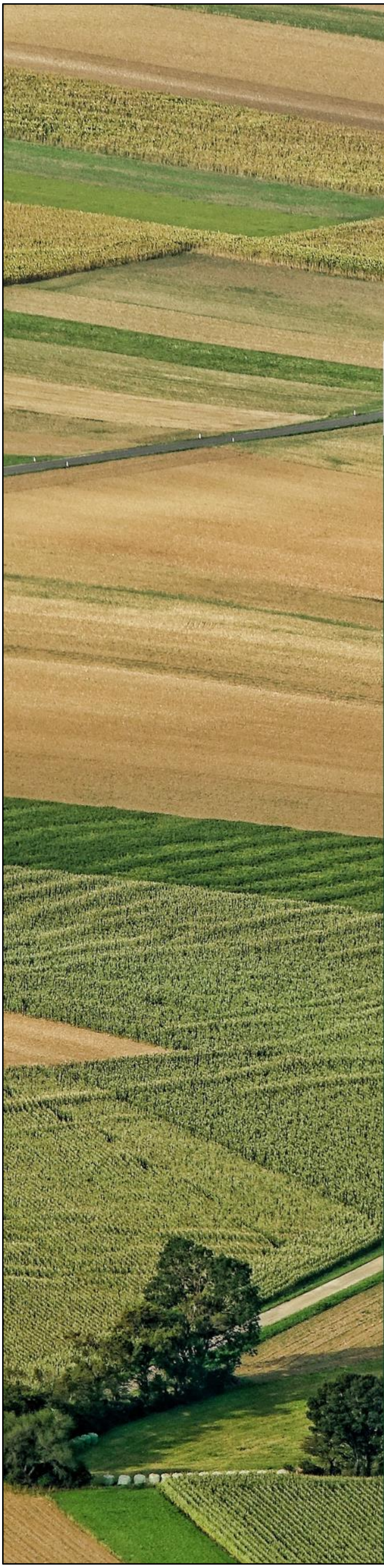

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Emerging Trends in Agriculture and Allied Sciences

Editors:
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PREFACE

Welcome to "Emerging Trends in Agriculture and Allied Sciences". In this book, we embark on a fascinating journey through the dynamic and ever-evolving world of agriculture and its allied disciplines. As the global population continues to rise and environmental challenges become more pressing, the need for innovative and sustainable approaches in agriculture has never been more critical.

This book is a collective effort to shed light on the latest advancements, breakthroughs, and emerging trends in the agricultural sector. We have gathered contributions from experts, researchers, and practitioners who are at the forefront of their respective fields. Their invaluable insights and research findings offer a comprehensive view of the transformative changes taking place in agriculture and its allied sciences.

This book serves as a knowledge reservoir for scholars, students, policymakers, and industry stakeholders, providing valuable insights into the path agriculture is taking and the potential it holds for shaping the future. We hope the diverse perspectives presented here inspire collaboration and drive further research to address the complex issues facing agriculture and its allied sciences.

We extend our heartfelt gratitude to all the authors who have contributed their expertise and passion to make this book a reality. Their dedication and commitment to advancing agricultural knowledge are commendable.

Finally, we would like to express our appreciation to the readers. Your curiosity and enthusiasm for exploring "Emerging Trends in Agriculture and Allied Sciences" are integral to the journey we undertake in these pages.

Let us embark on this enriching expedition together, embracing the transformative power of knowledge to foster a sustainable and prosperous future for agriculture and all its stakeholders.

Editors

CONTENT

ROLE OF CONSERVATION AGRICULTURE FOR SUSTAINING SOIL QUALITY

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Abstract:

India is a country of more than a billion people. Seventy percent or more of India's population lives in rural areas with agriculture as their main occupation. Indian agriculture is characterized by small farms. About 93% of farmers have land of less than 4 hectares with an average farm size of only 1.57 hectares. Only 1.6% of farmers have farm land over 10 ha and use 17.4% of the total farmed land. The inelasticity of the soil factor and the growing population with the threat of environmental degradation are the main concerns of today's series. Therefore, there is a need to develop and improve the concept of conservation agriculture. Conservation agriculture in the Indian context becomes a distinct and integrated body of total agricultural production, due to its feature of allocating inelastic factors of production among competing crop choices. Conservation agriculture plays an important role in maintaining the physical, chemical and biological properties of the soil, thereby ensuring the goal of maintaining soil quality. Conservation agriculture also helps to improve crop production in a sustainable manner and hence there is an intense need for conservation agriculture to not only meet the current and future demand of the ever-growing population but also halt environmental degradation.

Keywords: Population, degradation, soil conservation, sustainable

Introduction:

Global agriculture faces many challenges and adversely affects food and nutrition security. Intensive agriculture and the excessive use of external inputs lead to, among other things, the degradation of soil, water and genetic resources and negatively affect agricultural production. Degradation of natural resources seriously threatens meeting future demand for food, feed, fodder and fiber. Widespread soil erosion, nutrient extraction, water table depletion and biodiversity loss are global issues that threaten food security and the livelihoods of farmers, especially the poor and disadvantaged. Soil degradation due to erosion and compaction processes is the most serious environmental problem caused by conventional agriculture. About 10 million hectares of good quality land for agricultural use are lost annually due to land degradation processes that adversely affect agricultural production and profitability. Degradation of natural resources adversely affects the livelihoods of the poor and traps them in poverty. A study by the Food and Agriculture Organization of the United Nations (FAO) revealed that an estimated 1.5 billion people directly depend on land that is being degraded. Another FAO study suggested that land degradation is getting worse rather than improving, with declining trends detected on about

24 percent of the world's land area. According to this study, the main driver of degradation is poor land management (Paroda, 2009). In addition, a huge amount of soil carbon is lost due to inefficient production methods. Soil carbon is crucial for crop production and is considered black gold. Mechanization has been reported to have resulted in a loss of carbon in the form of carbon dioxide of up to 78 billion metric tons (Lal, 2004). The recent fuel and food crisis has forced the global community to take appropriate measures to substantially increase food production in a sustainable manner to feed a growing population.

In the Indian context, particularly in the western Indo-Gangetic plains, the production system is facing serious challenges from land and water degradation, rising production costs and increasing uncertainty in the form of: (i) loss of soil organic matter and organic carbon; (ii) practicing intensive agriculture by adopting extensive tillage, nutrient imbalances and residue burning to catch up with the next crop; iii) falling groundwater level; (iv) high wages and labor shortages; and (v) rising and uncertain fuel prices. These factors are degrading the quality of natural resources, adversely affecting crop yields and witnessing unprecedented growth in production costs. These are fuelling farmers' unrest and represent key constraints on the supply side of agricultural commodities. It is therefore important to provide solutions to effectively increase agricultural production and prevent the degradation of natural resources, especially land and water.

To conserve soil and water resources and overcome agrarian problems, the role of conservation agriculture is well recognized by most developed countries and many developing countries. Many global treaties have created a concern for the conservation of natural resources to improve the livelihood opportunities and improve the quality of millions of small and marginal farmers living in abject poverty. It is well known that the goals of the Millennium Development Goals can only be achieved through improved technological capabilities, institutional arrangements and appropriate policies in collaboration with all stakeholders. Conservation agriculture has been identified as one of the technological options to meet the global challenges of increasing food production and preserving the environment, thereby improving food and nutrition security and alleviating poverty. A global movement will be necessary to promote conservation agriculture in order to address the complex challenges facing world agriculture today.

Protection of agriculture

The concept of conservation agriculture is relatively new in modern farming practices. It is different from conventional farming. They argue that conventional agriculture encourages extensive tillage and burning of plant residues. Bare ground is also allowed for weeks or months. In general, conventional agriculture is characterized by intensive tillage, straw burning and external inputs. Such practices lead to soil degradation through loss of organic matter, soil erosion and compaction. In Brazil, it was estimated that the harvest of 1 ton of soybeans means the degradation of 10 ha.

Conversely, conservation agriculture is a land management practice that minimizes effects on composition, structure and natural biodiversity and reduces erosion and degradation.

Conservation agriculture practices largely include (i) no-tillage/no-tillage, limited-tillage/minimum-tillage, (ii) surface incorporation of crop residues, and (iii) establishment of cover crops in both annual and perennial crops. These concepts are limited to improving soil health and do not relate to farm income. The Food and Agriculture Organization of the United Nations (FAO) focused this concept on producing resource-efficient agricultural crops to incorporate farm income and soil health through conservation agriculture. According to the FAO definition, conservation agriculture should (i) achieve acceptable profits, (ii) high and sustainable levels of production and (iii) protect the environment (FAO, 2009). They further argue that conservation agriculture is based on enhancing natural biological processes above and below the soil surface. These go beyond zero tillage and provide a range of technologies and management options. Conservation agriculture practices apply to virtually all crops, including cereals, horticulture, and plantation crops. However, these are more popular with corn, soy, rice, and wheat. Conservation agricultural practices hold enormous potential for diverse soils and agroecological systems. These are neutral to the size of enterprises, but their adoption is urgently required by small farmers to reduce their production costs, increase profit and conserve resources (Derpsch, 2008).

Conservation agriculture is often considered organic farming. There is little difference between the two terms. Although both are based on natural processes to improve soil health, organic farming prohibits the use of chemical inputs, while conservation agriculture does not. For example, herbicides are an important component in conservation agriculture, especially in the transition phase until a new equilibrium is reached in the weed population. Given the importance of soil life in the system, agricultural chemicals, including fertilizers, are also applied very carefully. Despite these facts, global experience shows that conservation agriculture farmers use fewer chemical inputs than comparable conventional farmers, and the amount of chemical inputs tends to decrease over the years.

History and adoption of conservation agriculture

Some say it started with the Mayans, who used a stick to plant corn in unprepared soil. Others trace its principles back to the Egyptians. But conservation agriculture (CA) in the modern sense began in the mid-20th century with the introduction of effective herbicides. No-till direct seeding of crops was first successfully demonstrated in the USA in the 1950s. At first, adoption was slow, but began to accelerate as experience was gathered and better planters and herbicides were developed.

But "conservation agriculture" is more than no-till no-till seeding. It came to mean agriculture characterized by: little or no soil disturbance; no burning; direct sowing into previously cultivated soil; crop rotation; and permanent soil cover, especially by retaining plant residues. In recent decades, CA, or elements thereof, have made progress in the US, the Southern Cone of Latin America, Australia, China, and South and Central Asia. It has made less progress in other parts of the world, especially sub-Saharan Africa. This brief history focuses on the experience of CAs in Latin America and South Asia and the challenges of obtaining CAs for work in sub-Saharan Africa.

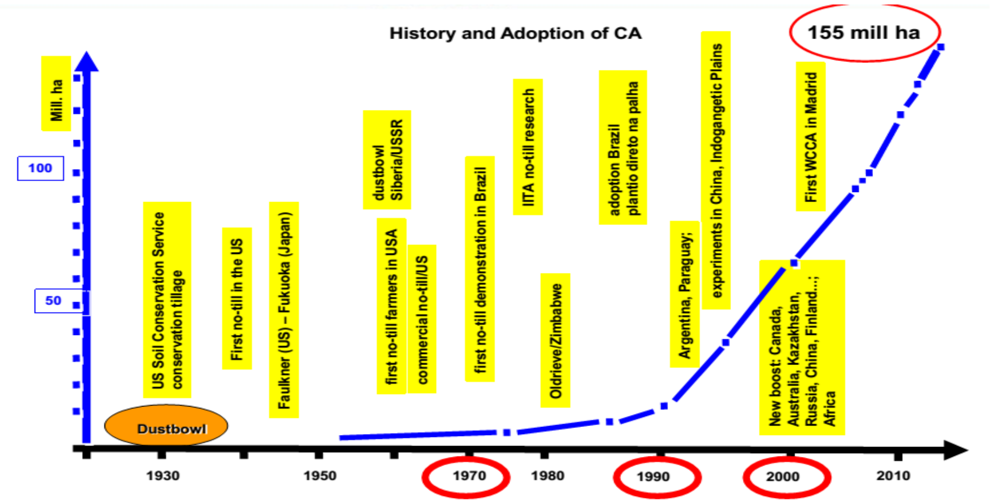
CA emerged from events that occurred in Brazil in the 1970s and 1980s. The story begins with government policy, the response of farmers and the subsequent crisis. Government policy was the decision in the 1960s to promote the transition from livestock to crop-based systems in southern Brazil's sloping, high-rainfall areas. Farmers' response was to plow pastures and plant soybeans. By the end of the 1970s, an effective no-till/CA package was developed, which began to be adopted by larger farmers and later, in the 1990s, by a large number of smaller farmers.

In the second half of 1988, CIMMYT delivered four more Aitcheson drills from New Zealand to India. One of them was sent to the Department of Agricultural Machinery and Power Engineering at Pantnagar University. In the 1990-91 season, zero tillage testing using the Aitcheson seed drill began on the farm under the direction of two university scientists. Zero till wheat performed well, with good crop establishment, higher yields and lower costs compared to conventional crops. Despite this promising start, progress in promoting farm testing was slow: Only one seeding machine was available for testing, and even that was not well adapted to sowing wheat into standing rice stubble.

In the following season, one of the scientists took a simple but significant step. He took the "inverted t" openers for seed placement from an Aitcheson seed drill and attached them to a drill frame of his own design. This was the original Pantnagar drill. The Ludhiana-based company has a sales office near Pantnagar. A salesman learned about the Pantnagar drill and in 1992 introduced the scientist to one of the company's owners. The company soon learned to make its own inverted t openers and install them on the frame of a conventional drill. In 1994, after a series of improvements, the customized tool was ready for large-scale production. Adoption of this tool was precipitated by the herbicide-tolerant Phalaris minor problem that emerged in 1994-96.

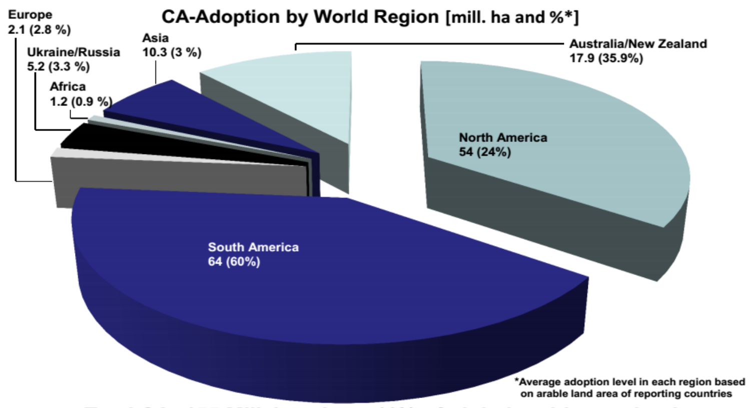
In the 1995-96 wheat season, it turned into a crisis. Scientists began to feel that "desperate times call for desperate measures", one of the "desperate measures" being zero tillage. It was originally thought that zero tillage could reduce production costs and free up cash to buy herbicide. It was later found that fewer weeds sprouted in the no-till areas. Farm testing of zero tillage for weed control was organized by Haryana Agricultural University. However, this required practice. Fortunately, the Pantnagar coreless drill, as perfected by private companies, was just now available. The combination of new herbicides and zero tillage worked well. Crop emergence was good, Phalaris populations declined dramatically and yields were excellent. Participatory methods were used in early no-till farming experiments. The researchers left the exercise with the farming communities throughout the harvest season. This allowed many farmers to get to know the performance of the seed drills so that they could decide whether to buy the implement or not. The greatest interest for farmers was a significant reduction in production costs without penalizing yield. In 2006-07, the area under zero-tillage wheat was estimated at approximately three million hectares, and several dozen companies were busy producing no-till seeders. Such widespread adoption can be traced to high short-term farm profitability; quick availability of high-quality tools at a reasonable price; substantial technical support from branch staff (especially in India); a favorable policy environment, including some subsidies for the purchase of seed, a good understanding from research of how to make zero tillage work; and traveling seminars where stakeholders from different states and countries shared their experiences. For many years, much of this research and these traveling seminars have been coordinated or otherwise supported by the Rice Wheat Consortium for Indo-Gangetic Plains.

Indian farmers adopted no-tillage in rice-wheat dual production system and it was mainly adopted for the wheat crop (Derpsch R. *et al.*, 2010) because due to the time required for tillage, sowing was delayed and thus yields were reduced. Official data provided by FAO (2014) shows that last year India had 1.5 million ha under this scheme.

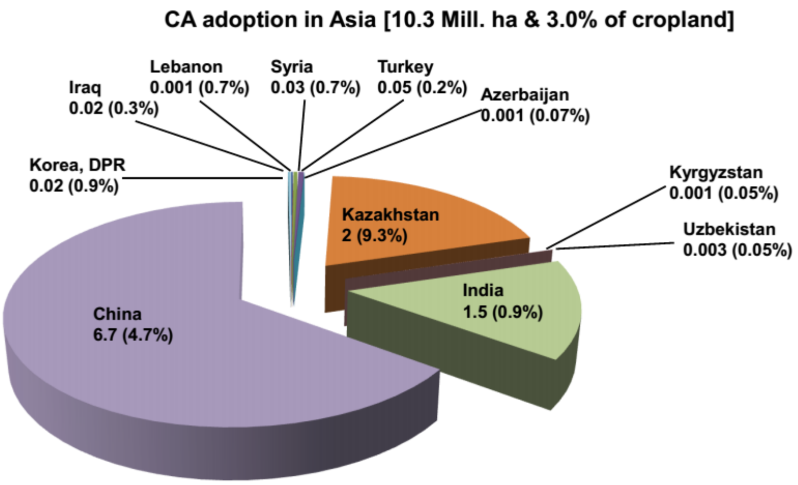


Area of arable cropland under CA by continent
(source: Kassam et al., 2014; FAO AquaStat: www.fao/ag/ca/6c.html)

Continent	Area (Mill. ha)	Per cent of global total	Per cent of arable land of reporting countries
South America	64.0 (55.5)	41.3	60.0
North America	54.0 (40.0)	34.8	24.0
Australia & NZ	17.9 (17.2)	11.5	35.9*
Asia	10.3 (4.7)	6.6	3.0
Russia & Ukraine	5.2 (5.1)	3.4	3.3
Europe	2.1 (1.4)	1.4	2.8
Africa	1.2 (1.0)	0.8	0.9
Global total	155 (125)	100	10.9 (8.8) % global arable



Total CA: 155 Mill. ha, about 11% of global arable cropland



Difference in traditional and conservation agriculture

Issues	Traditional Agriculture	Conservation agriculture
Practice	Disturbs the soil and leaves a bare surface	Minimum soil disturbance and soil surface permanently covered
Erosion	Wind and water soil erosion maximum	Minimum
Soil physical health	Poor	Good
Compaction	Reduces compaction by tillage operation	Compaction can be a problem but use of mulch and promotion of biological tillage helps to reduce this problem
Soil biological health	Poor due to frequent disturbance	More diverse and healthy biological properties and populations
Water infiltration	Lowest after soil pores clogged	Best water infiltration
Soil organic matter	Oxidizes soil organic matter and causes its loss	Soil organic build-up in the surface layers even better than TA (Traditional Agriculture)
Soil temperature	Surface soil temperature more variable	Moderated variable
Fuel use and cost	High	Low
Production costs	High	Low
Yield	Can be lower where planting delayed	Yields same as TA but can be highest if planting is done more timely

Principles of conservation agriculture

Conservation agricultural practices used in many parts of the world are built on ecological principles that make land use more sustainable (Wassmann, 2009; Behera *et al*. 2010;

Lal, 2013). Adoption of CA to increase resource use efficiency (RUE) and crop productivity is a must as a powerful tool for managing natural resources and achieving sustainability in agriculture. Conservation agriculture is fundamentally based on 3 principles that are interconnected and must be considered together for appropriate design, planning and implementation processes. These are:

1. Minimal mechanical soil disturbance

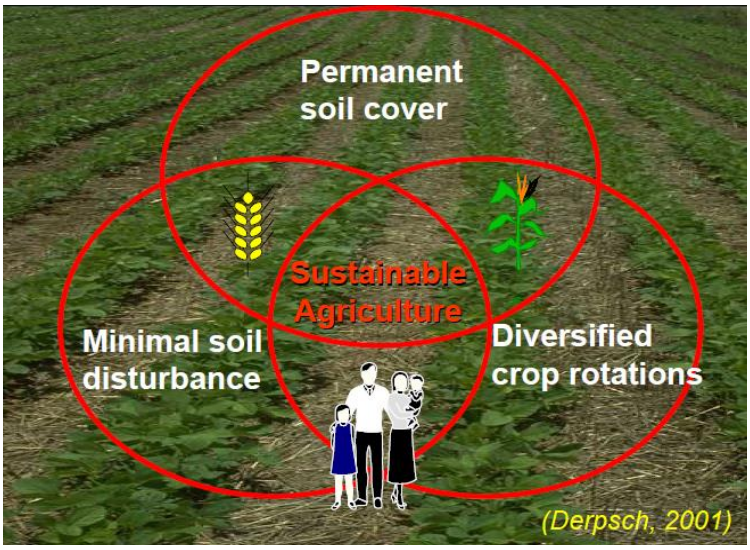
Soil biological activity creates very stable soil aggregates as well as different pore sizes that allow air and water infiltration. This process can be called "biological tillage" and is not compatible with mechanical tillage. When the soil is disturbed mechanically, the biological processes of soil structuring disappear. Minimal soil disturbance ensures/maintains optimal root zone respiratory gas ratios, moderate oxidation of organic matter, porosity for water movement, retention and release, and limits weed seed re-exposure and germination (Kassam and Friedrich, 2009).

2. Permanent organic soil cover

A permanent ground cover is important to protect the soil from the harmful effects of exposure to rain and sun; provide a constant supply of "food" to microorganisms and macro-organisms in the soil; and change the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. On the other hand, it improves soil aggregation, soil biological activity and soil biodiversity and carbon sequestration (Ghosh *et al.*, 2010).

3. Diversified crop rotation

Crop rotation is not only necessary to offer a diverse "diet" to soil microorganisms, but also to explore different soil layers for nutrients that have been leached into deeper layers that can be "recycled" by the crops in the rotation. In addition, the variety of crop rotations leads to diverse soil flora and fauna. A cropping and rotation sequence involving legumes helps to minimize the population build-up of pest species through life cycle disruption, biological nitrogen fixation, off-site pollution control and increased biodiversity (Kassam and Friedrich, 2009; Dumanski *et al.*, 2006).



Effect of tillage treatment on soil properties

Ismail *et al.*, (1994) and Rahman *et al.*, (2008) reported that exchangeable Ca, Mg and K were significantly higher in surface soil under NT compared to plowed soil. According to Ali, Ayub and Ojeniyi (2006), the lowest values of soil OM, N, P, K, Ca and Mg were recorded in conventional plowed plots and this could be due to the inversion of the topsoil during plowing which moves less. fertile subsoil to the surface in addition to possible leaching. In southwestern Nigeria, Busari and Salako (2013) observed that ZT soil had significantly higher pH at the end of the first year after treatment, but the pH decreased significantly compared to CT soil at the end of the second year after treatment. However, soil organic C (SOC) and effective cation exchange capacity (ECEC) were significantly higher under ZT than under CT at the end of the two-year study (Table 1).

Table 1: Effect of tillage on soil chemical properties after maize harvest (Source: Busari and Salako, 2013)

Year	2008					2009				
Tillage	pH (H_2O)	OC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	ECEC (cmol kg^{-1})	pH (H_2O)	OC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	ECEC (cmol kg^{-1})
CT	6.0	16.50	1.38	26.64	6.31	6.69	2.79	0.32	65.59	8.05
MT	6.2	19.80	1.52	24.33	6.24	6.79	4.59	0.55	40.47	8.51
ZT	6.1	21.20	1.58	33.28	7.36	6.64	5.00	0.53	61.13	9.39
LSD ($P \leq 0.05$)	0.05	2.20	ns	7.13	0.49	0.04	0.44	0.08	13.25	0.79

OC = organic carbon; TN = total nitrogen; Avail. *P* = available phosphorus, ECEC = effective cation exchange capacity; ZT = zero tillage; MT = minimum tillage; CT = conventional tillage; LSD = least significant difference; ns = not significant.

Crop residues play an important role in improving soil physical properties, but the degree of improvement depends on the particle size distribution. The addition of crop residues or manure will increase microbial activity, which in some studies has led to SOM accumulation and the formation of macro- and microaggregates (Sparling *et al.*, 1992; Angers *et al.*, 1993). formation and stability of aggregates through the growth of microbial cells and excludes microbial and breakdown products released during the death of microorganisms (Lynch and Elliott, 1983). Chaudhary and Ghildhyal (1969) obtained a close relationship (r ¼ 0.76) between organic C increased by the addition of organic materials and soil aggregate stability under wetland rice.

The bulk density in the top layer of no-till soils was increased, leading to a decrease in gross pore volume and a decrease in saturated hydraulic conductivity compared to conventional and reduced tillage soils (Tebrugge and Rasmussen, 1999). Similarly, Srivastava *et al.*, (2000) also found significantly lower hydraulic conductivity in no-tillage plots compared to mowing and rotary tillage, which may be due to more favorable physical conditions created by mowing and rotary tillage.

Table 2: Effect of rice straw application on soil physical properties in rice–rice cropping system over a 10-year period on a clayey soil

Treatment to Summer Rice	Bulk Density ($Mg\ m^{-3}$)	HC ($cm\ h^{-1}$)[a]	Water Stable Aggregates (%)	Porosity (%)	Water retention ($kg\ kg^{-1}$)		Maximum Water Retention capacity ($kg\ kg^{-1}$)
					33 K Pa	1.5 M Pa	
Inorganic fertilizers	1.43	1.18	37.6	46	0.35	0.21	0.49
Rice straw to meet 50 % N	1.26	1.93	51.3	52	0.43	0.28	0.58
Rice straw to meet 25 % N	1.27	1.78	49.6	52	0.41	0.26	0.56
Green leaf manure to meet 50 % N	1.29	1.80	50.1	50	0.42	0.26	0.50

Note: [a]HC, Hydraulic conductivity, From Bellakki *et al.* (1998).

Table 3: Effect of methods of planting and levels of nitrogen on bulk density of wheat

Planting Method	Bulk Density ($g\ cm^{-3}$)		
	0-15 cm	15-30 cm	30-45 cm
Happy seeder	1.40	1.45	1.52
Zero tillage	1.44	1.44	1.55
Rotavator	1.53	1.59	1.56
Conventional tillage	1.46	1.62	1.49
Initial bulk density	1.47	1.46	1.44

Crop residue management effects on nutrient availability in soils

Table 4: Effects of residue removal for 13 consecutive years on soil properties and corn grain and stover on yields on an alfisol in Western Nigeria

Soil Properties	With Residue Mulch	Residue Removal	LSD (.05)
Soil organic carbon	14.5	12.5	4.0
Soil pH	5.1	4.6	0.30
Exchangeable Ca^{+2} (cmolc/kg)	3.6	1.2	1.4
Exchangeable Mg^{+2} (cmolc/kg)	0.4	0.25	0.35
CEC (cmolc/kg)	4.5	2.9	1.7
Grain yield (Mg/ha)	2.7	1.5	0.4
Stover yield (Mg/ha)	2.6 1	1.3	0.8

Rice straw is characterized by a high C: N ratio and abundant K, Si, and C (Ponnamperuma, 1984). Wheat straw has comparable properties except for low Si and low K concentration. The successful utilization of crop residues as a nutrient source relies on manipulating the biological processes in the soil to optimize nutrient availability with respect to plant demand. This conceptual model depicts the flow of carbon and nutrients among organic residues, organic and inorganic pools in soil, and the plant.

Table 5: Effect of straw management on the nutrient status of mahaas clay and grain yield averaged for five cultivars after the 16th crop

Straw Treatment	Organic C (%)	Total N (%)	Olsen P (mg kg^{-1})	Exchangable K (mg kg^{-1})	Grain yield (t ha^{-1})
Removed	1.81^{b}	0.167^{b}	9^{a}	10.5^{b}	3.2^{b}
Burned	1.94^{b}	0.173^{ab}	11^{a}	12.5^{a}	3.4^{b}
Incorporated	2.17^{a}	0.182^{a}	12^{a}	11.6^{ab}	4.1^{a}

Irrigation did not significantly affect soil bulk density and organic carbon content (data not shown). Straw mulch significantly reduced bulk density (from 1.47 g cm $^{-3}$ in treatment M0 to 1.37 g cm $^{-3}$ in treatment M6) in the surface 0–15 cm soil layer and increased soil organic carbon content (Fig. 4a and b). Gła and Kulig (2008) reported that bulk density in the topsoil (0–10 cm) decreased with mulch residues and reached a value similar to conventional tillage (1.25 g cm $^{-3}$). Soil organic carbon increased from 0.148% without mulch to 0.189% with M6 treatment continuously over three years. Straw mulch is an excellent source of carbon, which becomes part of soil organic matter through decomposition. Several reports in the literature (Jiafu, 1996; Singh *et al.,* 2007; Yadvinder-Singh *et al.,* 2009) show a significant increase in soil organic matter and a decrease in bulk density in the topsoil. Soil Carbon is considered the "blind gold", an optimal level of SOC is needed to conserve soil, water and nutrients and to support biological activity and high productivity in any system. Resource conservation practices such as zero tillage allow farmers to plant crops soon after rice harvest so that the grain matures before the onset of pre-monsoon rains, in addition to conserving soil moisture, nutrients and SOC.

Table 6: Organic carbon and biological activity under different tillage practices (at the end of four cropping cycles)

Treatment	OC (%)	SMBC (µg/g soil)	Earthworm population	Dehydrogenase activity (µg TPF/g/24 h)
Conventional tillage	1.47	91.3	60,000	29.5
Zero tillage	2.23	128.5	160,000	131.5
Double no-till	2.51	134.1	380,000	166.6
Minimum tillage	2.17	121.3	100,000	127.5
CD (P = 0.05)	0.78	12.1	–	27.5

OC, organic carbon; SMBC, Soil microbial biomass carbon.

Benefits of conservation agriculture

The benefits of conservation agriculture can be seen at the agricultural, regional and national levels. The benefits can be divided into three broad categories: (i) agronomic benefits that improve soil productivity; (ii) economic benefits that improve production efficiency and profitability; and (iii) environmental and social benefits that protect land and make agriculture more sustainable. Some of the benefits of conservation agriculture are listed below:

1. Improve the sustainability of various production systems.
2. It provides the soil as a sink for carbon dioxide, thereby improving the organic carbon content of the soil and contributing to the reduction of global warming. Conservation agriculture is now globally focused on its carbon sequestration potential. It is estimated that the total potential of soil carbon sequestration by agriculture could reduce approximately 40 percent of the estimated annual increase in CO2 emissions (FAO, 2009). The introduction of carbon credit payments to farmers practicing conservation agriculture is now being seriously considered and is expected to further increase the income of those farmers who implement them.
3. Improves water infiltration and thereby reduces surface and groundwater runoff and increases groundwater recharge.
4. Improves the settlement of organisms, from larger insects to soil fungi and bacteria, which improve the biological, physical and chemical properties of the soil, thereby contributing to increased crop productivity.
5. Reduce production costs (15-16 percent) by saving energy, labor and water, thereby increasing farm income.
6. Increase biodiversity and improve the value of environmental services.
7. Reducing poverty and enhancing food and nutrition security through higher, more stable yields and lower food prices.
8. Higher rural incomes leading to control of rural-urban migration.

In the changing context of climate change, conservation agriculture is now a global focus for its carbon sequestration potential. Available studies have shown that conservation agriculture provides soil as a sink for carbon dioxide; improves the organic carbon content of the soil and contributes to the reduction of global warming. It is estimated that the total potential of soil carbon sequestration by agriculture could reduce approximately 40 percent of the estimated annual increase in CO_2 emissions (FAO, 2009). The introduction of carbon credit payments to farmers practicing conservation agriculture is now being seriously considered and is expected to further increase the income of those farmers who implement them. Early experiments in Brazil revealed that the best no-tillage systems contribute to carbon sequestration of more than 1 tonne per ha per year. Now more than 105 million ha of area in conservation agriculture, showing the great potential of this practice to remove atmospheric carbon dioxide. In India, Erenstein and Pandey (2006) conducted several systematic studies to quantify the benefits of conservation agriculture in the Indo-Gangetic plain. Some of the measured benefits are listed below:

- Zero tillage yield in rice and wheat by 10-17 percent over conventional tillage.

- Cost reduction of around Rs. 5,760 per hectare (roughly 5 to 10 percent); ranging from Rs. 3055 to Rs. 8500 per hectare in different soils and ecoregions.
- Water savings of 20-35 percent and energy savings, especially tractor time, saved by 60-90 percent.
- Estimated saving of 1 million barrels of oil if zero tillage practice is implemented on approximately 3.5 million hectares of Indo-Gangetic plain. High internal rate of return (57 percent) assuming 33 percent adoption of conservation agriculture in India's Indo-Gangetic Plain.

Challenges in conservation agriculture

Conservation agriculture as an upcoming paradigm for raising crops will require an innovative system perspective to deal with diverse, flexible and context specific needs of technologies and their management. Conservation agriculture R&D (Research and Development), thus will call for several innovative features to address the challenge. Some of these are:

(A) Understanding the system – Conservation agriculture systems are much more complex than conventional systems. Site specific knowledge has been the main limitation to the spread of CA system (Derpsch, 2001). Managing these systems efficiently will be highly demanding in terms of understanding of basic processes and component interactions, which determine the whole system performance. For example, surface maintained crop residues act as mulch and therefore reduce soil water losses through evaporation and maintain a moderate soil temperature regime (Gupta and Jat, 2010). However, at the same time crop residues offer an easily decomposable source of organic matter and could harbour undesirable pest populations or alter the system ecology in some other way. No-tillage systems will influence depth of penetration and distribution of the root system which, in turn, will influence water and nutrient uptake and mineral cycling. Thus the need is to recognize conservation agriculture as a system and develop management strategies.

(B) Building a system and farming system perspective – A system perspective is built working in partnership with farmers. A core group of scientists, farmers, extension workers and other stakeholders working in partnership mode will therefore be critical in developing and promoting new technologies. This is somewhat different than in conventional agricultural R&D, the system is to set research priorities and allocate resources within a framework, and little attention is given to build relationships and seek linkages with partners working in complementary fields.

(C) Technological challenges – While the basic principles which form the foundation of conservation agriculture practices, that is, no tillage and surface managed crop residues are well understood, adoption of these practices under varying farming situations is the key challenge. These challenges relate to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance, developing crop harvesting and management systems.

(D) Site specificity – Adapting strategies for conservation agriculture systems will be highly site specific, yet learning across the sites will be a powerful way in understanding why certain technologies or practices are effective in a set of situations and not effective in another set. This learning process will accelerate building a knowledge base for sustainable resource management.

(E) Long-term research perspective – Conservation agriculture practices, e.g. no-tillage and surface maintained crop residues result in resource improvement only gradually, and benefits come about only with time. Indeed in many situations, benefits in terms of yield increase may not come in the early years of evaluating the impact of conservation agriculture practices. Understanding the dynamics of changes and interactions among physical, chemical and biological processes is basic to developing improved soil-water and nutrient management Strategies (Abrol and Sangar, 2006). Therefore, research in conservation agriculture must have longer term perspectives.

Constraints in adoption

Several problems are encountered in adopting conservation agriculture. Most important is the mindset of the farming community, which has been extensively educated and convinced of intensive agriculture and the use of external inputs. In the past, farmers realized enormous economic benefits from intensive farming practices. A complete transition from intensive tillage to zero or minimal tillage requires an extensive educational program demonstrating the benefits of conservation agriculture.

The second problem is related to the high price of machines and tools. Farmers in the Indo-Gangetic Plain are small and poor and therefore may not immediately switch from existing or available machinery to conservation farming machinery.

The third problem is related to access to information about conservation agriculture. Farmers need complete information regarding tillage practices, cultivation methods and improved varieties.

The fourth issue is related to skill development. New machines (zerotill machine) and cultivation methods require the development of farmers' skills. There are agro-ecological technologies of conservation agriculture that require the capacity of farmers to adopt and implement them in their production environment. Most farmers lack the skills to use zero-tillage machinery and cultivation practices, which hinders the adoption of conservation agriculture practices.

Conservation agricultural technologies are the future of sustainable agriculture. There are potential benefits of conservation agriculture across different agro-ecoregions and farmer groups. The benefits range from the nano-level (improvement of soil properties) to the micro-level (saving inputs, reducing production costs, increasing farm income) and the macro-level by reducing poverty, improving food security and mitigating global warming. Considering the huge expected benefits as witnessed during the green

a period of revolution can be aggressively promoted conservation agriculture. The advantage of this technology is its easy adaptability in a heterogeneous agro-ecological and socio-economic environment. Aggressive demonstration and information dissemination programs are needed and well complemented by skill development of farmers. There is a need for a global movement to promote conservation agriculture. Institutions such as the World Bank, the Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development, the Asian Development Bank and the African Development Bank, in cooperation with various networks, are launching aggressive programs in poor countries. In India, NABARD (National Bank for Agriculture and Rural Development) can take the lead in making conservation agriculture a national movement in a consortium mode by involving government agencies, research institutes, financial and insurance institutions, NGOs and the private sector (producers and agricultural enterprises). business).

Appropriate institutional arrangements need to be developed to develop small and marginal farmers who cannot afford to maintain machinery and other equipment to practice conservation agriculture. In addition, a large-scale training program needs to be developed to develop the capacity of farmers. Krishi Vigyan Kendras (KVKs) in collaboration with research institutions engaged in agricultural conservation research and development can take the lead in this effort.

Given the urgency and complexity of the challenges in agriculture, a mission program to support agricultural conservation is needed to increase and sustain agricultural production and increase the incomes of farmers in developing countries and to make them more competitive as global markets rapidly integrate. In India, the concept of conservation agriculture can be integrated with various government programs by making policy advisors, experts and financial institutions aware. The benefits of conservation agriculture must be effectively communicated to all stakeholders in order for them to be widely adopted by the farming community. Otherwise, the sustainability of agriculture would be threatened and natural resources and agricultural production would be adversely affected. Disadvantaged and poor farmers in disadvantaged and marginal areas would be most affected.

References:

Bhanl, S. and. Behera, U. K (2014). Conservation agriculture in India – Problems, Prospects and policy issues, *International Soil and Water Conservation Research*, Vol. 2, No. 4, pp. 1-12

Busaria, M. A., Kukal, S. S., Kaur, A., Bhatt, R. And Dulazi, A. A. (2015). Conservation tillage impacts on soil, crop and the environment, *International Soil and Water Conservation Research* 3, 119–129.

Derpsch, R., Friedrich, T., Kassam, A. & Li, H.W. (2010). Current status of adoption of notill farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering*, 3, 1-25.

Derpsch, Rolf (2008), "No-Tillage and Conservation Agriculture: A Progress Report" in eds by Zoebisch, M.A., Y.T. Gan, W. Ellis, A. Watson and Sombatpanit, No-till Farming Systems S. Special Publication No 3, *World Association of Soil and Water Conservation*, Bangkok.

Food and Agriculture Organization of the United Nations (FAO) (2009), Conservation Agriculture. http://www.fao.org/ag/ca Rome, Italy.

Ghosh P. K., Das, A., Sah, R., Kharkrang, E., Tripathi, A. K., Munda, G. C. and Ngachan S. V. (2010). Conservation agriculture towards achieving food security in North East India, *Current science*, VOL. 99, NO. 7.

Jat M. L., Singh, R.G., Saharawat, Y.S., Gathala, M. K., Kumar, V., Sidhu, H.S., & Gupta, R. (2009b). Innovations through conservation agriculture: progress and prospects of participatory approach in the Indo-Gangetic plains. In Pub Lead Papers, 4^{th} *World Congress on Conservation Agriculture* (pp. 60-64). 4-7 February, 2009, New Delhi India.

Joshi, P. K. (2011). Conservation Agriculture: An Overview, *Ind. Jn. of Agri. Econ*. Vol.66, No.1.

Kumar, V., Kumar, M., Singh, S. K. and Chandra, S. K. (2015). Impact of conservation agriculture on yield, nutrient uptake and quality of wheat crop in calciorthen, *Plant Archives* Vol. 15 No. 1, pp. 371-376.

Lal, R. (2004), Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science*, Vol.34, pp. 1623-1627.

Mandal, K. G., Misra, A. K., Hati, K. M., Bandyopadhyay, K. K., Ghosh, P. K. and Mohanty, M.(2004). Rice residue- management options and effects on soil properties and crop productivity, *Food, Agriculture & Environment* Vol.2 (1): 224-231.

Ram, H., Dadhwal, V., Vashist, K. K. and Kaur, H. (2013). *Agricultural Water Management*, 128 92– 101.

Sidhu, H.S., Singh, M., Humphreys, E., Singh, Y., Singh, B., Dhillon, S. S., Blackwell, J., Bector, V. M., & Singh, S. (2007). The happy seeder enables direct drilling of wheat into rice straw. *Australian Journal of Experimental Agriculture*, 47, 844-854.

Yadvinder-Singh, Bijay-Singh, & Timsina, J. (2005). Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. *Advances in Agronomy*, 85, 269-407.

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RECENT TRENDS IN VEGETABLE PRODUCTION

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Abstract:

Food consumption rises along with population growth everywhere in the world. Humans require access to water, food, and a place to live. The current agriculture system is struggling with various issues, therefore there is concern that it won't be able to supply the demand for food in the near future. This chapter's goal is to examine organic farming, vegetable grafting, tissue culture, drip irrigation, methods for soilless culture, the development of vegetable crops, and the benefits and drawbacks of a hydroponic greenhouse system. In terms of input utilization and increased crop production, soilless agriculture is a preferable alternative. Instead of using soil for crop development, soilless culture systems are contemporary agricultural practices that utilize substrate Medias with the nutrient solution or the nutrient solution alone.

Keywords: vegetable crops, organic farming, tissue culture, hydroponics, drip irrigation.

Introduction:

In order to solve the problems with agriculture, modern farming methods are being adopted everywhere. In Pakistan, vegetable farming has a lot of promise, but traditional methods result in low yields. The newest trends can guarantee environmental and food safety. While underdeveloped nations still lack several innovative ideas, they are being adopted in rich nations. To enhance vegetable output, international organizations are working hard to introduce these technologies in developing nations.

Necessity of new methods:

Heavy losses of vegetable production in field and of field due to disasters and poor handling.

