels of heavy metals and other developing pollutants. The preservation of the environment and the protection of human health should be the primary goals in regulating or managing the use of organic waste in agriculture.

For farmers wishing to sell their goods abroad, regulation and certification may be introduced. For peasant farmers who are just growing a few hectares of land or involved in home farming alone for a living, this might be challenging. Due to their ignorance of the harmful effects of these toxic pollutants on the environment and ultimately on local consumers, peasant and poor farmers are unable to manage the levels and amounts of toxic compounds that may be present in organic waste, which results in regulations only being helpful to commercial farmers.

Concerns have been raised about the agricultural goods (crops) coming from farms that use organic farming practices, and they have been documented in the literature. For instance, if plants are not boiled before eating, the use of human and animal wastes (feces and urine) for the production of food, feed, or fertilizer may introduce various infections into the crops. The purported benefits of using the waste might be adversely impacted by plant absorption of pharmaceutical drug residues in soil and availability of pharmaceutical medicines in animal feces. There have also been reports of additional new contaminants in wastewater, soil, sludge, or other types of waste that might be utilized for organic farming. An overview of what has been reported and documented in the literature on the incidence, behavior, and persistence of organic pollutants in unsorted organic materials used for farming will be provided by the current review[3].

Plants collected from soil treated with various organic wastes or materials, such as urine and sludge, include pharmaceutical residues.

Pharmaceutical residues from medications including antibiotics, analgesics, and anti-retroviral therapies have been found in urine, feces, sludge, soil, wastewater, and plant tissues. Pharmaceutical medications are widely used on mammals (both people and animals) to treat illnesses, increase reproductive rates, and enhance meat quality. Some medications may be metabolized or not inside the body after administration, and they may then be eliminated via the urine and feces. Urine provides around 64% of pharmaceuticals, 80% of nitrogen, and 50% of phosphorus to the waste water body while making up just 1% of the volumetric flow of typical wastewater. As a consequence of pharmaceuticals' partial environmental degradation, they are likely to build up in water bodies or sludge. Even after it has been held for a long time as a treatment step, urine still includes pharmaceutical product residues even if it may be considered an outstanding complete fertilizer of plants since it contains phosphate, nitrogen, and potassium.

As a result, there is a chance that using urine in organic farming would spread pharmaceutical residues over the land. Throughout the years, it has been noted that the predominant pathway for medications to leave the body is via urine. Just a small fraction of pharmaceuticals are eliminated through feces, which has an ecotoxicological risk of around 50%. The research also revealed that urine samples that had been kept for use in agriculture for more than 1.5 years contained antibiotics. Additional research on human exposure to medicines produced from wastewater carried out in two Hebrew universities verified that pharmaceuticals like carbamazepine were found in human urine when the individuals ate food that had been irrigated with wastewater. The paper mentions carbamazepine as an anticonvulsant medication that was found in reclaimed wastewater, was very persistent in soil, and may be absorbed by crops. In addition to Carbamazepine, it has been reported that some pharmaceutical drugs, such as antibiotics, can persist for an extended period of time and cause an increase in the growth of antibiotic-resistant bacteria, even at low concentrations in river base flows. This can also lead to an increase in the drug resistance of microorganisms[4].

Even after treatment, some prescription drug residue may remain in wastewater that may be utilized for irrigation, despite the substantial advancements in water treatment technology. In South Africa, for instance, over 2, 150,880 individuals are taking antiretroviral medications to combat HIV/AIDS, making South Africa the top nation in terms of the epidemic. So, it becomes sense to assume that these medications' remnants may be found in wastewater or sludge in the environment. Nevirapine, a non-nucleoside reverse transcriptase inhibitor that is frequently used for the treatment of HIV as well as the prevention of mother-to-child transmission, was found in all of the surface water samples used in the study and detected in 9 out of the 24 sampling locations, according to a study on the presence of anti-retroviral compounds used for HIV treatment in South African surface water. Another research suggested that this substance's persistence in the environment or its regular therapeutic usage as the reason for its prevalence. According to reports, the substance is not biodegradable. Nevirapine and efavirenz levels in the wastewater utilized in the study before treatment were as high as 2100 and 17,400 ng L-1, respectively, according to a similar study done by other researchers. Nevertheless, 50% of the antiretrovirals (ARVs) were withdrawn throughout therapy, which caused nevirapine and efavirenz concentrations to reach 350 and 7100 ng L-1, respectively. The research also revealed that the quantities of antiretroviral medications in the treated wastewater were unaffected by the addition of chlorine.

Antibiotics have also been found in treated wastewater, in addition to antiretroviral medications. Due to excretion of used medicines and inappropriate disposal of unwanted or expired antibiotics, antibiotics may be discharged into hospital wastewater. By encouraging the selection of antibiotic resistance genes and antibiotic resistant bacteria, which might represent a severe danger to the public health of the whole world, this may constitute a huge health concern. The 2016 study on antibiotics in wastewater revealed the presence of ciprofloxacin and metronidazole in hospital waste water released both before and after the treatment of the wastewater in Vietnam, demonstrating that the removal of pharmaceutical drugs from wastewater is not always the result of wastewater treatment. Similarly, measured the concentrations of the antibiotics ofloxacin (OFC), ciprofloxacin (CI), levofloxacin (LVX), oxytetracycline (OTC), and doxycycline (DOX) in wastewater and found that the antibiotics accumulated in wastewater, soil, and plants before eventually seeping into groundwater.

DISCUSSION

The presence of PAHs in the environment may result from both natural and human causes, and they can linger there for a long time (in the air, water, and soil), with the latter serving as the predominant source. Incomplete combustion of fossil fuels during heating processes, waste incineration, and from automotive exhausts are the main causes of PAH emergence. These are carcinogenic substances, and several research have been done to determine human exposure points. Benzoanthracene, benzofluoranthene, benzopyrene, and dibenzoanthracene are a few of the chemicals that have been linked to cancer in the literature[5].

According to reports, the primary method for PAHs to enter plants is by gaseous deposition, which happens when stomata open and close. Yet, a clear correlation between soil and plant PAH concentrations has also been found, pointing to a potential soil absorption and translocation from contaminated soils inside the plant tissues. Sludge commonly contains PAHs in quantities ranging from 7.8 to 13.3 mg kg1. With extensive sewage irrigation, more than 1.9 104 hectares of farmland in China were poisoned with PAHs. The breakdown of PAHs in soil is often extremely slow in nations with low temperatures and frequent soil freeze-thaw cycles, which may result in highly hazardous residual PAHs in surface soil that are bad for the environment and can contaminate agricultural goods. The majority of developing nations, where waste management is still a major issue, apply and dispose of sludge directly on the field, endangering the soil that will eventually be used for agricultural production[6].

According to reports in the literature, soils are polluted with PAHs either as a result of the application of sludge or from anthropogenic sources. This contamination might be dangerous for farming since plants could absorb the PAHs and bio-accumulate them in other plant tissues. The recognized and documented method for PAH uptake in plants comprises root uptake from soil solution, followed by translocation from roots to shoots during transpiration, and absorption of volatilized organics from the surrounding air by either the plant's roots or shoots. The other significant intake from polluted soil and dust may be held in the cuticle or pass via uptake and transport through oil channels, which are present in certain oil-containing plants like carrots. It should be highlighted that lower molecular weight, 2-4 ring structured PAHs have a greater likelihood of uptake than those with higher molecular weight. High molecular weight PAHs, which are lipid soluble, are mostly maintained in plant roots.

According to a 2002 research, PAHs were present in the soil and could be found in all plants growing on polluted soils, however their levels were low compared to those in the soil, with the exception of potatoes that had been peeled. According to the research, the predominant channel for high molecular weight PAH absorption was via the roots. It was also noted that maize roots had considerably high amounts of pyrene and that sunflower aboveground biomass had a high concentration of phenanthrene. In a comparable investigation on the prevalence of PAHs in fruits and vegetables carried out in India, cabbage (8.34 g kg1) was found to have the highest quantities of PAHs, including benzoanthracene, benzopyrene, benzofluoranthene, and benzofluoranthene. The research also found dietary exposure to PAHs ranging from 0.20 to 0.85 g per day.

Also, it has been shown in the literature that organically grown plants contain PCBs. PCBs, which are man-made organic compounds composed of carbon, hydrogen, and chlorine atoms and are often known as man-made organic chemicals, are present in the environment and are directly related to humans. They may also last for a very long time by cycling via soil, water, and air. While the major reason for the cause and effect linkages are difficult to show, the evidence may still be unclear at this point. PCBs have been associated to immune system illnesses, dermatological difficulties, reproductive abnormalities, neurobehavioral impacts, and cancer. Since many countries, including those in America, Europe, and other parts of the world, have outright banned the production of PCBs and other organochlorine compounds, they are still present in trace amounts in the environment and pose a threat to both the environment and food due to their mobility and long-term persistence[7].

Similar to PAHs, PCBs may accumulate in plants via root absorption and may move to higher plant sections. Another mechanism for atmospheric deposition has been reported; it includes the absorption of both wet and dry contaminated ppapers onto exposed plant surfaces as well as the uptake of airborne vapours by aerial plant parts through the stomata. According to a research done in Poland, PCBs may still be found in both conventional and organically grown veggies and soil. The outcome of the investigation also revealed that, as compared to conventional farming practices, the PCB levels in beets collected from organic farms were higher. Comparatively to the control locations, the research also found a substantial difference in the levels of PCBs in the milk of goats who grazed on contaminated areas. According to the research, the investigated PCB concentrations above the acceptable level established by the European Union. The research found a connection between PCB levels in this milk and those in the plants the goats ate. This further demonstrated the fact that these toxins may go up the food chain from the soil to plants to consumers agricultural goods containing heavy metals that were grown in soil that had been treated with organic matter

Trace metals in the environment may arise from either human or natural sources. The anthropogenic sources may emerge from activities like the kind of fertilizers, the nature of the organic manure, solid waste disposal, smelting, automobile emissions, and emissions from industry. The natural sources include weathering of rocks, erosion, and the nature of the soil. Recently, there has been significant worry about a rise in the levels of trace metals in the environment. The rise, particularly from emerging nations, may be attributable to the different development initiatives taken by these nations. As the amount of trace metals in the environment has increased, they are now found in the soil, water, and air. The biggest issue with trace metals in the environment is that they are not biodegradable, which means that they might linger in the ecosystem for a very long time.

After skin absorption and inhalation, the food chain is one of the most significant human exposure routes to heavy metals, according to research. In general, trace metals and other important nutrients are translocated to various regions of the plants, which may adversely impact their physiological, metabolic, and biochemical activities. Yet, several academic works have revealed and shown that certain plants may either reject or bio-accumulate trace metals from the soil. In the event of a bio-accumulator, it is conceivable for plants to absorb or translocate these harmful metals from the soil to their tissue. In addition, certain plants may be able to absorb these metals via their leaves. The concentration of heavy metals in soils, soil organic matter content (complexion and adsorption rates), soil pH (metals are less soluble at high pHs and more soluble at low pHs), soil redox potential (trace metal mobility depends on their oxidation state), type of vegetables, and species are some of the factors that have been suggested to affect the uptake of toxic trace metals by bio-accumulators (differences in plant physiology, morphology and anatomy)[8].

Typically, sewage sludge, farmyard manure, and the reusing of cleaned wastewater for irrigation are used in organic farming. Farmyard manure has been shown to have changing levels of harmful trace metals throughout the years, depending on the source and regions where the manure was collected. Certain potentially harmful metals, such as arsenic, cadmium, and lead, may pollute soil over an extended period of time and with continual application of contaminated farmyard manure. Proved that adding bovine dung to the soil enhanced its organic matter content and caused the soil to be very productive, but the maize that was treated with that manure accumulated heavy metals. The research also revealed that pig dung included greater quantities of arsenic (As) and cadmium (Cd) than did cow manure. The research also demonstrated that excessive cadmium (Cd) contamination in Gynostemma pentaphyllum, a herbal tea utilized for the study, was caused by the use of pig manure as a soil supplement. Also, it was discovered that soil and plants both had positive cadmium (Cd) concentrations. The research came to the conclusion that adding certain organic fertilizers or animal manures to agricultural soil might make some potentially poisonous substances in the soil more abundant, which could be harmful.