- Chemicals threatening the ecology
- Over-come food security threats
- Sustainability
- High quality
- Economical benefits

New trends:

1. Organic farming
2. Tissue culture
3. Hydroponics

4. Drip irrigation
5. Aeroponics
6. Off-season farming
7. Vegetable grafting

1. **Organic farming:**

It is a method of integrated production management that promotes the health and productivity of autonomous communities of life, including plants, animals, and people, while avoiding the use of synthetic fertilisers and pesticides and reducing pollution of the air, soil, and water. With a focus on crop rotation, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, ground mineral bearing rocks to maintain soil productivity, and bio-pesticides for the control of weeds, pests, and diseases, organic farming can be defined as "a production system, which avoids or largely excludes the use of synthetically produced inputs like fertilisers, pesticides, growth regulators, etc." In several nations of northern Europe, this method is sometimes referred to as "ecological farming." In order to practise organic farming, the surface and subsurface must accumulate a suitable level of P (from rock phosphates) and have an ideal level of organic carbon. In order to sustain soil health and to restore what has been taken from nature, the ultimate goal is to feed the soil rather than the crops. In actuality, an organic farming production system attempts to support and improve the health of the soil, biodiversity, and biological processes. Soil organic matter management is essential for preserving an organic system that is both productive and of high quality. The soil receives organic matter from a variety of organic sources.

Objectives of organic farming

- ✓ To keep the industrial system's genetic variety.
- ✓ To keep and improve the soil's long-term fertility.
- ✓ To promote and improve the farming system's biological system, which includes microorganisms, the flora and fauna of the soil, plants, and animals.
- ✓ To engage with natural cycles and processes in a positive and life-improving manner.
- ✓ To employ sustainable resources in regionally focused production systems.
- ✓ To achieve a healthy balance between crop production and livestock management.
- ✓ To reduce pollution in all its forms.

Benefit of organic farming

1. Make various production techniques more sustainable.
2. Allows soil to act as a carbon dioxide sink, increasing soil organic carbon content and helping to slow global warming. Due to its ability to store carbon, organic farming is currently gaining attention on a global scale. The entire potential for soil carbon sequestration by agriculture has been calculated to be enough to offset around 40% of the predicted annual increase in CO_2 emissions.

3. Increase agricultural revenue by lowering production costs (15–16%) by conserving energy, labour, and water.
4. Enhances ground water recharge by increasing water infiltration, which lowers surface and groundwater discharge.
5. Provide all the nutrients that plants need.
6. Increase plant physiological processes and growth.
7. Improve the value of experimental services while increasing biodiversity.
8. Promotes the presence of beneficial organisms that enhance the biological, physical, and chemical characteristics of the soil and help to increase crop productivity.
9. Fruits grown organically are said to be healthier and more nutrient-dense.
10. Fruits cultivated organically have higher disease and pest resistance.

Use of organic manures in vegetable crops has revealed that these crops have responded well to these fertilisers, as evidenced by an increase in yield and produce quality.

The beneficial effects of organic manures on vegetable crops are enumerated below.

1. Plant nutrients from both organic and inorganic sources improved the fruit quality of okra.
2. The dry matter content and nutrient uptake of brinjal were improved by the application of poultry manure.
3. Cabbage quality from organic sources showed sustainability.
4. Vegetables grown with organic manures showed improved protein and vitamin C content, lower nitrate levels, and longer shelf lives.
5. The P and Ca content of tomato plants was increased by organic manures.
6. Tomatoes produced organically include less dietary fibre, more sugar, and more malic acid.
7. The development of nematodes in okra was greatly reduced by the application of FYM, poultry manure, sheep dung, and cakes.
8. The lowest tomato galls per plant were seen after the application of linseed cake fertiliser.

2. Tissue culture

Tissue culture is a technique for transferring plant tissue fragments to an artificial environment where they can continue to function and thrive. One cell, a group of cells, an entire organ, or a portion of an organ may make up the cultured tissue. Cells in culture have the capacity to divide, alter shape, size, or function, display specialised activity, and collaborate with other cells. Plant tissue culture, an emerging technique, has a significant impact on agriculture by supplying the necessary plants to meet the growing global demand. In the area of vegetable crops, substantial advancements have been accomplished. The most potential areas of application at the moment and looking ahead are those involving plant tissue culture. An effective in-vitro plant regeneration system is essential for all biotechnology methods used to improve characteristics in vegetable crops, such as genetic Meristem culture, haploid induction, and somatic hybridization. Potato viruses are one of the main reasons for crop loss and a decline in seed tuber quality. PVX, PVS, and PLRV were all three viruses removed by meristem culture and thermotherapy with success rates of 86%, 100%, and 83%, respectively (Biniam and Tadesse, 2007). Due to sexual incompatibility, many sources of beneficial genes cannot be used to improve crops, however somatic hybridization in potatoes can easily do this (Tiwari *et al.*, 2011). The tomato is extremely vulnerable to biotic stress, particularly from diseases, insects, and nematodes. Through somatic hybridization, key features from wild species can be transferred to already cultivated and well-liked species using tissue culture techniques (Kharkongar *et al.*, 2013). Important planting material is cryopreserved for long-term preservation to cut down on time and labour costs as well as chemical costs. Different crops have been cryopreserved, such as the melon shoot primaeval, by gradual freezing (Ishikawa *et al.,* 1996). Garlic's apical meristem was vitrified (Niwata *et al.,* 1995). By using protoplast fusion, anther culture, and microspore culture instead of traditional breeding, tissue culture techniques allow for the production of homozygous plants in a very short amount of time (Hussain *et al.,* 2012). The production of enhanced varieties, the preservation of endangered species, the large-scale manufacture of secondary metabolites or plant-made vaccines or antibodies are the current and future state of plant tissue culture in vegetable crops. supplying planting material for plants whose seed cannot be multiplied to satisfy the rising global demand.

3. Hydroponics

The term "hydroponics" refers to a method of growing plants in nutrient solutions with or without the use of an inert medium to give mechanical support, such as gravel, vermiculite, rock wool, peat moss, sawdust, coir dust, coconut fibre, etc. The Greek terms hydro means water and ponos means labour, hence the phrase hydroponics literally translates to "water work." Professor William Gerick first used the term "hydroponics" in the early 1930s to refer to the practise of growing plants with their roots suspended in nutrient-rich water. In 1940, Purdue University researchers created the nutriculture system. Commercial hydroponics farms were created in a number of nations during the 1960s and 1970s, including Arizona, Abu Dhabi, Belgium, California, Denmark, Germany, the Netherlands, Iran, Italy, Japan, and the Russian Federation. According to the needs of various plants, the majority of hydroponic systems automatically adjust the amount of water, nutrients, and photoperiod (Resh, 2013). The environment is being negatively impacted by conventional farming practises as well as the rising urbanisation and industrialisation that are reducing the amount of arable land. A significant amount of food must be grown using new techniques in order to sustainably feed the world's expanding population. A substitute for unsustainable production is changing the growth medium in order to conserve the water and land resources that are quickly running out. In the current environment, soilless agriculture may be successfully introduced and taken into consideration as an alternate choice for raising plants, crops, or vegetables that are healthy (Butler and Oebker, 2006). Hydroponics, Aquaponics, Aeroponics, and substrate culture are all forms of agriculture that are carried out without the use of soil. One of these hydroponic approaches is rising in popularity due to its effective resource management and food production. Hydroponics can be used to cultivate a variety of speciality and commercial crops, including green vegetables, tomatoes, cucumbers, peppers, strawberries, and many more. The usage of pesticides and the toxicity they cause is reduced or eliminated when using the clean, simple hydroponic approach because there is no risk of soil-borne disease, bug, or pest infection of the crops. In addition, plants grow more quickly than crops grown in fields since there are no mechanical obstacles in the way of their roots and because all of the nutrients are readily available to them. According to Polycarpou *et al*. (2005), this method is extremely helpful in areas where environmental stress (cold, heat, and desert) is a significant issue. Because hydroponic crops are not affected by climate change, they can be grown all year round and are not regarded to be in season (Manzocco *et al.,* 2011). Commercial hydroponic systems are also automatically run and are anticipated to reduce labour, and various conventional agricultural practises, such as tilling, spraying, watering, and weeding, can be done away with (Jovicich *et al.*, 2003). As irrigation and other types of sprays are not required with hydroponics, and water logging never happens, a significant amount of water is saved. Pest and disease issues are easy manageable, whereas weed is essentially nonexistent. Since there are more plants per unit than in traditional agriculture, better yields can be produced. Although soil-less cultivation is a beneficial technology, there are several serious drawbacks. For commercial scale cultivation, technical expertise and a significant initial investment are essential (Resh, 2013). Water-borne illnesses can easily transfer from one plant to another in a hydroponics system since all the plants share the same fertiliser (Ikeda *et al.*, 2002).

Advantages

- Even in areas where the soil is unsuitable for plant growth, crops can be cultivated.
- The potential yield is maximum.
- Labour costs have been largely eliminated.
- The preservation of nutrients and water.
- The environment can be changed to suit our preferences.

Disadvantages

- Construction cost is high.
- Trained person must be required.
- Consumption of electricity is high.

4. Drip irrigation:

With the use of pipes attached to water tanks, water is applied to the plant's root zones in this system.

- Water can also be used to provide nutrients.
- Water was supplied in the ideal quantity.
- Decreased Runoff.
- Minimal possibility of weed and fungus.

5. Aeroponics:

It is a sophisticated type of hydroponics. It entails cultivating plants in a trough or other container where the roots are suspended and nutrition mist is sprayed on them. The rooted plants are put in a specific kind of box with a humid environment that is computer controlled. Utilising fewer resources, this strategy leads to healthier plants, increased development, and higher production. In this arrangement, oxygen is constantly present around the roots.

Advantages

- Unrestricted and natural growth

- Reduces the incidence of disease
- Disease free environment
- Plants grow with higher density
- Propogation from a single stem is possible

Disadvantages

- It requires constant monitoring
- It is highly susceptible to power outages
- Requires technical knowledge

6. Off-Season vegetable production

A form of agricultural technology known as "off-season vegetable production" refers to the fresh cultivation and production of vegetables before or after their typical season. There could be a days-, weeks-, or even months-long delay or early construction. Utilising various agroclimatic zones, maintaining or altering planting times, choosing varieties, building an artificial and controlled environment through the use of tunnels, polythene houses, glass houses, hot beds, etc. are all ways to acquire this off-season vegetable producing technology. Vegetable growing is a significant part of the agribusiness industry due to its greater farm-gate values and productivity (Mariyono, 2017). From small-scale commercial farming to household subsistence farming, it has helped farmers support their way of life (Van Veenhuizen and Danso, 2007). Producing and supplying veggies to consumers at times of low supply and at the cheapest pricing for goods is the primary goal of off-season vegetable production. For farmers, this technology means higher prices. Additionally, this method guarantees food security during times of high demand to support timely employment. Off-season vegetable farming is one of the best ways to get money from others and a successful strategy for reducing poverty, unemployment, and ongoing malnutrition. Commercial vegetable farming has been a significant factor in improving farmer economic status and offers marginal farmers and their families consistent work and income throughout the year by generating economic gains (Panta, 2001). Off-season vegetables are typically planted with important crops including tomato, cauliflower, cabbage, onion, green peas, radish, carrot, and brinjal. According to earlier research (Weinberger and Genova II, 2005), the implementation of enhanced vegetable technology can result in significant increases in economic well-being. Farmers have been advised to use off-season production techniques for tomatoes, onions, cucumbers, cabbage, and cauliflower.

Techniques of off-season vegetable production:

1. Changing the Planting Time By changing the time of cultivation, some vegetables can be cultivated. Cucurbitaceous plants, for instance, can be grown 2 months earlier in a warmer climate.
2. Utilising various agroclimatic regions Like Nepal, many other nations have a wide range of climatic variations. The same vegetable can be cultivated as seasonal in one location and off-season in another location within the same country by utilising this variation (micro cliamtes).
3. Variety Selection: Many hybrid vegetable kinds are frequently utilised to grow

crops in the early and late seasons. Because of the use of these types, vegetables are now produced all year round and are more readily available.

4. establishing a regulated environment Temperature is the primary barrier to off-season vegetable cultivation, hence various types of structures are employed to maintain temperature.

6.1 Plastic Tunnel

It is a simple, less expensive approach of managing the environment to build a small greenhouse-like structure and cover the plants in a row with polythene sheets. By raising the temperature, it promotes early plant growth and offers protection from rain, frost, and other elements. A seed bed is raised by about 1 m, and bamboo stakes are bent over it to form a semicircle. Polythene is then tied over the whole thing. This is typically done to grow summertime seedlings in the winter. Low-cost plastic tunnels can be used to protect crops from excessive rainfall and create a favourable environment for the production of higher-quality crops over time (Popescu *et al.,* 1984; Borrelli, 1983; Haupt, 1986). They have also been reported to result in earlier maturity, higher quality, and higher yield in various tomato cultivars grown for protected culture.

6.2 Polythene House

By using polythene sheets, bamboo stakes, or galvanised iron pipes, polythene houses can be constructed in a variety of sizes to suit our needs. Typically, tall-growing plants like cucurbits and tomatoes are planted in this kind of arrangement.In the hills, a large number of small and marginal farmers are producing off-season plastic house tomatoes (Chapagain *et al*. 2011).

6.3 Glass House / Green House

In a greenhouse, plants that require controlled climatic conditions are produced. A greenhouse is a building with walls and a roof composed of transparent material, such as glass or plastic (Smitha *et al.,* 2016). It is a sort of structure created specifically for the production of vegetables and the protection of plants during the off-season from extreme cold or heat. The ability to control temperature, humidity, soil moisture, light, and other factors according to plant needs is offered in glass houses. Although pricey, production and output from this structure are of the highest calibre. The advantages of greenhouse crop farming include year-round crop production, crop protection, higher yields, the ability to produce vegetables on small plots of land, and greater product quality (Wachira *et al.,* 2014).

6.4 Hot Bed

A hot bed is a mound of organic waste that produces heat as a result of microbial activity. According to the hot bed's operating theory, fresh manure (cow dung, sheep yard manure and poultry manure) that is ready for fermentation produces heat that is used to hasten germination by creating favourable conditions for germination and promoting the seedlings' rapid growth, which leads to an early maturity of the crop. The use of cold frames, plastic mulching, hormones, polypots, thatches, net houses, and other structures is also possible.

Benefits of off- season vegetable production

- Off-season produce enables farmers to command better prices for their goods.
- Customers can purchase fresh goods all year round, even during the off-season.
- If production is high-quality and substantial, there is a likelihood that it will be exported to other nations, creating year-round work opportunities and high earnings.
- Farmers can increase their knowledge, understand concepts and particular practises, and gain confidence so they can begin using this technology on a large scale.
- Small, underprivileged, subsistence and commercial farmers may find this technology useful.
- Additionally, it encourages farmers to focus their efforts on producing off-season vegetables, making good use of the farm and the soil.
- It contributes to the scarcity of food.

8. Vegetable grafting

Grafting is the practise of fusing two plant sections (a rootstock and a scion) together using tissue regeneration so that they physically reunite and develop into a single plant (Janick, 1986). Vegetable grafting is a relatively new technique in olericulture, although the practise of grafting fruit trees dates back thousands of years. One of the finest methods for ensuring sustainable vegetable output is commercial vegetable grafting, which uses resistant root stocks. For organic agriculture, vegetable grafting lessens reliance on agrochemicals (Rivard *et al.*, 2008). Additionally, vegetable grafting increases vigour, precocity, yield and quality, survival rate, lowers infection by soil-borne pathogens, and increases resistance to abiotic stresses. In order to boost yield under biotic and abiotic challenges such sub- and supra-optimal temperature, salinity, drought, pest damage, diseases, etc., one approach is known as vegetable grafting. Since a few decades ago, commercial vegetable grafting has been practised, and the area being grafted is steadily expanding. Vegetable grafting has the potential to increase the area under vegetable cultivation in non-traditional settings and unstable agro-ecosystems, where it has the potential to boost productivity per unit of available land. In the production of stress-resistant cultivars, vegetable grafting is one of the simplest and least expensive tools available. It uses desirable rootstocks. Using robust and disease-resistant rootstocks to assure appropriate yields in situations where biotic and abiotic stressors limit productivity (Lee and Oda, 2003; Chang *et al.*, 2008), vegetable grafting is becoming more popular worldwide.

Grafting method

The amount of grafts needed, the purpose of the graft, the experience of the farmer, and the availability of the necessary infrastructure and machinery all have a role in the decision to graft a crop (Lee *et al.*, 2010).

7.1 Tongue / approach grafting

For grafting, rootstock and scion must be of equal size. Although this method demands more work and space, it has a high rate of seedling survival and is most frequently used by small nursery producers. In rootstocks having hollow hypocotyls, this approach is not employed.

7.2 Cleft grafting

Another name for it is wedge or apical grafting. This approach involves creating a slant angle in the lower stem, pruning the scion to have 1-3 true leaves, splitting the scion, and attaching a clip between the scion and rootstock (Johnson *et al.*, 2011). This primarily occurs in solanaceous crops.

7.3 Hole insertion

This is mostly used in China and is also referred to as top insertion grafting. Since watermelon seedlings are smaller than bottle gourd or squash rootstock, this is mostly done with them. The ideal temperature range needed for transplanting is 21–36 °C.

7.4 Splice grafting

This method is mostly used by growers. It can be practice by hand or machines in most Cucurbits and Solanaceous vegetable crops.

7.5 Pin grafting

In this method designed pins are used to hold the grafted position instead of placing grafting clips. It is similar method as splice grafting

Benefits of grafting a vegetable plant

- Healthy and strong plant.
- Disease free plant
- Longer production period
- More yield

Healthy and strong plant:

The rootstock affects this characteristic. Scion is frequently supported by rootstock. Strong rootstock makes the growing portion healthier and stronger.

Disease free plant:

By grafting, we may produce disease-free plants. One of the most dangerous ailments affecting many vegetable plants is soil-born illness. This horticulture technique can solve this issue.

Longer production period:

The commercial production period of a grafted plant is longer than a normal vegetable plant.

More yield:

A grafted plant with perennial rootstock will give more yield.

Conclusion:

Only China produces more vegetables than India, which is the world's second-largest vegetable grower. The most difficult challenge is making sure that there is a steady and enough supply of veggies for the expanding population. Urban areas are seeing significant population growth, which is also accompanied by changes in eating patterns and growing worries about the quality of the food. Here, the term "food quality" refers to the quantity of nutrition that a food contains at its optimal level as well as the amount of chemical (pesticide/fertilizer) residues that were left over after the food was produced. Vegetables require careful processing and shipping because they are perishable, highly seasonal, and labour- and resource-intensive. The production is severely hampered by environmental stress (climate change) and a lack of water and land resources. Although science and information technology advancements have created a more comfortable society with connections throughout the globe, they have also changed how things are produced.

References:

Biniam, T. and Tadesse, M. (2007). A survey of viral status on potatoes grown in Eritrea and in vitro virus elimination of a local variety „Tsaeda embaba". *African Journal of Biotechnology*, 7: 397-403.

Borrelli, A. (1983). The adaptation of some cultivars of table tomatoes of green house culture. Culture Protette, 12: 31-36.

Buitelaar, K. (1987). Better varieties of cherry tomatoes. *Goenten Fruit*, 42: 30-32.

Butler, J.D. and Oebker, N.F. (2006). Hydroponics as hobby growing plants without soil. Circular 844, Information Office, College of Agriculture, University of Illinois, Urbana, IL 6180p

Chang, C.Y., Suming, C. and Yi-Chich, C. (2008). Proceedings of the 4th International Symposium on Machinery and Mechatronics for Agriculture and Biosystems Engineering (ISMAB),

Chapagain, T. R., Khatri, B.B. & Mandal, J.L. (2011). Performance of tomato varieties during rainy season under plastic house condition. *Journal of Science and Technology*,12

Hussain, A., Qarshi, I. A., Nazir, H. and Ullah, I. (2012). Plant tissue culture: Current status and opportunities. *Intech*.

Ikeda, H., Koohakan, P. and Jaenaksorn, T. (2002). Problems and counter measures in there use of the nutrient solution in soilless production. *Acta Horticulturae*, 578:213-219.

Ishikawa, M. P., Tandon, A. C., Yamaguishi and Miyazaki, S. (1996). Cryopreservation of bromegrass cells with slow pre freezing and rapid pre freezing methods. Proceedings of the Annual Meeting of Japanese Plant Physiologists, 96.

Johnson, S., Kreider, P. and Miles, C. (2011). Vegetable Grafting Eggplants and Tomatoes.Washington State University, 4.

Jovicich, E., Cantliffe, D.J. and Stoffella, P.J. (2003). Spanish pepper trellis system and high plant density can increase fruit yield, fruit quality and reduce labour in a hydroponic, passive-ventilated greenhouse. *Acta Horticulturae*, 614: 255-262

Kharkongar, H. P., Khanna, V. K., Tyagi, W., Rai, M. and Meetei, N. T. (2013). Wide hybridization and embryo rescue for crop improvement in *Solanum lycopersicum*. *Agrotechnology*, 10.4172/2168- 9881.S11-004.

Lee, J.M., Kubota, C., Tsao, S.J, Biel, Z., Hoyos, E. P. and Morra, L. (2010). Current status of vegetable grafting: diffusion, grafting techniques, automation. Journal of *Horticulture Science*, 127:93- 105

Lee, J.M. and Oda, M. 2003. Grafting of Herbaceous vegetables and Ornamental Crops.*Horticultural Reviews*. 28: 61-124.

Manzocco, L., Foschia, M., Tomasi, N., Maifreni, M., Costa, L.D., Marino, M., Cortella, G. and Cesco, S. (2011). Influence of hydroponic and soil cultivation on quality and shelf life of ready-to-eat lamb's lettuce (*Valerianella locusta* L. Laterr). J*ournal of the Science Food and Agriculture*, 91:1373-1380.

Mariyono, J. (2017). Profitability and determinants of smallholder commercial vegetable production. *International Journal of Vegetable Science*, 24: 274-288.

Niwata, E., Ito–Ogawa R., Ishikawa, M., and Oosawa K. (1995). Cryopreservation of apical meristems of garlic and high subsequent plant regeneration. *Cryogenics,* 16:102–107.

Panta, S. (2001). Final Report on Commercial Off-Season Vegetable Production and Marketing Program (1997-2001). Agro Enterprise Centre, FNCCI, Kathmandu, Nepal.

Polycarpou, P., Neokleous, D., Chimonidou, D. and Papadopoulos, I. (2005). A closed system for soil less culture adapted to the Cyprus conditions.

Popescu, V., Costache, I. and Ghita, D. (1984). New hybrids for green house cultivation. *Horticultural*, 33: 10-12.

Resh, H.M. (2013). Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower. CRC Press,

Rivard, C.L. and Louws, F.J. (2008). *Horticulture Science,* 43, 2008-2111.

Smitha, S., Parvathy, A. and Madhavan, M. (2016). Role of social and economical characteristics of farmers in adopting greenhouse technology. *Advances in Life Sciences*, 5:1973-1978.

Tiwari, J. K., Poonam, Sarkar, D., Pandey, S. K., Gopal, J. and Kumar, S. R. (2011). Molecular and morphological characterization of somatic hybrids between Solanum tuberosum L. and S. etuberosum Lin. *Plant Cell Tissue Organ Culture*, 103:175-187.

Van, V. R. and Danso, G. (2007). Profitability and sustainability of urban and periurban agriculture: *Food and Agriculture Orgnization*, 19:1-4.

Wachira, J.M., Mshenga, P.M. and Mwanarusi, S. (2014). Comparison of the profitability of smallscale greenhouse and open-field tomato production systems in Nakuru North District, Kenya. *Asian Journal of Agricultural Science*, 6:54-63.

Weinberger, K. and Genova, C.A. (2005). Vegetable production in Bangladesh commercialization and rural livelihoods. (Technical Bulletin No. 33).

ABIOTIC STRESS MANAGEMENT IN VEGETABLE PRODUCTION

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Abstract:

Due to continuous climate change, horticultural crops are currently susceptible to a number of abiotic stressors. Abiotic stressors, such as nutrient deficiency, salt, drought, and extremely high temperatures, are resulting in growing losses in yield and product quality. Plants are subjected to harsh environmental challenges in a changing climate, including high and low temperatures, drought, flood, salt, heavy metals, and nutrient deficiencies. These biotic stressors have a significant impact on plant growth and development. Abiotic stressors of many kinds brought on by local and global climate change present considerable obstacles to raising vegetable crop output. The major abiotic stresses that impair growth and production and can result in a variety of morphological, biochemical, physiological, and molecular changes in diverse vegetable crops include heat, cold, drought, and salinity. To adapt to various abiotic pressures in the environment, plants either generate or adopt a number of mechanisms. For the purpose of enhancing current cultivars and introducing new cultivars with enhanced tolerance to such stresses, it is imperative to study plant responses and the physiological changes that occur during these conditions. The impacts of high-temperature stress, drought, and salinity on plant growth and development as well as the physiological responses of plants are finally covered. A brief discussion on adapting mitigation measures to deal with these stressors is also included.

Keywords: Abiotic stress, management, vegetable crop, stress tolerance mechanism

Introduction:

In today's climate change scenarios, crops are exposed to abiotic stress episodes as drought, salt, high temperatures, submersion, and nutritional deficits more frequently. Crop output is limited by these pressures. Our understanding of how crops respond to these stresses and the underlying causes of varietal differences in tolerance has significantly improved in recent years as a result of discoveries in physiology, molecular biology, and genetics. The many abiotic pressures and their effects on agricultural output will be precisely defined in this chapter.

Environmental stress

Unfavourable environmental conditions like moisture deficit/excess, radiation exposure, low and high temperatures, soil and water salinity, nutrient deficiency or toxicity, and pollution of the atmosphere, soil, and water are likely to have an impact on crop growth in terms of morphology (plant size, architecture, malformation of plant organs, growth (height, volume, weight), physiological and metabolic processes, and yield of crop plants.

Stress and strain

Any unfavorable condition that affects a plants metabolism, growth and development is called stress.

Stress is two types-

1. Biotic stress
2. Abiotic stress

1. Biotic Stress

The term "biotic stress" refers to stress that results from harm done to plants by other living things including weeds, cultivated plants, or native plants, as well as bacteria, viruses, fungus, parasites, beneficial and harmful insects.

2. Abiotic Stress

Abiotic stress is the adverse effect of non-living forces on living things in a particular habitat. A few examples include cold (freezing and frost), heat (high temperature), salinity (salt), drought (water shortage condition), excess water (flooding), and radiation (high intensity of UV and visible light).

Strain

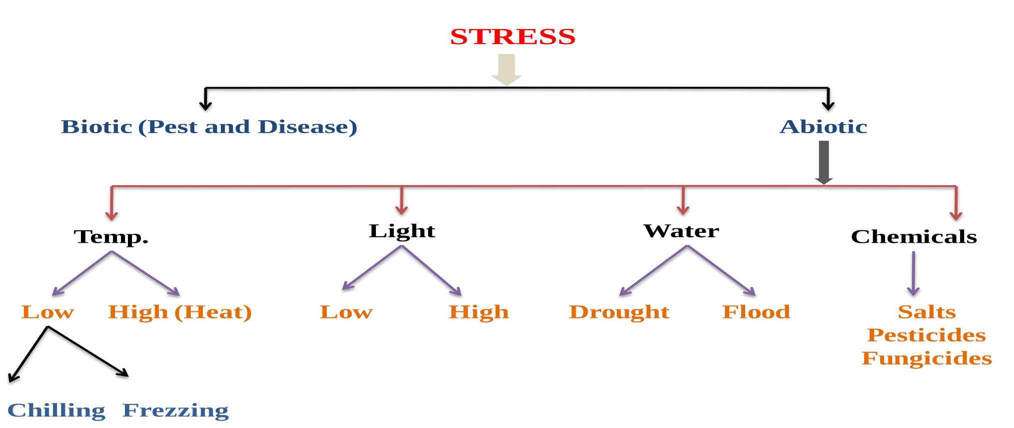
The effect of stress on plant condition is called strain.

Strain is two types-

1. Elastic- Recoverable, Temporary
2. Plastic- Non- recoverable, Permanent

Stress is the action and whereas strain is the reaction.

Classification of Stress



1. Temperature Stress

High temperature stress and low temperature stress are both types of temperature stress. Frost injury or heat injury are terms for low or high temperatures, respectively.

Most plant activities are influenced by temperature:

- Seed germination
- Maturation

- Fruit ripening
- Plant growth rate
- Crop quality

1.1 Low temperature stress

Low temperature stress causes chilling injury and freezing injury.

Chilling injury

When the temperature falls to a level that is close to zero degrees Celsius, tropical plants suffer damage. Chilling damage refers to harm brought on by low temperatures but above zero degrees Celsius (0–5°C).

Frozen injury

When the temperature is 0°C or lower, freezing injury happens. Two things can cause plant damage from freezing. Freezing of plant fluids as well as soil water freezing

Effect of freezing and chilling injury on plants

- The cell membrane's lipid molecules solidify, or transform from a liquid to a solid state. As a result, the membrane loses its semi-permeable properties and starts to leak.
- Mitochondrial inactivation.
- Protoplasmic streaming has been stopped.
- An accumulation of very hazardous respiratory metabolites.
- Ice starts to form inside the cell.

Prevention of cold injury

Some plants alter their growth patterns.

- During this time, the growth is fully halted.
- Unsaturated fatty acid concentration is rising in cell membrane.
- There is less intracellular ice production.
- There are more free proteins, carbohydrates, and enzymes.

Mitigation of Low Temperature Stress

- At key times of stress, spray foliar surfaces with 0.1% ammonium molybdate and harden seeds with 0.01% ammonium molybdate.
- A 2% calcium nitrate foliar spray to maintain membrane integrity.
- A 2% DAP + 1% KCl (MOP) foliar spray.
- Brassinolide (0.5 ppm) is used to increase plant photosynthetic activity.
- Using Pink Pigmented Facultative Methnaotrops (PPFM) @ 106 as a cytokinin source, seed treatment, soil application, and foliar spraying.

1.2 High temperature stress

Heat stress is another name for high temperature stress. Heat stress is frequently described as an increase in temperature that lasts for long enough to permanently harm plant growth and development. Heat Injury is a result of extreme temperatures. Heat injury happens when a plant's temperature exceeds 35°C, which is higher than the ambient temperature. Effects of high temperatures generally

- Seedling vitality and growth

- Intake of nutrients and water
- Transport of solvent
- Respiration and photosynthesis
- Basic metabolic functions
- Fertilisation and development.

Heat Shock Proteins (HSPs)

Plants are able to interact with their surroundings in a variety of ways and may endure extremely stressful abiotic and possibly also biotic situations. Despite being extensively conserved among organisms, plants' sensitivity to heat stress is crucial because of their sessile lifestyle.

2. Light Stress

Light is the one of most important and variable components of plant environment.

2.1 Low Light Stress

In some locations (such as Thanjavur), the light intensity may reach as high as 60000 lux during the first season but drop to as low as 30000 lux during the second, leading to extremely low productivity. The light quality is likewise very bad, with wavelengths of roughly 400-440 nm rather than the usual 600-640 nm. Reduced production is a result of the anomalous light intensity and quality in all crops.

Mitigation of Low Light Stress

- A 2% DAP + 1% KCl (MOP) foliar spray.
- Use 2% coconut water as a mist.
- Spray of 0.5 ppm Brassinolide.
- A 100 ppm salicylic acid spray.
- Applying N and K fertilisers separately.
- Seed treatment, soil application, and foliar spray of Pink Pigmented Facultative Methanotrophs (PPFM) @ 106 as a source of cytokinins. Foliar spray of 0.3% Boric acid and 0.5% Zinc sulphate.

3. **Water stress**

The absence of sufficient soil moisture required for a plant to grow correctly and finish its life cycle is known as water stress.

Type of water stress

3.1 Drought stress

Definitions: A prolonged stretch of rainfall that is below the region's statistical mean is known as a drought.

3.1.1 Meteorological drought is qualified by any significant deficit of precipitation.

3.1.2 Hydrological drought is manifest in noticeably reduced river and stream flow and critically low groundwater tables.

3.1.3 Agricultural drought:

Denotes a protracted dry spell that affects crop stress and productivity. When the amount of moisture in the soil is insufficient to meet the needs of growing crops, it results in drought, which has an effect on agriculture. This happens when there is a sustained shortage of moisture input from irrigation or rainfall. Since the soil moisture deficit depends on both the rate of input and the rate of loss, it is impossible to define a period of time without rain as an agricultural drought. Additionally, the vulnerability of various crops at various phases of growth affects how much stress is put on crops. Crop establishment, growth, typical development patterns, and ultimately final yields can all be impacted by a lack of soil moisture.

3.2 Flooding stress

Plant can't absorb the water due to the salinity, osmotic stress, water logging condition.

Factors responsible for water stress

In the context of a changing climate, water stress is one of the most detrimental elements for plant development and productivity and is regarded as a serious danger to the sustainability of crop production.

- Unreliable Rainfall
- Poor Water Storage in the Soil
- Soil with less capillary water
- Irrigation channel
- Use of saline water for irrigation
- Ineffective drainage
- Water-logging
- Plant architecture (transpiration and water uptake rate)

Management of drought stress

1. Mulching

Mulching is a method of soil conservation that involves covering the soil with organic agricultural waste or plastic sheets. Vegetable crops can be mulched using agricultural wastes and other organic material found on the farm.

2. Use of Plant Growth Regulators

Enhancing plant tolerance through foliar application of both natural and synthetic EPGR has been shown to boost growth against a range of abiotic stresses, such as drought. In response to drought stress, EPGR treatments increase water potential inside cells and improve chlorophyll content. Plants' ability to withstand drought is attributed to salicylic acid, gibberellin, brassinosteroids, jasmonic acid, ethylene, auxins, and cytokinins. Paclobutrazol and CCC many plant species have water stress tolerance. Abscisic acid (ABA) is in charge of controlling stomata, root growth, and the start of an ABA-dependent pathway.

3. Antitranspirants

In general, antitranspirants hinder photosynthesis. Their application is therefore restricted to preventing crop death in situations of extreme moisture stress. Stomata closing: On the surface of the leaf, the stomata are where the majority of transpiration takes place. Stomatal closure is induced by phenylmercuric acetate (PMA) and atrazine, i.e. 2, 4 - D, Phosphon-D. Type of film-forming Physical barriers are created by a thin film of plastic and waxy material that forms on the surface of leaves. Example: Waxol, Folicot, and Mobileaf Reflexion style. They are white substances that cover the leaves and make them more reflective. Examples include lime water, kaolin, China clay, and calcium bicarbonate. Growth inhibitor. These substances allow the plants to endure dryness by decreasing branch growth and increasing root growth. They could cause stomatal closure as well. Cycocel is very useful to improving water status of the plant.

4. Hydrogel

By grafting and cross-linking water-absorbent polymers (polyacrylamide) onto a backbone polymer chain made from a cellulose derivative (carboxymethyl cellulose), hydrogel is created. Because hydrogel gives growing plants water when they need it, it can be employed successfully. the use of hydrogel Field circumstance Prepare a hydrogel-to-fine-dry-soil admixture in a 1:10 ratio and sprinkle it on top of the seeds or fertiliser or in the prepared furrows before sowing. A cot for a transplant Apply a uniform 2 g/m2 coating of hydrogel to the top 2 inches of the cot mattress. Before planting in a pot culture, mix 3-5 g/kg of hydrogel into the soil. When transplanting, prepare a free-flowing solution by thoroughly combining 2 g of hydrogel per litre of water; let it sit for 30 minutes. Plant roots should be dipped in the solution before being transplanted into the ground. Six businesses have been granted licences to commercialise Pusa Hydrogel. One of IARI's major technologies, it has the potential to play a key role in the second green revolution.

5. Grafting technique

Roots in plants are the first to notice when there is a water shortage. However, the H+-ATPase enzyme is more active in grafted plants, which encourages the development of broad, deep roots that can draw water from the soil. (1999; Sze et al.). Different grafting techniques include the tongue approach (for melons and cucumbers), the splice, side, and cut grafts (for watermelons), the cleft and tube grafts (for tomatoes, brinjal, and capsicums), the apical wedge graft (for capsicums), and the micrograft (for tomatoes).

Table 1: Potential rootstocks with special features of resistance against drought

Crop	Species	References
Tomato	*Solanum pennelli*	Bolger *et al*. (2014)
	S. chilense	Zamir *et al*. (1994)
Brinjal	*Solanum elaeagnifolium, Solanum macrocarpum*	Christodoulakis *et al*. (2009)

6. Use of resistant varieties

Table 2: Varieties developed through breeding method for drought resistance

Crop	**Drought tolerant varieties**
Tomato	Arka Vikas, Arka Meghali, Kashi Aman
Chilli	Arka Lohit
Onion	Arka Kalyan

Basic methods of drought management

Drip irrigation

It reduces water losses from runoff and deep percolation, and when compared to the majority of conventional surface irrigation systems, it achieves water savings of 50–80%.

Water harvesting

In many arid and semi-arid locations of the world, water harvesting for dry land is a traditional water management technology to reduce future water scarcity. Harvesting flood and rainwater can potentially boost the production of arable land.

Protected cultivation

Protected structures can play a significant role in reducing the effects of temperature variation, excess or insufficient precipitation, and varying sun shine hours, as well as their function in reducing the effects of climate change. Growing in popularity among farmers are seedling raising in pro-trays and crop production inside agro-shade nets.

Effect of water logging stress

- Gas diffusion is hampered by metabolic poisons in the soil or roots, decreased respiration, and decreased root conductivity to water.
- A lack of minerals and nutrients Conclusion By using mulching, PGRs, antitranspirants, hydrogel, proper irrigation techniques, protected structures, grafting on resistant rootstock, and cultivation of resistant varieties for water stress conditions, it can be concluded from the discussion above that water stress conditions can be managed to maximise vegetable production.

4. Salinity stress

Salinity

Salinity is derived from the Latin words salinium, which means "salt cellar," and ity, which means "state of being." Salts that are soluble in water or soil are referred to as salinity. According to West (1978), a plant's natural ability to survive the effects of high salt concentrations in the root zone or on its leaves without suffering major harm is known as salt tolerance or resistance. In soils, surface waters, and groundwater systems, salt is a natural occurrence. Sodium chloride is the salt that causes salinity most frequently, however other salts like magnesium, calcium, or potassium may also contribute to salinity.

Salt affected areas

One of the most significant degraded areas where soil productivity is decreased owing to salinization (EC> 4dS/m), sodicity (ESP> 15), or both is salt affected areas. In the current situation, soils with EC greater than 2 dS/m in black soils and greater than 4 dS/m in non-black soils were deemed to be salinized. Soil pH levels greater than 8.5 cause an increase in the proportion of exchangeable sodium (ESP) in soils (>15), and these soils are referred to as sodic. It has been split into three categories: saline, sodic, and saline-sodic.

Mechanism of salt tolerance

a plant's innate capacity to endure the impacts of excessive salt concentrations on its leaves or in the root zone without suffering serious consequences. By limiting ion uptake into the shoots and then making the necessary osmotic adjustments, plants can escape the damaging effects of salt. Alternatively, they can allow ion uptake and then adjust to excessive salt concentration in the green tissues. It is necessary to redirect a certain percentage of photosynthate, which is typically channelled towards growth, for salinity reactions. The additional energy required to maintain homeostasis is the cause of the greater respiration rate observed in salt-affected plants. Salt can cross root membranes passively or actively, moving against concentration gradients. Ion passage has been demonstrated to be selectively regulated in the xylem parenchyma, tonoplast, or in specialised cells. The concentration of other ions affects the function of particular ion-specific ATPs that control this ion migration. As a result, the ability to control ions may vary between species and even cultivars. Under reaction to salt stress, plants under saline conditions synthesise and store osmotic chemicals.

Table 3: Vegetable crops classified based on tolerance to soil salinity

Less tolerant	Moderate Tolerant	Highly tolerant
Pea, Radish, Snake gourd, Beans, Brinjal, Sweet Pepper, Potato and Sweet Potato	Tomato, Chilli, Watermelon, Cumber, Summer squash, Bottle gourd, Cabbage, Cauliflower, Muskmelon, Onion and Broccoli	Asparagus, Beet, Kale, Turnip, Bitter gourd, Ash gourd, Palak and Lettuce

Methods for resolving the salinity issue Improvement of drainage, leaching, use of chemicals, development of salt-tolerant cultivars through breeding techniques, and grafting of high yielding crops onto resistance rootstock are some methods to address the salinity issue.

Table 4: Management of salinity

Management methods	Application in vegetables	Reference
Salt leaching	Bell-peppers - higher the salinity of the irrigation water the higher the leaching process	Ben *et al.*, 2008
Primer and companion plants	Pepper- Salsola soda used as a companion plant	Colla *et al.*, 2006
Soil mulching	Swiss chard-Mulching with gravel, rice straw improving crop yield	Zhang *et al.*, 2008
Potassium	Potato -increased tuber yield	Elkhatib *et al.*, 2004
Calcium	Tomato and Pepper-reduces blossom end rot and increase fruit quality & yield.	Rubio *et al.*, 2009
Nitrogen1mM ammonium and 7mM	nitrate -minimizing salinity effects on fruit yield	Ben-Oliel *et al.*, 2004
Phosphorus	Radish-reduced the sensitivity to salinity up to a level of 3.5 dS m^{-1}	De Oliveira *et al.*, 2010
Sulfur	Brassica and legume crops- increased salinity stress-defense mechanisms	Rausch and Wachter. 2005
Zinc	Pepper-Zn reduced excess uptake of Na under saline conditions	Aktas *et al.*, 2006
Biofertilizer	Lettuce-Phosphorine and Nitrobein increases proline and glycine contents	Hasaneen *et al.*, 2009
Manures	Pepper -humic acid was dampen the deleterious effects of salt stress	Cimrin *et al.*, 2010
Elevated CO2 concentrations	Application of non-nutritional additives Spinach under salinity increases the activities of SOD and CAT	Eraslan *et al.*, 2008
Grafting to tolerant rootstocks	Combinations of melon & pumpkin rootstocks, pumpkin exclude 74% of available Na, while there is nearly no Na exclusion by melon rootstock	Edelstein *et al.*, 2011

Heavy Metal Stress

Supra optimal concentration of heavy metals such as Cd, Pb, Hg, Cu, Zn and Ni affect growth, development and yield of plants, though Cu, ZN, and Ni are essential micronutrients at low concentration Heavy metals affect several physiological and metabolic processes plants have developed several mechanisms that control and responds to the uptake and accumulation of both essential and non essential heavy metals.

Heavy metal stress tolerance mechanisms:

Vary from species to species and their genetic background. The important heavy metal tolerance mechanism include metal binding to wall, reduced transport across cell membrane, active efflux of metals, compartementation, chelation and sequestration of heavy metal by particular ligands such as phytochelatins and metallothioneins.

Conclusion:

Abiotic stressors are a key source of worry for the safety of the world's food supply. The search for remedies for the vast abiotic stress brought on by climatic change and other factors has nearly reached its limit in conventional knowledge. The value of GE has been demonstrated in improving the plants' capacity to deal with diverse abiotic stressors. The ability of GE to bypass the species barrier is its main benefit. To utilise the most recent technology to their greatest capacity, much work must be done.

References:

Aktas, H., Abak, K., Ozturk, L. and Cakmak, I. (2006). The effect of zinc on growth and shoot concentration of sodium and potassium in pepper plants under salinity stress. *Journal of Agriculture and Forestry,* 30:407-412.

Ben, G. A., Ityel, E., Dudley, L., Cohen, S., Yermiyahu, U., Presnov, E. and Zigmond, L. (2008). Effect of irrigation water salinity on transpiration and leaching requirements: A case study of bell peppers. Agric. *Water Manage,* 95:587-597.

Ben-Oliel. G., Kant, S., Naim, M., Rabinowitch, H.D., Takeoka, G.R. and Buttery, R.G. (2004). Effect of ammonium to nitrate ratio and salinity on yield and fruit quality of large and small tomato fruit hybrids. *Journal of Plant Nutrition,* 27:1795-1812.

Bideshki, A. and Arvin, M.J. (2010). Effect of salicylic acid (SA) and drought stress on growth, bulb yield and allicin content of garlic (*Allium sativum*) in field. *Plant Ecophysiology,* 2:73-79.

Christodoulakis, N.S., Lampri, P.N. and Fasseas, C. (2009). Structural and cytochemical investigaction of the silverleaf nightshade (*Solanum elaeagnifolium*), a drought-resistant alien weed of the Greek flora. *Australian Journal of Botany,* 57:432-438.

Colla, G., Rouphael, Y., Fallovo, C., Cardarelli, M. and Graifenberg, A. (2006). Use of Salsola soda as a companion plant to improve greenhouse pepper (*Capsicum annuum*) performance under saline conditions. *New Zealand Journal of Crop and Horticulture Science,* 34:283-290.

De O., Oliveira F., Medeiros J.F.D., Sousa, F.L.D and Freir, A.G. (2010). Phosphorus-salinity interaction in radish. *Revista Ciencia Agronomica,* 41:519-526.

Edelstein, M., Plaut, Z. and Ben-Hur, M. (2011). Mechanism responsible for restricted boron concentration in plant shoots grafted on pumpkin rootstocks. *Journal of Plant Science*, 59:207-215.

Elkhatib, H.A., Elkhatib, E.A., Allah, A.M.K., E.l. and Sharkawy, A.M. (2004). Yield response of salt-stressed potato to potassium fertilization: Apreliminary mathematical model. *Journal of Plant Nutrition*, 27:111-122.

Eraslan, F., Inal, A., Pilbeam, D. and Gunes, A. (2008). Interactive effects of salicylic acid and silicon on oxidative damage and antioxidant activity in spinach (*Spinacia oleracea* L. cv. Matador) grown under boron toxicity and salinity. *Plant Growth Regulater*, 55:207-219.

Hasaneen, M.N.A., Younis, M.E. and Tourky, S.M.N. (2009). Plant growth metabolism and adaptation in relation to stress conditions. III. Salinity bio-fertility interactive effects on growth, carbohydrates and photosynthetic efficiency of *Lactuca sativa*. *Plant Omics*, 2:60-69.

Patel, A.J., K.D., Rathod. and Satodiya, B.N. (2021). Effect of water stress and its management in vegetable crops. *International Journal of Chemical Studies*, 9(1): 1382-1385

Rausch, T., Kirsch, M., Low, R., Lehr, A., Viereck, R. and Zhigang, A. (1996). Salt stress responses of higher plants: the role of proton pumps and Na^+/H^+ antiporters. *Journal of Plant Physiology*, 148:425-433.

Rausch, T. and Wachter, A. (2005). Sulfur metabolism a versatile platform for launching defense operations. *Trends Plant Science*, 10:503-509.

Rubio, J.S., Garcia, S. F., Rubio, F. and Martinez, V. (2009). Yield, blossom end rot incidence and fruit quality in pepper plants under moderate salinity are affected by K^+ and Ca^{2+} fertilization. *Scientia Horticulture*, 119:79-87.

Sze, H., Li, X. and Palmgren, M.G. (1999). Energization of plant cell membranes by H^+ pumping ATPase regulation and biosynthesis. *Plant cell*, 11:677-689.

West, D.W. (1978). Water use and sodium chloride uptake by apple trees. II. The response to soil oxygen deficiency. *Plant Soil*, 50:51-56.

Zamir, D., Ekstein, M.I., Zakay, Y., Navot, N., Zeidan, M. and Sarfatti, M. (1994). Mapping and introgression of a tomato yellow leaf curl virus tolerance gene, Ty-1. *Theoretical and Applied Genetics*, 88:141-146.

Zhang, Q.T., Inoue, M., Inosako, K., Irshad, M., Kondo, K., Qio, G.Y. and Wang, S.P. (2008). Ameliorative effect of mulching on water use efficiency of Swiss chard and salt accumulation under saline irrigation. *Journal of Food, Agriculture and Environment*, 6:480-485.

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ACID SULPHATE SOIL AND ITS MANAGEMENT

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Abstract:

Acid sulphate soils also known as cat clays contains sufficient sulphides which become highly acidic when drained and aerated enough for cultivation. They may have normal pH and are only potentially acid sulphate soil before drainage. Acid sulphate soil are found in Kerela, Orissa, Andra Pradesh, Tamil Nadu and West Bengal in India. For further agricultural development implication is necessary in other comparable areas to know the extent of potential acid sulphate soils. It is important to maintain the water table above the sulphide datum.

Introduction:

Acid sulphate soils (ASS) are most abominable soil in the world. Soils developed near sea and estuarine areas under anoxic reducing conditions beneath the water table due to microbial activities and consists of iron pyrites are acid sulphate soils (Wallin *et al.*, 2015). Globally, ~170,000 sq. km. of ASSs are found in tropics and subtropics (Huang *et al.*, 2017). They remain stable under anoxic reducing conditions, thereby, causing no harm to the surrounding habitat (Nath *et al.*, 2013). Around the world they are considered as the nastiest type of soils as they have potential to produce sulphuric acid and extremely low pH in presence of water (Dent and Pons, 1995). The sulphide minerals (in the form of iron pyrites) present in these soils and/or sediments along with organic matter are rapidly oxidized in presence of air (Boman *et al.*, 2008). Acid sulphate soil contains sufficient sulphides. Acid sulphate soils are formed when sulphides are oxidized in soil. These soils are the potentially acid soil which when drained off produce sulphuric acid. Problems arise whenever the rate of acid production from oxidation of sulphides exceeds the buffering capacity of the soil. The generated sulphuric acid can bring the pH as low as 2.0 and the acid might leaks into drainage and flood waters. In these soils, aluminium and other toxic elements kill vegetation and aquatic life or, in sub-lethal doses, render many species stunted and sickly. Generations of people depending on these soils have been impoverished and, probably, poisoned by their drinking water. Dutch farmers named them as Kattakali meaning Cat Clays, because of their pale yellow colour and infertile nature.

It is found in coastal, deltaic and estuarine conditions of humid regions. These soils mainly suffer from aluminum toxicity and nutrient deficiency, especially phosphorus.

Distribution of acid sulphate soils:

Acid sulphate soils are formed in influence of saline or brackish water of coastal areas. They may also form in Pleistocene terraces with high water swamps that are near to sulphur sources. In India these soils mainly occur in West Bengal’s coastal saline zones known as Sunderban, Andaman Nicobar Islands and in Kerela they are found in coastal area formed by deltic alluvium of four rivers i.e. Meenachil, Manimala, Achencoil and low laying area of

Vemband lake. In general, the area covered in 0.26 million hectare (Mohsin *et al.*, 1995). In India, approximately 390000 hectare lands are found for acid sulphate soils.

In India approximately 390,000 hectares of acid sulphate soils is present. These are found in Kerala, Tamil Nadu, West Bengal, Andhra Pradesh and Orissa. In Kerela approximately 110 thousand hectares area is highly orgaic sulfaquepts. Among these area approximately 26 thousand hectares is affected by salinity. West Bengal has 280 thousands hectares of acid sulphate soil belongs to great group sulfaquents. They are mainly distributed in Sundarban region. The estimate that about 0.26 million hectares area in Kerala and the Andaman and Nicobar group of islands are occupied by acid sulphate soils in the coastal areas.

Table 1: Global distribution of acid sulphate soils

Country	Area ('000' ha)	Source
Australia	3000	Galloway, Aust. draft nat. Strategy, 1997
Venezuela	2000	Van Breman, 1980
Brazil	1111	FAO, 1974
Vietnam	2140	Bui Quan Tran, 1990
Indonesia	4109	Soekardi, 1990
Malaysia	657	Dent, 1990
Guyanas	1246	Brinkman and Pons, 1968
Central America	650	FAO, 1974
Madagascar	528	FAO, 1974
Thailand	1500	Krishnamra, 1990
Central America	650	FAO, 1974
India	390	Van Breemen and Pons, 1978

*****source: Attanandana *et al.*, 1986; Angeloni *et al.*, 2004

Genesis of acid sulphate soils

Inundated lands with water, specially salt water, contains sulphates. Sulphates of acid sulphate soils are reduced to sulphides by bacteria in poorly aerated soils. These soils are not so acidic when they are first drained. But after drainage of water when soil become aerated the sulphide present in soil is oxidized to sulphate and form sulphuric acid by combination of chemical and bacterial actions. The magnitude of acid development is decided by the amount of sulphide present.

There are two main processes involved in formation of acid sulphate soils: formation and oxidation of pyrite. The accumulation of pyrite is brought about by the combined effect of somewhat unique conditions that occur in tropical coastal areas. The sulphur in pyrite comes from the sulphate in sea water. These sulphurs are biologically reduced to sulphide in the anaerobic mud. Bacterial sulphate reduction requires an energy source. The abundant plant growth in coastal organic matter act as the source of energy. Sulphur, iron and sometimes sea water plays an important role. Pyrite (FeS_2) and murcasite are the main source of iron. Brackish and sea water contribute sulphur (> 800 mg kg^{-1} $SO_4{}^{2-}$ sulphur), sediments and biological materials (like algae and diatoms) contain large amount of sulfides. Ferrous iron (Fe^{2+}) are also available and is derived from weathering clay by reduction of insoluble ferric compounds. The formation and accumulation of pyrite in tropical coastal wetlands is caused by combination of sulphate from sea water, organic matter from plant growth, anaerobic conditions caused by exclusion of atmospheric oxygen by the excess water, and the presence of Fe^{2+}.

Reaction involved in formation of Acid Sulphate Soils

In acid sulphate soils on drainage, oxidation of sulphides occurs. Above pH 4.0 there is slow oxidation of sulphides in soils due to non- biological process. Below pH 4.0, the bacteria, *Thiobacillus ferroxidans* are the most active oxidizers and the activity buils up rapidly.

$2S + 3O_2 + 2H_2O \rightarrow H_2SO_4$

(Elemental Sulphur) (Sulphuric acid)

$H_2S + 2O_2 \rightarrow H_2SO_4$

(Hydrogen sulphate) (Sulphuric acid)

Non-biological

$2FeS + 2H_2O + 7O_2 \rightarrow 2FeSO_4 + 2H_2SO_4$

(Iron Pyrite)(Ferrous sulphate) (Sulphuric acid)

Accelerated by Bacteria

$4FeSO_4 + O_2 + 2H_2SO_4 \rightarrow 2\ Fe_2\ (SO_4)_3 + 2H_2O$

(Ferrous sulphate) (Ferric sulphate)

Rapid in Acid pH (Non-Biological)

$2FeS_2 + 7Fe_2\ (SO_4)_3 8H_2O \rightarrow 15\ FeSO_4 + 8H_2SO_4$

(Ferric sulphate)

Oxidation of sulphides in soils leads to formation of acid sulphate soils. When the wet soil is drained and then allowed to get aerated,the sulphide in such soil is biochemically oxidized to sulphate and form sulphuric acid. Amount of formation of acid sulphate soil directly depends on the amount of sulphides are present in soil. Leachate from acid sulphate soil may persist impact over a long period of time and/or peak seasonally (after dry periods with the first rains). In Australia, some areas are still releasing acid even after soils drained 100 years ago. Bacteria called *Thiobacillus ferroxidans* are most active oxidizers below pH 4.0 and ares responsible for acid sulphate soil. *Thiobacillus ferroxidans* bacteria convert sulphate (dissolved salt) from various sources into sulfide. Sulfide thus produced reacts with metals especially iron to produce metal sulfides (the main components of acid sulfate soils), in the soil sediments or water column.

Classification of acid sulphate soils:

Main classes and properties of acid sulphate soils are given in Table - 1 (Kevie, 1973). To distinguish soils, the classification uses environmental characteristics like active and potential acidity, salinity, texture and composition, depth and seasonal variation of water table, quality of flood water and depth and duration of flooding.

Some of the iron sulphate is precipitated as Jarosite. Formula of jarosite is $(AB)_3(SO_4)_3(OH)_6$ where "A" may be K, Na, Pb, NH_4 or H_2O and "B" may be Fe^{3+} or Al^{3+}. Jarosite is insoluble in water and has a pale yellow colour. In presence of saline water some of the reaction products are neutralized and pH remains above 5.0. But, if Ca and Mg are not present extreme acidification occurs and pH may be as low as 1.2. The ferric iron (Fe^{3+}) co-ordinates with water molecules like aluminum and behave as acid.

Table 1: International classification of Acid Sulphate Soils

Climate zone	Soil Taxonomy	Main characteristics
Potential acid sulphate soils		
World Wide	Typic Sulfaquents	pH (1:1 water) of dried soil < 3.5 within 50 cm if n > 1.0 within 30 cm if n < 0.7
World Wide	Sulfic Hydraquents	pH (1:1 water) of dried soil < 4.5 in upper 25 cm, or more acid between 50 and 100 cm; in n > 0.7 between 20 and 50 cm
Wet	Sulfic Trapaquents	Acidity requirements of sulfichydraquents, but n < 0.7 between 20 and 50 cm
Temperate	Sulfic Fluvaquents	Same as SulficTrapaquents
World wide	Typic Sulfihemists	Sulfidic materials within 100 cm; pH (1:1 water) of dried soil <3.5

Mineralogy of acid sulphate soils:

Kari soils of Kerala has Kaolinite as dominant clay mineral (34.3%) associated with Smectite (18.32%). Besides these Illite (6- 12%), Chlorite (0-11%), Vermiculite (0-5%), Amphibole (0-4%), Gibbsite (0-17%), Quartz (0- 2%) and Fledspar (0-2%) were also present (Ghosh *et al.*,1976).

Characteristics of acid sulphate soil

Acid sulphate soil has a *sulphuric horizon* having pH < 3.5 along which has sulphide content (yellow colour). *Sulphuric horizon* has thickness of 15 cm or more having pH of 3.5 or less due to the presence of sulfuric acid in the soil.. It is composed of either mineral or organic soil material. Mineral or organic soil materials that have a pH > 3.5. Sulphidic materials containing oxidizable sulphur compounds is also present in the soil. Organic matter content is higher in acid sulfate soils as compared with normal soil. In acid sulfate soils higher the organic matter content tend to the lower the pH of the surface soil. Great group involved in acid sulphate soil are *Sulphaquepts, Sulphaquents, Sulphihemists and Sulphohemists*. Akoichi disease is caused by hydrogen sulphide often formed in lowland rice. It retards rice plant roots to absorb nutrients. It is because of the lower pH retard the ammonification by retarding decomposition of organic matter, regardless of the high organic matter content.

Fertility Problems

Acid sulphate soils generally reduces farm productivity as they are not productive. Low productivity is caused due to soil acidity, aluminium toxicity, iron toxicity, salinity, low content of major nutrients, low base status and hydrogen sulfide toxicity. Lower soil pH caused due to high sulphuric acid content reduced the availability of several soil nutrients. Aluminium and iron are available to plant in toxic quantities as acid helps in dissolving them. The ill effect of acid sulphate soils are due to hydrogen ion, especially below pH 3.5 to 4. At this pH range, aluminium toxicity is of more importance. Acid sulphate soils when used as landfill can affect plant growth and landscaping. Acid sulfate soils also affect the productivity of animals. The acid discourages good

- Low productivity of these soils is due to-
  1. Injury of hydrogenions.
  2. Low pHcausing
     - Reduced availability and absorption of plant nutrients.
     - Iron, aluminum and manganese toxicity due to increased solubility.
     - Decreased availability of phosphorus and molybdenum.
  3. Leaching causes low base saturation.
  4. Unfavorable condition causing impaired mycorrhiza and virulence of plant diseases.
  5. Salt injury.
  6. Telicity due to hydrogen sulphide (H_2S).
  7. Production of organic acids
- Hydgrogen ions causes' injury to plant roots particularly if the pH is < 4.0. If concentration of polyvalent cations is less, plants can tolerate concentration of hydrogen ions (H^+). As hydrogen ions has adverse effect on cell cytoplasm and cell permeability, it suppresses the growth and branching of roots. There are less number of plant roots having thick and dull grey to brown colour. It reduces the nutrient absorption capacity of root. If the pH is around 4.0 rubber, oil palm, coconut, cassava and banana can be grown. As Paddy can tolerate high concentration of aluminum (1.2 to 25 mg kg^{-1}) it can be grown under submergence as, if supply of other nutrients can be maintained because concurrent increase in pH due to continuous submergence lowers the concentration of aluminum. The concentration of aluminum which was 74.5 mg kg^{-1} at pH 3.11 is reduced to 0.3 mg kg^{-1} at pH 4.0. This may be because ferric hydro oxide is reduced to ferrous hydro oxide and the OH released causes the precipitation ofaluminum.

  $$Fe(OH)_3 \longrightarrow Fe(OH)_2 + OH^-$$

  $$Al^{3+} + OH^- \longrightarrow Al(OH)^{++},\ Al(OH)_2^+ \text{ and} Al(OH)_3$$

- High concentration of Fe^{2+} (200 mg kg^{-1}) can be tolerable to Paddy. Excess of H_2S present in this range causes Akiochi disease in Paddy. As a result of Akiochi disease reduces the respiratory activity of root and plants become deficient in K, N, Si and bases, iron content in the plant increases to toxic levels. Plants are infected with Helminthosporium which causes wide spread damage. Suffocation disease caused by H_2S can be corrected by application of nitrate nitrogen. Another disease called Brusone also develops which is caused by *Pricularia oryzae* and the plant suffers.
- Plant roots become brittle, branching reduces with thick root tips and brown lateral roots due to high concentration of aluminum. When aluminum gets attached to phosphate in the DNA structure it inhibits cell division and protein synthesis. Excess of aluminium in cell causes precipitation of nucleic acids and increases the water potential of plants.
- Decreases translocation of calcium to leaves and increases oxidation of Indole Acetic Acid (IAA) is seen in presence of high concentration of manganese and hence growth of plant tops is affected. Mn activated enzyme system's activity and functioning is reduced.

Marginal chlorosis of young leaves and necrotic spots on leaves can be observed due to excess of Mn. Very few of these soils suffer from Mn toxicity, since considerable quantities of Mn is lost during formation of these soils (due to leaching)Several organic acids, such as acetic acid, propionic acid and n-butyric acid accumulate in these soils and are phytotoxic.

- When pyritic soils undergo oxidation and drying, the concentration of soluble salts also increases. The electrical conductivity (EC) may be as high as 10 dSm^{-1}. Flooding of acid sulphate soils with sea water can accelerate the salt problem in the soil. Because of these reasons the productivity is low and–
  1. Lower yield of crops
  2. Unable to icrease the yield with fertilizer application
  3. Further complications arising out of dry spells accentuating the soilacidity.
  4. Blocking of drains.
  5. Inundation due to seawater.
  6. H_2S toxicity is caused due to continuous water logging.

Soil quality problems of acid sulphate soils:

Acid sulphate soils are generally unproductive or have low productivity. It may be due to one or more of the unfavourable factors i.e. soil acidity, salinity, aluminium toxicity, and iron toxicity, low content of major nutrients, low base status, and hydrogen sulphide toxicity.

- **Soil Acidity:** In acid sulphate soils it is due to direct effect of hydrogen (H+) ions, especially below pH 3.5 to 4. Aluminum toxicity is of more importance in this pH range.
- **Soil Salinity:** Acid sulphate soils of tidal areas are affected by salinity. Salinity shows the toxicity, by weakening the plants and increasing iron and aluminium concentration in solution.
- **AluminiumToxicity:** One cause of stress on the growth of certain plant species is aluminium toxicity. A high Al level affects cell division, disrupts certain enzymesystems, and hampers uptake of phosphorus, calcium and potassium. Most plants grown on acid sulphate soils which have a pH below 4 suffer from Al toxicity.
- **Iron Toxicity:** Dissolved iron in excess of 300-400 mg kg-1 is toxic to rice crop.
- **Low Nutrient Contents:** In the absence of iron and aluminium toxicity and harmful salinity, phosphorus deficiency is the most important problem of acid sulphate soils. Supply of nitrogen increases the phosphate response.
- **Low Base Status:** During the formation of acid sulphate soils, bases are removed as sulphate and most of the exchange complex is occupied by aluminium. Therefore, acid sulphate soils are likely to be deficient in Ca and K.
- **Hydrogen SulphideToxicity:** Hydrogen sulphide has been shown to be toxic to the rice plant through its suppression of the oxidizing power of the roots.

Reclamation and management of acid sulphate soils:

Important factors governing the reclamation and improvement in use of these soils are: the degree of acidity developing upon the drainage, depth of non-acid top soil covering acid and

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potential acid sulphate soil horizon buried below, case of controlling water table during dry season besides intensity of dry season.

1. Prolonged submergence.
2. Leaching with rain water, sea water or in succession with these.
3. Addition of lime and manganese dioxide.
4. Ridging, growing of tolerant crops, deep ploughing to mix calcareous horizons, liming fertilizer application and water table control.
5. Improvement of drainage and leaching out of soluble salts repeatedly.

Bandopadhyay (1989) and Mongia and Bandopadhyay (1993) have also reported beneficial effects of liming, leaching and MnO_2 application singly and in combination in improving acid sulphate soils. Mongia *et al.*, (1998) found additive effect of liming and superphosphate application on yield of rice in acid sulphate soils. Manorama *et al.* (1998) suggests that lime should be added in small quantities at short intervals to obtain better rice yield by minimizing the effect of potential acidity.

Management of Acid Sulphate Soil

Acid sulphate soil should be managed when they are disturbed or exposed to oxygen. Typically, excavating or otherwise removing soil or sediment, lowering of groundwater levels or filling or surcharging of low-lying land causes disturbance of acid sulphate soil. There are many management techniques used to minimize this possibility and its effects of acid sulphate soils. The general approaches for reclamation are suggested below:

1. ***Avoidance:*** Avoidance is the most cheap and easy way to tackle the acid sulphate soil. Acid sulphate soil when remain submerged and undisturbed they are inert. It should be considered in all the sites.
2. ***Minimisation of Disturbance:*** if cropping cannot be avoided in acid sulphate soil the three should be minimum of disturbance in the soil. Detailed investigation of acid sulphate soil is necessary for minimization of disturbance of soil. Once the characterization of the soil is done, strategies to minimize the disturbance can be investigated.
3. ***Neutralisation:*** Acid sulphate soil can be reclaimed through liming. Liming refers to physical incorporation of neutralising/alkaline materials into the soil to raise soil pH. Lime is alkaline in nature. It buffer the acids produce while raising the pH to desired levels. When right type and right amount of lime is added to acid sulphate soil, it can be reclaimed by neutralizing the soil acidity. Lime required can be reduce by leaching the soil in early stage of acidification.
4. ***Re-flooding:*** The objective of re-flooding is to neutralise actual acidity and reduce the pyrite oxidation rate. Conditions where the reduction of the Fe, Mn, S and N can take place is created in re-flooding. The reduction of these elements is responsible for the increase in pH commonly observed in acid soils after water logging. Re-flooding work as water table height-management tool to prevent the oxidation of PASS or further oxidation of ASS.
5. ***Seawater re-flooding:*** Ii is a simple and cheap method to improve the situation. Re-flooding the soil with seawater traps the existing acid leachate and force it deeper into the soil profile. It also limits the export of oxidation products and slow diffusion into the

tidally exchanged seawater.

6. ***Hydraulic separation:*** Hydraulic separation method is used in sandy soil that contains iron sulphides. Hydrocycloning or sluicing hydrolically seperates the sulphides from the sandy materials. This method can be used and found effective in soil having low organic matter and contain <10–20% clay and silt. Sulphide material separated in the process requires special management including neutralization and reburial.
7. ***Bioremediation:*** Reducing conditions are restabalized within the bunded area and pyrites are regenerated by sulphate reducing bacteria. This will reestablish the sulfide formation process that operate in the mangroves soils. Chemical changes occur in the water and soil, and in the sediment that may accumulate due to bioremediation. Bioremediation is a cost-effective and natural process.
8. ***Cover in-situ soils with clean fill:*** If groundwater levels are not affected by earthworks, undisturbed *in-situ* potential acid sulphate soil can be covered with a significant volume of clean fill. A minimum depth of fill cannot be specified for residential or commercial/industrial development. A suitable depth of fill should rather be determined on a site specific basis, dependent on the severity and extent of acid sulphate soil, as identified in the investigation. Once a site has been covered by clean fill, any associated infrastructure may be placed within the fill, thereby not disturbing any *in-situ* acid sulphate soil by excavation or dewatering.
9. ***Flooding and Intermittent drainage:*** To maintain saturated state to minimize acid sulphate soil, soils may be flooded (anaerobic) or buried in water. This solution limits the use of soil for rice cultivation. But in case drought occurs it causes soil acidification in short time period. Then the water used to flood the potential acid sulphate soil often developes acidity and injure the crop. Rice grown under intermittent drainage had healthier root systems, less empty grains, heavier weight per panicle. Continuous submergence of rice have shown strong bronzing symptoms but had more tillers.
10. ***Water table management:*** When a non-acidifying layer covers sulphuric horizon in acid sulphate soils, then drainage to keep only the sulphuric layer under water (anaerobic) is possible. By raising the water table, the soils can be restored, after damage has been inflicted due to over-intensive drainage.
11. ***Deep soil mixing:*** Deep soil mixing is carried out with a large diameter (one to three metres) hollow-flight auger. It also has special mixing '*paddles*' which mixes soil. As holes are drilled into the soft substrate lime or cement and a variety of binding agents are mixed with the soil slurry which form solid supportive columns in the soil after cementation.
12. ***Growing of suitable crops:*** Rice is highly acid tolerant and is preferred mostly. Growing rice crop in acid sulphate soils reduces the iron and aluminium toxicity and increases the pH of soil. For the cultivation of upland rice, peanut and soybean in acid sulphate soils, widely spaced subsurface drainage system have yielded promising results.

Conclusion:

It may be concluded that for improving soil health and sustaining livelihood, proper management and planning can reduce extent of acid sulphate soil, in order to meet the ever increasing demand of food, fiber, fuel and fodder. Government should also take some initiatives in this regard.

References:

Angeloni J, Peek A, Appleyard S, Wong S and Watkins R. (2004). Acid sulfate soils: distribution, impacts and regulation (A western perspective). *Corrosion &Prevetion*, 106:1-13.

Attanandana T and Vacharotayan S. (1986). Acid sulfate soils; their characteristics, genesis, amelioration and utilization. *Southeast Asian Studies*, 24: 154-180.

Bandopadhyay, A.K. (1989). Leaching of acid saline soils of Sunderbans. *Journal of the Indian Society of Soil Science*, 37: 416-17.

Brown AD and Jurinak JJ. (1989). Mechanism of pyrite oxidation in aqueous mixtures. *Journal of Environmental Quality*, 18: 545—550.

Chenery, E.M. (1954). Acid sulphate soils in central Afric. Trans. 5th International Congress Soil Science, Lepoldville.

Dent DL. (1986). Acid Sulphate Soils: a baseline for research and development. International Institute for Land Reclamation and Improvement Publication No. 39, Wageningen.

Ghosh S.K., Das D.K. and Deb D.L. (1976). Acid soils of India: their genesis characteristics and management, Bulletin – 11, *Indian Society of Soil Science*, New Delhi, 117:133.

Huang, Q., Tang, S., Huang, X., Zhang, F., Yi, Q., Li, P., & Fu, H. (2017). Influence of rice cultivation on the abundance and fractionation of Fe, Mn, Zn, Cu, and Al in acid sulfate paddy soils in the Pearl River Delta. *Chemical Geology*, *448*, 93-99

Kevie, W.V.D. (1973). Physiography, classifications and mapping of acid sulphate soils. Proceeding International Symposium on Acid Sulphate Soils, IIRL 18, I: 204-231, Managing Acid Sulphate Soil, department of Environment and Resource Management.

Manorama T.K.C., Cherian, S. and Iyer M.S. (1998). Influence of liming material on soil acidity characteristics of an acid sulphate soils. *Journal of the Indian Society of Soil Science*, 46(2): 296-299.

Mohsin M.A., Sarkar A.K. and Mahur B.S. (1995). Mineralogy of acid soils. Kalyani Publishers, New Delhi, pp.-69-81.

Mongia A.D. and Bandopadhyay A.K. (1993). Management of two acid sulphate soils for low land rice cultivation. *Journal of the Indian Society of Soil Science*, 41(2): 400-412.

Mongia A.D., Singh N.T., Mandal L.N. and Guha A. (1998). Effect of liming super phosphate and rock phosphate application to rice on yield and uptake of nutrients on acid sulphate soils. *Journal of the Indian Society of Soil Science,* 46 (1): 61-66.

Palko J. (1986). Mineral element content of timothy (*Phleum pratense* L.) in an acid sulphate soil area of Tupos village, northern Finland. *Acta Agric. Scand*., 36: 399-409.

Somani, L.L. (1994) Use of pyrite in agriculture. Agrotech Publishing Academy, Udaipur, pp 255.

Wallin, J., Karjalainen, A. K., Schultz, E., Järvistö, J., Leppänen, M., & Vuori, K. M. (2015). Weight-of-evidence approach in assessment of ecotoxicological risks of acid sulphate soils in the Baltic Sea river estuaries. *Science of the Total Environment*, *508*, 452-461.

FIG: A FRUIT FOR HEALTH

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Abstract:

Fig or anjeer as it is known in India is a small pear or bell shaped flowering plant that belongs to the mulberry family and scientifically termed as *Ficus carica*. It is the first grown tree in food history. It is one of the first fruits to be dried and preserved by humans. It is grown in many parts of the world with moderate climate. Figs are eaten dry and fresh both, as fresh figs are highly perishable, so fresh figs are consumed only in nearer market but dry figs are exported for long distance markets. Fresh and dry both fruits are rich in fibre, potassium, calcium, and iron. Fresh figs are highly sensitive to physical damage and susceptible to disease and infections. The plant has been used traditionally to treat various ailments such as gastric problems, inflammation, and cancer. Pre harvest and post-harvest conditions are very important to improve fruit quality and post-harvest life. Due to its nutritional quality, fresh fruit breeders are taking it as a challenge for development of new improved varieties for long shelf life of fresh fruits.

Keywords: *Ficus carica*, fig composition, miraculous properties

Introduction

Fig is botanically called *Ficus carica* (synonyms – forbidden fruit), it comes under family Moraceae. It is originated in the southern parts of Arabian Peninsula, Italy and USSR and its cultivation spread through Asia minor and into all countries of the Mediterranean region. It has 26 chromosomes and inflorescence hypanthodium with terminal bearing habit on current season growth. Fig fruit represents an important constituent of the diet, because of their nutritional and medicinal values (M. Flaishman 2008). This type of diet is consider one of the healthiest and is associated with longevity. Fruit is tasty and sweet with total soluble solids 17 °Brix with good processing quality for export use as a dry fruit. Fig is one of the oldest fruit crops, morphologically it is called as syconium which is a vegetative fleshy tissue, with tiny true fruits enclosed inside.

Table 1: Classification of Fig

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnolipsida
Order	Rosales
Family	Moraceae
Genus	Ficus
Species	Ficus carica

Fig is a gynodioecious species and some female types need pollination, while others set fruits parthenocarpically. Pollination is mostly performed by a wasp (*Blastophaga psence*). Fig is grown as a subtropical and temperate crop. It is one of the most salt and drought tolerant fruit tree.

Bearing of fruits in plants

Nutritional value

Fig is a highly nutritious fruit with high sugar and low acid content, rich in calories (269), protein and calcium (higher than milk), iron and highest fibre content among fruits. Fig fruits are often consumed as fresh, dried or canned. The nutritional index of dry fig is 11 as compared to 9 of apple, 8 of raisin and 6 of date and pear. The chemical composition and flavor of fig vary with the cultivar. Fresh and dehydrated figs both are rich in nutritional and biochemical content.

Table 2: Nutritional composition of Fig (Source: Akath *et al.*, 2015)

Protein	1.3 g
Fat (total lipids)	0.2 g
Carbohydrates	7.6 g
Calories (energy)	80 k Cal
Moisture	88.1 g
Fibre	2.2 g
Minerals	0.6 g
Thiamine	0.1 mg
Calcium	35 mg
Phosphorus	22 mg
Iron	0.6 mg
Vitamin A	80 IU
Vitamin C	2 mg

Uses

Fig fruits are consumed as fresh, preserved and dried or canned form. This is very much reputed as a dried fruit and is processed into jelly and paste. Latex is used to coagulate milk. The latex of the unripe fruits and of any part of the tree may be severely irritating to the skin if not removed promptly. Fig leaves are used for fodder in india. Fig fruit cake among all the bakery products are more signification and widely used snacks by children and adult (Dhankar, 2013). Therefore, attempts made for the formulation of fig fruit powder incorporated in cake at different variations. In southern France, there is some use of fig leaves as a source of perfume material called fig-leaf absolute. Dried latex powder use in coagulating milk to make cheese and junket. It can be isolated the protein-digesting enzyme ficin which is used for tenderizing meat, rendering fat, and clarifying beverages. In tropical America, the latex is often used for washing dishes pots and pans. The latex is widely applied on warts, skin ulcers and sores, and taken as a purgative and vermifuge but with considerable risk. In Latin America figs are much employed as folk remedies. A decoction of the fruits is gargled to relieve sore throat, figs boiled in milk are repeatedly packed against swollen gums. The fruits are much used as poultices on tumors and other abnormal growths. The leaf decoction is taken as a remedy for diabetes and calcifications in the kidneys and liver also. Fresh and dried figs have long been appreciated for their laxative action.

Table 3: Biochemical parameters in fresh and dehydrated fig

Biochemical parameters	**Fresh fig (Irfan *et al.* 2013)**	**Dehydrated fig (Naikwadi *et al*. 2010)**
Total soluble solids	17.43 %	35.0 %
Total sugar content	17.55 %	26.3 %
Reducing sugar	13.35 %	24.1 %
Non- Reducing sugar	5.70 %	2.2 %
Titratable acidity	0.35 %	0.09 %
Ascorbic acid	0.85 mg/ 100g	1 mg/ 100g

Plant description

Fig is moderate sized deciduous tree in subtropics but performs as evergreen in tropics. Branches are irregular, shoots develop at base of trunk, and leaves are very broad, ovate and long stalked. Fruits mostly long stalked, pear shaped with a velvety or glabrous skin, purplish or black in color. Fig is a multiple fruit, botanically a Syconium which consists of a hollow receptacle with a narrow aperture at the tip and numerous small tiny fruits lining in inner surface.

Varietal diversity of Fig

Nearly 700 varieties of fig have been listed in the world. Based on pollination pattern and sex of flower. Figs are classified into three types:1. Fruit green or yellow – Adriatic Kadota 2. Fruit shaded with bronze or copper colour – Brunswick 3. Fruit dark violet or purplish black - Pattridge eye, Poona fig is most popular cultivar grown in india. it is bell-shaped, medium size, weighing about 1.5 oz (42 g), thin-skinned, light-purple with red flesh of sweet good flavour. Some well-known fig hybrids from California have performed well in comparison to Poona fig under Bangalore conditions, they produce parthenocarpic fruits. In india Adriatic fig is commonly grown. Most common varieties grown are Black ischia, Brown Turkey, Turkish white, Kabul, Marseilles, Lucknow and Poona figs. A type of Adriatic fig of high quality introduced at Coimbatore and locally known as Coimbatore fig is reported to be highly superior than Poona fig. There are many cultivated varieties in each class of figs. In fact over 700 varietal names are in use but many are synonyms. Here we need only present those that are suited to warm areas and do not require pollination. Most popular among these are Celeste and brown Turkey followed by Brunswick and Marseilles but some hybrids from California have reportedly performed better over Poona Fig.

Harvesting indices

Fresh figs should be harvested when they are soft, slightly wilted at the neck and drop, no milky latex flow at the cut end of the stalk, sudden increase in fruit size and opening of ostiole. Figs are handpicked from the trees by twisting the neck at the stem end. Harvested fruits are spread out in the shade for a day so that the latex will dry a little. In india a fig tree bears 180 to 360 fruits per year.

Grading

After picking figs are carefully stored. Diseased and damaged ones are culled. Fruits are graded for size as 50 g, 40-50 g and 30-40 g.

Packing

Fig fruits packing should be done in a corrugated box (CFB) carton of 3 ply having 12 holes for ventilation and arrange in thearton in 2 layers each of 28(4 rows of 7 figs in a line). Fig leaves are used for cushioning material.

Storage

Fresh figs are very perishable so storage needs very much care and fresh fruits can be stored at 40° to 43°F (4.44°-6.11°C) and 75% relative humidity. Figs remain in good condition for 8 days but have a shelf life of only 1 to 2 days when removed from storage. At 50°F (10°C) and relative humidity of 85% than figs can be kept no longer than 21 days and fruits remain in good condition for 30 days when stored at 32° to 35°F (0°-1.67°C). If frozen whole they can be maintained for several months.

Conclusion

As discussed above, fig is very nutritious and delicious in taste as fresh and processed both but needs cultivation of some improved varieties for longer shelf life like Poona and Black ischia figs. Some improved technology like modified atmospheric storage, cold storage and controlled atmospheric storage conditions are required for increasing shelf life of fresh fruits.

Reference;

Akath, S., Jai, P., Meghwal, P.R., Ranpise, S.A. (2015). Breeding of underutilized fruit crops part I, Edition: I, Chapter: 12, Publiser: Jaya publishing House New Delhi, Editors: SN Ghosh, pp. 149-179.

Dhankar, P.A. (2013). Study on development of coconut based gluten free cookies. *International Journal of Engineering Science Invention*, (2): pp. 10-19.

Flaishman, M., Rodov, V. and Stover, E. (2008). The fig: botany, horticulture and breeding in horticultural Reviews, vol. 34, pp. 113–197.

Irfan, P.K., Vanjakshi, V., Keshava Prakash, M. N., Ravi, R. and Kudachikar, V.B. (2013). Calcium chloride extends the keeping quality of fig fruit (*Ficus carica* L.) during storage and shelf life, vol. 82, pp. 70-75.

Naikwadi, P.M., Chavan, U.D., Pawar, V.D. and Ryszard amarowicz. (2010). Studies on dehydration of figs using different sugar syrup treatments. Journal of Food Science and Technology, 47(4): pp. 442-445.

DRONE: IT'S IMPORTANCE IN INDIAN AGRICULTURE

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Abstract:

Drones additionally known as Unmanned Aerial motors (UAV) have witnessed an extraordinary improvement in latest a long time. In agriculture, they have got changed farming practices via imparting farmer's substantial fee savings, extended operational performance and higher profitability. Over the past decades, the subject of agricultural drones has attracted tremendous instructional interest. Agriculture represents the primary meals source of the arena (Friha *et al*. 2021) and it has been dealing with excessive demanding situations due to the increasing call for meals products, meals safety, and protection issues in addition to requires environmental safety, water uptake and sustainability (Inoue 2020). Irrespective of Indian agriculture's contribution to the GDP, our country is yet to enhance productivity and efficiency in the area to reach the highest ability. Several dimensions and worries require to be diagnosed, supported, and geared up with resolutions. Unsuitable techniques for tracking plants, water irrigation, using pesticides and many different necessary farming sports are presently followed. Resources are insufficient, now not allotted in keeping with climate conditions or have now not been exploited to their maximum capability-a cause why there is usually a decline in the return on investment (ROI).

Why Undertake Agricultural Drones?

Drone technology has gotten maximum of the popularity within the industry due to its diversity and considered the destiny for the agrarian community. The army to begin with used them. Drones don't simply beautify ordinary performance however also inspire farmers to remedy different assorted limitations and get hold of lots of benefits through precision agriculture. Agricultural drones accomplishing fill up the gap of human error and inefficiency through traditional farming techniques. The purpose of adopting drone generation is to do away with any guesswork or ambiguity and as a substitute consciousness on correct and reliable data.

Outside elements like climate, soil conditions, and temperature play a crucial position in farming. Agriculture drone empowers the farmer to evolve to particular environments and make attentive choices for that reason. The won statistics allows adjust crop health, crop remedy, crop scouting and irrigation and perform area soil evaluation and crop damage tests. The drone survey helps raise crop yields and limit time and charges.

How Does Drone Generation Work?

Simplest after entire reputation of drones characteristics can benefit in-intensity knowledge about agriculture drones. Typically, drones consist of a navigation system, GPS, more than one sensors, cameras, programmable controllers, and tools for self-reliant drones. Most farmers currently use satellite imagery as an introductory manual for farm control. Furnished with modern-day technology, unmanned aerial cars (UAVs) can get extra precise facts than satellites for precision agriculture. They then procedure the records captured into agri-tech software program to produce beneficial expertise, taking pictures facts from agriculture drone takes area as inside the following tiers:

Reading the location: This identifies the territory being tested. Therefore, the first step consists of establishing a boundary, analyses of the place, and then finally, importing the technical GPS data into the drone's navigation machine.

The usage of self-sustaining Drones: In view that unmanned aerial motors (UAVs) are unbiased, they input flight patterns into their already installed machine to collect required information.

Importing the information: After capturing all the required data through sensors consisting of the multispectral sensor/RGB sensor and it became processed through numerous software for addition analysis and interpretation.

Output: After gathering the records, they format it so that farmers can recognize the information and not using a trouble, bringing them a step towards precision farming. 3-D mapping or Photogrammetry are popular techniques to show enormous facts accumulated.

Assessment of the agricultural enterprise in India

The provider zone is asserted to be the best sized contributor to India's GDP. Our united states in the world because the maximum distinguished producer of pulses, milk, rice, wheat, sugarcane, spices, and so on. These additionally upload beneficent fee to the financial system with their activities within the agrarian quarter. The Indian agricultural area contributes a tremendous 18% to India's GDP (Gross domestic Product). It is considered the top source of livelihood for about 58 % of the United States's population, specifically for rural regions. Indian agriculture area, alongside forestry and fishing, effects in a gross delivered value of round Rs 18.55 lakh crores as of 2019. The agricultural region expands with parallel industries at a growth rate of 2.1% (2019-20).