It is not uncommon for treated and untreated wastewater to be utilized for irrigation in urban and peri-urban regions of many developing nations. Undiluted wastewater was thought to deliver nutrients and be more affordable than other water sources by farmers. However, using wastewater that hasn't been properly treated or that hasn't been treated at all for irrigation can lead to serious issues like the buildup of heavy metals in agricultural soils and their absorption by food crops, which can be dangerous for consumers of these products, especially the local population. Human excrement is combined in municipal wastewater treatment facilities with other effluents that include pathogens, harmful metals, organic residues, and medications. Conducted a study in China and found that there is an accumulation of heavy metals in wastewater-irrigated soils, which also increased the concentrations of trace metals in plants grown on the soil, with some trace metal values recorded in the plants exceeding the permissible limit for human consumption. Moreover, lead (Pb) and cadmium (Cd) concentrations in the vegetables utilized for the research were higher than those allowed for human consumption, according to a study on trace metal concentrations in vegetables conducted in Ethiopia. Radish, and carrots that had been watered with treated wastewater had greater amounts of iron (Fe), copper (Cu), chromium (Cr), and zinc (Zn). Despite the fact that the research found that cadmium (Cd) levels were over the permitted limits for agricultural land, the concentrations of trace metals in soil and vegetables were all below these limits[9].

On the other hand, applying municipal sewage to agricultural land for disposal is a desirable alternative due to the potential for enhancing soil qualities and raising plant production via the recycling of important components like organic matter. Consumers of goods made from sludge-fertilized soil, however, may be seriously endangered by the usage of sludge. In rare cases, it has been reported that sludge contains significant levels of hazardous metals. As a by-product of the sewage treatment process, sewage sludge contains harmful bacteria as well as organic and inorganic materials. Due to the presence of trace metals in sludge, it has been suggested in a number of credible reports that before applying sludge to agricultural soils, it may be necessary to take into account variations in metal affinities and soil acidity tolerance as demonstrated by particular vegetables and fruits. Despite several techniques used to assess a sludge's acceptability for use in agricultural applications after various treatment procedures, the presence of pathogens and other contaminants in the sludge continues to be of concern. According to the findings of a research carried out in Nigeria, lead (Pb) levels in vegetables grown on soil treated with sludge were higher than those advised for human consumption. The intake of vegetables grown on soil treated with sludge for agricultural purposes in India was studied, and large zinc (Zn) and cadmium (Cd) hazard quotients were noted[10], [11].

CONCLUSION

Since this approach does not include the exclusion of dirty materials from farming, the usage of organic materials in agriculture shouldn't be considered to be organic farming. There is strong evidence from the literature that when grown on contaminated soils or treated with contaminated organic materials, plants may absorb many kinds of contaminants from the soil. Notwithstanding this data, the practice of using polluted organic resources for agriculture, particularly in underdeveloped nations, is expanding. Particularly when organic materials are obtained from unidentified sources and utilized for cultivation, poor farmers and members of their close families face significant risks. A concerted effort should be made to inform, train, and educate peasant farmers and the general public on the types, timing, and use of organic materials in agriculture. The elimination of persistent organic pollutants from the environment has to be the focus of improved and renewed efforts (Soil, water and wastewater). This might include using new technologies in waste treatment facilities and researching the potential of various plants to bio-accumulate these toxins from the soil.

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CHAPTER 22

USING ORGANIC FARMING METHODS IMPROVES SOIL QUALITY BY CHANGING THE BACTERIAL ECOLOGY IN THE SOIL

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ABSTRACT:

Throughout time, the importance of organic farming has increased in support of both environmental sustainability and food security. The low yield is a persistent problem with organic management, notwithstanding the benefits for the environment. One possible solution may be based on the soil microbiome, which is important to the soil system. Here, we compared the bacterial population in the soil's structure and makeup between organic and conventional farming, while also accounting for the soil's tropical climate. Several organic management practices, such as the so-called natural and organic management systems, which use different organic sources, affect the composition of the soil bacterial population, which indicates that the activities of the bacteria are altered. Our findings also assisted in the identification of target bacterial groups in trophic organic farming systems and altered the chemical composition and enzymatic activity of the soil, both of which may have an effect on crop yield.

KEYWORDS:

Biodiversity,Bacterial Population, Environment, Crop Yield, Natural Resources, Pollution, Sustainable Agriculture.

INTRODUCTION

The link between K and Al and conventional treatment is adverse, but the correlation between pH, Ca, P, alkaline phosphatase, and -glucosidase activity and organic systems is favorable. Our data also show how the soil bacterial population has transformed in organic systems, with Acidobacteria, Firmicutes, Nitrospirae, and Rokubacteria being the most common phyla. These phyla were associated with modifications in organic systems' soil biochemistry, which increased crop yields[1]. As it contributes to the production of food, energy, and a broad variety of manufactured commodities, agriculture is crucial for human life. Since the green revolution, there has been an increase in agricultural productivity due to the greater use of synthetic fertilizers and pesticides, better irrigation systems, and novel soil management strategies.

As a consequence of this intensification of agriculture, new concerns about the impacts on soil ecosystem services, the advantages of biological soil components for agriculture, and productivity loss over a long period of cultivation are arising. The ecological services that soil provides are often negatively impacted by intensive agricultural practices, including soil degradation, biodiversity loss, insufficient nutrient cycling, greenhouse gas emissions, pesticide accumulation, and nutrient leakage. Surface runoff and nutrient leakage are often caused by extensive plowing and chemical fertilization, especially in tropical regions. A third of the chemicals and degraded soil, according to estimates, are poured into rivers and lakes, harming the aquatic ecology.

Other strategies to increase soil ecosystem services include organic farming and reduced or no-tillage techniques. These techniques increase soil fertility and encourage soil biology in order to maintain high agricultural yields. By banning toxic residues that are harmful to both humans and animals, organic farming stresses maintaining the natural balance of the soil-plant system while producing high-quality, healthy food. In actuality, organic farming avoids the use of genetically modified organisms and substitutes organic matter fertilization and biological pest control techniques for synthetic chemical fertilizers and pesticides. Crop rotation, the addition of organic matter, and the control of biological disease also preserve the fertility of the soil for organic systems. Globally, it is estimated that about 6.98 107 hectares of farmland are managed utilizing organic practices, and these numbers are steadily growing. This trend is being driven by consumer demand for nutrient-dense food and scientific proof of environmental protection, such as an improvement in soil quality.

To grow an organic system and substitute mineral fertilization, a variety of sources of organic matter are utilized as fertilizers. The most often recommended fertilizers for use with organic techniques are green manure or combinations of composted animal dung and straw (such as that from chickens, pigs, or cows). Organic fertilizers should have a C/N ratio of fewer than 30 parts carbon to 1 part nitrogen by weight in order to promote mineralization processes. Other factors, such as enzyme activities, should be taken into consideration since soil microorganisms are crucial for maintaining beneficial soil conditions (such as soil aggregation, biological control, nutrient cycling, organic matter decomposition, and nitrogen fixation).

According to this approach, utilizing soil management practices that boost the microbial population and its activity could be a potential option for enhancing crop output. If the soil is rich in organic matter and all of the biological and biochemical processes are running well, we consider the soil to be healthy, with a successful microbiome and offering all ecosystem services for maximum output. Healthy soils sustain soil fertility, enzyme activity, and microbial balance. In more recent research comparing organic and conventional farming, next-generation sequencing tools have shown changes to the microbial community structure (NGS). Organic farming techniques have been found to be advantageous by increasing soil organic matter content, soil porosity, structural stability, moisture, nutrient availability, biological activity, and reducing soil erosion.

Despite the benefits, organic farming is known for producing subpar crops. According to observations, crop outputs in the conventional sector are typically 20% higher than those in the organic sector. Traditional crop management prescribes a certain amount of each nutrient input and the appropriate timing for each farm activity for each crop. In organic systems, every farmer uses a different form of organic material without considering the type, quality, or quantity. This disregards numerous aspects of the soil's organic matter cycle that are essential for plant growth. Hence, studies on the kind and quantity of organic matter in relation to the soil microbial population may provide insight on the reasons for low productivity and offer suggestions for controlling organic systems[2].

In our study, we compared the use of composted chicken dung as fertilizer in organic farming and natural farming, which employs bokashi and green manure as fertilizers. As a conventional technique of growing maize, we combined the classic cropping system with mineral synthetic fertilizer (one of the most important agronomic crops in the world). Not to mention, we looked at the effects of switching from conventional to organic farming, which requires a five-year transitional period and a progressive transition from conventional to organic management utilizing composted chicken manure. As we began our studies, we were beginning the second year of this methodology.

We looked at changes in the bacterial community, soil quality indicators, and crop yields for each of the four management strategies. We predicted that (1) organic farming increases production that is on par with or greater than conventional farming, and (2) soil fertility and soil biology are improved throughout the transition from conventional to organic farming, in addition to maintaining soil health. Moreover, we hypothesized that (3) different organic management systems, also known as natural and organic management systems, that employ different organic sources change the soil bacterial population, which implies that these systems also change the roles of the bacteria.

DISCUSSION

The diversity and richness indices did not substantially differ across the experimental treatments studied in this study. We attained stronger faith PD variety and richness or observed ASV values in the second year when comparing these indices between the cropping years. The clearly demonstrates how the bacterial community structure differs across the treatments, where the soil samples generally cluster in accordance with the fertilization source (mineral, composted poultry manure, or green manure). It was shown that the same chemical properties and enzyme activity acted as the main regulators of bacterial community structure in both years. The OM and TM treatments used composted chicken manure and grouped together without a clear link with any soil parameter, but the CM and NM treatments exhibited the highest variability amongst them all. The bacterial community was discovered to be clearly associated with pH, alkaline phosphatase, -glucosidase, Mg, labile carbon, and P in NM as opposed to CM, where they were demonstrated to be connected with inorganic N, ammonium, nitrate, Al, and K. We identified the classes that are most often associated with each style of management by identifying statistically significant relationships between the ASVs and each type of soil management (Deseq2 analysis).

The Deseq2 analysis produced 481 ASVs and 420,448 sequences overall, both of which were significant at 5%. The classes Subgroup 6, Blastocatellia, and Nitrospira from the phylum Acidobacteria, as well as Nitrospira from the phylum Nitrospirae, were more prevalent in the treatments that received organic fertilization. Class Bacilli (phylum Firmicutes) and NC10 (Rokubacteria) were more prevalent in NM than in the CM therapy. TK-10, Chloroflexia, Anaerolineae from the phylum Chloroflexi, Phycisphaerae (phylum Planctomycetes), Acidobacteriia (phylum Acidobacteria), Thermoleophilia (phylum Actinobacteria), Verrucomicrobiaceae (phylum Verrucomicrobia), and Chloroflexia and Anaerolineae from the phylum Ch. Yield, pH, and alkaline phosphatase showed favorable and unfavorable results with the Spearman correlation for the classes that were previously identified as being more common in treatments NM and CM, respectively. The exception was the class Blastocatellia, where there was no correlation between the -glucosidase activity and the aforementioned data[3].

Organic farming is a different kind of farming that doesn't have a detrimental impact on ecosystem services or the environment. In addition to the benefits of this environmentally friendly management, several studies have shown that its main disadvantage is its low average yields. Moreover, the dearth of scientific evidence confirms this scenario of low yields and impedes the development of organic approaches. Here, we evaluated the diversity of conventional management practices (CM, NM, and OM) and organic management strategies (OM and NM) on the soil bacterial community (CM). The Mokiti Okada Research Center suggests an internal practice that says moving to organic management requires five years of progressive transition from one management technique to another in order to restore the soil's natural fertility. Due to this, we decided to add the transition management (TM) in our experiment. Previous maize study comparing conventional and organic management used more than 160 kg ha-1 of N in the form of green manures and chicken manures. In our experiment, the low-nitrogen organic systems 120 kg ha-1 of composted poultry manure for OM and 60 kg ha-1 of composted green manure plus 60 kg ha-1 of Bokashi for NM—led to yield improvement and changes in the bacterial community structure, which may improve the cycling of soil nutrients, especially carbon and phosphorus (as will be discussed later)[4].