Drone Operations in Indian Agriculture:

In India, currently, drones are being encouraged normally as an automatic spray device that can be tasked with pesticide and so forth. Spraying over vegetation to reduce health risks related to manual spraying and store time, assets and human labour. The Indian Agriculture Ministry estimates that the service of a drone that has the capability to carry a 10 kg payload will cost Rs 350-450 per acre. The calculation is based totally on the idea that a drone ready with multiple batteries will be utilised for at least six hours an afternoon, overlaying approximately 30 acres of farmland. Those have been taken from an facts sharing webinar conducted by using the agency Iffco Kisan in which an professional, Dr. Shankar Goenka shared the information of drone operations from their reports in rolling out drones income in addition to spray services (on lease/acre spray foundation). According to Dr. Goenka, uniform depth/unfold of spray is performed through drones even for vegetation with higher heights like sugarcane, mango orchards and so on. Discount in enter prices of spray gadgets (pesticides/weedicides) is anticipated at around 25-30% due to computerized processes. Citing an example of nano urea right here, considering a value of Rs.240/bottle for spray on an acre, if financial savings are 25%, then input price is decreased to that volume for the farmer. Consequently round eighty-ninety%

reduction in water is likewise achieved due to tiny droplet sizes of approx. 50 microns as against manual spray droplet length of approximately 500 microns. Drone sprays keep time as 1 spray takes round 5-7 minutes/ acre whereas manually typically someone can cover best three-four acres in an afternoon. Amongst different capabilities of drones, a 10 Litre capacity drone has a tank capability of 11 litres.

Hence it can load 10 litres of water and 1 litre of spray object (weedicide/pesticide/germicide/fungicide) and so forth. Standalone drone weight is 12-13 kg and absolutely loaded 10 litre potential drone can hence fly with a weight of upto 25-27 kg. The drone has a flying variety of five km however it is freezed at 500m and it can fly to a top of 120 feet however it has been freezed through producers to 30 feet height to take care of security issues. Going ahead, innovators are looking to equip drones to be additionally capable of spray pellets, powdery depend and even seeds additionally. The camera within the drone permits it to seize pix and the obstacle radar inside the drone allows it to manoeuvre any limitations like wires, poles and many others that can seem inside the drone flight route. Automated top adjustment through terrain radar permits the drone to modify its spraying top as in line with the height of the plant and terrain etc., go with the flow meter inside the drone guarantees an automated return to the launch factor in case battery/spray liquid/water is exhausted. Night vision light is also available to allow spray at night time. Krishi Viman drone Made in India from the factor of view of farmer protection and fitness issues thanks to spraying and different activities in the area, drones provide an excellent answer around 58000 farmer deaths are suggested due to snake bite in India. Around 0.3 million farmers be afflicted by breathing diseases due to spraying pesticides and so on. Drones provide a potential to mitigate those sufferings of farmers significantly due to the fact farmer doesn’t must task extensively internal vegetation for spray functions.

Great drone practices

Drone technology speedy reestablishes traditional agrarian practices and is subsequently accomplishing them as follows; Irrigation monitoring, crop fitness, crop harm assessment, discipline soil evaluation, precision agriculture, faraway sensing, synthetic intelligence (Dutta and goswami 2020)

Irrigation tracking

Drones consisting of hyper spectral, thermal or multispectral sensors, recognize areas which might be too dry or need development by using the farmer. Drone survey allows improve water performance and disclose potential pooling/leaks in irrigation by using supplying irrigation tracking yields calculations of the flowers index to assist comprehend the health of crops and emitted heat/energy.

Crop health tracking and Surveillance

It's far crucial to track the health of the plants and see bacterial/fungal plagues in the early tiers. Agriculture drones can see which vegetation reflect distinctive amounts of inexperienced green light and near-infrared spectroscopy (NIRS) mild light. This information enables produce multispectral pics to save crop fitness. Short monitoring and discoveries of any defects can assist

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to save crops. In circumstances of crop failure, the farmer can also fill the damages for accurate coverage claims.

Water strain monitoring

The characterization of water strain on vegetation is a complex mission because the results of drought have an effect on (and can be laid low with) several factors (Espinoza *et al.* 2017). Variables derived from thermal snap shots frequently depend on very slight temperature variations to hit upon stresses and other phenomena. As a end result, thresholds and regression equations derived underneath certain situations generally do no longer preserve under even barely extraordinary instances. As an example, one-of-a-kind genotypes of a given crop may also gift extensively one of a kind canopy temperatures under the same situations because of inherent differences in stomata conductance and transpiration charges (Berni *et al.* 2009, Gonzalez-dung *et al.* 2013, Park *et al.* 2017).

Crop harm evaluation

Agricultural drones geared up at the side of multispectral sensors and RGB sensors also come across field areas inflicted via weeds, infections, and pests. In line with this statistics, the exact quantities of chemical compounds needed to combat those infestations are known, and this enables decrease the prices inflicted via the farmer.

Nutrient status and deficiency tracking

Plants need the proper stages of nutrients that allows you to thrive and bring a strong yield. The appropriate ranges of nitrogen will make sure robust boom of plant life and foliage, suitable ranges of phosphorous are required for robust root and stem growth and suitable degrees of potassium are essential for improving of the resistance to sickness and additionally to make sure a higher quality of crop. If soil lacks any of these nutrients, the plant becomes confused and could war to thrive. Greater correct evaluations require laboratorial leaf analyses, which might be time ingesting and require the utility of particular techniques for a correct interpretation of the information. There are some indirect alternatives to be had for a few vitamins, along with the chlorophyll meter (Soil-plant analyses improvement (SPAD) for nitrogen predictions, but this is a time consuming technique and the estimates aren't constantly accurate. Consequently, considerable effort has been devoted to the development of new strategies for the detection and estimation of nutritional troubles in plants.

Field soil analysis

The drone survey lets in farmers to achieve records about their land's soil situations. Multispectral sensors allow seizing facts beneficial for seed planting styles, thorough subject soil evaluation, irrigation, and nitrogen-level management. Unique Photogrammetry/ 3D mapping permit farmers to research their soil situations thoroughly.

Diseases tracking

Crop sicknesses may be devastating and labeled as fungal, bacterial or viral. Drones equipped with Infrared cameras can see inside plants (Klemas 2015), giving a clear photo of the condition thereof. If a farmer can come across an infection before it spreads, preventative measures may be taken - like doing away with the plant - before the infection spreads to neighbour plant life. Image-primarily based equipment can hence play an vital function in detecting and recognizing plant illnesses when human evaluation is fallacious, unreliable or unavailable (Altas *et al*. 2018, Dang *et al.* 2018) specifically with the prolonged insurance furnished by way of UAVs. RGB and multispectral pics were preferred techniques for acquiring facts about the studied areas however hyper spectral and thermal photos have additionally been examined. The latter is hired in the main to hit upon water strain signs probably due to the targeted disorder (dash *et al*. 2018).

Weed control

Weeds aren't desirable plants which develop in agricultural plants and might cause numerous issues. They're competing for available sources including water or maybe area causing losses to crop yields and in their boom. Yield losses due to weed in India; Rice (10-100%), Wheat (10-60%), Maize (30- 40%), Sugarcane (25-50%), vegetables (30-40%), Jute (30-70%), Potato (20-30%) and many others. The use of herbicides is the dominant choice for weed manage. In conventional farming, farmers uprooted weeds after publish emergence and the maximum common exercise of weed management is to spray the identical amounts of herbicides over the whole area even within the weed-free regions. However, the overuse of herbicides can result in the evolution of herbicide-resistant weeds and it may have an effect on the increase and yield of the vegetation. The usage of hyper spectral pix to discriminate between the spectral signatures of some weeds with unique resistances to glyphosate (Li L. *et al.* 2016), using RGB sensors to categorise numerous weed species (Huang *et al.* 2018). Researchers used drone with hyper spectral sensors to screen weed as a feature of the plant canopy chlorophyll content and leaf density (Malenovsky *et al.* 2017). Similarly, it poses a heavy pollutants hazard to the environment, to conquer the above issues website online precise weed management is used to reap this aim, it's miles necessary to generate an correct weed cover map for precise spraying of herbicide. Drone can collect photos and derive records from the complete discipline that can be used to generate a unique weed cover map depicting the spots wherein the chemical compounds are needed.

Planting

Drone startups in India have invented drone-planting systems that allow drones to shoot pods, their seeds, and critical nutrients into the soil. This technology does not only reduce fees by using almost 85% but also increases consistency and efficiency.

Drone for Evapotranspiration (ET) estimation

Evapotranspiration (ET) is an essential process with the aid of which water is transferred from the land to the atmosphere with the aid of evaporation from the soil and by means of transpiration from living plants. Estimates of ability ET are utilized by experts inside the fields of hydrology, agriculture, and water management. Estimating evapotranspiration has been one of the most crucial researches in agriculture these days because of water scarcity, developing population, and weather trade. Many styles of unmanned aerial vehicles are used on exclusive studies functions for ET estimation. Commonly, there are 3 one of a kind UAV structures, aircraft, fixed-wings, and quad copter. Plane is normally pricey, however it may fly longer and bring heavy sensors. As compared with plane, constant-wings and quadcopter are less luxurious. Fixed-wings can generally fly approximately 2 hours that is suitable for a huge scale of discipline. Quadcopter can fly approximately half-hour that is used for short flight task in a small scale of discipline, getting used as a far flung sensing platform, UAVs also arouse new research troubles, along with drone image processing, and flight course making plans. A fixed-wing UAV to accumulate thermal facts to estimate ET with two supply strength balance models.

Insecticides spraying

Through, drone crop spraying, human contact with such dangerous chemicals is limited. Agri-drones can carry out this challenge a great deal faster than motors/airplanes. Drones with RGB sensors and multispectral sensors can precisely perceive and deal with difficult regions. Specialists say that aerial spraying is 5 instances faster with drones when in comparison to different techniques.

Farm animals tracking

The drone survey allows the farmers now not to keep track in their crops handiest but additionally reveal the movements of their livestock. Thermal sensor era enables locate lost animals and discover a damage or sickness. Drones can carry out this feature favorably, and this adds comprehensively to the manufacturing of flowers.

Blessings of drone generation

As innovators introduce new technology, their commercial uses boom day by day. The government has been easing restrictions for drone usage and is supporting startups to provide you with novel ideas. As drone surveys become greater common place, additionally they turn out to be extra cost-effective. In agriculture, they have a plethora of blessings. A few are as follows:

Better production - The farmer can enhance production abilities through complete irrigation planning, good enough monitoring of crop health, multiplied information approximately soil fitness, and adaptation to environmental changes.

Effective and Adaptive techniques - Drone usage outcomes in regular updates to farmers about their plants and allows increase bolstered farming techniques. They are able to adapt to weather situations and allocate assets with none wastage.

Extra protection of farmers - It's far more secure and greater handy for farmers to use drones to spray insecticides in terrains challenging to attain, inflamed areas, taller plants, and strength traces. It additionally facilitates farmers save you spraying the vegetation, which leads too much less pollutants and chemical compounds in the soil.

10x quicker information for quick choice-making - Drone surveys back farmers with correct information processing that encourages them to make short and conscious choices without second-guessing, allowing farmers to store the time invested in crop scouting. Diverse sensors of the drone permit shooting and studying information from the complete discipline. The statistics can cognizance on complicated areas consisting of inflamed crops/bad vegetation, unique colored plants, moisture tiers, etc. The drone can be fixed with numerous sensors for other vegetation, allowing a extra accurate and numerous crop management machine.

Less wastage of assets - Agri-drones enables finest usage of all assets such as fertilizer, water, seeds, and insecticides.

99% Accuracy rate - The drone survey enables farmers calculate the correct land size, segment the numerous crops, and bask in soil mapping.

Useful for insurance claims - Farmers use the statistics captured thru drones to assert crop coverage in case of any damages. They even calculate dangers/losses related to the land while being insured.

Proof for coverage corporations - Agricultural coverage sectors use Agri-drones for green and sincere facts. They capture the damages that have took place for the proper estimation of financial payback to the farmers.

Locust swarm - Locust swarms are recognised to feed on crops, timber, and other kinds of vegetation. This feeding can ruin plants planted, causing famine and deprivation in societies that solely depend upon these crops for survival. These days, swarms of locusts have invaded several regions in India, mainly Rajasthan. With nearly 90,000 Hectares of land affected throughout 20 districts, these developing swarms are threatening to enlarge into an agrarian disaster.

Maximum international locations combating locust swarms depend drastically on organophosphate chemical compounds. These are utilized in little concentrated plenty by means of vehicle-installed and aerial sprayers. Rajasthan has stationed drones to carry out the spraying successfully. Drones can diffuse insecticides on about 2.5-acres in merely 15 mins. The usage of drones to combat the locust swarms is an instantaneous, cozy, and practical technique.

Latest government initiatives that guide/facilitate drone use in Agriculture:

The government of India to make drones low cost to the farmers and numerous stakeholders and sell drone use has introduced a number of subsidies on the purchase of drones. For promoting using Kisan Drones, the Indian Agriculture Ministry is offering 50% or most INR 0.5 million subsidy to SC-ST, small and marginal, ladies and farmers of north-jap states to buy drones. Farmer's producers businesses (FPOs) are furnished grants @ 75% for purchase of drones for its demonstration at the farmers' fields. Economic help of 40% of general price of drone upto Rs. 0.4 million is supplied for drone purchase by means of present and new custom Hiring Centres (CHCs) beneath Cooperative Society of Farmers, Farmers producer businesses (FPOs) and rural marketers. Moreover, agriculture graduates setting up CHCs are eligible to get hold of financial assistance @ 50% of the value of drone up to a maximum Rs. 0.5 million. Therefore, with these subsidies in vicinity drones are unfastened for agri-education and studies institutes. Also, enforcing businesses are eligible for subsidies in keeping with hectare in the event that they lease drones for demonstrations in place of shopping for them. Elaborating at the various authorities regulations related to drones and capacity benefits for Indian farmers, the Civil Aviation ministry indexed the subsequent steps that have been taken by way of the government in the direction of facilitating and easing the coverage round drones. (Press quick, Ministry of Civil Aviation, might also 17, 2022 Press statistics Bureau, executive of India (PRID=1826135)

1. Liberal Drone rules, 2021 have been issued by way of the Ministry in August, 2021.
2. Drone Airspace Map, starting up almost ninety% of Indian airspace as a inexperienced sector for drone flying as much as four hundred ft, has been published in September 2021.
3. Production-connected Incentive (PLI) scheme for drones is in force from 30th September 2021.

4. United states of America site visitor's control (UTM) coverage Framework changed into published in October 2021.
5. The federal Agriculture Ministry announced financial furnish program for purchase of agricultural drones in January 2022.
6. Starting 26, January 2022, all five software forms underneath the Drone guidelines, 2021 were made online at the Digital Sky platform
7. Drone certification scheme turned into notified in January 2022, making it easier to obtain type certificates by way of drone producers.
8. Task 'Drone Shakti' has been announced for helping drone startups and selling Droneas-a-service (DrAAS) as part of the Union finances on 1st February 2022.
9. Import of overseas drones has been banned and import of drone components has been freed up through the drone import policy that turned into notified in February 2022.
10. The drone regulations were further amended in February, 2022 to get rid of the requirement of a drone pilot licence. The remote pilot certificates issued via a DGCA-authorized drone school is now ok for operating drones.

Conclusion:

Drones have wonderful ability to convert Indian agriculture. With the development of technology within the future, the manufacturing of drones is anticipated to become not pricey. The modern youngsters aren't attracted closer to farming because of hard work and drudgery worried in it. The implication of drones might also fascinate and inspire the youth toward agriculture. Drones provide actual time and excessive great aerial imagery compared to satellite imagery over agricultural regions. Additionally, programs for localizing weeds and sicknesses, figuring out soil houses, detecting vegetation variations and the production of a correct elevation fashions are presently possible with the assist of drones. Drones will permit farmers to recognise greater approximately their fields. Consequently, farmers can be assisted with producing greater meals while using fewer chemical substances. Nearly all farmers who have made use of drones have accomplished a few shape of benefit. They can make extra green use in their land, exterminate pests earlier than they spoil entire crops, and modify the soil first-rate to improve increase in trouble areas, enhance irrigation to plants stricken by heat stress and song fires earlier than they get out of control. Therefore, drones might also grow to be component and parcel of agriculture in the destiny by using assisting farmers in managing their fields and assets in a higher and sustainable manner.

References:

Altas Z, Ozguven MM, Yanar Y. Determination of Sugar Beet Leaf Spot Disease Level (*Cercospora Beticola*) with Image Processing Technique By Using Drone. *Curr. Investig. Agric. Curr. Res.* 2018; 5:621-631.

Berni JAJ, Zarco-Tejada PJ, Suarez L, Fereres E. Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring From An Unmanned Aerial Vehicle. IEEE Trans. *Geosci. Remote Sens*. 2009; 47:722-738.

Dang LM, Hassan SI, Suhyeon I, Sangaiah AK, Mehmood I, Rho S et al. UAV Based Wilt Detection System Via Convolutional Neural Networks. Sustain. Comput. Inform. *Syst*., 2018.

Dash JP, Pearse GD, Watt MS. UAV Multispectral Imagery Can Complement Satellite Data for Monitoring forest Health. *Remote Sens*. 2018; 10:1216.

Dutta, G. and Goswami, P. 2020. Application of drone in agriculture: a review. *International Journal of Chemical Studies* 8(5):181-187

Espinoza CZ, Khot LR, Sankaran S, Jacoby PW. High Resolution Multispectral and Thermal Remote SensingBased Water Stress assessment In Subsurface Irrigated Grapevines. *Remote Sens*. 2017; 9:961.

Friha, O., Ferrag, M.A., Shu, L., Maglaras, L.A., Wang, X., 2021. Internet of things for the future of smart agriculture: a comprehensive survey of emerging technologies. IEEE CAA J. *Autom. Sinica*., 8 (4), 718–752.

GhardeYogita, Singh PK. “Yield and Economic losses due to weeds in India”, ICAR-DWR, Jabalpur.

Gonzalez-Dugo V, Zarco-Tejada P, Nicolás E, Nortes PA, Alarcón JJ, Intrigliolo DS et al. Using High Resolution UAV Thermal Imagery to assess The Variability In The Water Status of Five Fruit Tree Species within A Commercial Orchard. Precis. *Agric*., 2013; 14:660-678.

Huang Y, Reddy KN, Fletcher RS, Pennington D. UAV Low-Altitude Remote Sensing for Precision Weed Management. *Weed Technol.*, 2018; 32:2–6.

Inoue, Y., 2020. Satellite- and drone-based remote sensing of crops and soils for smart farming–a review. Soil Sci. *Plant Nutr*., 66 (6), 798–810. https://doi.org/10.1080/ 00380768.2020.1738899.

Klemas VV. Coastal and environmental remote sensing from unmanned aerial vehicles: An overview. *Journal of Coastal Research*, 31.5, 2015, 1260-1267p.

Li L, Fan Y, Huang X, Tian L. Real-time UAV Weed Scout for Selective Weed Control by Adaptive Robust Control and Machine Learning Algorithm. In Proceedings of the 2016 American Society of Agricultural and Biological Engineers Annual International Meeting, as ABE 2016, Orlando, FL, USA, 17–20 July 2016; *American Society of Agricultural and Biological Engineers*: St. Joseph, MO, USA, 2016.

Malenovsky Z, Lucieer A, King DH, Turnbull JD, Robinson SA. Unmanned Aircraft System Advances Health Mapping of Fragile Polar Vegetation. Methods Ecol. Evol. 2017; 8:1842-1857

Park S, Ryu D, Fuentes S, Chung H, Hernández-Montes E, O’Connell M. Adaptive Estimation of CropWater Stress in Nectarine and Peach Orchards Using High-resolution Imagery From An Unmanned Aerial Vehicle (UAV). *Remote Sens*. 2017; 9:828.

Press Brief, Ministry of Civil Aviation, May 17, 2022 Press Information Bureau, Govt. of India https://pib.gov.in/PressReleseDetail.aspx?PRID=1826135

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IRRIGATION WATER QUALITY STANDARDS

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Abstract:

In the present study, the quality of water for the purpose of irrigation is important. Prior to use, the available water quality must be checked to ensure its suitability. Irrigation water, whether diverted from streams or pumped to wells, contains significant amounts of harmful chemicals in the solution, which can reduce agricultural productivity and damage soil fertility. In addition to crop production and the characteristics of the soil, the level of irrigation water can affect fertility requirements, irrigation system efficiency and durability, and the way water is used. Therefore, knowledge of irrigation water quality is important in understanding what management changes are needed in long-term production. Poor irrigation water can cause soil problems such as salt, moisture, alkalinity, toxicity, and water infiltration. The chapter on water quality irrigation is intended to include basic concepts such as water quality parameters, conditions, and standards for defining irrigation water quality. The information provided will help each student, including farmers, engineers, and agricultural professionals, to better manage their soil and water resources to be more productive.

Introduction:

The usefulness of water for a particular use, or how well it meets the needs of the user, is determined by its quality. Regarding all other hydrological features, water quality refers to the physical, chemical, and biological characteristics of water. For example, the river water having good quality with sediment load can be applied for irrigation successfully but may be objectionable for municipal use without treatment. Similarly, snowmelt water is acceptable for municipal purpose and may not be applicable for industrial due to its corrosion potential. The characteristics of the water quality have become important in water resources planning and development for drinking, industrial and irrigation purposes (Shakoor, 2015). Water quality is judge the fitness of water for its proposed application for existing conditions. The most effective development and management of water for its effective applications require the most recent information, which the water quality monitor provides. (Haydar *et al.*, 2009). Water scarcity is seen as a major constraint to intensifying agriculture sustainably as an attempt to meet the food requirements of a rapidly growing human population. The increasing human population, climate change due to increased emissions of greenhouse gases (GHGs) and intensification of agriculture are putting and thus passes a big challenge to produce sufficient food to meet the current food demand. In arid and semi-arid regions, the major constraints to agriculture are scarcity of water and poor-quality irrigation water. Over exploitation of groundwater for domestic and agricultural purposes are depleting good-quality water resources in arid and semiarid areas. Population of India is predicted to grow to 1.73 billion people by 2050 (Meena *et al.,* 2021). Majority of population in developing countries already faces food shortage. A 70 per cent increase in current agricultural productivity will be required to produce sufficient food if these human population growth predictions prove to be correct. In this context, concerted efforts are being made globally to enhance the effectiveness of water which will be utilized to increase the production of irrigated crops. Additionally, improvements are also being made to rain-fed agriculture's water harvesting and water conservation practices. The injudicious use of salty or brackish water leads to the development of soil salinity, sodicity, ion toxicity and groundwater contamination. Due to these negative repercussions, it is crucial to comprehend precisely how water quality affects the management of irrigated agriculture, particularly in arid and semi-arid locations. In irrigation waters, salinity, sodicity and ion toxicity are key issues. When rainfall in dry regions is insufficient to effectively remove salts from the soil, salt will build up in the root zone of the crop. To track any change in salt concentration, frequent monitoring of soils and waterways is necessary. Sodicity, or an overabundance of salt, can deteriorate the soil's structure and limit the amount of water that can enter and pass through it. Toxicology describes the critical concentration at which certain salts, including as chloride, boron, sodium, and several trace elements, negatively influence plant development. Several aspects of irrigation water quality and standards for judging water quality are covered in this chapter. It will also cover management concerns and how different irrigation water quality affects soil reactions. An extract from an older irrigation water quality manual was updated and improved using the information provided in this chapter. (Shahid, 2004).

The evaluation of quality water resulted to find out the causes and effect relationship among water constituents and level of acceptability. With enough reported experiences and measurable reactions, certain components become indications of quality-related issues (FAO, 2013). The significance concerns in terms of water quality and quantity are due to its insufficient distribution of fresh usable water on Earth's surface and the rapid declining of fresh useable water (Irfan *et al.,* 2014). The major contamination in water included organic matter, nutrients, suspended solids, heavy metals, pesticides and industrial chemicals. The anthropogenic activities within river basins, erosion, and atmospheric depositions were also the main negative impacts on the water quality most of the reservoirs (Haydar *et al.,* 2009). A significant aspect in determining the water quality is the salinity of the soil. The development of soil salinity occurs when water flow in the soil, often due to irrigation, causes the soil to become increasingly salty. Water quality is critical for the survival of humans, animals, industry and agriculture. Furthermore, the proper management is requisite to meet water quality standards and for ecosystem health. The agriculture success is highly dependable on the quality of water applied in an agriculture area. This necessitates the use of saline/alkali water in agriculture. Salinity, sodicity and ion toxicity are major problems in irrigation waters particularly in arid areas where rainfall does not adequately leach salts from the soil and accumulation of salts occurs in the root zone of crops.

The presence of excesses Na ion on clay complex results in the deterioration of soil structure, thereby reducing water penetration into and through the soil under sodic conditions. Poor-quality water surveys in arid and semi-arid regions of India reveal that they account for 32-84 per cent of the total ground water developments (Sharma and Minhas 2003). Estimates suggest that out of present ground water development of 13.5 million ha-m /year, poor quality ground waters account for about 3.2 million ha-m /year (Anonymous 1994). The agriculture land and soil are impacted and the crop production is harmed in a number of ways as a result of the application of water that is of poor or dangerous quality. Salt buildup in the root zone reduced water availability and reduced plant water uptake, resulting in significant plant stress and lower agricultural yields (Shakoor, 2015). Crop yield is negatively impacted by the presence of metals in irrigation water. Additionally, high salt concentrations can alter the balance of soil nutrients for plants, while certain salts are harmful to specific plants. (Shakoor *et al.,* 2015; Irfan *et al.,* 2014).

Quality of Irrigation water

The concentration and composition of soluble salts in water will determine its quality for various purposes (human and livestock drinking, irrigation of crops, etc.). The quality of water is, thus, an important component with regard to sustainable use of water for irrigated agriculture, especially when salinity development is expected to be a problem in an irrigated agricultural area.

There are four basic criteria for evaluating water quality for irrigation purposes:

- Total content of soluble salts (salinity hazard)
- Relative proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions – sodium adsorption ratio (sodium hazard)
- Residual sodium carbonates (RSC) – bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) anions concentration, as it relates to Ca^{2+} plus Mg^{2+} ions.
- Excessive concentrations of elements that cause an ionic imbalance in plants or plant toxicity

In order to achieve the first three important criteria, the following characteristics need to be determined in the irrigation waters: electrical conductivity (EC), soluble anions (HCO_3^-, CO_3^{2-} Cl^- and SO_4^{2-} where Cl^- and SO_4^{2-} are optional and soluble cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) where K is optional. Finally, boron level must also be measured. The pH of the irrigation water is not an acceptable criterion of water quality because the water pH tends to be buffered by the soil, and most crops can tolerate a wide pH range. A detailed description of the techniques commonly employed for the analysis of irrigation water is available (USSL Staff 1954; Bresler *et al*. 1982).

Furthermore, it should be noted that while most common plants can withstand a wide range of salt, pasture plants are not very salt-tolerant and would eventually perish under saltwater circumstances. Salinity, which causes soil loss through surface soil compaction and erosion, also affects soil's physical and chemical characteristics and chemical characteristics of soil. Salinity also dehydrates soil fungus and bacteria, which lowers the health of the soil. These bacteria are beneficial for the synthesis of organic materials and the recycling of nutrients. The quality of irrigation water is determined by a number of factors, including Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Residual Sodium Carbonate (RSC). (Shakoor *et al.*, 2015).

Water Quality Indices

The following list of water quality metrics and indices describes the water's quality

pH of water:

The pH of water is determined by the amount of hydrogen (H^+) and hydroxyl (OH^-) ions present. It is employed to identify if the behaviour of water is acidic, basic, or neutral. The pH scale spans from 1 to 14, therefore water that has a pH of less than 7 is considered acidic, whereas water with a pH of 7 or over is considered basic by nature. The pH of the soil and water cannot adversely affect plant development (Tahir *et al.*, 2003). Efficiency of the coagulation and flocculation processes is significantly impacted by pH (Kahlown *et al.*, 2006).

Electrical Conductivity (EC)

The ability of water to transport electric current is known as its electrical conductivity (EC). It depends on the charge and mobility of the dissolved ions in the water. Water dissolves mineral salts in the form of ions because it is an excellent solvent, and ions hold the electric current owing to ionic conduction. When the EC of water is high, it indicates that the ions are concentrated in the water at high levels. The EC measures the total amount of solids in water and is temperature-dependent. Water's electrical conductivity has an impact on plant development as well. The reference standard for EC at 25^oC temperature.

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) are an indicator of the salinity behaviour of water. TDS includes cations (+ve changes ions) and anions (negatively changing ions). Total dissolved solids alter the characteristics and colour of water. Total dissolved solids and EC have the following relationship:

TDS (mg/L) = EC (dS/m) × K (1)

Where, K = 640 in most cases (for EC: 0.5 -5 dS/m) or

K = 735 for mixed waters or

K = 800 for EC > 5 dS/m

According to Kahlown and Khan (2002), the aforementioned relationship is often used for EC values between 0.5 and 5 dS/m and is not relevant to wastewater. TDS is a measurement of the quantity of substances dissolved in water, such as sodium, calcium, magnesium, phosphate, sulphate, bicarbonate, and organic ions. The flow of water into and out of an organism's cells was governed by the density of the water, which might be hazardous owing to a rise in TDS concentrations. High TDS levels may also result in decreased water clarity, a reduction in photosynthesis, the combining of hazardous substances and heavy metals, and an increase in water temperature. The taste was flat and insipid, and the exceedingly low TDS level was unsatisfactory. (Kahlown *et al.*, 2006).

Total Suspended Solids (TSS) :

Total suspended solids (TSS) are the fine particles suspended in water that include microbes, algae, minerals, and organic stuff. Total suspended solids are a sign of erosion and sediment movement, and since they absorb solar heat, they raise the temperature of the water, which lowers the amount of dissolved oxygen because warmer water retains less oxygen than colder water.

Total Solids (TS):

Total solids (TS), which are measured in milligrammes per litre (mg/L), are the sum of all suspended and dissolved solids in the water. The dissolved solids pass through a 2 micron-sized filter. Clay, silt, algae, plankton, and other organic waste are examples of suspended solids that are larger in size than dissolved solids and would not pass through a 2-micron filter (APHA, 1992). Different sources, such as soil erosion, sewage, fertiliser, industrial discharges, and road runoff, contributed to the suspended and dissolved particles in the water.

Turbidity:

Turbidity, a measure of the degree of cloudiness in the water, is brought on by dissolved or totally suspended particles, which are frequently so small as to appear to the naked eye as smoke in the air. The criteria of measuring water quality is crucial. For example, silt, sand, and mud; bacteria and germs; and chemical precipitates can all contribute to turbidity. Nephelometric Turbidity Units (NTU), which are based on US Environmental Monitoring Standard unit, are used to measure turbidity. The degree to which water scatters or absorbs light is referred to as turbidity. People are more likely to get gastrointestinal disorders when there is a high amount of turbidity in their drinking water. Similarly, high level of material affects light penetration and productivity, recreational values, and habitat quality. In streams, the life of fish and other aquatics can be in danger due to increased sedimentation and siltation (Kahlown *et al.,* 2006).

Colour

The water colour is an important indicator to define water and pollutants source. Water colour represents the type of solid material present in it. Low dissolved solids levels in transparent water give it a blue hue, whereas dissolved organic matter gives it a yellow or brown hue. Selective light spectrum absorption and scattering is what gives aquatic bodies their apparent blue hue. Reddish or dark yellow waters can result from some algae. A similar green appearance can be seen in water that is abundant in phytoplankton and other algae. Filtering the water after eliminating all suspended matter would allow one to determine the hue accurately. (CWT, 2004).

Taste and Oder

Drinking water is frequently utilised for its taste and order. One of the classically recognised five senses, taste (gustation), is a type of direct chemoreception. It is the capacity to detect the flavour of many substances, including food, certain minerals, and toxins. The four primary flavours are sour, salty, sweet, and bitter. After being diluted to around 100, 300, and 30 mg/L, respectively, cations including sodium, potassium, calcium, and magnesium are the principal causes of taste in drinking water (Kahlown *et al.*, 2006). A substance's extremely low concentration may be detected by the human nose; this is known as scent (smells), which can be classified as either pleasant or unpleasant. Pure water has no smell. Algae and bacteria were the main causes of taste and odour, whereas human-made sources included sewage effluent and chemical spills that might have an impact on both groundwater and surface water (Hoehn, 2002). Some chemical pollutants have very low taste and smell thresholds and can be noticed by consumers at very low quantities. (Young *et al.*, 1996).

Calcium and Magnesium (Ca, Mg)

The disintegration of calcium and magnesium aluminosilicates, as well as the dissolution of limestone, magnesium limestone, magnesite, gypsum, and other minerals, contributed to the calcium and magnesium in water. In terms of the mineralization of bones and shells as well as cell physiology, calcium is a crucial component for all living things. Magnesium often occurs in water in less concentrations than calcium. Additionally, calcium is present in very high weight-based concentrations in both surface and groundwater. While water hardness refers to the combined calcium and magnesium contents. When soap is added to hard water, precipitates occur when the water is heated. In terms of overall hardness, which is expressed in mg/L, calcium carbonate is the most important component.

Carbonates and Bicarbonates (CO_3^{2-}, HCO_3^-)

When carbon dioxide (CO_2) is dissolved in naturally flowing fluids, carbonate and bicarbonate ions are produced. Carbonate is recognised as a chemical link between carbon and the hydrologic cycle. By photosynthesizing plants, atmospheric carbon dioxide is partially captured and transformed to cellulose starch and other related carbohydrates. Temperature, pH, dissolved carbon dioxide, cations, and other dissolved salts all influence the concentration of carbonates in natural waters. A salt of carbonic acid called carbonate is created when carbonate minerals dissolve. When a positively charged ion binds to the carbonate ion's negatively charged oxygen atoms, a carbonate salt is created. The conjugate acid of carbonate is the bicarbonate ion, also known as the hydrogenated-carbonate ion. Since rocks are often soluble in water and their concentration in water relies on water's pH, weathering of rocks contributes to the bicarbonate content in water. It effects the hardness and alkalinity of water since it is the main alkaline component in practically all water sources. Most notably sodium bicarbonate and magnesium bicarbonate, which both contribute to total dissolved salts, a typical measure for determining the quality of water, several kinds of bicarbonate are soluble in water at normal pressure and temperature. When it comes to water, carbonates and bicarbonates should not be present in excess amounts because doing so might be damaging to people, animals and plant.

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR), which is a simple characteristic to measure, provides data on the relative amounts of sodium, calcium, and magnesium.

$$SAR = [Na^+] / [(Ca^{2+} + Mg^{2+})/2]1/2$$

Where $[Na^+]$, $[Ca^{2+}]$, and $[Mg^{2+}]$ are the concentrations in meq/L of sodium, calcium, and magnesium ions.

The hydraulic conductivity (permeability) of soil is impacted by a high sodium ion content in irrigation water, which leads to issues with water penetration. This is because soil particles become dispersed when sodium, which is present in exchangeable form in the soil, replaces calcium and magnesium adsorbed on soil clays (i.e., if calcium and magnesium are the predominant cations adsorbed on the soil exchange complex, the soil tends to be easily cultivated and has a permeable and granular structure). Due to the high SAR value, the soil becomes hard and compacted when dry, which lowers the rates at which air and water can permeate the soil, damaging its structure. The pace of salt and the kind of soil are two other aspects that are connected to this issue. When sandy soils are watered with water that has a high SAR, for instance, they could not sustain damage as quickly as other heavier soils.

Residual Sodium Carbonates (RSC)

Calculating the residual sodium carbonate is used to anticipate the increased sodium risk brought on by CaCO3 precipitation. Another method of measuring sodium level in relation to calcium and magnesium is the RSC. This may be computed as follows:

$$RSC = (CO_3^{\ 2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{+2})$$

Where, all concentration is in meq/L.

Irrigation Water Quality Standards

In semi-arid and dry locations, tubewell water drawn from an aquifer and canal water are the two major irrigation water sources. These sources' water includes a sizable quantity of superfluous or undesirable compounds that are dissolved in the water and might harm crop development and production, as well as the fertility of the soil. These undesirable chemicals came from either natural or artificial sources (domestic and industrial effluents), and the severity depends on the kind of material and how much of it was present when the water quality was compromised.

Followings are the main characteristics to assess the quality of irrigation water:

- Electrical Conductivity (EC)
- Residual Sodium Carbonate (RSC)
- Total Dissolved Solids (TDS)
- Sodium Adsorption Ratio (SAR)

Varied organisations have varied requirements for the quality of the water. The US Regional Salinity Laboratory and Food and Agriculture Organization (FAO) have given the quality of irrigation water as shown in Table 1.

Table 1 Irrigation Water Quality Standards (US Regional Salinity Laboratory and FAO)

Water Quality Classification	**Salinity Hazard**		**SAR**	**RSC**
	EC at 25°C (Micromhos/cm)	**TDS (mg/L)**	**(meq/L)**	**(meq/L)**
Excellent	<250	<160	Upto 10	<1.25
Good	250-750	160-500	10-18	1.25-2.50
Medium	700-2250	500-1500	18-26	>2.50
Bad	2250-4000	1500-2500	>26	
Very Bad	>4000	>2500	>26	

Salt is included in irrigation water in varying degrees and types. Since salts in irrigation water can have a significant impact on the salt and sodic state of a soil. Agricultural crops primarily get the moisture they need for growth and development from two sources: irrigation water and rainwater. Below are some parameters for evaluating irrigation water that have acceptable limitations for agricultural development:

Salinity hazard or total soluble salt concentration or EC: The concentration of soluble salts in irrigation water can be determined in terms of electrical conductivity (EC) and expressed as dSm^{-1}.

Water class	Salt concentration ($g\ L^{-1}$)	EC (dSm^{-1})	Remarks
Low salinity (C1)	< 0.16	0.0 – 0.25	Can be used safely
Medium salinity (C2)	0.16 – 0.50	0.25 – 0.75	Can be used with moderately leaching
High salinity (C3)	0.50 – 1.50	0.75 – 2.25	Can be used for irrigation purposes with some management practices
Very high salinity (C4)	1.50 – 3.00	2.25 – 5.00	Cannot be used for irrigation purposes

Salt Index: When irrigation water contains salts in excess of sodium chloride, the salt index is used to assess its long-term viability. It is also employed to forecast sodium dangers. It is the connection between the presence of Na^+, Ca^{2+}, and $CaCO_3$ in irrigation water. Every salt content is stated in ppm.

Salt Index = (Total Na – 24.5) – [(Total Ca – Ca in $CaCO_3$) x 4.85]

For waters of high quality, the salt index has a negative value, whereas it has a positive value for waters unfit for irrigation.

Sodium hazard (SAR): High levels of Na+ in water are undesirable because they bind to the sites where cations exchange, resulting in the deflocculation of soil aggregates, closure of soil pores, and impossibility of water flow. The ratio of the sodium content to the calcium and magnesium content in irrigation water is used to evaluate the propensity for sodium to gain more share on the cation exchange site at the cost of other types of cations. SAR, or sodium adsorption ratio, is the term used for this.

SAR – It is the ratio of the concentration of Na^+ to the concentration of Ca and Mg and all these concentrations are expressed in me/liter.

$$\textbf{SAR} = \frac{[Na^+]}{\sqrt{[Ca^{2+}] + [Na^+] / 2}}$$

Water class	SAR value	Remarks
S1 – Low Na^+	< 10	Any type of crops grown and water used
S2 – Medium Na^+	10 – 18	Drainage water used for sandy soil
S3 – High Na^+	18 – 26	Sensitive crops are not take
S4 – Very high Na^+	> 26	This water is not used for crops.

Bicarbonate hazard (RSC): In irrigation water, the HCO3- anion plays a significant role. The amount of irrigation water is assessed using the residual sodium carbonate (RSC).

$$\text{RSC (me L}^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Water class	RSC value	Remarks
Low RSC	< 1.25	Can be used safely
Medium RSC	1.25 – 2.50	Can be used with certain management
High RSC	> 2.50	Unsuitable for irrigation purposes

Boron Concentration: It is obvious that boron is necessary for the plant to develop normally, but the amount needed is quite minimal. Due to the presence of boron in certain irrigation water at dangerous concentrations, this element must be taken into account while evaluating the water's quality. Below are the boron levels that are acceptable in irrigation water.

Water class	Boron concentration (ppm)			Remarks
	Sensitive crops	Semi tolerance crops	Tolerance crops	
Very Low	< 0.33	< 0.67	< 1.00	Can be used safely
Low	0.33 – 0.67	0.67 – 1.33	1.00 – 2.00	Can be used with management
Medium	0.67 – 1.00	1.33 – 2.00	2.00 – 3.00	Unsuitable for irrigation purposes
High	1.00 – 1.25	2.00 – 2.50	3.00 – 3.75	
Very High	> 1.25	> 2.50	> 3.75	

Apple, Grape, Cherry, Peach, Orange, and Lemon are among the boron-sensitive crops.
Sunflower, Potato, Cotton, Tomato, Radish, Field Pea, Barley, Wheat, Corn, Rice, Oat and Sweet Potato are among the semi-tolerant crops to boron.

Crops that may withstand the presence of boron include date palm, sugar beet, garden beet, alfalfa, onion, turnip, cabbage, lettuce, carrot, and cauliflower.

Chloride Concentration: Chloride ions are more common in irrigation water when electrical conductivity (EC) and sodium ions rise. As a result, water with extremely high salinities contains the most of these ions. The chloride ions, in contrast to sodium ions, do not alter the physical characteristics of the soil or become adsorbed on it. As a result, it has typically been excluded from contemporary categorization systems. But it is a consideration in several regional water categorization systems

Chloride concentration (me L^{-1})	**Water quality**
4	Excellent Water
4 – 7	Moderately good water
7 – 12	Slightly usable
12 – 20	Not suitable for irrigation purposes
> 20	

Soluble Sodium Percentage (SSP): The most dangerous component of irrigation water that is soluble is salt. Depending on whether sodium ions are present in excess in combination with carbonate or bicarbonate ions, the water is classified as saline or alkaline. In the past, the soluble sodium percentage (SSP), which is computed as follows, was used to assess the quality of irrigation water in terms of sodium.

$$\text{SSP (\%)} = \frac{\text{Soluble Sodium (Na) Concentration}}{\text{Total Cation (Ca + Mg + Na) Concentration}} \times 100$$

Since a high value denotes soft water and a low value hard water, it has proved helpful in describing water. A portion of water used for irrigation that has an excess of salt (SSP=66) is absorbed by the soil. High salt irrigation water has negative effects on both soils and plants. Sodium soils have a low air and water permeability. When wet, they become plastic-like and sticky and are difficult to till. These poor physical circumstances hinder germination and typically hinder plant development. Although sodium is not as necessary for plants as other nutrients are, many plants readily absorb it, and it may even be hazardous to plants.

Magnesium Hazard: Given that excessive Mg absorption by soils impacts their physical characteristics, it is thought that one of the crucial qualitative factors in evaluating irrigation water is its Mg level in proportion to total divalent cations. When the Ca: Mg ratio falls below 50, it has a negative impact on the soil. Magnesium contamination in irrigation water is anticipated when the Mg: Ca ratio exceeds one

$$\text{Mg- Adsorption Ratio} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}$$

Nitrate Concentration (me L^{-1}): High amounts of nitrate are typically present in ground water. Continuous use of this form of irrigation water changes the soil's physical characteristics, which hinders plant development.

Water class	**Nitrate Value (me L^{-1})**	**Remarks**
Low Nitrate	5.0	Good water No problem
Medium Nitrate	5.0 – 30.0	Moderately good water
High Nitrate	> 30.0	Unsuitable for irrigation purposes

Lithium: Most irrigated soils and salty groundwater contain trace amounts of lithium. Lithium has been discovered to have harmful effects on citrus plant development at low doses (0.05–0.1 ppm) in irrigation water. Additionally, it has been observed that India's variously salted soils contain lithium up to 2.5 ppm. Fortunately, this amount of lithium concentration in soils has little impact on the germination of the vast majority of crops, including rice, wheat, barley, and others.

Fluoride: Fluorides are soluble very little and are present in very minute levels. Fluoride levels in natural water range from traces to more than 10 mg L-1, and surface water concentrations never go over 0.3 mg L-1 until they are contaminated. Wheat yield has not been observed to be impacted by irrigation with fluoride-containing salty water (up to 25 mg L-1). Therefore, it is unlikely that fluoride in India has to be monitored in any way. Currently, it has been shown that the typical fluoride content is just 10 mg L-1.

Guidelines for irrigation water quality established by the World Food and Agriculture Organization (FAO)

Water Constituent	**Intensity of problem***		
	No problem	**Moderate**	**Severe**
Salinity (dSm^{-1})	< 0.75	0.75 – 3.0	> 3.0
Permeability (rate of infiltration affected) Salinity (dSm^{-1})	> 0.5	0.5 – 0.2	< 0.2
Adjusted SAR: Soils are Dominantly montmorillonite Dominantly illite – vermiculite Dominantly kaolinite – sesquioxide	< 6.0 < 8.0 < 16.0	6.0 – 9.0 8.0 – 16.0 16.0 – 24	> 9.0 > 16.0 > 24.0
Specific ion toxicity Sodium (as adjusted SAR) Chloride (meq L^{-1}) Boron (meq L^{-1})	< 3.0 < 4.0 < 0.75	3.0 – 9.0 4.0 – 10.0 0.75 – 2.0	> 9.0 > 10.0 > 2.0
Miscellaneous NO_3^-–N or NH_4^+–N (meq L^{-1}) HCO_3^- (meq L^{-1}) as damaged by overhead sprinkler pH	< 5.0 < 1.5 6.5 -8.4	5.0 – 30.0 1.5 – 8.5 -	> 30.0 > 8.5 0.0 – 5.0, 9.5+

*Based on the presumption that the soils range from sandy loam to clay loam, have adequate drainage, and are in dry to semi-arid climates. It is also assumed that watering will be via sprinkler or surface, and that root depths will be typical for deep soils.

Upper permissible concentrations of trace elements in irrigation water: -

Element	**Recommended Maximum Concentration (mg/L)**	**Remarks**
Aluminum (Al)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
Arsenic (As)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to < 0.05 mg/l for rice.
Beryllium (Be)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Copper (Cu)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
Fluoride (F)	1.0[3]	Inactivated by neutral and alkaline soils.
Iron (Fe)	5.0	Can be contributed to soil acidification and loss of availability of phosphorus and molybdenum.
Lithium (Li)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Acts similarly to boron.
Manganese (Mn)	0.20	Toxic to a number of crops but usually only in acid soils.
Molybdenum (Mo)	0.01	Can be toxic to livestock if forage is grown in soils with high concentrations of available Mo.
Nickel (Ni)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Lead (Pb)	5.0	Can inhibit plant cell growth at very high concentrations.
Zinc (Zn)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.
Cadmium (Cd)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended it may be harmful to humans.

References:

Anonymous, (1994). Ground water quality for irrigation in India. Central Soil Salinity Research Institute, Karnal, Haryana, 1.

APHA, (1992). Standard methods for the examination of water and wastewater. 18th edition. American Public Health Association, Washington, DC.

CWT, (2004). Clean Water Team, State Water Resources Control Board FACT SHEET 3.1.5.9. Color of Water Fact Sheet. pp 1-3.

FAO, (2013). Water quality for agriculture. Food and Agriculture Organization, Irrigation and Drainage Papers. http://www.fao.org/docrep/003/t0234e/t0234e00.htm.

Haydar, S., M. Arshad and J.A. Aziz 2009. Evaluation of Drinking Water Quality in Urban Areas of Pakistan: A Case Study of Southern Lahore. Pak. J. Engg. Appl. Sci., 5:16-23.

Irfan, M., M. Arshad, A. Shakoor and L. Anjum (2014). Impact of irrigation management practices and water quality on maize production and water use efficiency. J. Anim. Plant Sci., 24:1518-1524.

Kahlown, M.A. and A.D. Kahn, (2002). Irrigation Water Quality Manual.Pakistan Council of Research in Water Resources, Ministry of Science and Technology, Government of Pakistan, Islamabad.

Kahlown, M.A, M.A. Tahir, H. Rashid and K.P. Bhatti (2006). Water Quality Status. Fourth Technical Report 2004-06, PCRWR, Islamabad.

Meena, M.K., Yadav, B.L., Dotaniya, M.L. and Meena, M.D. (2021). Can addition of organic manures mediated sodicity toxicity in mustard cultivation. *Communications in Soil Science and Plant Analysis*, 53, 77-88.

Shahid S. A., (2013). Irrigation-induced soil salinity under different irrigation systems – assessment and management, short technical note. Clim Chang Outlook Adapt: Int J 1:19-24

Shakoor, A. (2015). Hydrogeologic assessment of spatio-temporal variation in groundwater quality and its impact on agricultural productivity. PhD Thesis, Department of Irrigation and Drainage, University of Agriculture, Faisalabad.

Shakoor, A., M. Arshad, A. Bakhsh and R. Ahmed, (2015). GIS based assessment and delineation of groundwater quality zones and its impact on agricultural productivity. *Pakistan Journal of Agriculture Scienec*, 52:1-7.

Sharma, D.R. and Minhas, P.S. (2003). Management options and policy guidelines for use of poor-quality groundwater in agriculture. *Groundwater Research and Management. Integrating Science into Management Decisions*, 183.

Tahir, M.A., R. Rasheed, M. Asghar and I. Anwar, (2003). Instruction manual for water quality analysis. Pakistan Council of Research in Water Resources. Islamabad, Pakistan, 6-7th March, Islamabad, Pakistan. Pub. No. 123, pp. 3-11.

USSL Staff, (1954). Diagnosis and improvement of saline and alkali soils. USDA Handbook No 60 Washington DC, USA, 160 pp

Young, W.F., H. Horth, R. Crane, T. Ogden and M. Arnott, (1996). Taste and odour threshold concentrations of potential potable water contaminants. *Water Resources*., 30:331-340.

MANAGEMENT OF ACID SOILS

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Abstract:

Soil acidity can be corrected easily by liming the soil, or adding basic materials to neutralize the acid present. The most commonly used liming material is agricultural limestone, the most economical and relatively easy to manage source. The limestone is not very water-soluble, making it easy to handle. The management of acid soils should aim at improving the production potential of the soil by either addition of amendments or manipulation of agricultural practices to obtain optimum yield under acidic conditions. For farming systems and the soil resource to be sustained over the long run, managing acid soils is crucial.

Management of acid soils

Combining these three management philosophies will result in effective management of acid soils:

1. Minimise acidification
2. Apply a liming product (amelioration)
3. Use acid tolerant crop and pasture varieties

1. Minimise acidification: It is understood that agricultural production is an acidifying process. For your chosen production system, management options available to minimise soil acidification include the types, rate, placement and timing of fertiliser application(s).

1. Using basic fertilisers like basic slag and sodium nitrate, etc.
2. Minimising the leaching of basic cations through the use of effective soil and water management techniques

2. Apply a liming product (amelioration): The only effective amelioration method is the introduction of limestone or other alkali materials that counteract soil acidity. Its efficacy depends on the product's quality, price, and application technique.

Liming Material: Materials required for the neutralisation of hydrogen (H') ions in soil solutions are referred to as liming materials. The oxides, hydroxides, carbonates, and silicates of calcium or calcium and magnesium are the most frequent materials used to lim soils. A substance is not regarded as a liming compound if it simply contains these components. A companion anion must also be present that will lessen the activity of hydrogen (H+) ions and, consequently, aluminium in the soil solution. These are "Agricultural liming materials".

Various Liming Materials

For the purpose of reducing soil acidity, various liming agents are employed.

1. Calcium limestone ($CaCO_3$): This is grinded limestone and contains more Ca than Mg.
2. Dolomite [$CaMg(CO_3)_2$]: This is formed by limestone which contain high Mg.

3. Quick lime (CaO): This is burnt lime. When we heat limestone CO_2 is released and CaO isformed.
4. Hydrated slaked lime $Ca(OH)_2$: When quick lime reacts with H_2O then hydrated slacked limeis produced.
5. Marl ($CaCO_3$): This is soft and powdered or fluffy calcium Carbonate.
6. Slags: Three slag types are typically considered to be crucial:
   (a) Slag from blast furnaces: It is a leftover from the production of pig iron. This slag performs essentially like calcium silicate when used as a liming material. Blast furnace slags have a neutralising value that varies between 75 and 90 percent.
   (b) Basic slag: It is a by-product of the traditional open-hearth process for producing steel from pig iron, which is created from high-phosphorus iron ores. The basic slags are created by fluxing the iron's impurities, such as silica and phosphorus, with lime. Its neutralising value lies between 60% and 70%.
   (c) Electric furnace slag: - This is created when phosphate rock is reduced in an electric furnace to create elemental phosphorus. This substance, which is mostly calcium silicate, is used as a liming agent.

(7) Other liming materials: - Coral shell, chalk, wood ash, press mud/by-products of paper mills, sugar factories, fly ash, and sludge, among other things, are all thought of as liming materials and are also employed to amelioration soil acidity.

Reactions of lime in soil

1. Reaction with CO_2: When lime is mixed in acidic soil in any form (oxide, hydroxide or carbonate), then it is converted to bicarbonate after reaction with CO_2. Hence acidity of soil decreased. Reactions are of following types:

   $CaO + H2O \rightarrow Ca(OH)_2$

   Calcium hydroxide

   $Ca(OH)_2 + 2H_2CO_3 \rightarrow Ca(HCO_3)_2 + 2H_2O$

   $CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$

Calcium bicarbonate

2. Reaction with Soil Colloid: Ca^{+2} ion displaces H^{+}ion after the adsorption of Ca^{+2} ion in colloidal particle of soil. Hence the acidity of soil decreases. These reactions are shown as follows:

   $H\ Clay\ H + Ca(OH)_2 \rightarrow Ca^{+2}Clay + 2H_2O$

   $H\ Clay\ H + Ca(HCO_3)_2 \rightarrow Ca^{+2}Clay + 2H_2O + 2CO_2$

   $H\ ClayH + CaCO_3 \rightarrow Ca^{+2}Clay + CO_2 + H_2O$

   $H\ Clay\ H + Ca.Mg(CO_3)_2 \rightarrow Ca^{+2}Clay\ Mg^{+2} + 2CO_2 + 2H_2O$

Efficiency of Liming Materials

Because the neutralising capacities of various liming materials vary, the effectiveness of liming materials can be evaluated using the following significant factors:

(i) Calcium Carbonate Equivalent (CCE) or Neutralising Value (N.V.)

(ii) Purity of the liming ingredients

(iii) Their degree of fineness.

(i) Neutralizing value (N.V.) or Calcium Carbonate Equivalent (CCE): Calcium carbonate equivalent is defined as the acid-neutralizing capacity of an agricultural (CCE) liming material expressed as a weight percentage of calcium carbonate.

$$\text{CCE of a liming material} = \frac{\text{Molecular weight of } CaCO_3}{\text{Molecular weight of a limiting material Whose CCE is to be determined}} \times 100$$

Table 1. Neutralizing Value of Some Liming Materials

Liming materials	Neutralizing value (N.V.) or CCE (%)
Calcium oxide (CaO)	179
Calcium hydroxide [$Ca(OH)_2$]	136
Dolomite [$Ca.Mg(CO_3)_2$]	108.7
Calcite ($CaCO_3$)	100
Basic Slag ($CaSiO_3$)	86

(ii) Purity of liming materials: The efficiency of liming material in reducing soil acidity will increase with its purity.

(iii) Degree of fineness of liming materials: The fineness of the liming material affects how quickly it reacts with an acidic soil because finer materials have more surface contact with the soil. The reaction will be weak if the liming materials are coarse. By monitoring the change in soil pH, it is possible to gauge the size of the reaction as it is influenced by the fineness of the liming materials. To reach a specific pH, substantially less of the finer proportion of liming materials will be needed than the coarser fractions. The ability of a material to pass through a sieve with 60 holes that are all the same size in one linear inch is how fineness is determined. A material passing through such a sieve is given a 100% efficiency rating and is known as a 60 mesh sieve.

Lime requirement

The amount of liming material that must be applied to raise the pH to a specific value is what is known as the "lime requirement" of an acid soil. Since this is an easily obtainable value within the ideal range of the majority of crop plants, the pH value is often in the range of 6.0 to 7.0.

There are four important factors that govern the lime requirement, viz.

(a) required change in pH,

(b) buffer capacity of the soil to be limed,

(c) chemical composition of the liming materials used, and

(d) fineness of the liming materials. A fine-textured acid soil needs a lot more lime than a sandy or loamy soil with the same pH level does. While burnt lime and hydrated lime respond more quickly and cause changes in soil pH within a few days, calcitic or dolomitic limestone reacts slowly with soil colloids.

Methods for calculating the amount of lime needed:

1. Schoemaker, McLean and Pratt (SMP) buffer method
2. Mehlich buffer method
3. Woodruff
4. Adams and Evans methods

The buffer method of Schoemaker, Mclean, and Pratt (SMP) is frequently employed in India to determine the amount of lime necessary. The pH of this solution is adjusted to 7.5 with diluted NaOH solution in this method by adding 5 mL of distilled water and 10 mL of extractant buffer (1.8 g nitrophenol, 2.5 mL triethanolamine, 3 g potassium chromate, 2 g calcium acetate, and 53.2 g calcium chloride dihydrate are dissolved in one litre of water). The pH of the suspension is then measured using a pH metre after stirring it continuously for 10 minutes or intermittently for 20 minutes. The SMP buffer method is based on a generalized relationship between the buffer indicated lime requirement and $CaCO_3$, incubation-measured LR of a group of soils. Complications in the interpretation of the changes in buffer pH, brought about by mixing soil and buffer, arise from the facts that much of the acidity is pH-dependent and only a fraction of the total soil acidity reacts with the buffer. The SMP method has been designed for soils having considerable exchangeable Al and high LR.

In the Mehich method $BaCl_2$-TEA buffer solution of pH 8.0 is shaken with the soil and the amount of acidity reacting with the buffer is determined by titrating a fresh sample of buffer with acid down to the measured pH of the soil+buffer. The difference between the two titrations, gives a measure from which lime requirement is calculated. This method is predominantly used in highly weathered and leached soils with low LR.

Liming factor

The term "liming factor" can be used to describe the factor used to convert an expected theoretical amount of lime into its real amount. It can range from 1 to 3. When converting the theoretical amount of lime required to bring the soil to a specific pH to the actual amount of limestone that needs to be put in the field, a liming factor of 1.5 to 2.0 is typically utilised.

Methods of lime application

For soil reclamation necessary lime is grinded properly and spread over the upper layer of soil. Amending acid soil with one time application of full dose lime as per lime requirement should be replaced by small doses of lime application to each crop. Application of 10-20% lime requirement dose, mixing with farm yard manure in rows below the seeds or behind the plough at the time of sowing the crop, is quite beneficial. There should be adequate moisture present in soil for completion of process.

Effects of Lime on Soil: There are following physical, chemical and biological effects of mixing of lime in soil.

1. Heavy soil becomes granular after mixing of lime in soil.
2. Lime increases infiltration capacity of soil by decreasing bulk density of soil. Hence infiltration rateof water increases.
3. Decrement in soil erosion.
4. Increment in growth of plant.

5. Air and water movement increases in the soil.
6. Concentration of H^+ion in soil decreases.
7. Concentration of OH^- ion in soil increases.
8. pH of soil increases.
9. Solubility of Fe, Al and Mn decreases.
10. Exchange of Ca and Mg increases.
11. Availability of phosphorus and molybdenum increases.
12. Lime increases the effectiveness of potassium in nutrition of plants.
13. By speeding up the decomposition of organic waste, lime enhances the availability of nitrate.
14. Activity of soil microorganisms increases after mixing the lime in soil.
15. Decomposition of organic matter becomes faster due to increment in activity of biotic bacteria.
16. Rate of ammonization, aminolysis and sulphur oxidation increases.
17. Lime increases the rate of nitrogen fixation and nitrification

Effect of overliming

The growth of plants is affected by the following factors when excessively high amounts of lime are given to an acidic soil:

(i) There will be an iron, copper, and zinc deficiency.

(ii) The availability of potassium and phosphorus will decrease.

(iii) Root development will be impeded along with tip swelling brought on by hydrations due to high OH ion concentration from overliming. Boron serves as a protective agent for excessive OH^- ion concentration because of its dehydrating effects.

(iv) Overliming will result in boron shortage.

$$2\ Alx_3 + 3CaCO_3 + 3H_2O \longrightarrow 3Cax_2 + 2Al(OH)_4 \downarrow + 3CO_2$$

(Precipitation)

Where 'x' is the exchange site.

The newly formed Al(OH)3 is then available for boron adsorption. This chemical process contributes to boron deficit.

(v) The prevalence of diseases like scab in root crops will rise as a result of excessive lime application.

Large applications of organic manures, such as compost, well-rotten farmyard manure, green manure crops, phosphorus, boron, or a combination of micronutrient fertilisers, can lessen all of these effects.

3. Use acid tolerant crop and pasture varieties: Crops can be divided into following groups:

Crop types	Examples
Highly acid tolerant crops	Rice, potato, sweet potato, oat, castor, Echinochloa, Paspalum
Moderately acid tolerant crops	Barley, wheat, maize, turnip, brinjal, cowpea, mung beans, pigeon peas, peanuts
Slightly acid tolerant crops	Tomato, carrot, red clover

Subsoil acidity: In some acid soils (e.g. Ultisols), the acidity extends down the profile into the subsoil. Increase in subsoil acidity depends on the leaching of H and Al ions from the surface horizons as counter ions of anions. Root growth is often limited to the surface horizons in such soils, due to subsoil acidity.

For a soil with sub-soil acidity, gypsum ($CaSO_4 .2H_2O$) or phosphogypsum (a by-product from phosphate factory) is useful. Calcium from surface applied gypsum moves down the profile much faster than lime. Lime applied to the surface, on dissolution, raises pH and pH dependent charge on the soil colloids, which hold calcium. Consequently, any anion released (OH^- or CO_3^2) is removed. Gypsum, on the other hand, does not raise the soil pH and CEC. The SO_4^{2-} anion released by the dissolution of gypsum, accompanies calcium in the process of leaching. So gypsum raises the level of calcium and reduces, the level of aluminium in both soil solution and exchange complex. Gypsum can be a source of sulphur for surface soil, but it cannot amend the surface acidity:

Conclusion:

In addition to liming, which helps raise soil pH and base saturation, acid soil management should strive to improve soil health by adding plant nutrients that are deficient in such soils. The application of lime in furrows at the sowing time, as mentioned in this chapter, is particularly advantageous in enhancing crop yields. For crops and cropping systems in acid soil locations, liming should be an important part of integrated nutrient management strategies. To encourage farmers to use this approach, state governments must secure the supply and availability of low-cost, high-quality liming materials. Based on the lime requirements of soils in the area, soil testing laboratories should produce ready reckoners for lime use.

References:

Bouldin D.R, Ritchey K.D. and Lobato E. (1985). Management of soil acidity. In IBSRAM Workshop on Acid Tropical Soils, Brazilia, Brazil, May 1985, pp 1–22.

Mandal, S.C., Sinha, M.K., and Sinha, H. (1975). Acid Soils of India and Liming. Technical Bulletin No. 75. Indian Council of Agricultural Research, New Delhi.

Sarkar, A.K., Mahapatra, P. and Kumar, A. (2007). Nutrient Management in Acid Soils (R.K. Rat tan, Ed.) ISSS Bulletin No. 25, pp. 10-27.

Sharma, P.D. and Sarkar, A.K. (2005). Managing acid soils for enhancing productivity. ICAR Technical Bulletin p. 1-23.

Shoemaker, H.E., McLean, E.O. and Pratt P.F. (1961). Buffer methods of determining lime requirement of soils with appreciable amounts of extractable aluminium. Soil Science Society of America Proceedings 25, 274-277.

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SOIL FERTILITY EVALUATION TECHNIQUE: A COMPREHENSIVE APPROACH TOWARDS SUSTAINABLE AGRICULTURE

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Abstract:

Soil fertility evaluation is a crucial aspect of sustainable agriculture, as it helps farmers understand the nutrient status of their soils and make informed decisions about nutrient management practices. This article provides an overview of soil fertility evaluation techniques, including soil sampling, analysis, and interpretation of results. It covers various parameters such as soil pH, nutrient levels (nitrogen, phosphorus, potassium, and micronutrients), organic matter content, and cation exchange capacity, among others. The importance of accurate soil fertility evaluation in optimizing crop production and minimizing environmental impacts is emphasized. Different methods for soil sampling and analysis are discussed, along with their advantages and limitations. The interpretation of soil fertility test results and the formulation of nutrient management recommendations are also addressed. Furthermore, the article highlights the role of precision agriculture in soil fertility evaluation, including the use of advanced technologies such as remote sensing, GIS, and precision nutrient application. Challenges and limitations of soil fertility evaluation techniques, as well as future perspectives in this field, are also discussed. Proper soil fertility evaluation is essential for sustainable agriculture practices that optimize nutrient use efficiency, reduce environmental pollution, and ensure long-term soil health and productivity

Keywords: Soil fertility evaluation, nutrient management, sustainable agriculture, soil sampling, nutrient analysis, precision agriculture.

Introduction:

Soil fertility is a crucial factor that directly impacts agricultural productivity and sustainability. Understanding the fertility status of soils is essential for farmers, agronomists, and policymakers to make informed decisions about nutrient management, crop selection, and sustainable farming practices. Over the years, various soil fertility evaluation techniques have been developed and used to assess the nutrient status of soils, ranging from simple chemical tests to advanced analytical methods. In this article, we will delve into the world of soil fertility evaluation techniques, exploring their significance, types, and applications in modern agriculture.

Significance of Soil Fertility Evaluation:

Soil fertility evaluation plays a critical role in optimizing agricultural production while safeguarding the environment. Fertile soils support healthy plant growth, enhance crop yields, and contribute to sustainable farming practices. On the other hand, nutrient-depleted soils can result in poor crop performance, reduced yields, and increased vulnerability to pests, diseases, and environmental stresses. Therefore, accurate assessment of soil fertility status is essential to determine the appropriate nutrient management practices, select suitable crop varieties, and make informed decisions on fertilization strategies.

Soil fertility evaluation also aids in identifying the factors that affect soil fertility, such as soil texture, organic matter content, pH, and nutrient levels. This information helps farmers and agronomists to understand the underlying causes of soil fertility issues and implement appropriate corrective measures. Moreover, soil fertility evaluation is critical in identifying nutrient deficiencies or imbalances, which can lead to overuse or underuse of fertilizers, resulting in economic losses and environmental degradation. By optimizing nutrient management practices based on soil fertility evaluation results, farmers can reduce the risks of nutrient losses, minimize fertilizer costs, and mitigate the negative impacts of excessive nutrient applications on water quality and greenhouse gas emissions.

Types of Soil Fertility Evaluation Techniques:

Soil fertility evaluation techniques can be broadly classified into two categories: conventional methods and advanced analytical methods. Conventional methods are relatively simple and inexpensive, often relying on visual observations, basic chemical tests, or field-based measurements. On the other hand, advanced analytical methods are more sophisticated and accurate, utilizing advanced laboratory equipment and techniques to analyze various soil properties and nutrient levels. Let's take a closer look at each type of soil fertility evaluation technique.

Conventional Methods:

1.) **Visual Observation:** Visual observation is one of the simplest and most common methods used to assess soil fertility. It involves observing the physical characteristics of the soil, such as color, texture, structure, and moisture content, to infer its fertility status. For example, dark-colored soils with a crumbly texture and good moisture retention are indicative of high organic matter content and fertility, while pale-colored soils with poor structure and low moisture retention may indicate low fertility.

2.) **Field-Based Tests:** Field-based tests involve simple chemical tests that can be performed on-site using portable testing kits or equipment. These tests provide quick and qualitative information about the nutrient levels in the soil. Examples of field-based tests include pH testing using pH meters or litmus paper, electrical conductivity (EC) testing to estimate the salinity level of the soil, and plant nutrient deficiency symptom observation to infer nutrient status based on visual symptoms on plant leaves.

3.) **Soil Testing Kits:** Soil testing kits are commercially available kits that provide a convenient and cost-effective way to assess soil fertility. These kits typically include pre-packaged reagents, test tubes, and instructions for performing basic chemical tests to estimate soil properties such as pH, nutrient levels (N, P, K), organic matter content, and cation exchange capacity (CEC). Soil testing kits are widely used by farmers, agronomists, and researchers to obtain quick and reliable information about the fertility status of soils in the field or laboratory.

Advanced Analytical Methods:

1.) **Soil Nutrient Analysis:** Soil nutrient analysis is a comprehensive and accurate method to assess the nutrient status of soils. It involves laboratory analysis of soil samples using advanced techniques and equipment to determine the levels of various nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and boron (B). Soil nutrient analysis provides quantitative data on nutrient levels, allowing for precise nutrient management recommendations based on crop requirements and soil fertility goals.

2.) **Soil Physical and Chemical Analysis:** Soil physical and chemical analysis involves a range of tests to determine various soil properties that affect fertility, such as soil texture, organic matter content, pH, cation exchange capacity (CEC), and nutrient holding capacity. These tests are conducted in the laboratory using specialized equipment and techniques, such as laser diffraction for particle size analysis, loss on ignition for organic matter content, potentiometric or colorimetric methods for pH determination, and titration or extraction methods for CEC and nutrient holding capacity. Soil physical and chemical analysis provides detailed information on soil properties that influence nutrient availability, uptake, and cycling, allowing for more precise nutrient management strategies.

3.) **Soil Microbiological Analysis:** Soil microbiological analysis focuses on the study of microorganisms, such as bacteria, fungi, and other microbes, in the soil and their impact on soil fertility. This includes assessments of microbial biomass, microbial diversity, and activity, as well as functional tests to determine specific microbial processes, such as nitrogen fixation, mineralization, and denitrification. Soil microbiological analysis provides insights into the biological processes that influence nutrient availability and cycling, and can help optimize nutrient management practices by promoting beneficial microbial activities and minimizing detrimental impacts on soil microbiota.

1. **Applications of Soil Fertility Evaluation Techniques:**

   Soil fertility evaluation techniques find widespread applications in modern agriculture for optimizing nutrient management practices, improving crop productivity, and ensuring sustainable farming practices. Some of the key applications of soil fertility evaluation techniques are:

1.) **Nutrient Management Planning:** Soil fertility evaluation techniques provide essential information for developing nutrient management plans tailored to the specific needs of crops and soils. By analyzing soil nutrient levels and other relevant soil properties, farmers and agronomists can determine the optimal rates, sources, and timing of nutrient applications to maximize crop yields while minimizing nutrient losses to the environment. Nutrient management planning based on soil fertility evaluation can result in efficient use of fertilizers, reduced costs, and minimized environmental impacts.

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2.) **Crop Selection and Rotation:** Soil fertility evaluation techniques also help in crop selection and rotation decisions. Different crops have varying nutrient requirements, and understanding the fertility status of soils can aid in selecting suitable crop varieties that are adapted to the prevailing soil conditions. Moreover, soil fertility evaluation can guide farmers in designing crop rotation strategies that optimize nutrient cycling, reduce pest and disease pressure, and improve soil health. By selecting appropriate crops and implementing crop rotation based on soil fertility evaluation, farmers can improve overall crop productivity and sustainability.

3.) **Diagnosis of Nutrient Deficiencies and Imbalances:** Soil fertility evaluation techniques are valuable tools for diagnosing nutrient deficiencies or imbalances in crops. Visual symptoms of nutrient deficiencies on plant leaves can be correlated with soil nutrient levels to identify specific nutrient limitations in soils. Soil nutrient analysis can also help diagnose nutrient imbalances, such as excessive levels of one nutrient that may negatively impact the availability or uptake of other nutrients. Diagnosis of nutrient deficiencies and imbalances through soil fertility evaluation allows for timely corrective measures, such as targeted fertilizer applications or adjustments in nutrient management practices.

4.) **Environmental Protection:** Soil fertility evaluation techniques play a crucial role in protecting the environment by optimizing nutrient management practices and minimizing nutrient losses to the environment. Overuse or underuse of fertilizers can result in nutrient runoff, leaching, and volatilization, leading to water pollution, eutrophication of water bodies, and air pollution. Soil fertility evaluation techniques enable farmers and agronomists to accurately assess the nutrient status of soils and make informed decisions on nutrient applications, ensuring that fertilizers are used efficiently and effectively. This helps to minimize nutrient losses to the environment, reduce the risk of environmental pollution, and promote sustainable agriculture practices.

5.) **Precision Agriculture:** Soil fertility evaluation techniques are an integral part of precision agriculture, which involves using advanced technologies and data-driven decision-making to optimize crop production. Soil nutrient analysis, along with other data sources such as remote sensing, weather data, and crop growth models, can be used to create nutrient management prescriptions for specific areas within a field. This enables farmers to apply fertilizers with precision, targeting specific nutrient needs of crops based on soil fertility levels, resulting in optimal nutrient use efficiency, reduced costs, and minimized environmental impacts.

6.) **Soil Health Assessment:** Soil fertility evaluation techniques are also used in assessing soil health, which refers to the capacity of soils to function as a living ecosystem that supports plant growth, regulates nutrient cycling, stores carbon, and protects water quality. Soil health assessment involves evaluating various physical, chemical, and biological properties of soils, including soil fertility status. By understanding the nutrient levels and other soil properties, farmers and agronomists can identify potential issues, such as nutrient deficiencies, soil acidity, or soil organic matter depletion, that may affect soil health and crop productivity. This allows for appropriate management practices to be implemented to improve soil health and overall farm sustainability.

Conclusion:

Soil fertility evaluation techniques are essential tools for modern agriculture, providing accurate and comprehensive information on the nutrient status and other properties of soils. These techniques allow farmers and agronomists to make informed decisions on nutrient management, optimize crop production, protect the environment, and promote sustainable farming practices. Soil fertility evaluation techniques, such as soil nutrient analysis, soil physical and chemical analysis, and soil microbiological analysis, provide valuable insights into the complex interactions between soils, crops, and nutrients, enabling farmers to develop tailored nutrient management plans, diagnose nutrient deficiencies or imbalances, and optimize crop selection, rotation, and precision agriculture practices. Furthermore, soil fertility evaluation techniques play a crucial role in assessing soil health and promoting overall farm sustainability. Continued research and advancements in soil fertility evaluation techniques will further enhance our understanding of soil fertility dynamics and improve nutrient management practices, contributing to sustainable agriculture and food production for future generations.

References:

Brady, N.C., & Weil, R.R. (2008). The Nature and Properties of Soils. Prentice Hall.

Bünemann, E.K., Oberson, A., & Frossard, E. (2018). Phosphorus in Agriculture: 100 % Zero. Frontiers Media SA.

Dobermann, A., & Fairhurst, T. (2000). Rice: Nutrient Disorders & Nutrient Management. International Rice Research Institute.

FAO (2017). Sustainable Agriculture: Soil Management.

Gupta, R.K., & Abrol, I.P. (2014). Soil Testing and Analysis. Daya Publishing House.

Lobell, D.B., Cassman, K.G., & Field, C.B. (2009). Crop yield gaps: their importance, magnitudes, and causes. Annual Review of Environment and Resources, 34, 179-204.

National Research Council. (2006). Mineral Nutrition of Livestock. National Academies Press.

Nelson, D.W., & Sommers, L.E. (1982). Total carbon, organic carbon, and organic matter. In Page, A.L., Miller, R.H., & Keeney, D.R. (Eds.), Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties (2nd ed., pp. 539-579). Agronomy Society of America.

Precision Agriculture: Soil Sampling and Nutrient Management. (2018). Ontario Ministry of Agriculture, Food and Rural Affairs.

Subbiah, B.V., & Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in soils. Current Science, 25(8), 259-260.

Walkley, A., & Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29-38.

REMOTE SENSING

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Abstract:

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without being in contact with it. Remotely sensed data, obtained either by aircraft or satellite, containing electromagnetic emittance and reflectance data of crop can provide information useful for soil condition, plant growth, weed infestation etc. This type of information is cost effective and can be very useful for site-specific crop management programs. It is a useful technology for precision agriculture as it can give data for parameters of the field relatively easily.

Keywords: Horticulture, mapping, near infrared, remote sensing.

Introduction:

Fruits and vegetables make for about 90% of all horticultural production in India. India is presently the world's second-largest producer of fruits and vegetables and a pioneer in a number of horticulture products, including okra, cashew nuts, bananas, papayas, mangoes, and papaya (National Horticulture Board, 2015). The total area occupied by horticulture crops in India was 23.69 million hectares and total output was 283 million tonnes in 2015-16 (Source: Ministry of Agriculture and Farmers' Welfare). A significant portion of the country's overall crop sales value is made up of horticulture products including fruits, vegetables, spices, medicinal plants, and plantation crops, which also ensure the nutritional security of the nation's citizens. A database must be built for decision-making and planning in order to manage current crops in an organised and effective manner, bring additional land in the nation under the cultivation of horticulture crops, and boost total horticultural production in terms of time and area. A reliable tool that may be used to accomplish the aim is remote sensing. Several scientific disciplines, such as geography, land surveying, other earth science disciplines, and most recently, horticulture and agriculture, make extensive use of remote sensing. To address the issue of marginal farmers' marginal income generation, agricultural/horticultural experts usually utilise the phrase "precision farming," which is a vital concept. Across all areas of farming operations, dairy activities, horticulture, and even forest management, effect evaluation, growth observation, and prompt strategic reaction to slight fluctuations in crop. Precession farming may be accomplished using Site Specific Crop Management (SSCM), a method that combines spatial reference, crop and climatic monitoring, attribute mapping, decision support systems, and differential action (Panda *et al.*, 2010). SSCM requires the use of geospatial technologies, which are again a mix of four different tools, including remote sensing as a key component. The other three tools are geographic information systems (GIS), global positioning systems (GPS), and information technology or data management. When it comes to fruit and nut crops, SSCM is successfully used through the use of GIS and aerial or satellite images connected with GPS data (Sevier and Lee, 2005). The use of SSCM to horticultural crops like fruit and nuts can boost productivity and maximise resource use (Panda *et al.*, 2009). When an orchard is defined using spatial technology, additional information is produced that is useful for management decisions, such as when and how much irrigation is needed, the application of pesticides to control pests and diseases, the application of fertiliser, and the estimation of fruit yield (Panda *et al.*, 2010).

Remote sensing

The study of gathering data about distant things or places, generally from aeroplanes or satellites, is known as remote sensing (NOAA). By measuring the radiation that is reflected and emit at a distance from the targeted location, it is a procedure for identifying and keeping track of the physical properties of an area. In order to measure and record information about a location from a distance, remote sensing systems include four fundamental components. The energy source, transmission path, target, and satellite sensor are among these elements (Singh *et al.*, 2014).

Sensors mounted on aeroplanes or satellites detect the transmitted signal, and after evaluating the electromagnetic radiation, a specific landform or item on Earth is categorised. Active remote sensing is used when the sensor detects a reflection of a signal that was transmitted by the sensor's carrier, as opposed to passive remote sensing, which occurs when the sensor detects sunlight reflecting off a surface (Schowengerdt, 2007; Schott 2007). The assessment of area coverage, mapping, and categorization of land use and land cover elements, such as vegetation, soil, water, forests, and man-made activities, among other things, are all greatly aided by remote sensing (Singh *et al.*, 2014). Using remote sensing and satellite photos, vegetation may be recovered depending on interpretation factors such as picture colour, texture, tone, pattern, and association information, among others. While the near infrared band (>700 nm) of satellite pictures is invisible to the human eye, it is a band that receives a larger percentage of reflection from incident sunlight from healthy vegetation because it is sensitive to the water content and cell structure of leaves. In essence, the chlorophyll absorbs the blue and red spectrum and reflects the green, which is why a leaf seems green. The spectral features of matter are its distinctive properties (Singh *et al.*, 2014). So, it is possible to quickly, cheaply, and most importantly non-destructively gather information about plants, such as stress, damage, pest or disease infestation, by monitoring the reflectance of the visible and infrared band (VIR) (Zhang *et al.*, 2008; Naidu *et al.*, 2009)

Remote sensing applications in horticulture

One of the few nations in the world that integrates land-based observations and satellite technology to produce frequent updates on agricultural output data and provide suggestions for sustainable crop production is India. In India, the first known use of remote sensing technology occurred in 1970 during an experiment with wilting coconuts (Ray, 2016). Since that time, Indian scholars have significantly contributed to the development of internal software and the rise of digital image processing. Horticultural development, crop acreage and production estimation, precision farming, cropping system analysis, agricultural water management, drought assessment and monitoring, watershed development, soil resource mapping, potential fishing zone forecast, climate impact on agriculture, and other applications are just a few of these (Navalgund and Ray, 2000, Panigrahy and Ray, 2006, Navalgund *et al.*, 2007). Some of these applications are passed to user departments after being successfully tried out and thoroughly evaluated by solving real-world issues encountered in the field, ultimately contributing to the institutionalization of remote sensing applications in the nation (Parihar and Manjunath, 2013).

Monitor crop health:

Thanks to data and images from remote sensing, farmers are able to monitor the health and condition of their crops. Multispectral remote sensing can detect reflected light that is invisible to the human eye. The chlorophyll in the plant leaf reflects green light while absorbing the bulk of the blue and red light waves emitted by the sun. Plants under stress reflect light at various wavelengths from plants in good condition. Compared to stress plants, healthy plants' spongy mesophyll plant leaf tissue reflects more infrared light. If farmers can see regions of plant stress before it manifests itself, they will have more time to investigate the problem area and put a fix in place.

Soil moisture:

The water cycle, weather prediction, draughts and floods, and other processes all depend on the amount of moisture in the soil. Using the active and passive sensors (described above) from space, remote sensing techniques can be helpful in assessing the state of soil moisture. Although passive sensors measure naturally transmitted electromagnetic waves, which is extremely accurate but with poor resolution, active sensors light their target and record the backscatter, resulting in great spatial resolution but low accuracy. NASA, USA, has started a project called Soil Moisture Active Passive to obtain an optimum solution by combining the best of both procedures (SMAP)

Weed management:

Aerial remote sensing has not yet shown to be very successful at tracking down dispersed weed populations. Very largescale high-resolution imaging and weeds that regularly spread over a crop with comparable spectral characteristics cause difficulties. Photos will be needed for detection and identification. When weeds are recognised and identified utilising machine vision technology systems, remote sensors are mounted right on the spraying equipment. The closeness to the crop makes it feasible to achieve high spatial resolutions. Machine vision systems may be used in the field because they provide the real-time capabilities needed to control sprayer equipment.

Crop classification:

Multispectral photography is incredibly useful for differentiating these species from one another by the colour pattern they exhibit in order to classify horticultural crops from other bushes, shrubs, and trees with green leaves that have almost identical spectral signatures that of the other healthy vegetation (Dakshinamurti *et al.*, 1971). Fruit and nut trees may be separated from forest vegetation with comparable spectral properties using unsupervised clustering for picture segmentation, especially in places with unexpected land covers (Panda and Hoogenboom, 2009).

Crop area estimation:

Horticultural crops frequently experience significant fluctuations in their production and consumption, which leads to an extremely unstable market and pricing. For market planning and export of goods, accurate information on the area and output of horticultural items are crucial. Hence, remote sensing is crucial in evaluating the supply scenario. With over 90% accuracy, the size and output of crops like potatoes, which are grown in enormous fields, may be calculated (Nageswara Rao *et al*. 2004). Due to the overlap of spectral fingerprints, it is simple to estimate the area under mango orchards with trees older than five years, however this is not the case with younger mango trees. Early in the season, mulberry creates spectral fingerprints that are comparable to those of other vegetable crops, but subsequently displays considerable distinction (Nageswara Rao *et al.*, 2004).

Crop canopy measurement:

The volume of the crop canopy in horticulture crops is crucial because it dictates the quantity of fertiliser, pesticides, and other chemicals that must be applied. In addition, the crop canopy volume also provides information on the projected yield and the health of the crop. There have been cases when remote sensing technology has been used to estimate the canopy cover of significant crops for years, but sadly the majority of horticulture crops were not covered. The canopy cover of important horticultural crops in commercial fields with a variety of planting configurations and stages of maturity has been shown to be connected to remotely sensed NDVI.

Insect and disease detection:

Using aerial or satellite remote sensing, it has not been possible to directly identify and locate insects. In annual crops, plant stress identification as a method of indirect insect detection has frequently gone unutilized. The economic damage threshold for treatment is frequently met when plant stress is first detected through remote sensing. Entomologists prefer to do direct in-field scouting to locate insects in time for chemical treatments to be successful and economical.

In the horticulture business, pests and diseases are the two primary factors that affect productivity and, as a result, financial losses. Remote sensing has been shown to be an effective method for managing pests and nematodes by seeing changes in plant pigments, leaf skeletonization brought on by insect damage, and locating plant-vulnerable regions (Usha *et al.*, 2013).

An aerial multispectral digital imaging system linked to crop canopy reflectance and canopy density under various levels of phylloxera stress was developed by Johnson *et al*. in

1996. Cook *et al*. (1999) used multitemporal NIR videography to track the seasonal evolution of the southern root knot nematode (Meloidogyne incognita Chitwood) and soil-borne fungus complex in kenaf (*Hibiscus cannabinus* L.), an associated plant. Citrus leaves' spectral reflectance altered in the 600–700 nm range when citrus canker lesions appeared on them, as shown by Borengasser *et al*. in 2001. Using the NIR (near infrared) band, Hahn created a prediction model for mango anthracnose and late blight disease in tomatoes in 1999.

Plant nutrient stress:

Plant nitrogen stress areas in the field may be identified using high resolution colour infrared aerial photographs. The amount of nitrogen sprayed into the field is closely correlated with the reflectance of near-infrared, visible red, and visible green wavelengths. A solid indication of actual crop yields is the red reflection from the canopy.

Yield forecasting:

Although remote sensing is a highly helpful technique for estimating the yield of many annual crops, its application to fruit trees and vegetables has been fairly restricted thus far (Usha *et al.,* 2013). There are a few studies, such as the prediction of processing tomato yield using a crop growth model and remotely sensed aerial images and studies of the relationships between the modified normalised difference vegetation index and the leaf area index for processing tomatoes. Using aerial photos and reflectance spectra, assessed cabbage physical attributes and calculated cabbage production. Citrus groves were mapped using an automated ultrasonic system and a sensor-based automatic yield monitoring system.