In the first and second years, the crop yields for the two organic systems (OM and NM) were higher than for conventional management (CM), which is based on mineral fertilization. During the second year, we observed a reduction in rainfall at stages V5 and R1, which would have had a negative effect on the yield for the groups that received synthetic fertilizers (TM and CM). Surprisingly, the organic treatments didn't show any yield decrease (OM and NM). When rainfall and nutrient absorption data were compared at different phenological phases, it was shown that early nutrient acquisition (CM and TM) was not followed by considerable growth, suggesting a water scarcity just before R1. The organic treatments (NM and OM), which did retain more water in the soil as a consequence of their high contents of organic matter and, as a result, maintained a high growth rhythm, showed that this period generally marks the most intense development phase. Research from the past has shown that organic farming may be very fruitful during times of high drought.

This increase was associated with the ability of soil organic matter to retain moisture and improve soil aeration. Our results often showed lower Yield values compared to earlier studies, which was associated with a dry time. We would want to underline the major impact of the drought scenario on conventional maize yield in contrast to organic farming practices. To completely comprehend how the microbial community and changes in soil properties link to drought resistance, further investigation should be needed. Nutrient intake for plant feeding didn't vary in any noticeable ways. Hence, our results suggest that composted poultry manure (OM) and green manure with Bokashi (NM) may both provide the nutrients required for maize growth. It was discovered that composted organic materials are significantly more suitable for use in organic treatments because they frequently have a better nutritional content (primarily for carbon and phosphorus) than fresh organic matter. This is because chicken manure has a low C/N ratio and quickly mineralsizes in soil after composting, increasing the availability of nutrients.

Nevertheless, our research showed that using both Bokashi and green manure may have complementary benefits since Bokashi provides the microbiota with an easily available probiotic diet. Green manure with a high C/N ratio that hasn't been decomposed often results in N being immobilized and decreased crop yields in the first years. But, the fermentation of the green manure used in the Bokashi production could stimulate microbial activity and improve the plants' capacity to absorb nutrients. Bokashi, which was created by the Japanese and is often used to promote crop growth in the roots and soil organic matter. Lactic acid, which is included in bokashi, helps break down green manure in addition to bolstering the microbiota. Research from the past has shown how Bokashi may increase the yields of sweet potatoes and maize[5].

The dehydrogenase, urease, and protease activities as well as the carbon and nitrogen content of microbial biomass are all increased by organic farming, according to a recent meta-analysis. Our results showed that soil enzyme activity, such as phosphatase and -glucosidase, soil pH, and soil P levels were the strongest predictors of the differences between organic and mineral synthetic fertilizer. Our research points to the same conclusion in the tropical zone, despite the fact that the bulk of these data are from the temperate climatic zone. Minerals like ammonium and phosphorus may alter the microbiological properties of soil by releasing H+ and bringing down pH levels, or they can pollute the environment by releasing heavy metals. Nevertheless, organic matter increases the pH of the soil by chelating Al3+ and enhancing the soil's buffering capacity. Many soil enzymes become more active when pH levels rise. Our results are corroborated by prior studies that discovered a favorable association between soil pH and the enzymes glucosidase and alkaline phosphatase. There was a positive link between the soil P level and the increased activity of alkaline phosphatase in response to organic fertilization, particularly for the NM treatment. Phosphorus concentrations in soils are often inaccessible for plants for a number of reasons, including the immobile forms of phosphorus in soil (Halvorson & Black, 1985), the fixation of phosphorus in acidic tropical soils, and sometimes even leaching. Organic fertilizers have been shown to reduce soil phosphorus fixation, enabling plants to absorb more phosphorus. According to our research, even in tropical soils, where the soil is often acidic, boosting alkaline phosphatase activity may enhance the availability of phosphorus (P).

The addition of green manure was shown to yield the highest value for -glucosidase activity, as was seen. At the last step of cellulose decomposition, -glucosidase catalyzes the hydrolysis to produce glucose, making it a crucial soil indicator for the breakdown of green manure inputs in soil. The production of -glucosidase, which is released into the environment and utilized to accelerate the breakdown of cellobiose, is promoted in several bacterial species in soil. The enzyme -glucosidase breaks down cellobiose into two glucose molecules, which the bacteria subsequently take up since the bacterium's cells contain built-in sugar transporters. It is important to emphasize that, even for the organic treatments with low N input, no differences in soil ammonium or nitrate concentrations were identified. It has been shown that P availability corresponds with biological nitrogen fixation because of the critical role that phosphorus plays in supplying the energy needed to produce ATP during this process. Thus, nitrogen fixation has an influence on the amounts of both accessible N and P. The organic managements favoured both enzymes since they both increase the production of N and P, namely -glucosidase and alkaline phosphatase.

Using high-throughput sequencing of the 16S rRNA gene, we evaluated the changes in - and -diversity and identified the specific bacterial groups related to soil biochemistry in both conventional and organic farming systems. The examined treatments did not substantially vary in terms of diversity indicators. The microbial diversity of the soil has been subject to a number of postulated effects of organic and conventional management, which may increase, decrease, or conserve the microbial diversity. According to research, microbial diversity indices increased along with a rise in soil C levels after the application of organic fertilizer. We found no significant changes in the soil's C and N levels, which may help explain why the diversity indices were the same across the treatments in our study[6].

Thanks to the distance-based redundancy analysis, we were able to discover the differences in the diversity of the bacterial community between organic and conventional managements. This study also allowed us to pinpoint the significant soil traits that contributed to the variance. Our results show a substantial correlation between soil fertility and enzyme activity as well as the soil microbiome, suggesting that microbial community turnover is a precursor to the cycling of soil organic matter. This observation also remained true in TM, where the bacterial community structure is more similar to OM than to CM. Despite the fact that the transition treatment only received 40% of the total organic fertilization in our study, this statement was accurate. Soil pH has been shown to be one of the major regulators of the composition of the microbial community in both pristine and agronomic environments.

Variations in soil chemical properties and enzyme activity are directly related to changes in the microbial community. Our results demonstrated that the most important bacterial groups that positively correlate with CM are all inversely related to soil pH, alkaline phosphatase activity, and -glucosidase activity.

The four bacterial phyla most often seen during CM treatment are Verrucomicrobia, Chloroflexi, Planctomycetes, and Actinobacteria. The most abundant phyla in organic farming (NM and OM) are Acidobacteria (classes Subgroup 6 and Blastocatellia), Firmicutes (class Bacillus), Nitrospirae, and Rokubacteria. Actinobacteria and Chloroflexi are associated with conventional farming, however prior studies that examined bacterial community changes in temperate climates found that Acidobacteria and Planctomycetes were becoming more prevalent in organic systems. Our results in a tropical setting confirmed that these groups are relatively abundant in both organic and conventional systems, with the exception of the phylum Planctomycetes, and they also demonstrated that additional phyla were associated with similar agronomic strategies[7].

Conflicting results for Actinobacteria and Acidobacteria when these two groups are compared with soil pH are common in the literature. Actinobacteria and soil pH had previously been demonstrated to be highly positively associated however this association was not evident in regular arable soils. Thermoleophila, a class of the phylum Actinobacteria, seemed to be declining in population in this area and showed a negative correlation with the alkaline phosphatase and pH levels of the soil. The addition of organic fertilizers to soils is expected to hinder the growth of acidobacteria, an oligotrophic species that has been observed to prefer acid soils. Nevertheless, revealed a positive correlation between soil pH and class Subgroup 6 (phylum Acidobacteria). Blastocatellia and Acidobacteria have differing habitat preferences, according to recent study by the authors in arctic soils.

The former are positively linked with soil pH and negatively correlated with nitrogen availability, while the latter have the opposite tendency. Also, although the class Acidobacteria shown a negative connection with soil pH, Subgroup 6 and Blastocatellia displayed a positive link, confirming the hypothesis that various phylogenetic affiliations may display various ecological features in agronomic soils. Moreover, other soil characteristics (such soil enzymes, C and P availability), management practices, or other variables may have affected these conflicting results in the relationship between Acidobacteria and Actinobacteria and soil pH. (e.g., organic fertilization). Previous studies have shown that Acidobacteria, Actinobacteria, Chloroflexi, Cyanobacteria, Firmicutes, Gemmatimonadetes, Planctomycetes, Proteobacteria, and Verrucomicrobia are the most abundant phyla that may produce alkaline phosphatase in soil.

Although though most of these groupings are present as significant phyla in conventional or organic systems, only the phyla Firmicutes and Acidobacteria, which are both related to organic systems, were positively correlated with alkaline phosphatase in our data. Because of this, the use of organic techniques improved P cycling in this environment by increasing the activity of several phyla connected to alkaline phosphatase. The phyla Rokubacteria and Nitrospira associated with organic systems, especially NM, may be crucial for C cycling and N nitrification. The first phylum in Amazon soils has just been described, demonstrating its capacity to break down complex hydrocarbonates.

According to our research, there is a positive link between this phylum and the activity of the enzyme -glucosidase in soil, suggesting that Rokubacteria may be engaged in the decomposition of green manure. The nitrification process is carried out by Nitrospira in soil, and the fact that this species is more prevalent in organic systems suggests that the low N intake in these treatments boosted it.

The assumption that organic farming may increase maize yield more than conventional farming was validated by our study. The quality of the soils used in the experiments might be a factor in the varying results of organic management's yield output. Most studies that compare conventional and organic management techniques start on soil that has already undergone conventional farming. Because of its partial degradation, this soil only yields well when heavily fed with synthetic fertilizers and several additional chemical inputs. We included a five-year transitional phase before designating the system organic as a result. The soil had to be recovered and given all the biological characteristics of a healthy soil, which serve as the cornerstone for an efficient organic growth system, when bringing an organic system to a region that had previously been farmed using a conventional system. Failure is more likely to happen in this case. So, further study is needed before an organic management system is implemented to consider the abiotic and biotic variables' conditions. Based on our research, we suggest that picking the right moment to go from conventional to organic management improves the quality of the soil, the cycling of organic matter, and the microbiota that promotes plant nutrition and development. Not to mention, we found that organic managements—natural and so-called organic encourage changes to the soil's bacterial population and its functioning.

CONCLUSION

According to our findings, crop yields from organic farming systems may be on par with or even better than those from conventional farming when N input is low and organic fertilization is well selected. Improvements in the soil's organic processes are connected with changes in certain bacterial groups in the soil microbiome. Also, this study aids in identifying beneficial traits of bacteria relevant to organic farming in tropical soils. Future studies should use a similar approach in other tropical regions to permit manipulation of the soil microbial activity, as per our recommendation.

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CHAPTER 23

POLLUTION PREVENTION, GOOD MANAGEMENT PRACTICES AND CONSERVATION

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ABSTRACT:

Agriculture-related externalities are undesirable in society. It is influenced by a number of things, such as the usage of pesticides, nutrient runoff and overflow, biodiversity loss, and soil erosion. Positive externalities include things like respect for the environment, freedom, unrestricted entrepreneurship, and air quality. Natural mechanisms may lower some of these costs. A move to organic farming has been proposed as a way to mitigate some of the unfavorable externalities related to (conventional) farming. Organic farming seems more acceptable since it considers the sustainability of the environment and natural resources. The most crucial component of sustainable agriculture is the protection of natural resources. In the next years, as natural resources become increasingly limited, it will be crucial to focus primarily on the shift to a more resource-efficient economy. Agriculture is the most important industry for preserving food security for next generations while lowering resource usage and enhancing resource recycling. Organic farming practices are less hazardous than conventional ones, according to several studies comparing the two types of farming. This is because organic agricultural practices consume less energy, generate less waste, and have lower biodiversity levels.

KEYWORDS:

Biodiversity, Environment, Natural Resources, Pollution, Sustainable Agriculture.

INTRODUCTION

Comparing organic and conventional farming revealed, according to researchers from multiple studies, that organic agriculture has less of an impact on the environment. According to experts, the best conclusion would be the development of strategies to combine these two agricultural practices in order to produce the largest yields possible as well as the creation of a new system for the environment, land, and sustainable forests. The biodiversity created by organic farming is advantageous to humans. Organic agricultural ecosystems are more sustainable because they need less human inputs, such as pesticides and fertilizers[1]. The rate at which developed and developing countries are now depleting the resources of the globe is alarming. The world's population is continually growing. More people are inhabiting the earth, and as a result of shifting consumption patterns, they are need more basic human requirements including food, water, shelter, and energy. This leads to the conclusion that we need to reconsider how we manage our natural resources.

The development of agricultural techniques is what has brought about human existence as it is now. There would be famines all throughout the world without these vital instruments for survival. For many thousands of years, agriculture has been an organic activity that hasn't destroyed the land it was performed on. Farmers used such methods for farming that the soil would remain fertile after many generations, despite the fact that modern agricultural techniques have started the process of agricultural pollution and are causing the degradation of land, ecology, and ecosystem as a result of agricultural by-products. There is no one cause for the widespread agricultural pollution we are now seeing. Agriculture is a sophisticated enterprise where the growth of both crops and animals must be precisely balanced. Agricultural pollution development is a consequence of the many growth stages they go through.

A well-planned optimal management technique must include a measure that increases crop productivity while minimizing environmental impact. This suggests that the best management techniques, such minimizing pesticide usage, should be employed for a healthy crop. Since horticulture crops must be grown intensively, healthy crops rely on healthy soil, which must be maintained properly. Farming practices use a lot of dangerous chemicals, which depletes the natural resource base. Organic farming focuses on controlling soil organic matter to enhance the physical, biological, and chemical properties of the soil in order to optimize crop yield.

The management of the soil affects the nutrients that are available to the crops. Moreover, soil activities are essential for eradicating weeds, illnesses, and pests. Experts should generate technology-based agricultural research, which should subsequently be shown to farmers. As they are essential for managing erosion, a modest quantity of chemicals, such as insecticides and herbicides, are employed in ecologically friendly farming techniques. Many authors have already examined the potential effects of conventional farming vs organic farming on the control of soil erosion[2].

Limited tillage, crop selection criteria, soil plant cover management, and other soil erosion-reducing methods are required by the International Federation of Organic Agricultural Movements in order to minimize the loss of top soil cover and increase crop yields. Farmers that grow organically should use conservation tillage, especially if they live in an area where erosion is a concern (IFOAM, 2000). Nutrient input is important in organic farming. Legumes fix nitrogen, which is then supplied to the crop via organic manure and crop rotation. Tillage is essential because it helps the topsoil spread and absorb nitrogen. This chapter looks at the many management strategies that organic farmers could use to achieve these more broad goals.

Inorganic Farming

Without the use of synthetic fertilizers, organic farming produces and processes food, yet it is still feasible to produce organic food by using pesticides derived from naturally occurring sources (NOSB 1995). Organic farming slightly lessens the negative impacts of conventional farming, such as soil erosion and the leaching of nitrogen and carbon [1-3].

In the US, organic farming has been practiced since the late 1940s. Since then, the company has grown from tiny farms to enormous farms, producing and selling products under specialized organic labels. Nowadays, there are more than forty different state organizations that certify organic food, but each has its own set of requirements. The use of the aforementioned synthetic and non-synthetic substances in organic farming would be outlawed countrywide under the 1990 Organic Food Production Act. The ecosystem and the natural world may be preserved with the aid of organic farming[3].

DISCUSSION

Environmental benefits of Organic Farming

Organic farming takes into mind the long-term consequences on the agro-intermediate ecosystem. In order to prevent problems with soil fertility and other related difficulties, organic farming aims to produce food while establishing an ecological balance. This method advances well instead of addressing problems as they arise.

Soil

Examples of methods to organic soil structure that are intermediate to organic include crop rotation, symbiotic interactions, and organic fertilizers. They promote soil flora and fauna by improving soil formation and structure. As a consequence, mineral fertilizers are not used, which enhances the soil's ability to retain nutrients and water while also increasing nutrient and energy cycling. Such management techniques are essential for stopping soil erosion. Despite the fact that farm-derived renewable resources often make up for crop nutrient export, organic soils sometimes need external potassium, phosphate, calcium, magnesium, and trace element additions.

Air

Less agrochemicals are needed for organic farming, which reduces the need for non-renewable energy. Using soil carbon contributes to lessening the greenhouse impact and global warming. Several continuing techniques include introducing additional nitrogen-fixing legumes, adopting crop rotations, putting carbon back to the soil to boost production, and often adding produce residues to the soil. The carbon content of soils used for organic farming is greater than that of other soils, according to a number of studies. With more organic carbon stored in the soil, agriculture is better able to slow down the effects of climate change[4].

Water

Ground water pollution by synthetic pesticides and fertilizers is a severe problem in many agricultural areas. Synthetic fertilizers are prohibited in organic farming; instead, compost, animal manure, and green manure are utilized as organic fertilizers. These organic fertilizers increase soil biodiversity, enhance soil structure, and increase soil's capacity for water penetration. Ground water pollution risk may be considerably reduced if organic systems are properly managed. Organic farming is expected as a promising option in areas where pollution is a major issue.

Genetically Modified Animals

They cannot be employed in organic systems since it is unknown how they may impact the environment and human health. This holds true throughout the whole process of making organic food. Organic farming promotes natural biodiversity. The organic label offers an assurance that these organisms weren't intentionally used in the production and processing of organic items. Due to the growing usage of genetically modified organisms in conventional farming and the manner of transmission of these organisms in the environment, organic farming will no longer be able to guarantee that organic products are entirely free from genetically modified organisms through pollen.

BiologicalFoundation

In the agro-ecology, natural farming's collision with conventional resources favors links that are crucial for both organic production and nature conservation. Outcomes of biological services include stabilizing and conditioning soil, recycling nutrients and waste, predation, and habitats. The expansion of environmentally friendly agriculture practices depends on consumer desire and capacity to pay a premium for organic products.

Organic Farming Protection against Pollution

To improve their access to agricultural and horticultural resources, people live on this planet. Farming is a resource that life need to survive; when these resources are few, famines break out all over the world. Growing crops organically did not harm the environment for a long time; several generations of crops were grown without depleting the fertility of the soil. Yet, as a consequence of modern farming practices, agricultural pollution that hurts the ecology, land, and environment has started to happen. Agriculture is a complicated industry where the growth of crops and animals must be properly managed[5].

Agriculture is a source of pollution

Synthetic fertilizers

Fertilizers are being employed to treat local pests with new, persistent species that have been around for a long time and are laden with synthetic chemicals, contrary to earlier beliefs that they were the primary source of pollution. Pesticides that have been applied mix with water and seep into the ground. Plants absorbing residual pesticide cause poisoning of nearby waters. When animals eat these crops, it has an effect on the animals.

Animals

Animals like cattle, lambs, pigs, and chickens were often kept by farmers on their own land, where they were fed a natural diet that was supplemented by agricultural waste. The outcome was that the animals also helped maintain the health of the farm as a whole. Nonetheless, cattle are now routinely transported to slaughterhouses, housed in close quarters, and fed unusual diets. They contribute to the contamination of agriculture via emissions.

Pests and weeds

In many places, it is standard practice to cultivate novel crops while eradicating native ones. New crops entering the local market have caused the growth of weeds and pest diseases that the populace cannot manage. Hence, the local flora and animals are permanently destroyed. This just adds to the pollution caused by the farming process.

One source of contamination is the use of contaminated water for irrigation. Groundwater reserves provide us with the fresh, clean water we drink. Some sources are polluted with organic compounds and heavy metals as a result of the disposal of industrial and agricultural wastes in close-by bodies of water. Agricultural pollution makes it harder to tackle when it poisons animals and ruins crops since crops are exposed to that water.

Sedimentation

Even though there are several layers in the soil, only the top layer is appropriate for agriculture. Reduced soil fertility is often caused by ineffective agricultural practices. By using these techniques, open soil is subjected to wind and water erosion. This soil is then discharged, which causes sedimentation. Its sedimentation increases soil in locations like rivers, streams, ditches, and nearby fields, while agricultural pollution prevents water, aquatic life, and nutrients from flowing normally to other productive areas.

Agriculture pollution's effects

Effects on aquatic life

Organic substances that reduce the quantity of oxygen in the water, such ammonia or fertilizers converted to nitrate, cause the extinction of many aquatic organisms. Animal faeces may carry bacteria and parasites that can significantly injure a variety of aquatic life and terrestrial animals. Controlling agricultural pollution is a task, despite how challenging it may seem to be. It is difficult to monitor water levels, soil cleanliness, and industrial pollution. In recent years, governments have tightened up on rule enforcement. Most farmers are moving to conventional farming as they become more aware of the hazards and look for solutions. But, if agricultural pollution is to be entirely eliminated, a fundamental shift in growing practices is necessary.

HealthEffects

The main factor for water and lake contamination is farming pollution. Pesticide and fertilizer contaminants are absorbed by groundwater, which poses a major health danger since they end up in drinking water. Drinking water contamination from agricultural machinery-related chemicals and metals may have negative health effects[6].

Pollution-prevention techniques

A crucial element of pollution control is lowering waste output. This will include taking steps to reduce pollution by making better use of raw materials, energy, water, and land while preserving natural resources. Pollution is prevented from being created in the first place and from entering the environment by minimizing it at the source. Environmental prevention includes reducing and addressing the pollution we often still make. It helps to reduce risks to human health and the environment in a variety of ways, including by reducing dangers connected to the discharge of pollutants into the environment, avoiding the transfer of pollutants from one medium to another, and protecting the natural resources for future generations. There are several ways to promote pollution prevention, including via partnerships, technical assistance, funding for demonstration projects, and the inclusion of reasonably priced pollution control measures in law. It also requires using systematic management strategies, such as grass and tree planting technology, the development of medium and low farms, and broad use of rural energy resources, in order to manage and improve the ecological environment.

Management strategies for organic farming

The soil's texture has a bigger role in manufacturing methods. The producer's capacity to till, the tillage methods used, and the frequency of green manure crops are all impacted. The produced production methods work well with the climate and soil texture of the farms.

Wholesome soil

The condition of the soil determines how well an organic agricultural system works. It is feasible to evaluate the health of the soil qualitatively. Many farmers look for soil that is rich in organic matter, smells earthy, is deep, and has a lot of color. An earthy smell is a sign that soil microorganisms, which are crucial to the health of the soil, are present. Some people keep an eye out for local wildlife; birds may be helpful scouts for the existence of earthworms and other organisms.

Some farmers may watch the development of the root systems and the color of the leaves as their crops expand. Low nitrogen levels are shown by yellow leaves, stress is indicated by red leaves and dead patches, and inadequate nutrition levels are indicated by dark green leaves that are growing slowly. Weeds growing there demonstrate the nutrients in the soil; they need the same nutrients, but in varying amounts.

Fertile soil is also referred to as healthy soil because it has sufficient amounts of the chemical components (macronutrients and micronutrients) needed for plant growth. Macronutrients, which comprise components like nitrogen, phosphorus, calcium, sulfur, and potassium, are those that are needed in larger amounts. Nitrogen is often only present in plants and is abundant in the air, but only a few free-living bacteria and rhizobium associated with legumes can fix the nitrogen from air. While other minerals from the underlying rocks may infiltrate the soil. As items are removed from the agricultural environment, nutrients are taken out of the soil. Among all of them, the most nitrogen is lost, but happily, it can be replaced by air. Good structure, ease of tilling, and efficient nutrient penetration and absorption are all characteristics of fertile soil. Examples of biological fertility include microbes that recycle the chemical nutrients made available by the decomposition of plant remains and animal feces. They form a symbiotic relationship that increases the amount of soil that plants may search for nutrients [7].

Soil Analysis

To ascertain the soil's fertility and nutrient level, a soil test may be necessary. Soil testing may disclose organic matter, pH, and soil nutrients. Some soil test results contain results for macronutrients. Normally, these soil tests result in recommendations for agricultural fertilizers.

Soil testing may be advantageous for organic producers. Farmers are helped by long-term changes in soil fertility to adapt soil management practices including crop rotation, crop choice, and green manure. Experienced farmers don't feel the need to test the soil since they can determine the health of the soil based on crop production. In the case of soil biology, where soil organisms may rapidly develop or die, which may invalidate the results, it is essential to collect and maintain soil samples for the soil test in accordance with the lab's instructions. Among the soil tests used by organic farmers are the following ones:

The business Soil Food Web Canada, Inc. evaluates the soil's biodiversity (the quantity of bacteria, fungi, and nematodes), suggests appropriate levels for different crops, and gives suggestions on how to make the soil more active.

A Plant Root Simulator probe is used by Western Ag Innovations Inc. to evaluate soil fertility. To achieve this, the quantity of nutrients moving through the membrane is measured using probes that have been put into the soil for various amounts of time. It will provide a trustworthy evaluation of the nutrients the plants can get.