In order to predict yield, plant tissue is employed, which absorbs a lot of red light and is highly reflective of energy in the near infrared (NIR) wavebands. The ratio of these two bands is known as the vegetation index (VI). The normalised difference VI is calculated by multiplying the differences between red and near-infrared measurements by their total (NDVI). For crops like grain sorghum, NDVI data has been related to production yields, leaf area index (LAI), crop height, and biomass. For yield forecasts to be somewhat accurate, this data must be combined with input from weather models during the growing season.

Soil mapping:

A soil map is a different type of map produced using remote sensing data. When the quantity of soil is known, these maps may be made using satellite or aeroplane images. Plant coverage is between 30 and 50% less. In soil maps, homogeneous soil zones with equivalent traits and agronomic conditions are depicted. These maps may be used to set up irrigation systems, find the optimum spots to collect soil samples for in-depth soil research, and locate soil moisture sensors. Remote sensing is an important technique for mapping and predicting soil degradation. The soil layers that rise to the surface during erosion have unique colour, tone, and structure from non-eroded soils, making it possible to identify the eroded areas of the soil with great clarity on pictures. Using multi-temporal images, we can analyse and map dynamical features like soil moisture and erosion expansion.

Monitoring abiotic stress:

A potent method to track how plants react to various abiotic challenges, such as drought, floods, salt, temperature changes, etc. is remote sensing. For instance, if any abiotic stress inhibits the formation of chlorophyll, then a rise in reflectance will be seen for wavelengths that are only faintly absorbed (Usha *et al.*, 2013).

References:

Borengasser, M., Gottwald, T.R., Riley, T., (2001). Spectral reflectance of citrus canker. In: Proceedings of the Florida State Horticultural Society, vol. 114:77–79.

Cook, C.G., Escobar, D.E., Everitt, J.H., Cavazos, I., Robinson, A.F. and Davis, M.R., (1999). Utilizing airborne video imagery in kenaf management and production. *Ind. Crops Prod*., 9:205–210.

Dakshinamurti, C., Krishnamurthy, B., Summanwar, A.S., Shanta, P. and Pisharoty, P.R. (1971). Remote sensing for coconut wilt. Proceedings of International Symposium on Remote Sensing of Environment, vol. 1, Ann Arbor, MI: 25–29.

Johnson, L., Lobitz, B., Armstrong, R., Baldy, R., Weber, E., DeBenedictis, J.and Bosch, D., (1996). Airborne imaging aids vineyard canopy evaluation. *Calif. Agr*., 50:14–18.

Nageswara Rao, P.P., Ravishankar, H.M. and Uday Raj, K.N. (2004). Production estimation of horticultural crops using irs-1d liss-iii data. J. Indian Soc. *Remote Sens*., 32:393–398.

Naidu, R.A., Perryb, E.M., Pierceb, F.J. and Mekuria, T. (2009). The potential of spectral reflectance technique for the detection of grapevine leafroll-associated virus- 3 in two red berried wine grape cultivars. Comput. *Electron. Agric.* 66(1): 38–45.

National Horticulture Board, Horticultural Statistics at a Glance (2015). Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare Government of India.

Navalgund, R. R. and Ray, S. S. (2000). Geomatics in natural resources management. In Proceedings of Geomatics-2000. 21-22 January, 2000, Pune, pp. NR1-NR14

Navalgund, R. R. and Ray, S. S. (2000). Geomatics in natural resources management. In Proceedings of Geomatics-2000. 21-22 January, 2000, Pune, pp. NR1-NR14.

Panda, S.S., Hoogenboom, G. and Paz, J.O. (2010). Remote sensing and geospatial technological applications for site-specific management of fruit and nut crops: a review. *Remote Sensing*, 2(8): 1973-1997.

Panda, S.S. and Hoogenboom, G.J.P. (2009). Distinguishing blueberry bushes from mixed vegetation land-use using high resolution satellite imagery and geospatial techniques. *Computers and Electronics in Agriculture*, 67 (1–2): 51–59.

Panda, S.S., Hoogenboom, G. and Paz, J., 2009. Distinguishing blueberry bushes from mixed vegetation land-use using high resolution satellite imagery and geospatial techniques. *Comput. Electron. Agr*., 67: 51-59.

Panigrahy, S. and Ray, S. S. (2006). Remote Sensing. In: Environment and Agriculture. (Eds. K. L. Chadha & M. S. Swaminathan). Malhotra Publishing House, New Delhi. pp. 361-375.

Parihar, J. S. and Manjunath, K.R. (2013). Agricultural Applications: Evolution during last 25 Years. NNRMS Bulletin. pp. 58-75.

Ray, S.S. (2016). Remote sensing for agricultural applications, GeoSmart India, Geomatics for Digital India, March 2, 2016

Sevier, B.J. and Lee, W.S. (2005). Precision farming adoption by florida citrus producers: probit model analysis; Circular # 1461; Institute of Food and Agricultural Sciences, University of Florida: Gainesville, FL, USA, 2005.

Schott, John R. (2007). Remote sensing: the image chain approach (2nd ed.). Oxford University Press. pp. 1. ISBN 978-0-19-517817-3.

Schowengerdt and Robert A. (2007). Remote sensing: models and methods for image processing (3rd ed.). Academic Press. pp. 2. ISBN 978-0-12-369407-2

Singh J. P., D. Deb and R. S. Chaurasia (2014). Use of Geo-spatial technology as an evolving technology of 21st century for natural resource management in different region of India. In Emerging Technology of 21st Century, New India Publishing Agency (11 May 2015). pp. 449-479. ISBN-10: 9383305339, ISBN-13: 978-9383305339.

Usha, K. and Singh, B. (2013). Potential applications of remote sensing in horticulture-A review. *Scientia Horticulturae*, 153:71-83.

Zhang, H., Chang, M., Wang, J. and Ye, S., (2008). Evaluation of peach quality indices using an electronic nose by MLR, QPST and BP network. *Sens. Actuators B: Chem*. 134 (1): 332-338.

GARDENING CROPS WITH NANOTECHNOLOGY

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Abstract:

An excellent opportunity to tackle the intricate technological problems of the food supply chain has been created by the advent of nanotechnology. The horticulture industry will lose out on the chance to gain from increased product visibility, food safety, quality, and security, as well as related economic benefits, if nanotechnology is not used. Because agricultural goods have so many different features, managing the supply chain for food and agriculture is complicated. Many horticultural crop and product varieties exist, many of which are perishable. Also, there hasn't been much progress in standardising the management of particular fruit products. The possible use of nanotechnology in horticulture is examined in this context. According to research, nanotechnology is being applied to horticulture gradually, starting with fruit packing and progressing to additional applications including tracking, tracing, storage, and distribution. In the agricultural supply chain today, the majority of nanotechnology applications are focused on packaging, particularly in the advancement of packaging materials for product security, quality, and safety. The use of intelligent packaging based on nano-sensors with the goal of enhancing information and management across all components of an agricultural supply chain is the natural extension from the perspective of the supply chain. Nano-sensors provide a number of benefits over conventional sensors, including high sensitivity and selectivity, close to real-time detection, cheap cost, and mobility. The economics of applying nanotechnology to the agricultural supply chain, however, are no different from applying other emerging technologies.

Keywords: Nano matarials, Nano plant growth stimulators, Nanofood, Nanotechnology, Self-life

Introduction:

Future food security might be aided by nanotechnology's enormous potential for increasing agricultural output. Maintaining the quality of harvested fruit and vegetables while minimizing spoiling is a very difficult challenge in agriculture. Many types of nanomaterials have proven to have a strong potential for horticulture crop quality improvement, productivity enhancement, shelf life enhancement, and post-harvest damage reduction. The storage and transportation of vegetables and fruits are ideal for antimicrobial nanomaterials as nanofilm on harvested items and/or on packing materials. The cut flower's vitality is also improved by nanomaterials. Nanofertilizers are very effective in increasing vegetative growth, pollination, and fertility in flowers, which increases floral production and improves the quality of produce for fruit trees and vegetables. They are also target-specific, slow-releasing, and highly effective. Target specific, environmentally benign, and extremely effective, manufactured nanopesticides. Nanosensors make it possible to monitor crop plants' growth, plant disease, and insect assault in real-world settings. With the help of these cutting edge sensors, crop pest populations, soil moisture, humidity, pesticide residues, and nutritional needs can all be determined accurately.

Nano, which in Greek means "dwarf," is the root of the phrase "nanotechnology." A famous quote from Nobel Prize winner Richard Phillips Feynman (Feynman, 1960). "There is plenty of room at the bottom," had a significant impact on the development of nanotechnology. Nanotechnology is the term used to describe the science, engineering, and technology carried out at the nanoscale (about 1 to 100 nanometers) (Curtis *et al.,* 2006; Bhattacharyya *et al.,* 2009; Servin and White, 2016). As a matter of fact, due to their high surface to volume ratio, nanoparticles exhibit fascinatingly unique characteristics from bulk materials. Also, every molecule, element, or material's catalytic activity is markedly increased by the quantum processes that take place at the nanoscale of that particular substance. Nanoparticles are therefore extensively employed in telecommunications, electronics, textiles, the automobile sector, biomedical equipment, environmental technology, biotechnology, and alternative energy. In agriculture, novel high-efficiency agrochemicals for the nourishment and protection of crop plants, hybrid varieties of crops, and unique high-potential nanomaterials for the production of new crop types, have all demonstrated significant promise. Moreover, the use of nanomaterials enhances food preparation, packaging, food safety, plant nutrition, pesticide and fertilizer effectiveness, the reduction of environmental pollution, and the creation of nutraceuticals (Handford *et al.,* 2015; Maqbool *et al.,* 2021).

Horticulture is a field of agricultural science and art that focuses on growing and managing beautiful plants, fruits, and vegetables. In the face of a changing global environment, ensuring the food and nutritional security of the world's ever-growing population is a difficult and hard undertaking (Duhan *et al.,* 2017). Hence, the most effective techniques for tackling this difficult challenge are seen to be boosting production and reducing post-harvest losses by adopting cutting-edge technical approaches like nanotechnology and biotechnology. The use of nanomaterials in agriculture appears crucial for improving productivity, product quality, and lowering fruit and vegetable post-harvest losses. It has been discovered that physiological and microbiological processes cause up to 30% of horticulture agricultural products to be lost in underdeveloped nations. We can considerably reduce these post-harvest losses to 5-10% by using nanofilm and nanopackaging with antimicrobial nanomaterials, which ultimately preserves enormous quantities of nutrient-dense crops. Minimizing these losses can boost farmers' revenue while also improving the nutritional value and quality of the food produced. The synthetic fertilizers and insecticides now in use are very costly, dangerous to the environment, and harmful to human health. Leaching, volatilization, evaporation, and rains all contribute to the loss of a significant amount of these applied chemical inputs. Yet, the novel formulations of nanopesticides and nanofertilizers are safe, highly effective, and specific to their intended targets.

The impact of nanomaterials on the development and growth of horticultural crops

Solid colloidal particles known as nanoparticles are made up of macromolecular substances. The nanoparticles can capture, dissolve, encapsulate, or absorb active components like medication molecules or bioactive compounds. The use of nanofertilizers, which promote extremely effective plant nutrition and are environmentally benign, increases agricultural production. The following three methods of providing nutrients to crop plants are used by nanofertilizers: I the nutrient can be coated by nanoparticles in the form of nanoporous materials or nanotubes; (ii) wrapped in a thin protective polymer film; and (iii) delivered as an emulsion or nanoscale particles. Nanofertilizers are given to the plants gradually, precisely, and effectively. The production of peanuts *(Arachis hypogaea*), for instance, is increased by ZnO nanoparticles (Prasad *et al.,* 2012). Similar to this, the use of SiO_2 nanoparticles improves plant biomass and the levels of biomolecules in the grains of maize, including proteins, phenols, and chlorophyll. the nanotubes of Hexaploidy wheat's root development is boosted by carbon at low concentrations, as are the germination and seedling growth of mustard, black gramme, and rice, as well as the cell growth (16% increase) of tobacco (Nicotiana tabacum). TiO_2 and SiO_2 nanoparticles are used to boost nitrate reductase activity, which in turn appears to speed soybean seed germination and seedling development (Changmei *et al.,* 2001). The use of nanomaterials fosters the growth and development of horticulture crops, much like it does for field crops.

Nanofertilizers are used in horticulture to boost floral fertility, pollination, and vegetative development, which increases fruit tree productivity and improves product quality. Under salt stress circumstances, exogenous nano-Ca supplementation on blueberries results in higher vegetative growth and increased chlorophyll content in the leaf. Similar to this, spraying nano-boron on mango tree leaves increases overall production and presumably improves fruit chemical characteristics. to be associated with an increase in the amount of important nutrients, such as nitrogen, phosphorus, potassium, magnesium, manganese, boron, zinc, and iron, in the leaves, including chlorophyll. Mango trees that have been sprayed with nano-zinc produce fruits that are heavier, more plentiful, contain more chlorophyll and carotene, and have higher concentrations of several nutrients including N, P, K, and Zn (Zagzog *et al.,* 2017). Similar to this, the use of nano-boron and nano-zinc fertilizers raises fruit yields and enhances fruit quality and quantity as well as pomegranate yields, total sugars, and total phenol content (Davarpanah *et al.,* 2016).

1. Nanofertilizers

Any synthetic or natural chemical (apart from liming materials) that is added to the soil or sprayed onto plant tissues to deliver one or more vital nutrients to support crop plant nutrition is considered a fertilizer (Bhardwaj *et al.,* 2014). Fertilizers can be obtained from a variety of natural or artificial sources. In contemporary agriculture, fertilizer application is essential for increasing crop output. One of the main problems with fertilizing crops is that a significant portion of the applied fertilizer gets lost in a variety of ways, which eventually damages the environment and raises the cost of production. The use of nanofertilizers is a noteworthy new development in decreasing the loss of applied fertilizers to the environment. By mixing plant nutrients with nanomaterials, coating nutrient molecules with a thin layer of nanomaterials, and creating nanosized emulsions, nanofertilizers are created. When compared to ordinary fertilizers, nanofertilizers and nanobiofertilizers, which include both natural and synthetic components, intelligently boost soil fertility and bioavailability (Sidorowicz *et al.,* 2019). Yet, the three most crucial properties of nanofertilizers are (i) a bulk size of about 100 nm; (ii) a particle size of less than 100 nm; and (iii) the nanoproduct must be durable and safe for the environment. A nano-ability fertilizer's to maintain its nanoscale and aggregates while interacting with agricultural plant roots or soil particles is another characteristic. The size and form of the nanoparticles have a significant impact on the reactivity of nanofertilizers. The most important features of nanofertilizers are increasing nutrient usage effectiveness, controlling the active ingredients, and minimizing residual influence on soil biodiversity (Sempeho *et al.,* 2014).

2. Nano-plant growth stimulator

In the last few decades, the use of NMs in horticulture has significantly risen. To improve plant growth and production, pest and disease control strategies employ the shape and components of NMs (Tarafdar *et al.,* 2014). However there have also been reports of both advantageous and harmful consequences of applying nanoparticles to plants (Table 1).

Table 1: Influence of nanoparticles (NPs) on germination, growth, development and yield of horticultural crops

Nanoparticles	Dose (mg/L)	Crop	Effect on Plant Growth and Development
CeO_2	125 to 4000	Cucumber	Negative impacts at the molecular and biochemical levels in plants.
TiO_2	1000 to 2000	Spinach	Promotes growth and photosynthesis.
Carbon nanotubes (MWCNT)	10 to 40	Tomato	Enhances germination and growth rate but inhibits elongation of root in tomato.
Carbon nanotubes (MWCNT)	10 to 40	Onion and cucumber	Enhances elongation of root.
Carbon nanotubes (MWCNT)	0, 500, 1000 or 5000	Zucchini, tomato, corn, soybean	Reduces biomass in corn and soybean (500 mg/kg), but the development of tomato andzucchini unaffected.
Fe_3O_4	0.67	Lettuce, spinach, radish, cucumber, tomato, peppers	Inhibits seed germination.
ZnO	100 to 1000	Garden pea	No effect on seed germination but affectsnodulation and root length
Ag	800	Faba bean	Declines germination

Table 1 provides a summary of the effects of NMs on the germination of seeds, growth, development, and yield of horticultural plants. Reports have shown that greater dosages of nanoparticles are hazardous to plants, despite the fact that the processes are not well understood.

3. Nutrient uptake and subsequent translocation in plant

Nano- to micrometer-scale natural holes in plant surfaces make nanoparticles readily absorbable by plants. Several mechanisms might be used for the absorption of nanoparticles (NPs) into the plant body. The surface characteristics and size of the NPs have an impact on uptake rates. The cuticle can be pierced by very tiny NPs. Large-sized NPs can enter through non-cuticle regions, such as hydathodes, stomata, and flower stigmas. To penetrate the protoplast of the plant cell, nanoparticles must pass through the cell wall. Many lines of evidence point to the efficiency of NPs with a diameter of less than 5 nm in traversing the wall of an intact plant cell (Tarafdar, 2015).

4. Nanopesticide

The most significant variables that limit agricultural productivity are pests, which must be effectively controlled. By using conventional methods of pest management, a lot of chemical pesticides are used, which causes environmental issues and raises production costs. Dilution of pesticides with water that has undergone nanotechnology might significantly increase their efficacy and lower the amount of chemicals utilised. In comparison to traditional pesticides, nanopesticides are more effective in controlling pests. In addition, using them costs half as much as using traditional pesticides (Huang *et al.,* 2014).

The majority of nanopesticide formulations are extremely target-specific and controlled release, and most are environmentally safe. These characteristics of nano-pesticides improve pesticide use while noticeably reducing residual levels and environmental contamination. For instance, highly polymeric nanomicrocapsule formulations have sluggish release and protective performance since they were made using components that are sensitive to light, humidity, temperature, enzymes, and soil pH. The dispersion and bioactivity of the active ingredient in pesticide formulations are improved by nanopesticide formulations, which also increase the adherence of droplets to plant surfaces. As a result, nanopesticides are more effective than traditional pesticide formulations. Because of their tiny size, wettability, improved pesticide droplet ductility, and target adsorption, nanopesticides have a better effectiveness. Nanoencapsulation can also be used to generate insecticidal value. This technique involves sealing off the active pesticide component at the nanoscale with a thin layer of shielding. This method dramatically increases efficacy while lowering the amount of pesticide used, as well as the associated environmental impact. One such are the "Halloysite" clay nanotubes. pesticide transporter, which significantly lowers the quantity of pesticides needed to control the target pests.

5. Enhancement of shelf-life of horticultural crops by nanomaterials

Most fruits and vegetables don't have good shelf lives when stored under normal settings because of their perishable qualities. There are a number of conventional preservation methods, however they are all costly, ineffective at extending shelf life, or constrained by an unfavorable residue. Due to many regulatory properties of nanoparticles, shelf-life augmentation strategies based on nanotechnology have the potential to reduce the shortcomings of traditional approaches.

6. Enhancing the vitality of cut flowers

Cut flowers are highly significant commercially and have decorative value, but their shelf life is quite short due to increasing microbial contamination. Early flower withering is caused by microbial and stem barrier infection, which results in stem blockage that restricts water intake and transport and produces water imbalances. Thus, it is crucial to manage microbial infections in order to overcome stem obstruction. According to some research, nano-silver may be able to extend the vase life of cut flowers. The most significant nanoparticle, graphene oxide (GO), is a graphene mimicking carbon-based NPs with a large surface area and a lot of oxygenated groups. This gives it a great capacity to transport nutrients for slow-discharge fertilizers (Zhang *et al.*, 2014).

7. Nanomaterials in food processing

Techniques for food processing are used to improve the flavour and maintain the product's quality for a longer time. Inadequate methods of food preservation are utilized in the preparation of food, including radioactivity, high hydrostatic pressure, and ohmic heat (Neethirajan and Jayas, 2011).

8. Nanosensors in precision horticulture

Any instrument that is able to transmit information and proof about the actions and traits of NPs at the nanoscale level to the macroscopic level is referred to as a nanosensor. Real-time monitoring of field crop, crop growth, and pest and disease incidence requires nanosensors. Metal nanotubes, nanowires, nanofibers, nanocomposites, nanorods, and nanostructured polymers are just a few examples of nanoscale materials that may be used to make sensors, as well as various allotropes of carbon like carbon nanotubes, graphene, and fullerenes. With real-time monitoring, agricultural production may use less pesticides and fertilizers than necessary, lowering both production costs and environmental impact. Using nanosensors transforms traditional farming into smart farming, which is more eco-friendly and energy-efficient for sustainable agricultural operations. Smart agricultural practises in horticultural crop production include (i) nanoformulation-based fertilizers or pesticide delivery systems, which increase the dispersion and wettability of nutrients; (ii) nanodetectors for pesticide or fertilizer residues; and (iii) remote-sensing-based monitoring systems for disease incidence and crop growth. In horticulture, nanosensors are used to measure soil moisture, pesticide residues, nutritional needs, and crop pest detection (Hoque *et al.*, 2021).

Conclusion:

The economics of applying nanotechnology to the agriculture supply chain are the same as those of applying other emerging technologies. The initial expense is high, which prevents adoption of the new technology. Although certain nanoscale packaging materials are now less expensive, nano-sensors still have a high cost. Nanotechnology prices will dramatically decline in the short to medium term as a result of large-scale applications and advancements in production technologies. Long-term use of nanotechnology will lower the cost of its application in the agricultural supply chain due to its growing popularity. Introducing fresh ideas and standardized testing practices. It is vitally necessary to investigate how nanoparticles affect live cells in order to assess any possible risks associated with human exposure to nanoparticles. It is commonly anticipated that in the upcoming years, people would have more access to food items made using nanotechnology.

References:

Bhardwaj, D.; Ansari, M.W.; Sahoo, R.K.; Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microb. Cell Fact*., 13, 1–10.

Bhattacharyya, D.; Singh, S.; Satnalika, N.; Khandelwal, A.; Jeon, S.-W. (2009). Nanotechnology, big things from a tiny world: *A review. Adv. Electron. Electr. Engin*., 2, 29–38.

Changmei, L.; Chaoying, Z.; Junqiang, W.; Guorong, W.; Mingxuan, T. (2001). Research of the effect of nanometer materials on germination and growth enhancement of Glycine max and its mechanism. *Soybean Sci*., 21, 168–171.

Curtis, J.; Greenberg, M.; Kester, J.; Phillips, S.; Krieger, G. (2006). Nanotechnology and nanotoxicology: A primer for clinicians. *Toxico Rev*., 25, 245–260.

Davarpanah, S.; Tehranifar, A.; Davarynejad, G.; Abadía, J.; Khorasani, R. (2016). Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (Punica granatum cv. Ardestani) fruit yield and quality. *Sci. Hort*., 210, 57–64.

Duhan, J.S.; Kumar, R.; Kumar, N.; Kaur, P.; Nehra, K.; Duhan, S. (2017). Nanotechnology: The new perspective in precision agriculture. *Biotechnol. Rep*., 15, 11–23.

Feynman, R.P. (1960). There's plenty of room at the bottom. *Eng. Sci*., 23, 22–36.

Handford, C.E.; Dean, M.; Spence, M.; Henchion, M.; Elliott, C.T.; Campbell, K. (2015). Awareness and attitudes towards the emerging use of nanotechnology in the agrifood sector. *Food Control*, 57, 24–34.

Hoque, M.I.U.; Chowdhury, A.N.; Islam, M.T.; Firoz, S.H.; Luba, U.; Alowasheeir, A.; Rahman, M.M.; Rehman, A.U.; Ahmad, S.H.A.; Holze, R. (2021). Fabrication of highly and poorly oxidized silver oxide/silver/tin (IV) oxide nanocomposites and their comparative anti-pathogenic properties towards hazardous food pathogens. *J. Hazard. Mater.*, 408, 124896.

Huang, S.W.; Wang, L.; Liu, L.M.; Fu, Q.; Zhu, D.F. (2014). Nonchemical pest control in China rice: A review. *Agron. Sustain. Dev*., 34, 275–291.

Maqbool, Q.; Barucca, G.; Sabbatini, S.; Parlapiano, M.; Ruello, M.L.; Tittarelli, F. (2021). Transformation of Industrial and Organic Waste into Titanium Doped Activated Carbon-Cellulose Nanocomposite for Rapid Removal of Organic Pollutants. *J. Hazard. Mater*., 423, 126958.

Neethirajan, S.; Jayas, D.S. (2011). Nanotechnology for the Food and Bioprocessing Industries. *Food Biol. Technol*., 4, 39–47.

Prasad, T.N.V.K.V.; Sudhakar, P.; Sreenivasulu, Y.; Latha, P.; Munaswamy, V.; Reddy, K.R.; Sreeprasad, T.S.; Sajanlal, P.R.; Pradeep, T. (2012). Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *J. Plant. Nutri.,* 35, 905–927.

Sempeho, S.I.; Kim, H.T.; Mubofu, E.; Hilonga, A. (2014). Meticulous overview on the controlled release fertilizers. *Adv. Chem*., 2014, 63071.

Servin, A.D.; White, J.C. (2016). Nanotechnology in agriculture: Next steps for understanding engineered nanoparticle exposure and risk. *NanoImpact,* 1, 9–12.

Sidorowicz, A.; Maqbool, Q.; Nazar, M. (2019). Future of Nanofertilizer. In Nanotechnology for Agriculture: Crop Production & Protection; Panpatte, D., Jhala, Y., Eds.; *Springer: Singapore*, pp. 143–152.

Tarafdar, J.C.; Raliya, R.; Mahawar, H.; Rathore, I. (2014). Development of zinc nano-fertilizer to enhance crop production in pearl millet (Pennisetum americanum). *Agric. Res.*, 3, 257–262.

Tarafdar, J. C. (2015). Nanoparticle Production, Characterization and its Application to Horticultural Crops; *ICAR: Jodhpur, Rajasthan*, pp. 222–229.

Zagzog, O.A.; Gad, M.M.; Hafez, (2017). N.K. Effect of nano-chitosan on vegetative growth, fruiting and resistance of malformation of mango. *Trends Hortic Res*., 7, 11–18.

Zhang, M.; Gao, B.; Chen, J.; Li, Y.; Creamer, A.E.; Chen, H. (2014). Slow-release fertilizer encapsulated by graphene oxide films. *Chem. Eng*. J., 255, 107–113.

VERTICAL FARMING

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Abstract:

With a growing human population, there is a growing need for sustainable practices, especially within agriculture. As the population increases, so does the amount of resources used to provide for it. Vertical farming technology has the potential to impact the world economically, environmentally, and socially and it is the advanced level of agriculture technology where this has to be practiced when there is unavailable of land and other requirements for the perfect structure of farming mode this is the new way or approach in the advanced level of crop cultivation & production. It offers an opportunity to increase crop production while reducing food miles and increasing product quality and the only way to grow crops close to urban centres where space is at a premium, and this has advantages in both reducing transport costs and increasing the quality of the delivered product.

Keywords: Crop, vertical farming, technology, quality

Introduction:

Only one fourth (nearly 27%) is the total land mass on the planet earth rest being water (nearly 73%). Out of this land mass, only three fourth is productive rest being high mountains, cold and hot deserts, etc. Over the years mankind has been able to convert nearly 57% of productive land for cultivation of various crops for food, often on expense of forest and grasslands (43%). With rising urbanization a worldwide phenomenon, it has been estimated that most of the world's population (>60%) by 2030 will shift to cities for urban dwelling. Interestingly in the same period (by 2030), the human population is expected to reach 8.6 billion from the current 7.6 billion, and expected to rise further exponentially to 9.8 billion by 2050 and explode to 11.2 billion by 2100. On the other side, the worldwide reduction in cultivated land is being caused by the rising urbanisation, which is placing pressure on the limited resources of accessible land (Ali and Srivastava, 2017). Urbanization has resulted in innumerable small and large concrete structures mostly to accommodate the ever rising population at the expense of farm land. Today, the skylines of major metropolises are dotted with high-rise buildings, but peri-urban agriculture, which grows vegetables and other food, is rarely visible. There is scarcely any room for additional crop cultivation in many locations because the amount of cultivable land has almost run out. The cultivable area in India has been essentially stable over the past few years. Cultivable land has become a limiting factor. The transportation of food to cities from rural production sites will add to the problem, compounded further in perishable and semi-perishable food especially from horticultural crops having shorter shelf life. One innovation that has potential to partly manage the above problem is by production of food items in cities itself in residential buildings, roof tops, public spaces, etc. Whereas the present improved agriculture practices put immense pressure on finite resources with diminishing returns on land, water, energy, etc., the innovative technology of vertical farming is expected to relieve this pressure to a large extent.

Brief history

The hanging garden of Babylon poses as the earliest method to grow plants vertically. In 1915, the American geologist Gilbert Ellis Bailey used the concept of the tall multi-story buildings for indoor cultivation Vertical farming as a concept was developed in the recent years (1999) through the advances in technology by Dickson Despommier, an Emeritus Professor of Microbiology at the Columbia University; He explains that hydroponic crops could be grown on upper floor and the lower floors would be suited for chickens and fish that eat plants waste.

How does vertical farming work

There are four critical areas in understanding how vertical farming works:

i. Physical layout
ii. Lighting
iii. Growing medium
iv. Sustainability features

First off, since generating more food per square metre is the main objective of vertical farming, crops are stacked vertically to grow. Second, to maintain the ideal lighting level in the space, the employment of both natural and artificial lighting is perfected. To increase lighting effectiveness, technologies like revolving beds are used. Finally, instead of using soil, we'll use hydroponics or aeroponics, which submerge plant roots in nutrient solution (spray-misting the plant roots). The growing mediums are aquaponic. In vertical farming, peat moss, coconut husks, and other similar non-soil mediums are frequently used. Ultimately, the vertical farming system reduces the energy cost of farming by including a variety of sustainability characteristics. In comparison to conventional farming, vertical farming really consumes 95% less water.

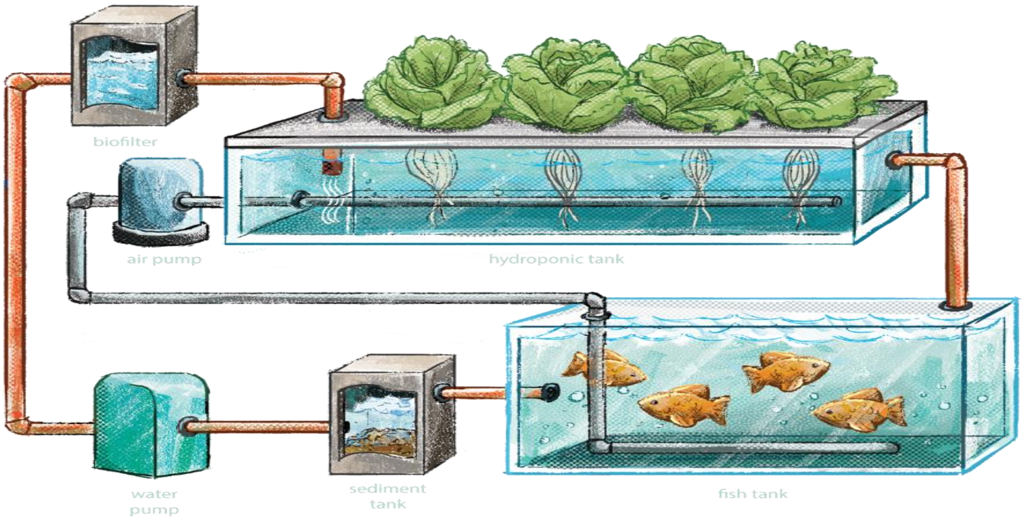
Techniques of vertical farming

Vertical farms occur in a variety of sizes and designs, from simple two-story or wall-mounted buildings to multi-story complexes in enormous warehouses. But to supply plant nutrients, all vertical farms use one of three soilless systems: hydroponic, aeroponic, or aquaponic. The following information explains these three structures that are growing.

Hydroponics: The method of growing plants without soil refers to hydroponics which is predominant growing system used in vertical farms. Plant roots are submerged in liquid solutions containing macronutrients such as nitrogen, phosphorus, sulphur, potassium, calcium and magnesium and minor elements like iron, chlorine, manganese, boron, zinc, copper and molybdenum in this systems. In addition, to provide protection for the roots, inert (chemically inactive) media such as dirt, sand, and sawdust are used as soil substitutes. The benefits of hydroponics include the potential to increase the yield per unit area and decrease the use of water. Due to these benefits, the predominant growing method used in vertical farming is hydroponics.

Aeroponics: The National Aeronautical and Space Administration (NASA) is in responsible for developing this revolutionary technique for indoor development. In the 1990s, NASA was interested in discovering efficient ways of growing plants in space and coined the word "aeroponics," defined as "growing plants without soil and very little water in an air/mist environment." Aeroponic systems in the vertical farming world are still an exception, but they are gaining considerable interest. With up to 90% less water than even the most effective hydroponic systems, the aeroponic system is by far the most efficient plant-growing system for vertical farms. It has also been shown that plants grown in these aeroponic systems consume more nutrients and vitamins, making the plants healthier and potentially more nutritious. Aeroponic systems have not been widely applied to vertical farming at the moment, but are beginning to attract considerable interest.

Aquaponics: The term aquaponics is coined by the combination of two words: aquaculture, referring to fish farming, and hydroponics, the technique of soil-free growing plants. An aquaponic system takes the hydroponic system a step further, integrating the same habitat with plants and fish. In indoor ponds, fish are raised to produce nutrient-rich waste that is used as a feed source for vertical farm plants. In addition, the plants extract and purify the waste water that is recycled into the fish ponds. While aquaponics are used in smaller scale vertical farming systems, only a few fast-growing vegetable crops are developed by most commercial vertical farming systems and do not include an aquaponic portion. The economic and output problems are simplified and productivity is maximised. New standardised aquaponic systems, however can contribute to making this closed-cycle system more common.



Controlled Environment Agriculture: The alteration of the natural environment to increase crop yield or prolong the growing season is controlled-environment agriculture (CEA). Usually, CEA systems are hosted in enclosed structures such as greenhouses or buildings, where environmental factors such as air, temperature, light, water, humidity, carbon dioxide, and plant nutrition can be monitored CEA is often used in vertical farming systems in combination with soil-free farming techniques such as hydroponics, aquaponics, and aeroponics.

Types of vertical farming:

Building-based vertical farms: Abandoned structures, such as a Chicago farm named "The Plant," which was converted from an old meatpacking plant, are frequently reused for vertical farming. New buildings, however, are also often built to house vertical farming systems.

Shipping-container vertical farms: An increasingly common alternative for housing vertical farming systems is recycled shipping containers. Often fitted with LED lighting, vertically stacked hydroponics, smart climate controls, and monitoring sensors, the shipping containers serve as standardized, modular chambers for growing a range of plants. In addition, farms can save even more space and achieve greater yield per square foot by stacking the shipping containers.

Deep farms: A "deep farm" is a vertical farm constructed from underground tunnels or abandoned mine shafts that have been renovated. Deep farms require less heating energy because the temperatures and humidity there are often moderate and steady. Deep farms may also use adjacent groundwater to reduce the cost of water supply. According to Saffa Riffat, chair of Sustainable Energy at the University of Nottingham, deep farming can generate 7 to 9 times more food than traditional farming above ground on the same land area, despite low costs. These underground farms, combined with automated harvesting systems, can be completely self-sufficient.

Advantages of vertical farming

Preparation for Future: By 2050, around 80 % of world population is expected to live in urban areas, and the growing population will lead to an increasing demand for food. The efficient use of vertical farming may perhaps play a significant role in preparing for such a challenge.

Increased crop production: Vertical farming allows us to produce more crops from the same growing area. In fact, 1 acre of an indoor area offers equivalent production to at least 4-6 acres of outdoor capacity.

Water saving: Vertical farming allows us to produce crops with 70- 95 less water than required for normal cultivation.

Not affected by unfavourable weather conditions: Crops in a field can be adversely affected by natural calamities such as high rainfall, cyclones, flooding or severe drought. Indoor vertical farms are less likely to feel the brunt of the unfavourable weather, providing a greater certainty of harvest output throughout the year.

Increased production of organic crops: As crops are produced in a well-controlled indoor environment without the use of chemical pesticides, vertical farming allows us to grow pesticide-free and organic crops.

Environment friendly: Indoor vertical farming can significantly lessen the occupational hazards associated with traditional farming.

Farmers are not exposed to hazards related to heavy farming equipment, diseases like malaria, poisonous chemicals and so on.

Limitations of vertical farming

No Established Economics: The financial feasibility of this new farming method remains uncertain. The cost of building skyscrapers for farming, combined with other costs such as lighting, heating, and labour, can be more than the benefits.

Difficulties with pollination: Vertical farming takes place in a controlled environment without the presence of insects. As such, the pollination process needs to be done manually, which will be labour intensive and costly.

Labour costs: In vertical farming, the labour cost can be very high due to the need for highly skilled workers. So, the hourly cost of workers may be significantly higher than for agriculture in general. And vertical farming technologies will require significant training, which will add to labour costs.

Fewer jobs: Automation in vertical farms may lead to the need for fewer workers. Manual pollination may become one of the more labour-intensive functions in vertical farms.

Lower worker efficiency: The layout of a vertical farm may pose a challenge for the workers to reach each layer. Climbing to upper layers takes time and energy, decreasing the overall employee efficiency.

Too much dependency on technology: the entire vertical farming is extremely dependent on various technologies for lighting, maintaining temperature, and humidity. Losing power for just a single day can prove very costly for a vertical farm.

Conclusion:

The practise of vertical farming is still developing. It is still working towards achieving its goal of bringing locally grown food to all individuals and communities by producing the freshest, best-tasting crops while utilising only 1% of the water used by a conventional farm. In addition, vertical farms employ a fraction of the land that conventional farms do and none of the pesticides, synthetic fertilisers, or genetically modified organisms (GMOs). Vertical farming has been incorporated into urban areas, and this connection to the city and its inhabitants has been recognised as important. In addition to improving human wellbeing, it simultaneously contributes to food safety, contextual sustainability, and poverty reduction.

References:

Ali, F. and Srivastava, C., (2017). Futuristic urbanism-An overview of vertical farming and urban agriculture for future cities in India. *International Journal of Advances Research Sciences and Engineering Technology*. *4*(4), pp.3767-3775.

Jegadeesh, M. and Verapandi, J., (2014). An innovative approach on vertical farming techniques. *SSRG International Journal of Agriculture & Environmental Science* 1.

Jie Sheng (2018). Vertical Farming Feasibility: The opportunities and challenges of adapting vertical agriculture. University of British Columbia, Vancouver, Canada Master of Land and Water Systems, Faculty of Land and Food System.

Kalantari, F., Mohd Tahir, O., Mahmoudi Lahijani, A. and Kalantari, S., (2017). A review of vertical farming technology: A guide for implementation of building integrated agriculture in cities. In *Advanced Engineering Forum* 24, pp. 76-91.

Naqvi, S.M.Z.A., Saleem, S.R., Tahir, M.N., Hussain, S., Ul Haq, S.I., Awais, M. and Qamar, S., (2022). Vertical Farming: Current Practices and Its Future. *Environmental Sciences Proceedings*, *23*(1), p.4.

Rashmi Maria Royston and Pavithra M.P. (2018). Vertical Farming: A Concept. *International Journal of Engineering and Techniques* 4 (3).

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ACID SOILS

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Abstract:

Soil acidification is an increasing problem in agricultural production and ecological stability worldwide. Soil is acidic if pH is less than 7 and alkaline if it is above 7.0. Plants suffer from suboptimal availability of nutrients at pH below 5.5 and above 8.5 resulting in lower yield of arable crops. Poor plant growth in acidic soils results from a variety of factors, including proton toxicity; deficiencies in nitrogen, phosphorus, calcium, magnesium; and toxicities of various metals (aluminum (Al), manganese, iron). Aluminum toxicity is generally the primary limitation for plant growth in acidic soils. The acid soils mainly occur in the hilly areas of north-east (NE) and north-west (NW) Himalayan region, eastern plateau and the western coastal plains of India with more than 1200 mm mean annual rainfall (MAR).

Introduction:

Soils differ considerably in their acidity or pH. In aqueous systems, an acid is a substance that donates H to some other substance. Conversely, a base is any substance that accepts H or donates OH. Pure water undergoes slight self-ionization [Equation (1)]:

$H_2O = H^+ + OH^-$ ... (1)

The H ion actually attaches to another H_2O molecule to give H_3O^+:

$H_2O + H^+ = H_3O^+$ ... (2)

Since both H and OH are produced by dissociation of a water molecule, H_2O is both a weak acid and a weak base. The product of H^+ and OH^- concentrations, is the dissociation constant of water or Kw:

$Kw = [H]\,[OH] = [10^{-7}]\,[10^{-7}] = 10^{-14}$ (at 25 °C) ... (3)

Adding of an acid to H_2O will increase [H] but $[OH^-]$ would decrease because Kw is a constant, viz. 10^{-14}. For example, in a 0.1 M HCl solution, the [H] is 10' M; thus the $[OH^-]$ is:

$Kw = [H]\,[OH] = 10^{14}$ $[10^{1}]\,[OH] = 10^{14}\,[OH] = 10^{13}$ M

The [H] in solution can be conveniently expressed using pH which is defined as:

pH = log 1/[H] = -log [H]

Soil pH measures H activity and is expressed in logarithmic terms. The practical significance of the logarithmic relationship is that each unit change in soil pH means a ten-fold change in the amount of acidity and basicity, as proposed by the Danish Chemist Sorensen in 1909.

Solutions having pH <7.0 are acidic, while those with pH >7.0 are basic or alkaline, and those with pH 7.0 are neutral. Soil pH represents the H^+ activity in soil solution (Active acidity) and does not measure the undissociated or potential acidity.

Soil acidity: Soil acidity may be defined as the soil system's proton (H^+ ions) donating capacity during its transition from a given state to a reference state.

Soil acidity involves intensity and quantity aspects. The intensity aspect is universally characterized by the measurements of H^+ ion activity, expressed as pH. The quantity aspect is characterized, directly or indirectly, by the quantity of alkali required to titrate soil to some arbitrarily established endpoint. Soil acidity is a major problem in relation to plant growth and therefore, acid soils are called a problem soil.

Causes of acidic soil formation: There are following reasons for the formation of acidic soil:

1. Nature of parent material: When amount of quartz and silica increases in rocks as compared to basic mineral then acidic rock is formed. Silica reacts with water to form orthosilisic acid $[(H_2O)SiO_2]$ and trisilisic acid $[(H_2O)_2.3SiO_2]_3$. Soil formed by acidic rocks are acidic in nature.

2. Removal of bases: In the region of heavy rainfall basic ions like Ca^{+2}, Mg^{+2}, Na^+, K^+ which are adsorbed by soil complex and dissolved in water and go to lower level while comparatively less soluble aluminium and iron (Fe) compounds remain in soil.