Kinsey's Agricultural Services analyzes the soil sample using the Albrecht methodology. They provide recommendations based on past crop performance, preferred fertilizer, and kind of activities.

The level of macronutrients and micronutrients in the soil are assessed by the ALS Laboratory group. This test measures organic matter, pH, cation exchange capacity, and the quantity of nutrients that can be extracted[8].

SoilBiology

To encourage soil biology, a variety of tactics might be applied. Using green manure is one of the best methods, in the opinion of many seasoned farmers, to maintain the vitality of soil. Using animal dung and straw residue, making sensible rotational decisions, and reducing tillage are other useful strategies. To replace the land's nutrients, some farmers suggested putting all of the straw back into the soil. They provide microorganism to increase the organic matter in the soil. Integration of legumes causes the microbial population to shift, becoming more metabolically active and creating more organic matter. Growers often try to reduce tillage and keep some cover on all fields throughout the growing season since tillage also impacts soil microorganisms. Covering the area with green manure, which keeps it from drying up, is the best strategy for this. Organic farmers must exercise care and make an effort to avoid methods that exacerbate soil erosion and eliminate soil microorganisms.

Soil Organic Matter

Organic matter is necessary to maintain the soil's health and water-holding ability. Animal and plant waste, as well as soil organisms like bacteria, fungi, and nematodes, make up the organic matter that remains in the soil worked from year to year. The warmth and plants that were there before the earth was cracked cause organic matter to develop. The four basic types of soil organic matter are new organic stuff, decaying organic matter, stable organic matter, and living organisms. Soil bacteria convert fresh organic plant matter into moderately degraded organic matter, which includes nutrients for plant development. The result of the decomposition process, stabilized organic matter, produces the soil structure, which enhances soil aeration and water retention capacity.

Compost and Fertilizer

Manure is an excellent organic fertilizer, but its use is closely regulated by organic regulations. Many livestock ranchers use it to boost soil fertility. Several methods of application are possible, such as spreading it on crops, applying organically composted manure, and applying manure that hasn't been composted.

For optimum decomposition, it must be supplied during the proper rotational peak and time of year. In order to maximize effectiveness and minimize nitrogen loss, fresh manure should be blended immediately and applied in a cool environment. Nevertheless, many farmers age manure for several years prior to application, which is not ideal.

Composting, which is the process of aerobically decaying organic matter to form compost, a substance similar to humus, is better than manure. This procedure includes the microbial conversion of manure into humus, which has an earthy odor and a darker color (fungi). Composting, which requires certain tools and labor, must be used to enhance manure's capacity to form humus.

If producers wish to meet composting requirements, they must carefully regulate the mass's air, moisture, and temperature. While composting, the proportion of carbon to nitrogen must be correct. Careful planning is necessary to account for the makeup of animal feces on farms. The location of the compost site is important for avoiding risks to nearby water sources and ground water. Cattle enclosure, compost and dung collection, transport, and distribution are all costly and inefficient. Some farmers use the simple tactic of allowing cattle to graze on fields while fertilizer is applied directly to the field[9].

Nutritional Changes

A few farmers use additives like foliar sprays and seed inoculants to apply to the soil or green crop regions. Organic amendments seldom rarely have any known applications. It's crucial to use these things sensibly. Before using any modification, it is essential to establish that it is valid for use in organic agriculture.

Input of seeds

Fixing nitrogen is essential for the growth of plants. Since they provide an environment that is beneficial to the bacteria that fix nitrogen, rhizobial inoculants containing legumes are used to fix nitrogen. Notwithstanding the claims of some seasoned farmers, who claim that seed inoculants are unnecessary, putting the inoculant on or below the seed will increase results.

Other products that respond to crops differently depending on the crop, crop cultivar, and management history include humates, mycorrhizal fungi, and other microorganisms.

An Organic Manure

In order to replenish the soil's nutrients for soil organisms and subsequently for crops, "green manure" is a crop that is grown there. For the soil to remain healthy, crop rotation must include the application of green manure. The availability of nitrogen is controlled by the growing environment, moisture content, and inoculation; a legume known as green manure fixes nitrogen into the soil. In order to boost the availability of phosphorus, farmers suggested oilseed and buckwheat. They also suggested sweet clover, alfalfa, red clover, field pea, and faba bean for nitrogen fixation.

Altering the crops

Crop rotation, which is the systematic succession of crops, is regarded as the most important aspect of organic farming. Several scientific studies support the idea that crop rotation is preferable than monocultures. The rotation is more diverse, the yield is steadier. To make better use of the available resources, crops with different qualities may be rotated. We are aware that different crops have different requirements for nutrients, water, and susceptibility to pests and diseases.

The succession of crops must be carefully selected and appropriately matched to the fertility level in order to avoid the disease potential that builds up in crops. Depending on the state of the soil, crops that need tillage should be balanced with crops that add organic matter, and crops that consume more nitrogen should be balanced with crops that produce nitrogen. Crop rotation is crucial for weed control. For distinct crops, a variety of weed control approaches are used. Every kind of management approach favors one weed species over the others. Winter crops are interspersed with annual crops, changing the pattern of disturbance and causing different times of hardship for different species. As a result, the marijuana community expands in diversity. As it increases the variety of food and habitat alternatives for the beneficial species, this diversity may be favorable. Insect and disease management also requires rotations. When insects and diseases are separated from a crop for a long time, they are unable to rapidly increase in population because they are specific to that crop. Rotation is seen by the majority of farmers as a work in progress that will change as the land changes. The majority of seasoned farmers suggest a flexible rotation to adjust to changes in microbial contamination, disease pressure, and market circumstances. Organic farmers take soil samples every few years and spend time researching how to improve their farming methods[10], [11].

CONCLUSION

The tilth and ppaper aggregation of the soil are also impacted by livestock and poultry manure, which supplies nutrients for plants. The organic components of manure act as binders to strengthen the structure of the soil. The addition of manure changes the soil's structure, which undoubtedly affects water infiltration, water retention, aeration, and resistance to wind and water erosion. A multitude of factors, such as animal species and age, feed type, straw content, storage method, and duration, affect the nutritional value of manure. The manure contains several micronutrients that are helpful in avoiding the signs of a plant deficiency. Depending on the kind of soil that is available, the slope, the location, and the different construction approaches, different soil testing laboratories that examine animal dung for nutrients will recommend a different quantity of manure application. In order to reduce environmental contamination, manure application rates shouldn't be more than what a crop can use in a single growing season. Manure should be incorporated into the soil as quickly as possible following application to reduce nitrogen loss and promote healthy plant growth.

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CHAPTER 24

RISK ASSESSMENT AND REMEDIATION FOR SOIL CONTAMINATION

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ABSTRACT:

The presence of synthetic chemicals in the natural soil environment is the main source of soil contamination, sometimes referred to as soil pollution. It often results from some kind of industrial activity, agricultural chemicals, or inappropriate waste disposal. Petroleum hydrocarbons, pesticides, lead, and other heavy metals are the most frequent compounds that contribute to soil contamination. Another cause of soil contamination is the rupture of subterranean storage tanks or the seeping of garbage from landfills. Mining, fertilizer application, oil and fuel dumping and a plethora of other environmental concerns may also create contamination of the soil.

KEYWORDS:

Environment, Pollution, Fertilizer, Natural Resource, Soil Contamination.

INTRODUCTION

The environment is a current, hot subject. Pollution affects soil, water, and air equally. As a "universal sink," soil takes the brunt of environmental pollutants. It is being contaminated in a lot of ways. In order to maintain soil fertility and boost production, it is vital to prevent soil contamination. An unfavorable alteration in the physical, chemical, and biological features of the air, water, and soil that has an impact on human life, the lives of other valuable living plants and animals, industrial development, livable circumstances, and cultural assets may be referred to as pollution. Everything that negatively affects people's health, comfort, property, or environment is considered a pollution. The majority of pollutants are often by-products or leftovers from the manufacturing of anything valuable, sewage, garbage, unintentional release, or other means. As a result, the land, water, and other valuable natural resources are contaminated[1].

Soil is the foundation of agriculture. It is necessary for all crops grown as food and for feeding animals. This precious natural resource is being lost to some degree due to increasing erosion. In addition, massive amounts of man-made waste, including sludge and other products from new waste treatment facilities and contaminated water, are contributing to or directly causing soil contamination.

The health of all living things will be improved by taking herculean management measures to protect the fertility and production of the soil. It is a difficult work with many related issues to evaluate the ecological risk of contaminated soil, pesticide application, sewage sludge amendment, and other human activities that expose the terrestrial environment to hazardous compounds. Terrestrial ecological risk assessment is not only a young scientific topic that has advanced quickly just since the middle of the 1980s, but it is also made difficult by the fact that, unlike most aquatic habitats, soil is often on private lands and sold as real estate. So, it is common for the interests of scientists, stakeholders, authorities, engineers, managers, attorneys, nongovernmental organizations (NGOs), and regulators to differ professionally and economically. Even if we ignore those factors, there are still a number of issues with how we now manage risk and the effects of human pollutants on the terrestrial environment.

Soil Contamination

The accumulation of persistent poisonous substances, chemicals, salts, radioactive materials, or disease-causing agents in soils that have a negative impact on plant and animal health is referred to as soil pollution. The thin covering of organic and inorganic substances that covers the rocky surface of the Earth is known as soil. The black topmost topsoil is where the majority of the organic material, which is made up of decomposing plant and animal remnants, is concentrated. The bedrock's physical and chemical weathering over thousands of years produced the inorganic component, which is made up of rock pieces. In order for agriculture to produce enough food to feed the globe, productive soils are required[2].

Poisonous Inorganic Substances

Inorganic residues in industrial waste present severe issues as respects their disposal. They include metals with high toxicity potential. Sulphur dioxide and arsenic fluorides are other major pollutants released by industrial operations (SO2). The superphosphate, phosphoric acid, aluminum, steel, and ceramic industries all contribute fluorides to the environment. Acidic soils may result from sulphur dioxide emissions from industry and thermal plants. These metals damage leaves and kill plants.

The elements that may build up in the soil include copper, mercury, cadmium, lead, nickel, and arsenic if they enter via sewage, industrial waste, or mine washings. Moreover, certain fungicides that include copper and mercury worsen soil contamination. Lead, which is hazardous to plants and is absorbed by soil ppapers, is present in the smoke from vehicles. By increasing soil organic matter, amending soils with lime, and maintaining an alkaline environment, the toxicity may be reduced.

Organic Wastes

Several kinds of organic waste provide pollution risks. When piled up or disposed of inappropriately, household trash, sewage from public facilities, and industrial waste pose a major threat to the health of people, plants, and animals. Borates, phosphates, and detergents are abundant in organic waste. These will have an impact on plants' vegetative development if left untreated. Phenols and coal are the principal organic pollutants[3].

Other pollutants include asbestos, flammable materials, methane, carbon dioxide, hydrogen sulfide, carbon monoxide, sulphur dioxide, and gasoline. Moreover, harmful soil contamination is caused by radioactive minerals including uranium, thorium, strontium, and others. Strontium vaporization concentrates in the sediments and generally stays on the ground. Continuous cropping and the application of chelate amendments are examples of decontamination techniques. These and other liquid wastes, such as sewage and sewage sludge, are significant contributors of soil issues.

Sludge from sewage and sewage

The unregulated discharge of sewage and other liquid wastes from home water usage, industrial wastes containing a range of contaminants, agricultural effluents from animal husbandry, drainage of irrigation water, and urban runoff are all common contributors to soil contamination. The irrigated soils undergo significant modifications as a result of sewage water irrigation. Physical changes like leaching, variations in humus content, and porosity, among others, as well as chemical changes like soil reaction, base exchange status, salinity, and the quantity and availability of nutrients like nitrogen, potash, and phosphorus, among others, are just a few of the changes that sewage irrigation causes in the soil. By collecting metals like lead, nickel, zinc, cadmium, etc., sewage sludges contaminate the land. This might result in plant toxicity.

Toxic heavy metals

In their elemental state, heavy metals are substances with a density higher than five. They generally locate particular absorption sites in the soil where they are held extremely firmly either on the inorganic or organic colloids. Throughout the environment, soils, plants, animals, and their tissues, they are extensively dispersed. In trace levels, they are necessary for both plants and mammals. Heavy metal pollution is mostly caused by urban and industrial aerosols, fuel combustion, animal and human waste, mining waste, industrial and agricultural chemicals, etc. All soils that have not been polluted contain heavy metals due to weathering from their parent elements[4].