The nature of these compounds are acidic and oxides and hydroxides of it react with water to release H^+ ion in soil solution which make acidic soil. Moreover, when soluble base lost by leaching the H^+ ions of organic acid and other acid substitute the base present on soil complex. As the base lost from soil then soil becomes acidic because of unsaturation.

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (Carbonic acid)}$$

$$Ca^{+2} \text{ (Clay)} + H_2CO_3 \longrightarrow H^+ \text{ Clay} + CaCO_3$$

(Insoluble calcium carbonate)

$$CaCO_3 + H_2CO_3 \longrightarrow Ca(HCO_3)_2 \text{ (Soluble in water)}$$

(leaching)

3. Continuous use of acidic fertilizers: Due to continuous use of acidic fertilizers soil becomes acidic in nature. Nascent hydrogen and acids are produced in soil by the use of urea, ammonium sulphate, ammonium nitrate etc., which replaces the cation and makes soil acidic. The cation forms the compound and get precipitated.

$$Ca^{+2} \text{ Clay complex} + (NH_4)_2SO_4 \longrightarrow NH_4\text{Clay complex } NH_4 + CaSO_4$$

Ammonium sulphate (Leachable)

$$Ca^{+2} \text{ Clay complex} + 2NH_4NO_3 \longrightarrow NH_4 \text{ Clay complex } NH_4 + Ca(NO_3)_2$$

Ammonium Nitrate (Leachable)

$$CO(NH_2)_2 + 2H_2O \longrightarrow (NH_4)_2CO_3$$

Urea fertilizer

$$(NH_4)_2CO_3 \longrightarrow 2NH_3 + CO_2 + H_2O$$

$$NH_3 + H_2O \longrightarrow NH_4OH \longrightarrow NH_4^+ + OH^-$$

$$2NH^+_4 + 3O_2 \longrightarrow 2HNO_2 + 2H_2O + 2H^+ \text{ (Nascent hydrogen)}$$

$$Ca^{+2} \text{ Clay} + 2H^+ \longrightarrow H^+ \text{ Clay } H^+ + Ca^{+2} + 2HNO_2 + O_2 \longrightarrow 2HNO_3$$

$$Ca^{+2} \text{ Clay} + 2HNO_3 \longrightarrow H^+ \text{ Clay } H^+ + Ca^{+2} + Ca(NO_3)_2$$

(Soluble)

4. Organic matter: Soil which contains more amount of organic matter, produce CO_2 and other carbonic acid due to decomposition of organic matter. Due to acid formation soil becomes acidic and simultaneously cations are replaced by H^+ ions.

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$$\text{Organic matter} \longrightarrow \text{decomposition} \longrightarrow CO_2$$

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (Carbonic acid)}$$

$$Ca^{+2}\text{ Clay} + 2H_2CO_3 \longrightarrow H^+\text{ Clay } H^+ + \underset{\text{(Soluble)}}{Ca(HCO_3)_2}$$

5. Microbiological action: Various microorganism are active in soil which are responsible for decomposition and nitrification. Due to activity of microorganism acid forms continuously. These acids react with base which is present in colloidal complex and neutralized. But because of deficiency of base on soil complexes these acids cannot be neutralized completely and due to this soil becomes acidic.

Types of soil acidity: Soil acidity is of three kinds

(a) Active acidity: The hydrogen ions in the soil solution contribute to active acidity. It may be defined as the acidity developed due to concentration of hydrogen (H^+) and aluminium (Al^{3+}) ions in the soil solution. The concentration of hydrogen ion in soil solution due to active acidity is very small, implying that only a meager amount of lime would be required to neutralize active acidity. Inspite of smaller concentration, active acidity is important since the plant root and the microbes around the rhizosphere are influenced by it and because a dynamic equilibrium exists among active, exchangeable and reserve acidities in the soil.

(b) Exchangeable acidity: In strongly acidic soils, the concentrations of exchangeable aluminium and hydrogen ions contribute to exchangeable acidity. It may be defined as 'the acidity developed due to adsorbed hydrogen (H^+) and aluminium (Al^{3+}) ions on soil colloids. However, this exchangeable aluminium and hydrogen ions concentration is meagre in moderately acidic soils.

(c) Reserve or residual acidity: Aluminium hydroxy ions and hydrogen and aluminium ions present in non-exchangeable form with organic matter and clays account for the reserve acidity. It is measured by titrating a soil suspension up to a certain pH, normally about 8.0, the amount of acidity in the soil being equivalent to the amount of NaOH used. When an acid soil is limed, gibbsite is formed from aluminium hydroxy ions with increase in pH. The potential acidity is much higher as compared to active or exchangeable acidity requiring much larger doses of lime to neutralize than what is required for neutralization of active acidity. Therefore, no attempt is made to neutralize reserve acidity. Liming is always limited to neutralize active acidy and part of the exchangeable acidity.

Extent and distribution of acid soils

The acid soils are found in the Himalayan region, the eastern and north-eastern plains, peninsular India and the coastal plains under different agro-climatic situations. The soils occupy about 90 million hectares, constituting over one-fourth of total geographical area of the country (Table 1). About half of the area is under cultivation and rest is under forestry and other uses. About 25 million hectares of cultivated lands with pH value less than 5.6, are critically degraded with very poor physical, chemical and biological characteristics and the rest 23 million hectares of land having soil pH range 6 to 6.5. The states having large areas under degraded acidic soils are: Arunachal Pradesh, Chhatisgarh, Kerala, Assam, Manipur, Nagaland, Mizoram, Meghalaya, Uttrakhand, Madhya Pradesh and Jharkhand. The degraded area in Chhatisgarh and Arunachal Pradesh is predominantly under forests. The alluvial acid soils are found in West Bengal, Bihar, Assam and parts of Orissa. The marshy acid soils are distributed across Assam, Kerala, West Bengal, coastal Orissa, South-east coast of Tamil Nadu and tarai regions of Uttrakhand, Bihar and West Bengal. The acid sulphate soils are unique to the Kuttanad area of Kerala.

Table 1: Extent of acid soils in different states of India (million ha)

States	Strongly acidic (pH < 4.5)	Moderately acidic (pH 4.5-5.5)	Slightly acidic (pH 5.5-6.5)	Total
Anurachal Pradesh	4.78	1.74	0.27	6.79
Assam	0.02	2.31	2.33	4.66
Bihar	-	0.04	2.32	2.36
Chhatisgarh	0.15	6.30	4.39	10.84
Goa	-	0.11	0.19	0.30
Himachal Pradesh	-	0.16	1.62	1.78
Jammu & Kashmir	-	0.09	1.48	1.57
Jharkhand	-	1.00	5.77	6.77
Karnataka	-	0.06	3.25	3.31
Kerala	0.14	2.87	0.75	3.76
Madhya Pradesh	-	1.12	10.60	11.72
Maharashtra	-	0.21	4.33	4.54
Manipur	1.44	0.43	0.32	2.19
Meghalaya	-	1.19	1.05	2.24
Mizoram	-	1.27	0.78	2.05
Nagaland	0.12	1.48	0.05	1.65
Orissa	-	0.26	8.41	8.67
Sikkim	0.28	0.32	-	0.60
Tamil Nadu	0.21	0.35	4.29	4.85
Tripura	0.06	0.75	0.24	1.05
Uttarakhand	-	1.18	2.30	3.48
West Bangal	-	0.56	4.20	4.76
All states	6.19	24.81	58.94	89.94

Source: NPSSLUP, Nagpur

Classification of Acidic soils

Mandal (1974) has classified acid soils of India into the following seven groups:

1. Laterite soils
2. Lateritic and laterite red soils
3. Mixed yellow red soils
4. Ferruginous red soils
5. Podzolic soils
6. Terai soils
7. Peaty soils

Table 2: Classification of acid soils of India and their distribution

Broad soil group	Type	PH range	Distribution
Laterites	Plinthaqults, Plinthustults and Plinthudults	4.8-7.0	Karnataka, Madhya Pradesh, Orissa, West Bengal, Kerala, Assam, Jharkhand
Lateritic soils	Paleudalfs, Hapludalfs, Hapludults, Trophumults, Dystropepts, Ustropepts, Oxic intergrades	5.0-7.0	Kerala, Orissa, West Bengal, Assam, North-Eastern States, Jharkhand
Mixed red and yellow soils	Dystrochrepts, Udifluvents, Hapludalfs	5.5-6.5	Karnataka, MP, erstwhile UP, Orissa, Chotanagpur and Santhal Praganas of Jharkhand
Ferruginous red soils	Paleudalfs, Udifluvents, Udorthents, Plinthaquepts, Tropaquepts, Ultic intergrades	5.0-6.8	Tamil Nadu, parts of Karnataka, Maharashtra, Andhra Pradesh, Orissa, Jharkhand, Goa
Ferruginous red and gravely soils	Haplustalfs, Rhodustalfs	5.2-6.7	Assam, North-Eastern States, WB, Orissa, erstwhile UP, Andaman Islands
(i) Brown forest soils of Western Himalayas	Hapludolls, Udifluvents, Udorthents, Dystrochrepts, Haplumbrepts	5.5-6.0	Upper regions of Western Himalayas, Jammu and Kashmir, Himachal Pradesh
(ii) Brown forest podzolic soils	Hapludolls, Udorthents, Haplumbrepts, Dystrochrepts	5.1-5.4	Upper regions of Western Himalayas, Jammu and Kashmir and Himachal Pradesh
(iii) Brown forest soils of central Himalayas	Hapludalts, Udorthents, Udifluvents, Dystrochrepts	5.2-5.7	Lower regions of Central Himalayas, erstwhile UP
(iv) Brown forest podzolic soils of central Himalayas	Mollic Hapludalfs, Ultic Hapludalfs, Haplumbrepts	4.7-6.0	Eastern Himalayas, North-Eastern States of Himalayan region, Arunachal Pradesh
Foot hill soils	Haplaquolls	4.5-6.5	Jammu and Kashmir, West Bengal, erstwhile UP
Peat soils	Histosols	3.5-4.5	Kerala, Assam
Alluvial soils	Haplumbrepts, "Udifluvents	4.2-5.8	Assam, West Bengal, Bihar
Coastal alluvial Soils	Tropofluvents, Sulfaquepts, Haplaquents, Udifluvents	3.5-5.8	West Bengal (Sunderbans), Kerala, some pockets of Tamil Nadu
Degraded saline and acid saline soils	Acid Fluvaquents	5.2-6.6	West Bengal, Orissa, parts of Tamil Nadu and Kerala

Source: Murthy *et al*. (1976)

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- According to the intensity of acidity, the acid soils are of the following five types:

(1) Slightly acidic (pH range 6.6 to 6.1)
(2) Medium acidic (pH 6.0 to 5.6)
(3) Strongly acidic (pH 5.5 to 5.1)
(4) Very strongly acidic (pH 5.0 to 4.6)
(5) Extremely strong acidic (pH 4.5 or lower)

Effects of soil acidity: Problems of soil acidity may be divided into three groups which are as follows:

1. Toxic effects
(a) Acid toxicity
(b) Toxicity of different nutrient elements
2. Nutrient availability
(a) Non-specific effects
(b) Specific effects
(i) Exchangeable bases (ii) Nutrient imbalances
3. Microbial activity.

1. Toxic effects

a) Acid toxicity: The higher hydrogen ion concentration is toxic to plants under strong acid conditions of soil. The acid toxicity includes possible toxicities of acid anions as well as H^+ ions.

b) Toxicity of Different Nutrient Elements

Iron and Manganese: The concentration of these two ions Fe^{2+} and Mn^{2+} in soil solution depends upon the soil reaction or pH organic matter and intensity of soil reduction.

Due to increase in organic matter content in the soil, the population of soil microbes increases and very rapidly used up the soil oxygen and results reduction of soil. As a result of soil reduction, the nutrient elements like Mn^{4+} and Fe^{3+} reduce to Mn^{2+} (manganous manganese) and Fe^{2+} (ferrous iron) respectively and increases their concentration to a very high and toxicity of those elements develops. Due to such toxic effects, a physiological disease of rice is found in submerged soils which is popularly known as browning disease.

Toxicity of Aluminium (Al): The toxicity of aluminium may be greatly influenced by the accompanying cations. The toxicity of aluminium tends to decrease with an increase in the concentration of other cations such as calcium. Aluminium toxicity is a problem in both upland and lowland soils. Aluminium toxicity in soils affects plant growth in various ways

(i) It restricts the root growth.
(ii) It affects various plant physiological processes like division of cells, formation of DNA and respiration etc.
(iii) It restricts the absorption and translocation of some important nutrient elements from soil to the plant like phosphorus, calcium, iron, manganese etc.
(iv) It causes wilting of plants.
(v) It also inhibits the microbial activity in the soil.

2. Nutrient availability

a) Non-specific effects. It is associated with the inhibition effect of root growth and thereby affects the nutrient availability.

b) Specific Effects

Exchangeable bases: There are two aspects of availability of exchangeable bases i.e. ion uptake process and the release of bases from the exchangeable form may be adversely affected due to soil acidity. Due to complementary ion effect exchangeable bases are released preferentially in a fractional exchange. Deficiency of bases like Ca^{2+} and Mg^{2+} are found in acid soils.

Nutrient imbalances: It is evident that soluble iron, aluminium and manganese are usually present in their higher concentrations under moderate to strong acid soils. Phosphorus react with these ions and produces insoluble phosphatic compounds rendering phosphorus unavailable to plants. Besides these, fixation of phosphorus by hydrous oxides of iron and aluminium or by adsorption, the availability of phosphorus is decreased. In acid soils, iron, manganese, copper and zinc are abundant, but molybdenum is very limited and unavailable to plants. In acid soils having very low pH, the availability of boron may also be decreased due to adsorption on sesquioxides, iron and aluminium hydroxy compounds. (Nitrogen, Potassium and Sulphur become less available in an acid soil having pH less than 5.5.

3. Microbial Activity: It is well-known that soil organisms are influenced by fluctuations in the soil reaction. Bacteria and actinomycetes function better in soils having moderate to high pH values. They cannot show their activity when the soil pH drops below 5.5. Nitrogen fixation in acid soils is greatly affected by lowering the activity of Azotobacter sp. Besides these, soil acidity also inhibits the symbiotic nitrogen fixation by affecting the activity of Rhizobium sp. Fungi can grow well under.

Conclusion:

Soil acidity is a serious barrier to agricultural output in more than a quarter of the country's total land area. These soils can be found in the Himalayan region, the eastern and north-eastern plains, peninsular India, and the coastal plains, all of which have different landscapes, geology, climate, and vegetation. It is critical to have a basic understanding of the subject, as this will aid in the planning and management of soil acidity concerns in the field. Low pH soils have a range of chemical and biological features that are detrimental to plant growth and soil health. The dissolution of Al under acidic conditions in acid soils which were attributed to the formation of acidic water triggered by the dissolution of sulfides influenced plant growth in mine site. It is necessary to select a proper plant for successful revegetation from the point of view of Al tolerance and the dissolution of Al with the formation of acidic water over time. The effects of acid soils on plant growth change according to plant species because Al tolerant mechanism of plants depends on the species. Moreover, plants can survive under acidic conditions by increasing the resistance against acidic conditions with the plant growth. Therefore, the timing of the transplant of plants and acidification of soils over time should be taken into account for the revegetation.

References:

Adams, F. (1984). Crop response to lime in the southern United States. In Soil Acidity and Liming. Second Edition. F Adams. pp 211–266. American Society of Agronomy, Madison, WI.

Brady, N.C. and Weil, R.R. (2013). The Nature and Properties of Soils, 14th Edition Revised. Dorling Kindersley (India) Pvt. Ltd. Licencees of Pearson Education in South Asia.

Jackson, M.L. (1973). Soil Chemical Analysis. -Prentice-Hall of India Pvt. Ltd, New Delhi, P. 40.

Maji, A.K., Reddy, Obi G.P. and Sarkar, Dipak (2012). Acid Soils of India - Their Extent and Spatial Variability. NBSS Publ. No.145, NBSS&LUP (ICAR), Nagpur. pp. 1-138.

Mandal, S.C., Sinha, M.K., and Sinha, H. (1975). Acid Soils of India and Liming. Technical Bulletin No. 75. Indian Council of Agricultural Research, New Delhi.

Murthy, R.S., Shankaranarayana, H.S. and Hirekerur, L.R. (1976). Distribution, genesis and classification of acid soils of India. Bulletin of the Indian Society of Soil Science 11, 1-17.

BIOCHAR AND IT'S ROLE IN AGRICULTURE

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Abstract:

To continue producing enough food for the world's expanding population, innovative and practical solutions are needed at a time when climate change is causing more desertification and drought worldwide. Agricultural soils have long used synthetic fertilisers to increase productivity, but some of these fertilisers leak into the environment and release greenhouse gases (GHG). Increasing the effectiveness of fertilisers as well as improving soil microbiology and water retention are some important concerns in agricultural techniques. A nutrient-rich product made from biomass known as biochar is gaining popularity for its use in soil amendment, crop yield improvement and carbon sequestration. This study provides an overview of the potential advantages of using biochar, with an emphasis on agricultural uses. It indicates that using biochar as a soil amendment increases soil nutrient density, water holding capacity, lowers the need for fertilizer, improves soil microbiology, and improves crop yields. Using biochar has various environmental advantages, economic advantages, and a possible role in carbon credit systems. The answer to these basic needs may lie in biochar, also known as biocarbon.

Introduction:

The word "biochar" comes from the Greek words "bios," which means "life," and "char," which means (Charcoal obtained by the carbonization of the biomass). Biochar is a fine-grained, carbon-rich, porous material used in agriculture and the environment that is created by the thermal decomposition of biomass with less oxygen supply. Biochar is a type of charcoal that differs from normal charcoal in that it is often produced at high temperatures as compared to low temperatures. It can be produced through the pyrolysis of any organic material, including wood, crop residues, municipal solid waste, manures, bones, pine needles, maize stalk, weed biomass, dried banana leaves, chickpea stover, outer shells of jatropha pods, millet cones, paper mill waste, saw mill waste, piggery waste, poultry waste, shells of palm fruit, and sugarcane trash. Pyrolysis is the process of heating organic material above 300-700^{0}C without the presence of air. Initially, some volatiles are lost, then unreacted residues are converted into volatiles, gases and biochar. Pyrolysis converts complex chemical substances into simple chemical substances. The quality of the biochar produced is better when the pyrolysis process takes place at a higher temperature. The best biochar is produced when the temperature is above 650^{0}C. The porosity and chemical composition of the biochar produced are influenced by the raw material and pyrolysis temperature, which impacts how it affects the soil. The initial moisture content of the substrate affects the yield of biochar. Once formed, biochar can be mixed into soil to increase fertility. In degraded soil as well as in soil with low nutrient levels, biochar is more useful.

Historical uses of biochar:

The Terra Preta, commonly referred to as "Indian black earth," was the first instance of biochar being used to improve soil. Western Amazonia is where the type of soil known as Terra Preta was first found. Its dark hue, high degree of aggregate stability due to the presence of more carbon, and high nutritional content related to an enhanced microbial population make it easy to identify.

The Terra Preta's most significant feature is the deliberate introduction of biochar to improve the soil profile by historic indigenous populations. The tropical rainforest has flourished due to the usage of biochar as a soil supplement. The Terra Preta of the Amazonian rain forest serves as an example of how deficient soils can be modified to increase fertility and soil health. Tropical sandy soils lack natural fertility; life is mainly supported by the organic matter that the forest canopy provides. Yet, it has been discovered that the Terra Preta contains larger concentrations of nutrients (nitrogen, potassium, calcium, and phosphorus) as well as improved soil rigidity and structure, which results in a more secure arrangement of soil particles. The very stable organic carbon contained in this soil that's what provides it its improved structure. Flakes from several types of mica that were previously used to make pottery were found in the soil sub-layers after *Lima et al.* analysed the Terra Preta's various properties. It is clear that the char was actually produced in clay ovens, and that both the clay particles and the resulting biochar were incorporated into the soil. This practice is said to have existed for almost 2000 years. There are several different types of microbial populations in the Terra Preta soils. Especially, there are several types of acido-bacteria, and the Terra Preta has a 25% wider diversity of bacterial species than other soils. This is essential because different bacteria must be developed in soils in order to provide a source of nitrogen to plants that are growing. The presence of the Terra Preta reveals that the original inhabitants of the Amazonia either understood how to produce biochar or knowingly added this substance to the soil to increase fertility.

Resources of biochar:

Different sources of bio-mass can be found throughout our daily lives, including dry leaves, straw from plants, and coconut shells. Switchgrass, corn, and other specifically cultivated energy crops have been tested for the manufacture of bio-char, while the majority of research trials have focused on the creation of biomass using materials like animal waste and forestry, etc.

Below current prices, it is unlikely that separate bio-mass production facilities for the primary purpose of producing bio-char will be advantageous. In addition to providing a concern for biodiversity management, bio-char produced by native forest cleaning doesn't affect net discharge reductions from a life-cycle perspective. There is contest among the sources of biomass. Because of this, current bio-char setups are used, especially in a variety of streams that are financially beneficial.

Plant residues and animal waste that have been left behind play a crucial role in carbon sequestration, water and soil management, bacterial activity, and agricultural productivity. They are now commercially available as fertilizer and their use reduces the need for further applications of synthetic fertilizers. Additionally, some plant byproducts are fed to cattle. Thus, plant residues and animal dung stand in for zero waste in agriculture, and bio-char must be carefully made from the soil. Planning for the required amount of feedstock exclusion is necessary; afterwards, biochar may be applied to the same land that produced the feedstock.

Heavy metals found in bio-char made from sewage waste that is used to treat household and municipal sewage waste have the potential to degrade rather than improve topsoil. As a result of this possibility, more research is needed to characterise different types of sewage sludge under varied conditions, as their level of pollution is likely to vary at different times and places. Additionally, when wet feedstock like sewage sludge and animal manure become more prevalent, concerns about the best carbonization technique to use arise because these materials require a lot of energy to heat up and remove moisture while undergoing slow pyrolysis.

Topsoil is made more potent by biochar, which encourages crop development. More carbon dioxide is consumed and transformed by healthy crops, which improves air condition.

Biochar characteristics:

The qualities of the feedstock used to prepare it are determined by its physical and chemical properties.

- It has many microscopic pores, providing it a large surface area to hold water and act as a habitat for microorganisms which are beneficial.
- Temperature increases during pyrolysis from 400 to 600^0C, increase the amount of ash and fixed carbon while decreasing the volatile and N components of the biochar.
- The total carbon content of biochar produced from various feedstocks ranges between 33 to 82%. Its C:N ratio ranges between 19 to 221.
- Low levels of N and S are present in biochar produced at high temperatures.
- Electrical conductivity, high pH, and extractable nitrate are all characteristics of high temperature biochars (>650^0C).
- Biochars made at a low temperature (350^0C) contain more extractable P, phenols and NH_4.
- The amounts of Ca, Mg, K and P in biochar are significant.

Advantages of biochar:

Biochar reduces the need for chemical enhancers since it can store soil nutrients for prolonged periods of time. Similar to this, it reduces soil acidity, which minimises the amount of liming required to maintain the optimum soil condition. A supportive environment for bacteria is provided by biochar's vast area and tremendous porosity. This promotes the development of smaller living organisms in the soil, which may facilitate greater nutrient uptake by crops. Recycling organic waste from agriculture and other sources into biochar can help reduce the amount of CO_2 and methane produced as biomass fuels disintegrate. Biochar provides a great way to get rid of the large amounts of manure that livestock produce.

- Increased rate of fertilizer efficiency.
- The preservation of toxins like pesticides and herbicides has improved the quality of the water.

- Reduced emissions of the potent greenhouse gases methane and nitrous oxide, as well as increased emissions of renewable energy sources, all contribute to the mitigation of climate change.
- Reducing the production of ammonia.
- Removal of bio-waste from forestry and agriculture.

In addition to the advantages listed above, there are a few other advantages:

- An increase in the soil's electrical conductivity capacity.
- Increase in soil moisture.
- Improved soil pH level (less acidic)
- Increase in the biomass of soil microbes.

Disadvantages of biochar:

- In a few conditions, by the biochar sorption of water and nutrients may cause production to reduce since the plants can access these resources less easily. Sometimes bio-char can also stop sprouting.
- Bio-char can absorb pesticides and weedkillers, which can reduce their efficiency.
- Pollutants such heavy metals, PAHs (Polycyclic Aromatic Hydrocarbons), DOC (Dissolved Organic Carbon), etc. may be produced by biochar.
- Nitrous oxide release can sometimes increase and rarely decline.
- Dust and breathing problems can also be caused by fine ash that has formed from bio-char.
- By reducing the quantity of soil microbes and interacting with internal nutrient-cycling, long-term eradication of crop residues, such as stems, leaves, etc. for the preparation of biochar, might reduce total soil strength. Increases in cation exchange capacity depend on the characteristics of the topsoil; they are low in topsoil with higher levels of organic matter or clay, especially when biochar is added in the right amounts.
- Increase in soil pH is not required in higher pH (basic) soils because plants only tolerate a particular range of soil pH.

Preparation of biochar is very easy. When the feedstock is fed to the pyrolysis equipment and the necessary heating, gas flow, time and temperature requirements are met, bio-char is produced. There are a few co-products formed during this process, including gas and bio-oil. However, earlier updates identified a few drawbacks of biochar application when employed on agricultural land, including (i) erosion damages to the land, (ii) soil compaction during application, (iii) risk of pollution, (iv) removal of plant residues and (vii) a decrease in insect life rates.

Earlier case studies evaluated the use of biogas in top soil management. For example, the soil fertility in the Amazon region is not only related to the application of biochar and other input. Even the production method & material source for the bio-char used were very similar. In a different instance, applying biochar to the ground would unnecessarily compact the soil and expose it to heavy metals, which are present in high concentrations in sewage biochar.

Additionally, the soil surface will be negatively impacted by bio-char made from plant debris, such as erosion brought on by wind or water (Bridle and Pritchard, 2004).

Uses of biochar in soils:

As soils need a specified amount of aggregates, solids and organic matter to provide the ideal growth medium for plants, the addition of biochar can significantly enhance soil integrity. In particular, a variation of particle sizes and a particular amount of aeration are essential for maintaining water holding capacity. Poor soils' physical structure can be improved with biochar. Through its varying degree of porosity, biochar may improve soil aeration if it is extremely compacted. As compared to fine, sandy soil types, biochar has a significantly higher porosity level and wider surface area. Using biomass compost in addition to the biochar made from that biomass has advantages as well. Due to the faster decomposition of the biomass, which provided a consistent flow of nutrients for plant absorption until the biochar's gradual release of nutrients started, the combination of compost and biochar proved to be just as beneficial for plant yields as biochar alone. A greater number of oxidation-reduction processes occur inside the soil matrix when biochar is added to the soil. Another advantage of biochar is that it lasts for years in fields due to its durability in the environment and soils. As a result, biochar may not need to be applied again every year, making it a more cost effective.

The amounts of soil organic matter decrease with time. Weathering, farming culture and other human activities all contribute to this. Biochar is highly stable and durable in soils due to its crystalline structure. Another interesting impact is the increased detection of ethylene, a major plant hormone used to control plant growth and ripening, when biochar is added to soils. Crop yields will rise as ethylene production increases as a result of the biochar amendment.

Impacts of biochar on agriculture:

The material utilized for making the biochar and the processing method used have an impact on both the properties of the biochar and its potential advantages when applied to the land. Applying nutrients and fertilizers may be retained by biochar, which will gradually release them to agronomic crops. Agriculture benefits from biochars' capacity to hold onto water and nutrients in the surface soil layers for extended periods of time because it prevents nutrients from evaporating from the crop root zone, potentially increases crop yields, and lowers the need for fertilizers. Thus utilizing biochar in production agriculture should increase yields and reduce adverse environmental effects. For clarity, it is essential to differentiate between charcoal and compost in this situation. In comparison to composts, which are frequently applied to soils for agricultural production, biochars are a source of nutrients indirectly through the subsequent breakdown of organic matter. So far, as biochars don't decompose down over time, more applications should not be required.

While applying biochars can have a positive impact on agricultural production, some reports of no crop yield benefits (*Schnell et al.,* 2012) or even negative yield responses have been made, according to a review of biochar articles by *Spokas et al.* (Lentz and Ippolito, 2012). Low rates of biochar application, limited nutrient release for plant uptake, biochar application on fertile soils or reported poor yields might all be contributing factors. High yields seen in certain biochar application cases were difficult to explain, although they could be related to the qualities of the biochar, the fertility of the soil, and the crop being considered. Ippolito, Laird and Busscher (2012) stated that the most recent biochar research has been done on extremely weathered and infertile soils, where the advantages of applying biochar were frequently observed.

Impacts of biochar on environment:

As previously mentioned, biochars can improve soil fertility, energy generation, carbon sequestration and waste management. Moreover, several biochars (produced from a variety of feedstocks) have been identified as very effective, relatively affordable sorbents for a variety of environmental pollutants. The ability of biochars to improve the sorption capacity of various soils and sediments has been studied at the laboratory and field scales as an in-situ remediation method for both organic and inorganic pollutants. For instance, Chun *et al.* (2004) showed that benzene and nitrobenzene (organic pollutants) were eliminated from wastewater by biochar produced by pyrolyzing wheat wastes at temperatures between 300^0C and 700^0C. Similar to this, atrazine and simazine were eliminated from an aqueous solution by biochar made from greenwaste (a combination of woodchips and bark from maple, elm, and oak trees) (*Zheng et al.*, 2010). Using biochar made from pine needles, naphthalene, nitrobenzene, and m-dinitrobenzene were removed from water (Chen *et al.*, 2008). Reactive brilliant blue and Rhodamine blue dyes were successfully removed from wastewater using biochar made from straw, which is superior and more affordable than activated carbon (*Qiu et al.* 2009). Significant levels of atrazine were also removed from wastewater using biochar made from dairy manures (pyrolysis at 200 to 300^0C) (Uchimiya *et al.*, 2010).

Biochars have been demonstrated to remove metal pollutants and nutrients from wastewater and soil in addition to organic contaminants. The sorption capacities of biochars made by pyrolyzing dairy manures at low temperatures (200^0C and 350^0C) were studied by Cao *et al.* (2009). They observed that compared to commercial activated carbon, biochar was six times more efficient at removing lead (Pb) from wastewater. The immobilisation of heavy metals such as cadmium (Cd), copper (Cu), nickel (Ni), and lead (Pb) in soil and water was improved by the use of broiler litter manure biochar (*Uchimiya et al.* 2011). According to Yao *et al.* (2011), phosphate was removed from the analysed water by 73% using biochar made from anaerobically Digested Sugar Beet Tailings (DSTC). Moreover, magnetic biochars were discovered to be efficient in simultaneously removing phosphate from solution and hydrophobic organic pollutants (Chen *et al.*, 2011). These results demonstrated biochar's ability to reduce nitrogen leaching in agricultural lands.

Conclusion:

Biochar can be produced by pyrolyzing biomass at temperatures above 300°C without oxygen. Applying biochar to agricultural land to improve the soil and increase agricultural productivity. It has been identified to enhance soil properties including pH, cation exchange capacity and water-holding capacity. Using the biochar can increase crop productivity and the efficiency of nitrogen. In addition to potentially lowering methane and nitrous oxide emissions from the soil, biochar has the potential to reduce greenhouse gas emissions by sequestering carbon. It is essential to find out how different soil types interact with biochar in terms of how the nutrient cycle, the physical characteristics of the soil and its biochemical composition change. Whether adding biochar to the farming system would result in a longer-term reduction in greenhouse gas emissions in agriculture.

References:

Alkharabsheh, Hiba M., *et al.,* (2021). Biochar and its broad impacts in soil quality and fertility, nutrient leaching and crop productivity: A review. *Agronomy*, 11:993.

Biochar Manual for Small farms: https://sites.google.com/site/fcfcbiocharmanual.

Cao, X., L. Ma, B. Gao, and W. Harris. (2009). Dairy-Manure Derived Biochar Effectively Sorbs Lead and Atrazine. *Environmental Science and Technology*, 43(9): 3285–3291.

Cha, Jin Sun *et al.,* (2016). Production and utilization of biochar: A review. *Journal of Industrial and Engineering Chemistry*, 40:1-15.

Ding, Yang *et al.,* (2016). Biochar to improve soil fertility. A review. *Agronomy for Sustainable Development*, 36.2: 1-18.

Faraaz Farooq and Permendra Singh (2022). Biochar: An alternative method for stubble burning, Just Agriculture multi-disciplinary E-news letter, Vol.2 Issue-6, 2022.

Glaser, B., L. Haumaier, G. Guggenberger, and W. Zech. (2001). The 'Terra Preta' Phenomenon: A Model for Sustainable Agriculture in the Humid Tropics. *Naturwissenschaften,* 88(1): 37–41.

Hanuman Singh Yadav, Satish Kumar Singh, Surendra Singh Jatav, vishnu D. Rajput, Manoj Parihar, Sonu Kumar Mahadev, Rajesh kumar Singh al and Sukirtee (2020). Importance of Biochar in Agriculture and its Consequence, intech open, DOI: 10.5772/Intech open,93049.

Ippolito, J. A., D. A. Laird, and W. A. Busscher. (2012). Environmental Benefits of Biochar. *Journal of Environmental Quality,* 41(4): 967-972.

Qiu, Y., Z. Zheng, Z. Zhou, and G. D. Sheng. (2009). Effectiveness and Mechanisms of Dye Adsorption on a Straw-Based Biochar. *Bioresource Technology,* 100(21): 5348–5351.

Rao Mylavarapu, Vimala Nair and Kelly Morgan, An Introduction to biochars and their uses in Agriculture. University of Florida, https://doi.org/10.32473/edis-ss585-2013.

Rehman HA, Razzaq R (2017). Benefits of Biochar on the Agriculture and Environment. A Review. *Journal of Environmental Analytical Chemistry*, 4:207.

Schnell, R. W., D. M. Vietor, T. L. Provin, C. L. Munster, and S. Capareda. (2012). Capacity of Biochar Application to Maintain Energy Crop Productivity: Soil Chemistry, Sorghum Growth, and Runoff Water Quality Effects. *Journal of Environmental Quality*, 41(4): 1044–1051.

Spokas, K. A., K. B. Cantrell, J. M. Novak, D. A. Archer, J. A. Ippolito, H. P. Collins, A. A. Boateng, I. M. Lima, M. C. Lamb, A. J. McAloon, R. D. Lentz, and K. A. Nichols. (2012). Biochar: A Synthesis of Its Agronomic Impact beyond Carbon Sequestration. *Journal of Environmental Quality*, 41(4): 973–989.

T.M.E. Shareef and B.W. Zhao (2017). The Fundamentals of Biochar in Agriculture scope: An overview for farmers and gardeners – Review. *Journal of Agricultural chemistry and Environment*, 6,38-61.

Tara Allohverdi, Amar Kumar Mohanty, Poritosh Roy and Manjusri Misra (2021). A Review on Current Status of Biochar Uses in Agriculture, *Molecules*.26(18): 5584.

Thakur Indu, Narendra Kumar Bhinda, B.M.V. Prasad Swamy (2021). Role of Biochar in Agriculture, Just Agriculture multi-disciplinary E-news letter, Vol.1 Issue-10.

Uchimiya, M., I. M. Lima, K. Thomas Klasson, S. C. Chang, L. H. Wartelle, and J. E. Rodgers. (2010). Immobilization of Heavy Metal Ions (CuII, CdII, NiII, and PbII) by Broiler Litter-Derived Biochars in Water and Soil. *Journal of Agricultural and Food Chemistry*, 58(9): 5538–5544.

Uchimiya, M., K. T. Klasson, L. H. Wartelle, and I. M. Lima. (2011). Influence of Soil Properties on Heavy Metal Sequestration by Biochar Amendment: 1. Copper Sorption Isotherms and the Release of Cations. *Chemosphere*, 82(10): 1431–1437.

Yao, Y., B. Gao, M. Inyang, A. R. Zimmerman, X. Cao, P. Pullammanappallil, and L. Yang. (2011). Biochar Derived from Anaerobically Digested Sugar Beet Tailings: Characterization and Phosphate Removal Potential. *Bioresource Technology*, 102(10): 6273–6278.

Zheng, W., M. Guo, T. Chow, D. N. Bennett, and N. Rajagopalan. (2010). Sorption Properties of Greenwaste Biochar for Two Triazine Pesticides. *Journal of Hazardous Materials*, 181(1-3): 121–126.

RECLAMATION AND MANAGEMENT OF SALT AFFECTED SOILS

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Abstract:

The arid and semiarid regions of the world is limited by poor water resources, limited rainfall, and the detrimental effects associated with an excess of soluble salts, constrained to a localized area or sometimes extending over the whole of the basin. In order to minimize vagaries of arid weather, bring more land under irrigation, and produce and stabilize greater yields per unit area, numerous water development projects have been commissioned all over the world. Extension of irrigation to the arid regions, however, usually had led to an increase in the area affected by shallow water tables and to intensifying and expanding the hazards of salinity. This is because irrigation water brings in additional salts and releases immobilized salts in the soil through mineral dissolution and weathering, and losing water volumes through evapotranspiration and concentrating the dissolved salts in soil solution. Fertilizers and decaying organic matter also serve as additional salt sources. Atmospheric salt depositions, though varying with location, may be an important source along the coasts. The relative significance of each source in contributing soluble salts depends on the natural drainage conditions, soil properties, water quality, soil water, and agronomic management practices followed for crop production.

Introduction:

Reclamation and management of saline soils

1. Management of saline soils: The reclamation of saline soils involves basically the removal of salts from the saline soil through the processes of leaching with water and drainage. Provision of lateral and main drainage channels of 60 cm deep and 45 cm wide and leaching of salts could reclaim the soils. Sub-surface drainage is an effective tool for lowering the water table, removal of excess salts and prevention of secondary salinization of ions like chloride, sulphate, etc.

2. Irrigation management: Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces the effect of salinity. Alternate furrow irrigation favours growth of plant than flooding. Drip, sprinkler and pitcher irrigation have been found to be more efficient than the conventional flood irrigation method since relatively lesser amount of water is used under these improved methods.

3. Fertilizer management: Addition of extra dose of nitrogen to the tune of 20-25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (Sunhemp, Daincha, Kolingi) and or green leaf manuring also counteracts the effects of salinity.

4. Crop choice / Crop management: Crops are to be chosen based on the soil salinity level. The relative salt tolerance of different crops is as follows:

Field crops Plant species	Threshold salinity (dSm-1)	Vegetables & Fruits Plant species	Threshold salinity (dSm-1)
Cotton	7.7	Tomato	2.5
Sorghum	6.8	Sugarbeet	7.0
Rice	3.0	Cabbage	1.8
Maize	1.7	Potato	1.7
Sugarcane	1.7	Onion	1.2
Soybean	5.0	Carrot	1.0
Groundnut	3.2	Citrus	1.7
Wheat	6.0		

5. Soil / cultural management: Planting the seed in the centre of the raised bed / ridge may affect the germination as it is the spot of greatest salt accumulation. A better salinity control can be achieved by using sloping beds with seeds planted on the sloping side just above the water line. Alternate furrow irrigation is advantageous as the salts can be displaced beyond the single seed row. Application of straw mulch had been found to curtail the evaporation from soil surface resulting in the reduced salt concentration in the root zone profile within 30 days

Reclamation and of alkali / sodic soils

Mechanical / physical method: This is not actually removing sodium from exchange complex but improve physical condition of soil through improvement in infiltration and aeration. The commonly followed physical methods include

1. Scarping of the salts: If the white salt concentrations are visible then they must be removed at once from the field with the help of domestic tools like khurpi.

2. Trenching: It is process of digging small pits on the field and taking the sub soil on the surface and vice versa in order to bury the saline soils. Also, deep ploughing is adopted to break the hard pan developed at subsurface due to sodium and improving free-movement water. This also helps in improvement of aeration.

3. Flooding and flushing of salts: Saline soils are first flooded with a high-quality water (water which is free from salts) and after the water now containing the dissolved salts are flushed through drainage channels. This process reduces the concentration of surface layer salts and if repeated, gives better results. Scofield (1940) evolved a term salt balance which relates the quantity of dissolved salts carried into an area in irrigation water to the quantity of dissolved salts removed by drainage water. If salt input exceeds the salts output then salt balance is regulated as adverse. Drainage is also practiced to improve aeration and to remove further accumulation of salts at root zone.

4. Leaching of salts: Leaching means the removal of salts below the solum of the soil. Leaching of soluble salts from root zone is essential in irrigated soils. When there is no leaching then salt accumulation. Concentration of salt in soil solution results due to water evaporation and transpiration. Depth of irrigation water (Diw) can be calculated which will create the salinity. Leaching requirement (LR): It can be defines as "Fraction of irrigation water that must be leached through root zone to control soil salinity at any specific level". It will depend upon:

(i) Salt concentration of irrigation water.

(ii) Permissible limit of salt at root zone.

5. Drainage: Salinity control depends upon the drainability of soil. The LR is only possible when required amount of water is passed through root zone. This may be improved by Improving drainage outlet facilities. Improving soil permeability

Other measures are: To check surface evaporation the reduce water table. To break the hard layers and pans of calcium carbonate, clay soil etc. Use salt free water with short intervals of irrigation. Provide better drainage conditions. Grow crops which are salt resistant,

Chemical method: Reclamation of alkali / sodic soils requires neutralization of alkalinity and replacement of most of the sodium ions from the soil – exchange complex by the more favourable calcium ions. This can be accomplished by the application of chemical amendments (the materials that directly or indirectly furnish or mobilize divalent cations, usually Ca2+ for the replacement of sodium from the exchange complex of the soil) followed by leaching to remove soluble salts and other reaction products. According to Thorne and Peterson (1954), three types of chemical amendments are available:

(a) Soluble calcium carbonate/direct Ca suppliers – Calcium chloride, Gypsum, Phospho-gypsum etc.

(b) Acid or acid former/Indirect Ca suppliers – Elemental Sulphur, Sulphuric acid, Lime sulphur, Iron sulphate, Aluminium sulphate, Pyrite, $FeSO_4$ etc.

(c) Low soluble calcium salts – Ground lime stone and press mud or byproduct lime from sugar factories.

Among them gypsum is, by far, the most commonly used chemical amendment. Calcium carbonate is insoluble in nature which of no use in calcareous sodic soils (have already precipitated $CaCO_3$) but can be used in non-calcareous sodic soils (do not have precipitated $CaCO_3$) since pH of this soils are low at surface and favouring solubilisation of $CaCO_3$. Some of indirect suppliers of Ca viz. Elemental sulphur, sulphuric acid, iron sulphate are also used for calcareous sodic soils. These materials on application solubilise the precipitated $CaCO_3$ in sodic soils and releases Ca for reclamation.

Conclusion:

Salt affected soils either due to excess soluble salts or due to high exchangeable sodium content have become non-productive, so to restore its productivity, it is highly essential to reclaim and manage these soils using different specific technologies. To achieve this restoration, there would be a need for the involvement of relevant stakeholders such as farmers, public institutions (research and extension institutions, other line department of government, KVK, NGO) for expansion, adoption and awareness about available technologies which not only help in restoring the productivity but also enhancing the productivity and directly or indirectly increase farmers' income.