DISCUSSION

Soil Contamination Causes

The presence of synthetic chemicals or other changes to the natural soil environment are the main causes of soil contamination. The most common causes of this kind of contamination are the failure of underground storage links, the use of pesticides, the application of contaminated surface water to subsurface strata, the dumping of oil and fuel, the leaching of waste from landfills, and the direct discharge of industrial wastes into the soil. Petroleum hydrocarbons, solvents, insecticides, lead, and other heavy metals are the most frequent compounds involved. This phenomenon's frequency and chemical use intensity are both connected to industrialisation levels. Any element that impairs the soil's quality, texture, mineral content, or biological balance of the organisms in the soil is considered a soil pollutant. Plant growth is adversely affected by soil pollution.

1. soil pollution is connected to
2. fertilizers used carelessly
3. Use of pesticides, insecticides, and herbicides without restriction
4. large-scale disposal of solid waste
5. Deforestation and erosion of the soil
6. fertilizers used carelessly

Oxygen comes from the air and water, but the soil is also where other essential elements like nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and more are found. Fertilizers are often used by farmers to remedy soil deficiencies. Impurities from the raw materials used in the manufacturing of fertilizers pollute the soil. Ammonium nitrate (NH4NO3), phosphorus as P2O5, and potassium as K2O are common ingredients in mixed fertilizers. As, Pb, and Cd, for instance, are transported from rock phosphate material to super phosphate fertilizer. Since the metals cannot be broken down, their buildup in the soil above the dangerous levels caused by excessive phosphate fertilizer usage turns the soil into an unbreakable poison for crops. The number of vegetables and crops produced on soil decreases with time due to the excessive usage of NPK fertilizers. Moreover, it lowers the protein content of crops cultivated on that soil, such as wheat, maize, and grains. Such crops also lose some of their carbohydrate quality. Vegetables and fruits have less vitamin C and beta-carotene when there is too much potassium in the soil. Overly fertilized soil makes plants and fruits more vulnerable to pest and disease assaults[5].

Use of pesticides, insecticides, and herbicides without restriction

Food-producing plants must fight with weeds for nutrition while being attacked by insects, fungus, bacteria, viruses, rodents, and other animals. Farmers employ insecticides to eradicate undesirable populations that are present in or on their crops. With the conclusion of World War II, DDT (dichlorodiphenyltrichloroethane) and gammaxene were first widely used as insecticides. DDT was quickly overcome by insect resistance, and since it took a long time to degrade, it remained in the environment. It affected calcium metabolism in birds, generating thin and brittle eggshells, and biomagnified up the food chain because it was soluble in fat rather than water. Large raptors like the brown pelican, ospreys, falcons, and eagles were threatened as a consequence. Most Western nations have now outlawed DDT. Unfortunately, a lot of them, including the USA, continue to make DDT for sale to other developing countries whose requirements exceed the issues it causes.

Dumping of Solid Wastes

Garbage, home rubbish, and abandoned solid materials, such as those from commercial, industrial, and agricultural activities, are all considered to be solid waste. They are increasingly made of paper, cardboard, plastic, glass, recycled building materials, packaging, and other harmful or dangerous materials. The bulk of urban solid waste is recyclable or degradable in landfills since paper and food waste make up a significant portion of it. Similar to how mining waste is left on site, the majority of agricultural waste is recycled. We must pay close attention to the hazardous portions of solid waste, such as oils, battery metals, heavy metals from smelting industries, and organic solvents. They may in the long term, be deposited on the soils of the surrounding area and pollute them by changing their chemical and biological qualities[6].

Deforestation

As weathered soil ppapers are displaced and moved away by wind or water, soil erosion occurs. This erosion is a result of deforestation, agricultural expansion, temperature extremes, precipitation, particularly acid rain, and human activities. With building, mining, lumber harvesting, overcrowding, and overgrazing, humans hasten this process. Floods and soil erosion are the effects. The soil is kept clean and healthy by the great binding properties of grasslands and forests. They sustain a wide variety of habitats and ecosystems, which give rise to an endless number of food chains or feeding paths for all species. The existence of many species would be at danger if they disappeared. Quite a bit of enormous green terrain has been turned into deserts during the last several years. The value of South America's, tropical Asia's, and Africa's rain forests is being threatened by development and population expansion (especially timber, construction and agriculture). Several experts think that these trees contain a variety of therapeutic compounds, including a cancer and AIDS treatment. The world's most fertile places for flora and animals are being steadily destroyed by deforestation. These areas also make up large tracts of a very significant carbon dioxide sink.

A result of urbanization

Pollution of surface soils includes various non-biodegradable elements, including plastic bags, plastic bottles, plastic trash, glass bottles, glass pieces, stone/cement pieces, and animal and vegetable wastes, papers, wooden pieces, carcasses, and twigs and leaves. A approximate estimate puts the daily production of solid municipal garbage in Indian cities at between 50,000 and 80,000 metric tons. They contribute to a number of issues if they are not collected after they have decayed, including[7];

Drain blockage: This significant drainage issue might result in drainage pipes bursting or leaking, which can have negative health effects. Solid wastes have substantially hampered the natural flow of water, which has led to flooding issues, damage to building foundations, and risks to the public's health.

Increased microbial activity: When organic wastes decompose, enormous amounts of methane and other pollutants are produced, which contaminate the soil and water on its surface. Such solid wastes from hospitals produce a variety of health issues since they may include deadly pathogens in addition to dangerous drugs and injections.

1. contamination of the subsurface soil
2. Cities' underground soil is likely to contain pollutants.
3. chemical substances produced by industrial wastes
4. Materials made of sanitary waste that have partly or completely degraded

There is a good chance that subsurface soil will include harmful chemical compounds including cadmium, chromium, lead, arsenic, and selenium. Similar to this, sanitary waste-polluted subsurface soils produce a variety of dangerous compounds. They have the potential to harm subsurface soil ecosystems and regular activities.

1. Consequences of agricultural soil pollution
2. Soil fertility decline
3. Less nitrogen being fixed
4. Higher erodibility
5. More soil and nutrient loss
6. Silt accumulation in tanks and reservoirs
7. Decrease in agricultural yield
8. Soil flora and fauna are out of equilibrium.

Reducing Soil Pollution

The below actions have been recommended to reduce soil contamination. We may restrict development in critical areas to aid in preventing soil erosion. In general we would need less fertilizer and fewer pesticides if we could all follow the three R's: Reduce, Reuse, and Recycle. Less solid waste would result from this.

Techniques for extraction and separation

In solvent extraction, the contaminated oil is often combined with an extractant (an aqueous solution but preferably an organic solvent). You may also get rid of hydrocarbons and halogenated hydrocarbons.

Because contamination is frequently preferentially present in the soil's finer or coarser fractions or its organic components (such as humus), contamination can occasionally be eliminated using a process that divides the soil into fractions according to specific gravity, ppaper size, or settling velocity[8].

Thermal Techniques

In thermal procedures, there are two types of heat treatment: evaporation, which involves the removal of impurities by transferring heat directly from heated air or an open flame, and destruction, which involves transferring heat indirectly from heated air or an open flame. Any impurities or undesirable combustion products must be destroyed or removed from the gas that is released from the heating equipment. Stream stripping, a similar procedure, involves injecting steam into soil to help in the evaporation of relatively volatile pollutants that may or may not be water soluble.

Chemical Techniques

The two potential treatments include suspending the soil in an appropriate liquid and avoiding sludging. In these situations, regular and close soil-chemical interaction is necessary for the full completion of the detoxification process.

Microbial methods of therapy

The use of microbial treatment techniques to deal with a variety of organic pollutants, such as phenol, polychlorinated hydrocarbons, oil and oil products, dioxins, etc., seems more promising. The challenges may be approached in two distinct ways.On the location, a colony of bacteria already there is gathered and grown in a lab. In the laboratory, microorganism strains that can metabolize certain substances are created. The best opportunity to create ideal circumstances is via soil excavation before treatment. Using conventional earth movement methods, the excavated soil may be laid out in thin layers at different depths, and conventional agricultural methods like fertilizing, plowing, harrowing, etc. can be used to provide microorganisms and nutrients.

Treatment of solid waste

For the management of the disposal of solid waste, appropriate procedures should be used. In order to make industrial wastes less dangerous, they may be physically, chemically, and biologically handled. Waste that is acidic or alkaline should be neutralized first, and if it is biodegradable, the insoluble material should be allowed to break down under controlled circumstances before being disposed of. As a last option, new locations for storing hazardous waste, such as deep well injection and more secure landfills, should be researched. The easiest and most popular method of managing solid waste is to bury the rubbish in sites far from residential areas[9].

Soil Surveillance

The primary goal of soil monitoring is to avoid and reduce contamination by chemicals that might have a negative impact on the soil itself, as well as on air, water, and creatures that could come into contact with the soil. Throughout the approvals program, soil monitoring is mostly used to evaluate pollutants that have been discharged into the soil surface. Subsurface facilities may thus be the cause of groundwater monitoring but are often not the purpose for soil monitoring.

Nonetheless, an evaluation will be necessary if it is known or suspected that soil pollution comes from subterranean sources, such as underground tanks or pipelines. As stated in the Soil Monitoring Directive, the proponent is required to complete the following tasks when the aforementioned factors indicate that soil monitoring is necessary as a condition of approval: > create a soil monitoring proposal; > carry out the approved soil monitoring plan; > interpret and report the results of the soil monitoring; and > create and implement a soil management plan where necessary. This policy explains the history of the soil monitoring program and the specifications for the soil management program.

Legislative History

The majority of the soil monitoring program was created under the Environmental Protection in support of the following principles: > development must be sustainable, meaning that the use of resources and the environment today must not jeopardize prospects for their use by future generations; > the environmental impact of development must be prevented or mitigated; > polluters should be held accountable for the costs of their actions; > remediation costs should be incorporated Understanding that under the environmental protection is a shared duty, it follows that both the permission holder and the Department must have a mechanism to evaluate environmental performance with regard to the above principles and standards.

Standards for soil quality

Environmental Protection believes that permission holders will regulate their activities to avoid material leaks to soil. However there are substance leaks to the soil, and industrial establishments often have toxins exceeding background levels. As a result, Environmental Protection should establish standards for soil quality to help in evaluation and cleanup of soil pollution. Facilities that are now uncontaminated have the chance to keep their existing state, which permits unlimited land usage. The Tier 1 criteria or similar goals will set the minimum requirements for these facilities. Yet, older plants were often run under less acceptable environmental management techniques and regulations[10].

Risks of Soil Pollution

Risk-oriented strategies are being used more often to address the local consequences of soil contamination. These rules address dangers to human health, as well as environmental and toxicological issues. These hazards are described in terms of harmful consequences and probabilities (between 0 and 1) that such consequences will materialize. The United States of America, Canada, and nations in the European Union are a few examples of places where risk-oriented approaches are used to address soil contamination. Traditionally, strategies aiming at returning soils to their initial, "clean" condition have been abandoned and replaced with risk-oriented policies.

Using exposure-risk relations that have already been established, risk-based criteria or standards that were defined within the scope of risk-oriented policies are applied to risks evaluated using deterministic approaches. Decisions about soil remediation have been made using risk-based criteria, including sediment management in the United States, the use of soils for certain purposes, and soil clean-up requirements. The risk-oriented strategies under consideration here make the assumptions that there is no danger from background exposure to pollutants and that there is a maximum risk that local organisms can tolerate or accept from a certain degree of soil contamination. The latter forms the cornerstone of standardization.

Risk-based regulation on soil contamination contains certain qualitative policy objectives. For instance, the major UK law on contaminated soil describes land as contaminated and needing risk management "where considerable damage is being caused or there is a strong likelihood that such harm may be produced". Most often, however, rules have led to precise numerical limits for the amount of acceptable or bearable soil contamination. Analyzing the various industrialized nations has shown that there are extremely significant variations, generally up to a factor.

Risk factors for a specific soil pollutant

The appropriate determination of the real danger associated with one soil pollutant in practice is at odds with a number of things. They include the lack of pollution limits, disregard for background exposure, and disregard for exposure pathways to soil contamination, disregard for the existence of dose-effect research, and disregard for biological availability. We'll talk about them in greater depth now.

Lack of quality requirements

When information on soil contaminants is available, it should be compared to quality criteria that indicate the highest level of tolerated exposure risk. Such guidelines aren't often followed, however. For instance, the US Geological Survey found unregulated compounds those for which there were no established standards in groundwater samples. Similar to this, several substandard brominated ethenes were discovered in Australian groundwater.

Ecological Dangers

Maximum acceptable or maximum tolerated ecotoxicological hazards are often determined from a small number of laboratory investigations involving a single species. Field results often vary from those of laboratory research because real outdoor circumstances might differ greatly from those in the lab. Many elements that are often overlooked in laboratory research have been revealed to have a significant influence on the harmful effects of soil contaminants in field investigations. Among these include the size and adaptability of impacted organism populations, the existence of other environmental stressors, and the presence or absence of certain landscape features like buffer strips.

Biological Availability

Pollutants that are bioavailable determine risk. Several sorts of organisms may have very varying biological availability. Physical, chemical, biological, and geographical variables all affect a compound's biological availability in a particular soil. Examples of such variables include pH, the quantity and make-up of additional organic and mineral components, as well as the existence of organisms that might mobilize contaminants from the soil. In real life, biological availability and total concentrations could differ significantly[11].

Effect combinations

A lack of combined effects accounting

The combined impact of the many pollutants found in soils should be taken into account when assessing the overall risk of soil contaminants. The actual standard-setting process, however, has mostly concentrated on requirements pertaining to a single element or compound. There are sometimes requirements for groupings of chemicals. Such criteria restrict the quantity of certain chemical groups (in g/kg soil), but they often ignore the potential that the danger per unit of weight may vary for various compounds. Criteria for the presence of halogenated dioxins, benzofurans, and planar biphenyls are an exception to this rule. Addition based on equivalent toxicity is used to determine risk in the event of exposure to these substances. While it has been noted that this technique may still underestimate the likelihood of neurodevelopmental consequences, it is still a significant improvement.

A need for Combined Effects

Combination effects might be significant in two ways. The biological availability of coexisting soil pollutants may be impacted, first. On the basis of current information, certain dangers associated with pollutant mixes may be projected. For instance, when effects are receptor mediated, there is a good possibility that there will be dosage additivity. Joint-mixture ecotoxicological consequences may be anticipated in the event of narcotic effects as well. Response addition may be utilized if the replies are different. An approach to deal with the ecotoxicity of combinations giving rise to both dose-additive and response-additive effects has been presented. This two-step approach assesses the toxicity of mixtures using response additivity for distinct modes of action and concentration additivity for the same mode of action. A systematic approach to combination effects based on a combination of concentration addition and response addition has been proposed for determining the severity of ecotoxicological effects in cases of heavily polluted soils (in which legal maximum tolerable levels for one or more substances are exceeded).

Solutions to problems

It would seem that there are remedies that might greatly enhance risk assessments. Standards may be applied to unregulated substances. New dose-effect studies may be the foundation for routine standard updates. Estimates of risk may take into account both background exposure and every possible route of exposure to local soil contamination. By doing better bioavailability tests or using in-vivo monitoring, estimates of biological availability may be better included into risk assessments. Since the emphasis is on ecosystem functioning, the shortcomings in accounting for combination effects in ecotoxicity highlighted in section may be addressed by explicitly assessing ecotoxicity. It should be remembered, nevertheless, that tiny changes in how ecosystems work may, over time, have significant repercussions. Large numbers of replication experiments are required, which may go above and beyond what is customary.

Direct testing on people is a "unethical choice" for establishing how combinations affect human health. Yet, biomarker-based monitoring of certain human-relevant elements of soil contamination may be a choice. For instance, used a biomarker-based test on soils that had been first polluted and then cleaned up and contained a range of polycyclic aromatic hydrocarbons (PAH). They examined the cytochrome P 450 expression profile. The genotoxic risk of soil contamination was assessed using an in-vitro Salmonella test. Use of tests based on biomarkers for soil pollution is an intriguing alternative in dealing with combined impacts on people, even if the relationship between such biomarker-based data acquired and the in-vivo dangers need additional explanation.

Moreover, biomarkers that may be seen in persons exposed to soil contamination may be used to evaluate risk. These biomarkers have been discovered via epidemiological research that take into account how different drugs interact. The research by that discovered a graded correlation between blood lead concentrations and urine cadmium concentrations and oxidative stress-related indicators in the US population serves as an example of this. As a result, it is possible that oxidative stress might serve as a biomarker for the effects of combinations. Also, it has been suggested to measure glutathione conjugative metabolites to assess the effects of combinations of volatile organochlorines and nitroarenes as well as to assess the effects of exposure to nitroarenes by measuring haemoglobin adducts. A better alternative to the measurement of polyhalogenated aromatic hydrocarbons has been suggested, namely bioassays based on aryl hydrocarbon (Ah) receptor mediated processes. Taking into consideration cumulative combination effects in accordance with known cause-effect relationships and research into the impacts of real combinations is another method for estimating the hazards to human health.

Given that there are no chemical interactions between the components of the mixture under consideration, it has been shown that this holds true for receptor-mediated and reactive mechanisms of toxicity. Presently, this method is used with planar polybiphenyls, halogenated dioxins, and benzofurans, albeit non-linear interactions are not entirely absent and neurodevelopment effects may be underestimated, as previously noted. This strategy may be expanded to include, for example, polycyclic aromatics, including heterocyclic polycyclic aromatics, organophosphates that inhibit the enzyme cholinesterase, compounds that bind to estrogen receptors carcinogens, a range of petroleum products, and compounds that inhibit the MXR efflux pump.

Ecological Risk Assessment

Ecological risk assessment (ERA) is the process of gathering, compiling, and evaluating environmental data to determine the likelihood that different stressors connected to human activities may have unintended impacts on species, populations, or ecosystems. In various studies, the fundamental concepts of ecological risk assessment are explained. Uncertainties are a part of any kind of ERA. The value or utility of the various ERA techniques is influenced by costs, utility, predictability, and uncertainty. ERA often comes in two different forms. The first is prescriptive and often relates to the European Union's licensing and management of dangerous substances like pesticides or new and existing chemicals. The best time to conduct this sort of ERA is before an environmental release. The second sort of ERA, which evaluates changes in people or ecosystems at sites or regions that have already been contaminated, may be regarded as an impact assessment rather than a risk assessment. The predictive technique is based on general extrapolations from controlled and manipulated semi-field investigations or laboratory experiments to actual settings. The descriptive technique, which aims to track ecosystem changes in historically polluted soils like old dumpsites or gas facilities or in field plots following pesticide or sewage sludge amendment, is more site-specific.

ERA is often carried out in stages or tiers, and both predictive and descriptive methodologies may be used. As a general rule, the higher layers need more time, energy, and resources. The paradigm or schemes for ERA may differ significantly between nations, but they frequently include an initial formulation of the problem based on a preliminary site characterization, screening evaluation, characterization of exposure, characterization of effects, characterization of risk, and risk management. While exposure evaluation is often equally as essential or perhaps more so, impact assessment is the main topic. The majority of European nations use very straightforward methods for ERA of contaminated soils, such as soil screening levels (SSL) (also known as quality targets, quality standards, benchmarks, and guideline values) and simple bioassays for a preliminary risk assessment. A wide range of guideline values have been developed as a result of national research or remediation efforts.

While difficult to classify, the majority may be divided into two groups: general and site-specific. Whereas the site-specific rules need a characterisation of pH, organic matter, etc., at the site, general guideline values are more independent of modifying influences and consequently simpler to regulate. Ex situ bioassays, here defined as straightforward laboratory assays where single species are exposed to historically contaminated soils collected in the field, are here defined as simple laboratory assays where single species are exposed. Monitoring, analyzing, and mapping of population or community structures in the field round out the three main classes of tools for assessing ecological effects. Terrestrial model ecosystems (TME), mesocosms, and lysometers may also be helpful; they may be thought of as large (multispecies) bioassays or testing for ecotoxicity. TMEs have the benefit of working with the intrinsic soil populations, which make up a tiny food web and are (relatively) undisturbed. TME therefore enable the evaluation of toxicant effects that are mediated by adjustments in the food supply or by competition and predation.

CONCLUSION

Many human endeavors and experiments that end up poisoning the soil lead to soil contamination. The most frequent sources of soil contamination are industrial wastes such toxic gases and chemicals, agricultural pesticides, fertilizers, and insecticides. The others include faulty septic system management and maintenance, leaks from sanitary sewage, unfavorable and dangerous irrigation methods, and ignorance of soil management and associated systems. An urgent need exists for a tiered strategy in the evaluation of ecological risk associated with polluted soils. As a first rung, generic soil screening levels are required. Nonetheless, site-specific assessments have to be a part of higher levels of ecological risk assessment. Moreover, it is crucial to arrange the numerous studies in a framework or decision-support system that is clear to all parties and beneficial to them. To cope with these ambiguities, it may be clear to use a weight of evidence method. The TRIAD technique, which integrates and groups data from chemistry, toxicology, and ecology into a triangle, is a suitable tool for dealing with conceptual ambiguities. To address these flaws, many solutions have been put forward. Direct testing would significantly enhance risk estimations for ecotoxicity. Pertaining regards human health risks: integrating biological availability in risk estimations, increased use of up to date information regarding exposure pathways, dose-effect relations and combination effects, and biomonitoring of impacts are choices for improvement.

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CHAPTER 25

TECHNOLOGY FOR CLEANING UP POLLUTED SOIL

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ABSTRACT:

There aren't many bibliometric studies that demonstrate contemporary technology and how they work together to remediate polluted soils. In order to understand the trends in soil pollution treatment technology, a scientometric research was conducted. These days, soil contamination is a widespread occurrence brought on by the presence of man-made materials. The presence of human-made garbage is the primary cause of the soil's contamination. The soil is made more fertile by the waste that comes from nature itself, such as decayed fruits and vegetables, animal corpses, and dead plants. Yet the chemicals in our waste products, which come from sources other than nature, pollute the land. This essay focuses on the numerous kinds of typical soil contamination. In this study, the different soil pollution remediation techniques are discussed in depth. Thermal therapy, phytoremediation, soil vapor extraction, biosparging, and electric resistance heating works are some of these therapies.

KEYWORDS:

Environment, Pollution, Fertilizer, Natural Resource, Soil Contamination.

INTRODUCTION

Scientometric analysis details the development of scientific research papers and describes in detail the field of knowledge relevant to the subject. There have been several scientometric studies on soil remediation and remediation-related themes, but none that illustrate soil contamination treatment methods generally or the current and projected patterns in the growth of this field of study. This circumstance makes it more difficult for researchers, managers, and public authorities to make decisions about the best soil remediation technology. The need to research the theory and methods of restoring degraded soil was suggested looking into mitigation techniques in addition to aspects of soil, water, and atmospheric pollution. These studies highlighted the state-of-the-art in soil treatment technologies as well as current and upcoming challenges[1].

The United Nations Convention to Combat Desertification (UNCCD, 2019) experts on this topic explained that over 1.3 billion people live on degraded agricultural land and that 75% of the world's land has undergone transformation and 23% has undergone desertification (degradation without further soil production). It is evident that altering land use for urbanization, mining, or mineral extraction causes habitat degradation and is a significant factor in the loss of biodiversity worldwide. Pollutants introduced into the environment via a variety of channels, including flue gases, waste-based power production, leaded gasoline, heavy oil, and fossil fuels, slag, among others, have an adverse effect on the land, water, and atmosphere. Researchers are generally concerned about heavy metals found in soil, such as copper, chromium, and arsenic however, these pollutants are joined by organic substances, such as pentachlorophenol (PCP) and dioxins and furans (PCDD/F), which are a significant issue in industrialized nations. Understanding how soil degradation affects the goal of achieving climate neutrality by 2050 is crucial. According to preliminary calculations, this goal requires utilizing the full potential of European soils and the soil organic carbon pool in agricultural soils, so it is crucial to implement sustainable soil management practices. Additionally, Borrelli et al. (2020) highlighted that while agriculture only occupies around 38% of the earth's surface, it is useful to people and that, when not managed sustainably, agricultural systems end up being the primary causes of soil degradation. Countries must undertake sustainable land management (SLM) with suitable solutions to combat the issues of desertification, land degradation, drought, climate change, and threats to biodiversity in order to address this dire situation. For the cleanup of polluted soils, several researchers created chemical, thermal, biological, and physical techniques.

The following findings were obtained from a review of scientometric or bibliometric literature on soil deterioration and remediation: (A) cleaning up soils with significant metal contamination. Study situation on environmental contamination, including water, soil, and air, and (c) mitigation techniques. Using the software programs CiteSpace and VOSviewer as well as document cocitation and cluster analysis methodologies for data analysis, a scientometric research of the remediation of soil heavy metal contamination in the years 1999–2020 was completed[2].

The presence of xenobiotic (human-made) substances or other changes to the natural soil environment are what create soil contamination or soil pollution. Usually, industrial activities, agricultural chemicals, or inappropriate waste disposal are to blame. Petroleum hydrocarbons, polynuclear aromatic hydrocarbons (including naphthalene and benzo(a)pyrene), solvents, insecticides, lead, and other heavy metals are the most frequent compounds involved. The amount of industrialisation and the amount of chemical use are connected to contamination. Health hazards, direct contact with contaminated soil, fumes from pollutants, and secondary pollution of water sources inside and under the soil are the main causes of worry with soil contamination. In addition to extensive knowledge of geology, hydrology, chemistry, computer modeling, and GIS in Environmental Contamination, mapping contaminated soil sites and the ensuing cleanup are time-consuming and expensive tasks. They also call for an understanding of the development of industrial chemistry. Pesticides, herbicides, and fertilizers may all contribute to soil contamination. Open-air feces and urine discharge; oil and fuel dumping; coal ash disposal; leaching from landfills; drainage of polluted surface water into the soil; and electronic waste

Petroleum hydrocarbons, solvents, insecticides, lead, and other heavy metals are the most frequently used compounds. Coal ash - Until around 1960, locations that were industrialized often had coal ash depositions from heating systems used for homes, businesses, and industries as well as for industrial operations like ore smelting. As coal is formed, lead and zinc naturally concentrate throughout the process, along with several other heavy metals to a lesser extent. Most of these metals are concentrated in the ash after the coal is burnt (the principal exception being mercury). Coal ash and slag may contain enough lead to qualify as "characteristic hazardous wastes," which are those that have more than 5 mg/L of extractable lead as determined by the TCLP technique and are produced in the USA. Coal ash often includes varying but large quantities of polynuclear aromatic hydrocarbons in addition to lead (PAHs). The permitted amounts of these PAHs in soil are normally centered around 1 mg/kg, despite the fact that they are proven human carcinogens. Off-white soil grains, gray heterogeneous soil, or (for coal slag) bubbly, vesicular pebble-sized grains may all be used to identify coal ash and slag. Sludge from treated sewage systems, or biosolids as they are called in the industry, has drawn criticism for their use as a soil fertilizer. As a byproduct of sewage treatment, it often includes more toxins than ordinary soil, including organisms, pesticides, and heavy metals. Herbicides and pesticides: A pesticide is a chemical or a combination of compounds used to eradicate a pest. Any chemical product, biological agent (such a virus or bacterium), antibiotic, disinfectant, or tool used to control pests might be considered a pesticide. Insects, plant diseases, weeds, mollusks, birds, animals, fish, nematodes (roundworms), and microorganisms are examples of pests that compete with people for food, damage property, transmit illness or act as a disease vector, or just generally annoy people. While there are advantages to using pesticides, there are also disadvantages, such as the possibility of toxicity to people and other living things. Weeds are killed by herbicides, particularly on railroad tracks and paved surfaces. They resemble auxins and the majority of them can be broken down by soil microorganisms. One kind of trinitrotoluene, however, contains the contaminant dioxin, which is very hazardous and may be lethal even at low quantities (2:4 D and 2:4:5 T). The pesticide Paraquat is another (dipyridylium). Although being very poisonous, it quickly breaks down in soil thanks to bacterial activity and does not harm soil fauna. Pests that harm crops are eliminated from fields using insecticides. In the tropics, it is estimated that one third of the total yield is lost during food storage due to pest damage to both standing crops and stored ones. Similar to fungicides, Paris Green and other compounds of arsenic were among the first inorganic insecticides employed in the nineteenth century. From the late eighteenth century, nicotine has also been used[3], [4].

DISCUSSION

Various Soil Pollution Types

Pesticide and fertilizer use causes agricultural soil pollution. Application of fertilizers, herbicides, and insecticides is a common practice in farming to increase crop output. More food is produced, which is a wonderful thing, but can you imagine what will happen to the chemicals that wind up on the crops and soil? Occasionally larger creatures that consume kill insects and tiny animals.

Also damaged are little creatures that are part of food chains. Last but not least, the chemicals could be carried away during rainstorms and eventually wind up in the water table below. Above all of these, the majority of the fertilizers and pesticides applied end up in the subsurface soil, greatly contaminating it. Industrial Effluent and Solid Waste Soil Pollution Waste produced by chemical and nuclear power facilities has to be kept somewhere. Manufacturing companies for pharmaceuticals also generate a lot of solid and liquid waste. While they are often kept in ecologically friendly ways, some do wind up in landfills and other less secure storage locations. They may also manage to get into gutters and leaky pipes. They ultimately contaminate soils and produce crops that are unhealthy for us. Urban activity-related pollution for many things, including life, humans are dependent on trees. Trees remove carbon dioxide, a greenhouse gas, from the atmosphere and provide oxygen, a necessary component of life. In addition to giving us wood, trees are home to many birds, insects, and terrestrial animals. Moreover, trees restore soils and aid in the retention of nutrients that are washed away. Regrettably, we have never replanted the millions of acres of trees that we have felled for building, farming, mining, and lumber[5].

This kind of pollution affects the soil. Treatment Approaches First, phytoremediation In the process of phytoremediation, pollutants in the soil are either stabilized or removed by plants. This process may be mediated by a variety of processes, including phyto-stabilization and phyto-accumulation. In the former, pollutants are immobilized using chemical compounds produced by plants. The latter method stores pollutants, which often comprise metals, in the shoots and leaves of plants. The ability of the plants to absorb significant amounts of lead was a deciding factor in their selection. Several plants such as mustard plants, alpine pennycress, hemp, and pigweed have proved to be effective in rapidly accumulating pollutants at hazardous waste sites. Poplar trees are among the most popular plants used in phytoremediation and need a lot of land surface. Phytoremediation may be used to remove pesticides, explosives, fuels, and volatile or semi-volatile organic chemicals from contaminated sites in addition to metals. This method has been used in locations with soils polluted with lead, uranium, and arsenic over the last 20 years and has grown in popularity. While phytoremediation offers the benefit of allowing environmental issues to be addressed in situ, one significant drawback is that it requires a long-term commitment since the process depends on a plant's capacity to grow and survive in conditions that are not optimal for regular plant development. Wherever that the soil or static water environment has gotten contaminated or is experiencing persistent chronic pollution may benefit from phytoremediation. Restoration of abandoned metalmine workings, reduction of ongoing coal mine discharges, and minimizing the effect of areas where polychlorinated biphenyls have been deposited during manufacturing are examples of successful phytoremediation applications[6].

SVE Efficiency

A variety of parameters that affect the transfer of pollutant mass into the gas phase affect the efficacy of SVE, or the rate and degree of mass removal. The efficiency of SVE depends on the contaminant characteristics (such as Henry's Law constant, boiling point, vapor pressure, and adsorption coefficient), the subsurface temperature, the characteristics of the vadose zone soil (such as soil grain size, moisture content, permeability, and carbon content), the subsurface heterogeneity, and the air flow driving force (applied pressure gradient). Tailing and rebound are problems with SVE efficacy that arise from polluted zones with decreased air flow (i.e., zones with poor permeability or high moisture content) and/or lesser volatility (or higher adsorption). Layering and low permeability zones in the subsurface have been the subject of recent research at U.S. Department of Energy facilities. Enhancements for boosting the efficacy of SVE may include directional drilling, pneumatic and hydraulic fracturing, and thermal augmentation (e.g., hot air or steam injection). Enhancements to directional drilling and fracturing are often used to increase gas flow through the subsurface, particularly in zones with poor permeability. The temperature of the subsurface soil rises due to thermal improvements like hot air or steam injection, which increases the contamination's volatility. Injection of hot, dry air may also help to enhance soil's gas permeability by removing moisture from the soil. Biosparging, C Biosparging is a treatment method that breaks down dangerous soil components using natural microorganisms like yeast or fungus. Unharmed, certain bacteria have been known to consume harmful compounds. These contaminants are then transformed into less hazardous or harmless chemicals, often in the form of water and carbon dioxide. Increased bacterial growth in the soil, which improves living circumstances, promotes this. The microbes become less numerous when the pollutants are controlled since their food supply is eliminated.

Heating with Electric Resistance By passing an electrical current via many electrodes and into the soil, electric resistance heating works. The electrodes are positioned carefully to cover the whole region. The resistance that the electrical current faces as it travels through the subsoil warms the soil. The temperature of the soil steadily increases till the boiling point of the contaminating compounds. After their evaporation, fumes are eliminated using vapor extraction methods. The treatment may start at the soil's surface after the fumes have been eliminated. The advantages of this method include little disturbance and cleaning that usually takes six to ten months. In order to match the total remediation cost with the required cleaning duration, electrode spacing and operation time may be changed. Electrodes placed 15 to 20 feet apart and functioning for typically less than a year could be used in a typical cleanup. The amount of soil or groundwater to be treated, the kind of pollution, and the treatment objectives all have a role in the design and cost of an ERH remediation system. Heated remediations are preferable to most traditional procedures due to the principles that regulate the physical and chemical characteristics of the target components. 5 to 40% of the total cost of cleanup may be attributable to the electrical energy needed to heat the subsurface and volatilize the pollutants. There are various laws that regulate an ERH cleanup[7]–[9].

Thermal Treatment Henry's law determines the ratio of the contaminant in the vapor phase to the contaminant in the liquid phase, and Raoult's law governs the boiling point of mutually soluble co-contaminants. Thermal treatment is an environmentally and financially responsible method of handling non-recyclable and non-reusable trash. Thermal treatment produces thermal and/or electrical energy, lowers pollutant emissions to air and water, and reduces the volume and mass of the waste while rendering the dangerous components inert. In most thermal treatment techniques, contaminants are heated and destroyed via soil. Certain compounds may also be destroyed or evaporated by heat. Pollutants that have evaporated, in contrast to those that are solid, travel more freely. After treatment has started, contaminants are sent into subterranean wells where they are confined before being pumped to the surface. The impurities may then be cleaned using above-ground treatment methods.

Thermal treatment, also known as in situ treatment, often holds soil in place and has been especially effective with non-aqueous phase liquids (NAPLs). Steam injection, hot water injection, radio frequency heating, waste incineration, pyrolysis, and gasification are a few examples of thermal treatment processes. Waste incineration dominates the handling of waste in contemporary Europe. The procedures produce flue gas cleaning additives and residual waste products, which must then be disposed of in a controlled environment, such as a mine or landfill. Ferrous and non-ferrous metals may be recovered and recycled after thermal treatment. Moreover, grate ash or slag may be collected and used in construction. During heat treatment, nutrients and organic materials are lost and cannot be restored[10]–[12].

CONCLUSION

Soil contamination is caused by the presence of humanmade chemicals or other change in the natural soil environment. Several techniques of treating these contaminated soils have developed. In locations with soils polluted with lead, uranium, and arsenic, phytoremediation is an in situ method that employs plants to stabilize or remove soil pollutants. Soil vapour extraction is an in-place procedure that employs a vacuum to release a controlled airflow through the soil. Biosparging is an effective approach that is often more cost-effective than SVE or traditional air sparging. It uses natural microorganisms, such as yeast or fungus, to degrade dangerous soil compounds. The interruption and cleaning associated with electric resistance heating are minimal. Thermal treatment is an on-site method for handling nonrecyclable and nonreusable garbage in a manner that is both inexpensive and environmentally responsible. With this process, the waste's volume and bulk are decreased, and the harmful elements are rendered inert. In order to preserve our ecosystem for future generations, it is imperative that we recognize the significance of soil remediation.

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