References:

Abrol, I.P., Chhabra, R. and Gupta, R.K. (1980). A fresh look at the diagnostic criteria for sodic soils. In: International Symposium on Salt Affected Soils. Central Soil Salinity Research Institute, Karnal. February 18-21, pp. 142-147.

Abrol, I.P., Yadav J.S.P. and Massoud, F.I. (1988). Salt-affected soils and their management. FAO Soils Bulletin No. 39, Food and Agriculture Organization of the United Nations, Rome.

Chinchmalatpure, Anil R., Kad, Sanjay Vasant and Kamra, S.K. (2016). Evaluation Report of subsurface darainage project at Mulad, taluka Olpad, district Surat (Gujarat). ICAR-Central Soil Salinity Research Institute, Karnal 132001 (Haryana), 20 pp.

Chinchmalatpure, Anil R., Nayak, A. K. and Rao, G. Gururaja (2011). Saline Vertisols-characteristics, distribution and management. In: Salt affected soils of India, Bulletin No 28 (Eds. Rattan, R. K. and Singh, A. K.) Indian Society of Soil Science, New Delhi. pp117.

FAO (1988). World Agriculture toward 2000. An FAO Study. Alexandratos, N. (Ed). Bellhaven Press, London, 338 pp.

Ghassemi, F., Jakeman, A.J., and Nix, N.A. (1995). Salinisation of land and water resources. Human causes, extent and management and case studies. CABI Publishing, Wallingford.

Kaledhonkar, M.J., Gupta, S.K. and Singh, G. (2009). An overview of research, development, opportunities and challenges for subsurface drainage in India. In: 60th International Executive Council Meeting & 5th Asian Regional Conference, New Delhi, India, pp. 1–12.

Kamra, S.K. and Sharma, D.K. (2015). Critical evaluation of performance and organizational framework of subsurface drainage projects in Haryana and Maharashtra. Water and Energy International, 72(4): 64-72.

Nayak, A.K., Chinchmalatpure, Anil R., Rao, G. Gururaja and Tyagi, N.K. (2004). Effect of electrolyte concentration, ESP and soil texture on the flocculation, hydraulic conductivity and bulk density of Vertisols. Extended Summaries, International conference on Sustainable management of Sodic lands, Lucknow, India. Pp 203-205.

NRSA and Associates (1996). Mapping of salt affected soils of India, 1:250000 map sheets, Legend, NRSA Hyderabad.

Rao, G. Gururaja, Nayak, A.K. and Chinchmalatpure, Anil R. (2000). Dill (Anethum graveolens L.)- A potential crop for salt affected black soil. Technical Monograph No. 1 Central Soil Salinity Research Institute, Regional Research Station, Anand (Gujarat). P. 10.

Rao, G. Gururaja, Nayak, A.K., Chinchmalatpure, Anil R., Abhaynathand Babu,V. Ravindra (2004). Growth and yield of Salvadora persica, a facultative halophyte grown on saline black soil (Vertic Haplustept). Arid Land Research and Management, 18: 51-61.

Rao, Gururaja G., Chinchmalatpure, Anil R., Khandelwal, M. K. and Singh, Gurbachan (2009). Studies on enhancing water productivity of farming system components on Saline Vertisols of Bara Tract of Gujarat State, India. 4th World Congress on Conservation Agriculture, New Delhi, February 4-7, 2009.

Rao, Gururaja G., Chinchmalatpure, Anil R., Meena, R.L. and Khandelwal, M.K. (2011). Saline agriculture in saline Vertisols with halophytic forage grasses. J. Soil Salinity and Water Quality, 3, 41-48.

Szabolcs, I. (1974). Salt affected soils in Europe. Martinus Nijhoff, The Hague. 63 p.

Szabolcs, I. (1979). Review of research on salt affected soils. Natural Resources Research XV, UNESCO, Paris, France.

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SOIL HEALTH, SOIL QUALITY AND ITS MANAGEMENT

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Abstract:

Each soil's capacity to perform within its natural or managed ecosystems to sustain production, enhance water and air quality, support human and animal health, and provide habitation is referred to as soil quality. Although agricultural regions have experienced the greatest labour and review, this isn't limited to them. The state of the soil and its ability to support biological functions, preserve environmental quality, and promote plant and animal health is known as soil health. Soil health and quality are essential for long-term agro-ecosystem management and survival on the planet**.** You'll need a collection of indicators to evaluate soil quality. These indicators might be both qualitative and quantitative in nature. Physical and chemical attributes should be included in the indicators, and they should be available to a wide range of consumers. They must be adaptable to various climates and respond to various management procedures. A biological indication is required as well. Decomposition of organic materials and nutrient cycling are carried out by soil organisms. Worm activity in the soil is an easily recognised biological indicator. Earthworms are plentiful if the soil is healthy. Earthworms contribute to enhance soil tilth, aeration, infiltration, and drainage by modifying the physical structure of the soil by forming new aggregates and pores. Earth worms enhance soil porosity by digging and mixing the soil, and roots frequently follow earthworm tunnels and take advantage of the accessible nutrients in the worm castings.

Keyword: Soil quality, soil health, soil organic matter

Introduction:

Soil health, often known as soil quality, has grown in popularity in recent years, particularly since the early 1990s. It's gaining appeal among farmers and ranchers, as well as soil managers, scientists, agricultural Extension professionals, and other soil-related groups. Many agricultural organisations engaged in regenerative and sustainable crop, livestock, and land management are focusing on "soil health." While soil health is becoming more widely recognised, it is vital to have a complete understanding of what it entails, how it is assessed, and how to manage it for optimal and long-term delivery of the ecosystem services that soils provide.

We must evaluate the words that make up "soil health" in order to define it effectively. The Soil Science Society of America (SSSA) defines "soil" as "the unconsolidated mineral or organic substance on the earth's immediate surface that serves as a natural medium for land plant growth Merriam-Webster defines health as "the state of being sound in body, mind, or spirit." This idea of health can be restructured to apply to the soil. "Soil health" can be described as “The capacity of the soil to support the growth and development of land plants by being in good physical, chemical, and biological condition," according to the SSSA.

Soil quality refers to how well soil meets the needs of one or more biotic species, as well as any human demand or goal. The United States Department of Agriculture's Natural Resources Conservation Service, "Soil quality refers to a particular type of soil's ability to function within natural or controlled ecosystem limits to support plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. "Soil quality is an assessment of the soil's potential to offer ecosystem and social services through its capacities to perform its duties under changing conditions," according to a definition proposed by the European Commission's Joint Research Centre.

Component of soil

We must first understand the components of soil to realise the complexity of soil health in various agricultural systems. Soil is made up of solid particles that have accumulated through time as a result of soil formation processes. The size of these particles determines whether they are classed as sand, silt, or clay. The largest particles are sand (0.05–2 mm), then silt (0.002–0.05 mm), and finally clay (0.002 mm). Soils have pore holes in between these particles that, depending on the state of the soil, can be filled with air or water. Fine-textured or "heavy" soils have smaller particles and smaller holes than fine-textured or "heavy" soils. The relative proportions of sand, silt, and clay in a soil define its texture.

A typical soil includes around 50% solids (45% mineral and 5% organic matter) and 50% voids (or pores), of which half is occupied by water and the other half by gas. The percent soil mineral and organic content can be treated as constants (in the short term), while the percent soil water and gas content is extremely changeable, with an increase in one balanced by a decrease in the other. The pore space enables for air and water infiltration and movement, both of which are essential for soil life. Soil compaction, a common issue, restricts this area, limiting air and water from reaching plant roots and soil organisms.

Soil mechanics and genesis

Soil formation is the result of a combination of physical, chemical, biological, and anthropogenic processes operating on soil parent material. The B horizon is formed when organic matter accumulates and colloids are washed downhill, resulting in layers of clay, humus, iron oxide, carbonate, and gypsum. This is an arbitrary term because sand, silt, clay, and humus mixtures will support biological and agricultural activity prior to that period. Water and animal activity transport elements from one level to another. As a consequence, a layer of soil emerges in the soil profile (horizons). The weathering of lava flow bedrock, which produces the solely mineral-based parent material from which the soil texture originates, demonstrates how a soil forms. Soil development from exposed rock following recent floods would occur most quickly in a warm area with substantial and frequent rainfall. Plants quickly establish themselves on the surface (first nitrogen-fixing lichens and cyanobacteria, then epilithic higher plants). Basaltic lava under such conditions, despite the absence of organic matter. According to the Goldich dissolving series, basaltic minerals often weather very quickly. Because it is loaded with nutrient-bearing water that conveys minerals dissolved from the rocks, the porous rock supports the plants. Fine materials would be held in crevasses and crevices, as well as plant roots, in the local morphology of the rocks. Mineral-weathering mycorrhizal fungi are present in the growing plant roots.

Soil physical properties

The soil matrix is primarily responsible for controlling the physical qualities of the soil. The physical attributes of soils are texture, structure, bulk density, porosity, consistency, temperature, colour, and resistivity, in order of decreasing importance for ecosystem services such as crop production. The soil texture, which was discussed in the section on soil components, is one of the most essential physical qualities of soil. Soils aren't all the same. Agricultural fields can have a range of soil textures depending on the relative composition of distinct soil particles (sand, silt, and clay). The texture of your soil is difficult to change. Another physical feature essential to production agriculture is bulk density, which is a measurement of how firmly soil particles are packed together. A compacted soil has soil particles that are packed too closely together. Compacted soils obstruct both plant roots and water movement. Another important soil physical property that affects a number of soil activities is soil structure. Water mobility, erosion resistance, and nutrient cycling are all influenced by soil structure. The distribution and stability of soil aggregates within the soil are typically examined while examining soil structure. Aggregates are formed when soil particles adhere to one another in lumps of various shapes and sizes. The ability of the soil to survive wind or water erosion and its pore size distribution are affected by the size distribution of these aggregates. Soil aggregate stability is essential for soil function. Raindrops can quickly break down unstable aggregates at the soil's surface, blocking the pores. Water ingress into the soil will be greatly decreased when the surface pores are sealed. In a process known as runoff, any remaining water that cannot enter the soil travels on the soil surface, eventually spreading to other locations. Water running across bare surfaces carries soil particles, causing tonnes of soil to be moved. This is referred to as "soil erosion." Erosion depletes soil fertility and depletes organic matter by removing soil particles, dissolved nutrients, and organic matter particles from agricultural regions.

Soil chemical properties

The chemistry of a soil influences its physical qualities and the health of its living population, as well as its ability to supply available plant nutrients. The corrosivity, stability, and ability to absorb contaminants and filter water are all determined by the chemistry of a soil. The chemical characteristics of soil are influenced by the surface chemistry of mineral and organic colloids. A colloid is a microscopic, insoluble particle that is between 1 nanometer and 1 micrometre in size, small enough to stay suspended in a fluid medium through Brownian motion without settling. Most soils contain both organic and inorganic colloidal particles, known as humus and clays. The ability of soil to store and release ions is due to colloids' large specific surface area and their net electrical charges. Cation exchange occurs when negatively charged regions on colloids attract and release cations. Cation-exchange capacity (CEC) is measured in milliequivalents of positively charged ions per 100 grammes of dry soil (or centimoles of positive charge per kilogramme of soil; cmolc/kg). Anion exchange capacity (AEC) is determined by the ability of positively charged sites on colloids to attract and release anions in the soil.

Soil biological properties

Because it contains both live creatures and the dead organic elements they feed on, the biological component of the soil is possibly the most intriguing feature. It's vital to remember that bacteria, fungus, and a variety of other living organisms in the soil, in conjunction with living plants and dead organic matter, are the primary drivers of healthy soil function maintenance and regeneration. Different classes of species occupy different trophic (feeding) levels in the soil food web, which is exceedingly complicated. Organic compounds in agricultural soils are decomposing at various stages due to the presence of a variety of organisms. Organic compounds in the soil are divided into three groups based on their level of decomposition: "alive," "dead," and "extremely dead" (Magdoff and Van Es, 2000). Roots that are still alive, as well as bacteria and other soil creatures that are still active in the soil, make up "the living" component. Manure, compost, and other biological components added to the soil make up "the dead" component. Since these components provide sustenance for soil organisms to boost their rapid growth and population numbers in the soil, the dead component can also be seen as the active fraction of soil organic matter. The "extremely dead" component is a by-product of organic matter decomposition that remains after the organic elements have broken down quickly. Due to the material's stability and resistance to further breakdown, further disintegration is extremely sluggish. Humus or humic substances refers to the stuff that accumulates in the soil at this point. Unlike fresh plant remains, humus can absorb a lot of water (up to 20 times its weight; Stevenson, 1994) and prevents several plant nutrients from leaching.

Plant roots, in addition to soil organic content, are required for soil organisms to grow. The rhizosphere is a zone surrounding the plant roots where the majority of soil microorganisms can be located. Microorganisms associated with plant roots are 1,000–2,000 times more abundant in the rhizosphere than in soils outside of this zone. Microorganisms abound in rhizospheres because plants produce simple sugars in root exudates that microbes may consume. Approximately 35% of the products created during plant photosynthesis are released back into the soil as root exudates to support microbial activity. Microbial diversity is maintained across the soil profile by plants with varying rooting depths, such as those found in rangelands or various cover crops sown in croplands. As a result, the existence of living roots is critical for optimum soil health.

Soil nutrient

Carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, manganese, boron, copper, chlorine, iron, nickel, and molybdenum are among the 17 nutrients that most land plants require for productive growth and development (Epstein and Bloom, 2005). Because carbon, oxygen, and hydrogen are obtained from the air and soil water, they are rarely a concern. There are three types of elements to be concerned with while managing soil fertility. The first group of nutrients is known as primary nutrients, which includes nitrogen, phosphorus, and potassium. Plants require quite high amounts of these main nutrients. Calcium, magnesium, and sulphur are the secondary nutrients in the second category. These nutrients are required in significant amounts, although not nearly as much as the basic nutrients. Micronutrients are the third group, which includes zinc, manganese, boron, copper, chlorine, iron, nickel, and molybdenum. They're only required in little amounts, yet they're essential for plant growth and development. The importance of nutrients to plants is not determined by their classification. All of these nutrients are necessary for plant growth and yield, and their absence will result in plant diseases.

Why we take care of soil health and soil quality?

One of the natural resources that sustains human civilisation is soil. It is difficult to produce enough food to support an ever-increasing human population without a productive and healthy soil. Many degraded soils exist around the world that are no longer productive and can only be regenerated via the use of soil health principles. According to global trends, soil degradation is causing 20 percent of cropland, 16 percent of forest land, 19 percent of grassland, and 27 percent of rangeland to lose productivity.

While erosion can swiftly deplete soil, soil development takes a long time. Depending on the soil-forming processes that occur in a given region, an inch of soil could take anywhere from 100 to 10,000 years to create. Because soil is a slowly renewing natural resource, the slow rate of production makes it a finite resource if it is mishandled. Wind and water erosion are likely to cause losses in a sickly soil. As a result, to ensure long-term soil production and food security, healthy soils must be developed and maintained.

The environmental, economic, and public health ramifications of degraded and diseased soils are another reason why we should be concerned about soil health. When dust storms form, suspended sediments, for example, have been shown to be dangerous to road safety and to pose substantial health risks to people with respiratory disorders.

How we managing soil health and soil quality

- Reduce the amount of soil disturbance.
- Crop rotation techniques
- Plant diversity and living roots are promoted through cover cropping.
- Increase the variety of production systems.
- Incorporate organic additions into the soil.
- Make livestock a part of agricultural systems.
- Encourage a variety of plant species with varying rooting depths.
- Animal grazing practises that are sustainable.
- Be patient with the results and don't expect to see favourable effects right away.

Figure 1: Management strategies that lead to soil health maintenance and improvement

Conclusion:

Soil health or soil quality monitoring and management will continue to be important in arid and semi-arid agroecosystems' agricultural production systems. Healthy soil or soil quality is more resistant to changes in the growth environment. With yearly weather variations, the soil system's resiliency must be improved to cope with these changes. Building and enhancing the soil health of India and world agricultural and forest land will assure continuing productivity, increased farmer income, and increased food security. Building and sustaining good soil in the arid and semi-arid is a challenging task, especially in the face of droughts and other production challenges. It is possible to implement soil health techniques that will sustain and improve soil productivity with the resolve of the farming and ranching community.

References:

Berendsen, R.L., Pieterse, C.M. and Bakker, P.A. (2012). The rhizosphere microbiome and plant health. Trends in Plant Science, 17(8): 478-486.

Bonfante, A., Terribile, F. and Bouma, J. (2019). Refining physical aspects of soil quality and soil health when exploring the effects of soil degradation and climate change on biomass production: an Italian case study. Soil, 5(1):1-14.

Chen, S., Wang, W., Xu, W., Wang, Y., Wan, H., Chen, D., Tang, Z., Tang, X., Zhou, G., Xie, Z. and Zhou, D. (2018). Plant diversity enhances productivity and soil carbon storage. Proceedings of the National Academy of Sciences, 115(16): 4027-4032.

Darapuneni, M.K., Idowu, O.J., Lauriault, L.M., Dodla, S.K., Pavuluri, K., Ale, S., Grover, K. and Angadi, S.V. (2019). Tillage and nitrogen rate effects on corn production and residual soil characteristics. Agronomy Journal, 111(3): 1524-1532.

Diacono, M. and Montemurro, F. (2011). Long-term effects of organic amendments on soil fertility. Sustainable Agriculture, 2: 761-786.

Doran, J.W. and Zeiss, M.R. (2000). Soil health and sustainability: managing the biotic component of soil quality. Applied soil ecology, 15(1): 3-11.

Ghimire, R., Norton, J.B., Norton, U., Ritten, J.P., Stahl, P.D. and Krall, J.M. (2013). Long-term farming systems research in the central High Plains. Renewable Agriculture and Food Systems, 28(2): 183-193.

Ghimire, R., Thapa, V.R., Cano, A. and Acosta-Martinez, V. (2019). Soil organic matter and microbial community responses to semiarid croplands and grasslands management. Applied Soil Ecology, 141: 30-37.

Idowu, O.J., Sultana, S., Darapuneni, M., Beck, L. and Steiner, R. (2019). Short-term conservation tillage effects on corn silage yield and soil quality in an irrigated, arid agroecosystem. Agronomy, 9(8): 455.

Kremen, C., Iles, A. and Bacon, C. (2012). Diversified farming systems: an agroecological, systems-based alternative to modern industrial agriculture. Ecology and society, 17(4):19.

Li, J., Okin, G.S., Alvarez, L. and Epstein, H. (2007). Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA. Biogeochemistry, 85(3): 317-332.

Maikhuri, R.K. and Rao, K.S. (2012). Soil quality and soil health: A review. International Journal of Ecology and Environmental Sciences, 38(1):19-37.

Muhammad, I., Wang, J., Sainju, U.M., Zhang, S., Zhao, F. and Khan, A. (2021). Cover cropping enhances soil microbial biomass and affects microbial community structure: A meta-analysis. Geoderma, 381:114696.

Mulholland, B. and Fullen, M.A. (1991). Cattle trampling and soil compaction on loamy sands. Soil use and management, 7(4): 189-193.

Peralta, A.L., Sun, Y., McDaniel, M.D. and Lennon, J.T. (2018). Crop rotational diversity increases disease suppressive capacity of soil microbiomes. Ecosphere, 9(5): 2235.

Thapa, V.R., Ghimire, R., Acosta-Martínez, V., Marsalis, M.A. and Schipanski, M.E. (2021). Cover crop biomass and species composition affect soil microbial community structure and enzyme activities in semiarid cropping systems. Applied Soil Ecology, 157: 103735.

Vukicevich, E., T. Lowery, P. Bowen, J.R. Úrbez-Torres, and M. Hart. (2016). Cover crops to increase soil microbial diversity and mitigate decline in perennial agriculture. A review. *Agronomy for Sustainable Development*, 36: 48.

Yang, T., Lupwayi, N., Marc, S.A., Siddique, K.H. and Bainard, L.D. (2021). Anthropogenic drivers of soil microbial communities and impacts on soil biological functions in agroecosystems. Global Ecology and Conservation, 27: 1521.

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IMPLEMENTATION AND ADOPTION OF INTEGRATED PEST MANAGEMENT APPROACHES IN INDIA: CHALLENGES AND POTENTIAL

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Abstract:

Integrated Pest Management (IPM) is the approach that India uses the most when it comes to plant protection. IPM techniques have been developed for the long-term management of insect pests in several agricultural crops. The fundamental driver behind the global development of the IPM programme is the improper use of pesticides and their consequences. The use of IPM techniques in Indian agriculture, such as the creation of bio-pesticides, semi-chemical and refuge crops, push-pull techniques, and biological control, helps farmers manage crop pests like insects.

Integrated Pest Management (IPM)

Food and Agricultural Organization (FAO, 1967) defined IPM as "a pest management system, that, in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury".

- The term **"Integrated Pest Management**" was used for the first time by Smith and Van dan Bosch (1967).
- Prior to the invention of pesticides, cultural and mechanical methods of control were the mainstays of pest management in India.
- The use of agrochemicals (fertilisers and pesticides) and high yielding varieties was widely adopted by Indian agriculture after the green revolution was introduced in 1968. The majority of entomologists, agriculture policy makers, and extension workers have suggested the use of pesticides is effective to control the insect pests.
- After a while, pesticides have a detrimental effect on both the environment and human health. After Rachel Carson's 1962 book "Silent Spring" raised awareness about the harmful effects of pesticides, several plant protectionists began putting IPM programme strategies into practise.
- In India, the use of insecticides—a type of pesticide—started rising from the time before the green revolution till the time of the green revolution. Pesticide use peaked in many green revolution-affected states like Punjab, Haryana, Andhra Pradesh, and some regions of Uttar Pradesh, with cotton crops reporting the highest use (50%) of pesticides. The widespread usage of pesticides is the fundamental justification for India's adoption of IPM programmes.

Step in the implementation of IPM

- Inspection
- Planning Preventive Strategies

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- ➢ Identification
- ➢ Analysis
- ➢ Treatment Selection
- ➢ Monitoring
- ➢ Documentation

Step 1 Inspection

- The cornerstone of an effective IPM program is a schedule of regular inspections.
- For food processors weekly inspections are common and some plant inspect even more frequently.
- The routine inspections should focus on areas where pests are most likely to appear
- Receiving docks
- ▪ Storage areas
- ▪ Employee break room
- ▪ Sites of recent ingredient spills etc. Identify any potential entry points, food and water sources, or harborage zones that might encourage pest problems.

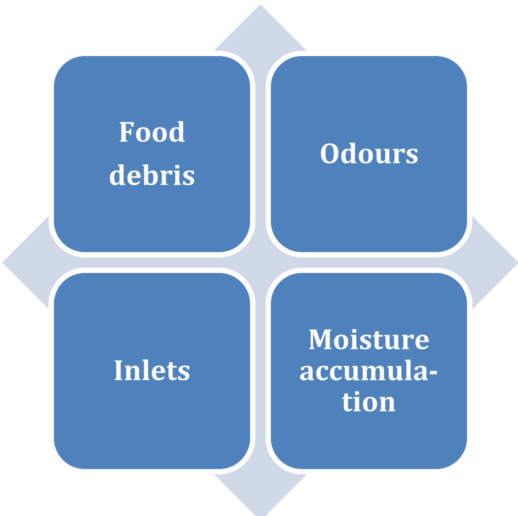
Step 2 Preventive action

- ➢ One of the most effective prevention measures is exclusion.
- ➢ Performing structural maintenance to close potential entry points revealed during inspection.
- ➢ Sanitation will eliminate potential food and water sources, thereby reducing pest pressure.

Step 3: Identification

- ➢ Pest management always starts with the correct identification of the pest in question.
- ➢ Verify that your pest control service provider receives thorough instruction in identifying and interpreting pest behaviour.
- ➢ Different pests exhibit different behaviours, therefore it is possible to get rid of them more successfully and with the least chance of endangering other creatures by identifying the troublesome species.

Step 4: Analysis



Step 5: Treatment selection

Use the right treatments in the right places, and only as much as you need to get the job done

- IPM stresses the use of non-chemical control methods, such as exclusion or trapping, before chemical options.
- Chemicals may be employed to treat a specific pest in targeted regions when less volatile formulations of conventional control approaches have failed or are ineffective for the scenario.
- Often, the "right treatment" will consist of a combination of responses, from chemical treatments to baiting to trapping.
- By prioritising non-chemical methods, you can make sure that your pest management programme effectively gets rid of pests with the least amount of risk to the environment, non-target organisms, and your food safety programme.

Step 6: Monitoring

- Constantly monitoring your facility for pest activity and facility and operational changes can protect against infestation and help eliminate existing ones.
- Staff needs to be the daily eyes and ears of the IPM program.
- Employees should be cognizant of sanitation issues that affect the program and should report any signs of pest activity**.**

Step 7: Documentation

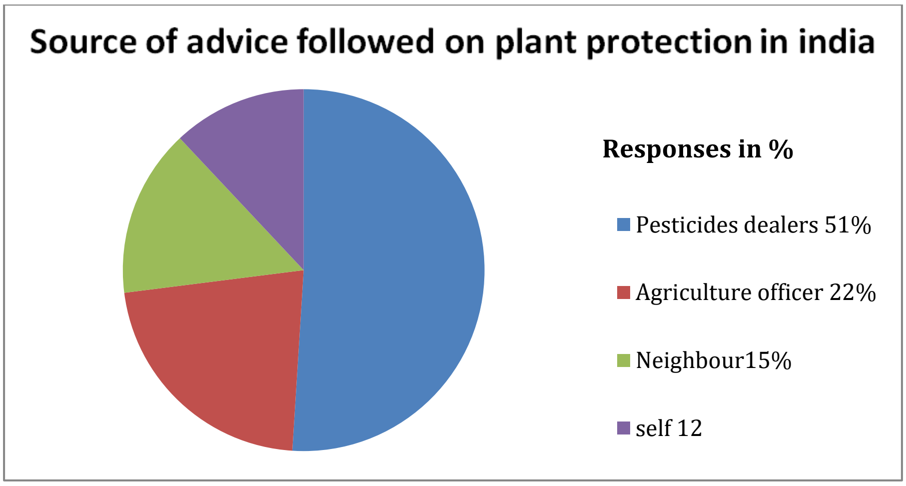
- Up-to-date pest control documentation is one of the first signs to an auditor that your facility takes pest control seriously.
- Important documents include
- A scope of service,
- Pest activity reports,
- Service reports,
- Corrective action reports,
- Trap layout maps,
- Lists of approved pesticides,
- Pesticide usage reports and applicator licenses.

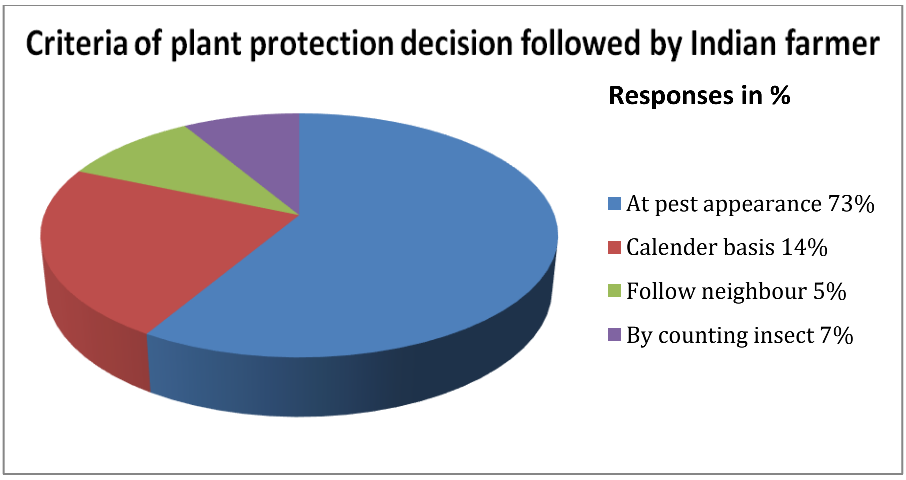
Adoption of IPM in Indian agriculture

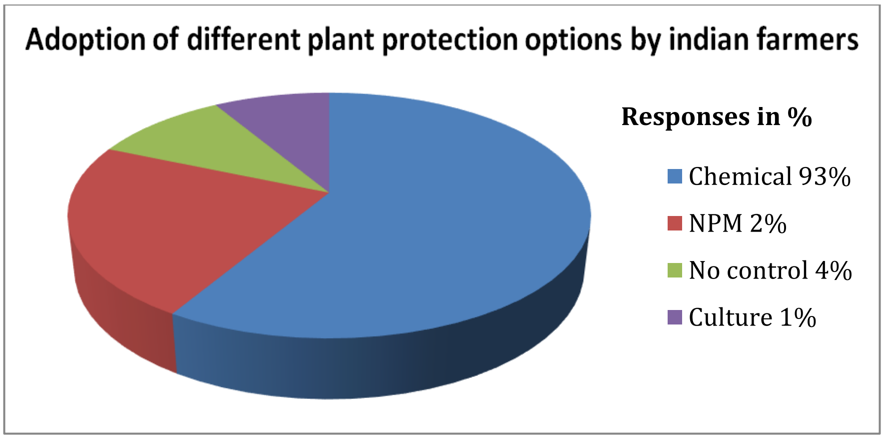
- In the scope of plant protection, Integrated Pest Management (IPM) is the most extensively used policy in India.
- For the long-term management of insect pests in many agricultural crops, IPM tactics have been developed.
- The injudicious use of pesticides and after effects are the main reason to develop the IPM programme at worldwide level.
- Development of IPM technologies, biopesticide development, semiochemical and refuge crops, push-pull techniques, and biological control are some of the IPM strategies used in Indian agriculture. These strategies help farmers manage agricultural insect pests.

Status of IPM in Indian agriculture

- Insect pests are well recognized as one of the major limiting factors in enhancing and sustaining agricultural production in India.
- Recent interactions with farming communities have shown that 93% of Indian farmers use chemical control, 51% get advice on plant protection from dealers, while 22% get it from extension agents, and the majority of farmers (73%) start the plant protection process when the pest first appears, regardless of its population, crop stage, or damage relationships.
- For different crops, the cost of plant protection ranged from 7 to 40% of the entire cost of agricultural production. Although integrated pest management (IPM) has been promoted for the past twenty years, just 3.2% of farmers have started using IPM techniques on different crops.
- IPM research in the past decade brought out changes in the farmers' attitude in pest management, which resulted 20-100% reduction in pesticide use in different crops.
- The adoption of IPM in Indian agriculture involves increasing funding for both basic and applied plant protection research to combat the three "evil "Rs" of Resistance, Resurgence, and Residues.







Present status and challenges

- Eco friendly approach
- Monitoring
- Host plant resistance
- Agronomic practices
- Biological Approach
- Chemical Approach

Eco friendly approach

The integrated pest management (IPM) approach for managing pest problems emphasises the adoption of available methods and techniques like cultural, mechanical, biological, and the prudent use of chemical pesticides in order to contain the pest populations below economic threshold levels (ETLs). Farmers have been using environmentally friendly methods since prehistoric times.

Monitoring

- Effective monitoring of pests is a prerequisite for any successful plant protection program.
- The decision on whether and when to follow control measures is based on the information available on the pest population at a particular time.
- Plant protection has a number of precise monitoring tools at its disposal (directly by field sampling, indirectly through the installation of traps like light, suction, sticky, pit fall, and pheromones).
- Sex pheromones were well adopted for monitoring key pests such as *Helicoverpa*, *Spodoptera*, *Pectinophora*, *Rhinoceros*, *Aproaerema*, *Scirpophaga* populations in different cropping systems (Ranga Rao *et al.*, 2004).
- Pheromone technology for various species was made available it's adoption was still in infancy.
- At this stage strict adoption of any surveillance is not in place for effective implementation of IPM programs in India.
- Considering the importance of the surveillance and monitoring technologies the policies need to be readdressed to make best use of it.

Host plant resistance

- The most cost-effective strategy to cut losses is to grow bug pest-resistant cultivars. In many crops, including rice, sorghum, groundnut, pigeonpea, green gramme, black gramme, and horticultural crops, thousands of germplasm samples have been tested for biotic stressors with notable results. Over many years and under intense pest pressure, more than 14,000 germplasm accessions of both pigeonpea and chickpea have been tested in research facilities and in farmers' fields.
- Bt toxin genes were put into crop plants in the middle of the 1980s. Since then, the area devoted to transgenic crops has rapidly increased in the USA, Australia, China, India, etc. Over 100 million ha of land have now been planted with transgenic crops, up from 1.7 million ha in 1996.
- The present pest management programmes should incorporate the selective use of recently developed, high-yielding, and disease-resistant varieties that serve as the cornerstone of an IPM programme. Crops with insect pest resistance will continue to be grown.
- In addition to the reduction in losses due to insect pests, the development and deployment of transgenic plants with insecticidal genes will also lead to:
  - A major reduction in insecticide inputs.
  - Increased safety to operators and non-target.
  - Enhanced natural enemy activity.
  - Reduced amounts of pesticide residues in the environment and food chain.
  - A safer environment.

Agronomic practices

- In pigeonpea, for the control of pod borer, shaking technology was found to be very effective and economical. This gentle shaking can dislodge 97% of caterpillars of all sizes from the plants instantaneously. This operation is repeated twice or thrice in case of further infestation and found environmentally compatible and economically viable.
- There are numerous ways to alter farming operations. These methods include planting early or late, choosing intercrops or trap crops, changing plant density or layout, spreading genetic combinations, erecting bird perches, manually collecting and destroying bugs, and using irrigation techniques to lessen the impact or severity of insect pests. These techniques must be created to meet regional practises and pest-specific pest requirements.
- insect pests show considerable host-preference for their oviposition and feeding.
- Trap crop in population suppression of the two most important defoliators of groundnut (*S. litura, H. armigera) that prefer* sunflower for oviposition and larval feeding than the main groundnut crop. Behavior changes and insectivorous also seen in groundnut.

Biological approach

- Their main feature is specificity to avoid non-target mortality and associated problems.

- Biological alternatives to chemical pesticides include the release and enhancement of parasites and predators, entomopathogens, antagonistic microorganisms, endophytes, animal wastes, botanicals, and agricultural residues. The phrase refers to a variety of natural chemical substitutes.
- The best-known examples are the neem-based products which have shown to be effective against a number of pests.
- NPV being used for control of important pests like *Helicoverpa armigera and Spodoptera* spp.
- *Bacillus thuringiensis (Bt) has gained* importance in suppressing pest populations in crops like cotton and vegetables (Raheja, 1998).
- approximately 175 registered bio-pesticide active ingredients and 700 products globally.
- Only 12 biopesticides have been registered in India thus far, and 5 of them were bacteria (four Bacillus species and one Pseudomonas fluoresens). Two viruses (Helicoverpa and Spodoptera), three fungi (two Trichoderma species and one Beaveria species), and two plant products (Neem and Cymbopogan) round out the list.

Chemical Approach

There are numerous synthetic pesticides available in the market. These are employed both individually and in different combinations.

In response to the slow and certain acquisition of insecticide resistance, particularly in *H. armigera, farmers have resorted to the* use of innovative insecticide cocktails, applying these indiscriminately on different crops.

The occurrence of insecticidal resistance to a variety of chemicals in key species and the outbreak of secondary pests (whiteflies in cotton and the recent mealy bug infestation on a number of crops across India) provided ample evidence of crop failures regardless of registration and other policies (Kranthi *et al.,* 2002). The existence of fake pesticides on the market and the current heavy reliance on the dealer advise system with adequate financing facilities are additional factors to keep in mind as they undermine the credibility of the knowledge that has been produced. The adverse impacts of chemical control are certain to have detrimental repercussions on the IPM programmes as long as these current issues are not addressed.

Development and adoption of IPM programs

- In India, the research on IPM was started in 1974–75 under the Operational Research Projects (ORP) with major concern on IPM of cotton and rice.
- In 1980, the Government of India (GOI) reintroduced their own plant protection strategies to control insect pests.
- FAO started inter country program in 1980 and India also become one of the member country of this programme and resulted in minimized pesticides usage and maximizing the productivity of agriculture crops.
- IPM was first used in the mid-1990s by several state agriculture departments. From 1993, the scenario of IPM programmes introduction in India.

- In 1993 FAO launched an inter-country programme for IPM in rice crops and Regional Program on IPM of cotton by CABI in 1993.
- Since 1994, the DPPQ&S, GOI, which is the primary organisation in charge of managing IPM programmes, has increased its efforts and adopted the FFS model for training farmers through its 26 CIPMCs (there are currently 31 CIPMCs). It has also conducted season-long trainings for IPM-extension workers to further the cause of IPM (Bambawale *et al.,* 2004).
- The Central Institute for Cotton Research (CICR), Nagpur developed an IPM system based on insecticide resistance management in 2002. The FAO and the European Union also developed an IPM programme for cotton in 2000.
- In the year 2000, the Government of India launched the Cotton Technology Mission (Barik *et al., 2002).*
- Pest monitoring was completed in 10.20 million hectares, while bio-control chemicals were discharged in 7.79 million hectares in 2006–2007, according to CIPMC centres. During the same time period, 10562 IPM-FFS were implemented, with 318246 farmers and 43301 extension officials receiving training (DPPQ&S).
- The IPM–FFS programme was created for CIPMCs to implement in partnership with state agriculture departments (India's principal extension agency) and with technical assistance from state agricultural institutions (Barik *et al., 2002).*
- After the IPM training intervention was stopped, the impact and adoption of different IPM courses in India were not documented. The success of various IPM projects depends on farmers using IPM techniques widely, hence a "IPM Innovation System Approach" must be built to coordinate research, extension, farmers, the public sector, and the private sector.

Constraints:

- Lack of information, a lack of expertise, the laborious and sophisticated form of IPM processes, and the unavailability of IPM inputs and instruments.
- Small farm size, lack of knowledge about modern pest control tactics, extension services, engagement of IPM specialists, and community participation were all mentioned as important obstacles by farmers.
- There seemed to be no synchronization among state agricultural institutes and CIPMCs (Peshin and Kalra, 2000).
- Eco-friendly management practices lacks Government support On case of severe infection, very limited alternatives available against pesticides
- Leadership, coordination, management of human and financial resources, and the assessment process of these programmes all have a negative impact on IPM activities.
- These organizations execute their own IPM initiatives independently or in tandem, and they may serve the same hamlet one after the other (Peshin, 2009).

For better adoption IPM programme, activities need to be addressed

- Effective training programs on IPM practices for benefits of farmers.

- Impart better knowledge in pest management in an integrated manner at farm level.
- To know the pest status, crops must be monitored at their vulnerable stages.
- Use of bio-rationales and indigenous technology
- Periodic surveillance of insect pests and disease.
- Resistance varieties to biotic stress need to be identified.
- Augmentation of natural enemies through various effective agronomic practices.
- Encourage community involvement.
- Development of village basis IPM programme.
- Pesticide should be used as a last option.
- Central Government should manage, coordinates, and draws a roadmap for IPM implementation.

In order to over come the existing evils of Indian plant protection it is believed that the following activities need to be strengthened for the benefit of farming communities, environment and health.

- Investment in the development and implementation of plant protection research need to be enhanced to arrest further degradation of natural resources due to toxic residues and to reclaim them
- Generating and sharing data on toxic residues in food, feed and water bodies is of high priority
- Develop capacity at farm level to impart better knowledge in pest management in an integrated manner
- Intensive monitoring of crops at their vulnerable stages by effective means and linking it to weather based advisory system is essential
- Periodic pests and disease surveys to update the incidence, distribution, economic importance in different geographic regions
- Crop varieties with resistance to biotic stresses need to be identified and made available to farmers through farmers networks
- Adoption of agronomic practices for pest management that augment natural enemies should be of high priority
- Use of bio-rationales and indigenous technologies as an alternative to toxic chemicals need to be encouraged
- Encourage community involvement with effective farmer participation at every stage
- Strategic research generated at the research stations need to be shared periodically through farmer participatory approach.
- Establish farm clinics for greater sustainability
- Future IPM need to be focused on village basis rather than crop based
- Registration, marketing and utilization of IPM inputs with reference to biopesticides need to be readdressed in order to encourage eco-friendly approaches for the benefit of environment and health

- Appropriate certification for IPM/residue free products should be put into practice with input and output market intelligence.

Conclusion:

The major challenge in evaluating the performance and acceptance of IPM projects around the world is that they have a far lower success rate than pesticide use. IPM initiatives are not being embraced by large landholders or even communities because most countries are concentrating on small landholder farmers, who may have had some success in raising productivity and reducing pesticide usage. IPM programmes are established and put into action gradually in both developed and developing nations. Many IPM projects still rely heavily on pesticides as their main strategy. To devise tactics to defeat IPM research and extension programmes, "real-world" barriers faced by farmers must be taken into consideration.

References:

Amit Sethi, Bons M.S., Dilawari, V.K. and Sethi, A. (2002). Response of whitefly *Bemisia tabaci* to selection by different insecticides and genetic analysis of attained resistance. *Resistant Pest Management Newsletter* 12(1): 30-35

Anonymous (2005). Very high levels of pesticides found in blood samples in Punjab, India. *The Hindu daily* June 8, 2005.

Anonymous (2007). Pesticide consumption lowest in India. http:/ /www.rediff.com/money/2007/may/11pest.htm.

Anonymous (2009a). Indian pesticides industry, Vital for ensuring food security. http//www.bharatbook.com.

Anonymous (2009b). Biopesticides market to reach $ 1 billion in 2010. http://www.ien.com/article/biopesticides-market-to/ 8648.

Ashok Kumar, Anju Baroth, Inderpal Soni, Pradeep Bhatnagar and John, P.J. (2005). Organochlorine pesticide residues in milk and blood of women from Anupgarh, Rajasthan, India. *Environmental monitoring and assessment* 116(1-3): 1-7.

James, C. (2007). Global Status of Commercialized Biotech/GM Crops: 2006. ISAAA Briefs no. 35. Ithaca, New York, USA: International Service for Acquisition on Agri-Biotech Applications (ISAAA). http://www.isaaa.org/resources/ publications/briefs/35.

Kranthi, K.R., Jadhav, D.R., Kranthi, S., Wanjari, R.R., Ali, S.S. and Russell, D.A. (2002). Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* 21: 449-460.

Logiswaran, G. and Mohanasundaram, M. (1985). Effect of intercropping, spacing and mulching in the control of groundnut leafminer, *Aproaerema modicella* (Deventer) (Gelechiidae: Lepidoptera). *Madras Agricultural Journal* 72: 695-700.

Mancini, F. (2006). Impact of Integrated Pest Management Farmer Field Schools on Pesticide Use and Farmers' Ecological Knowledge on Cotton Farming in India. Chapter 3 of the thesis.

Pratap, S. Birthal and Sharma, O.P. (2004). Integrated Pest Management in Indian Agriculture: An Overview pp. 1-10 in Proceedings on Integrated Pest Management in Indian

Agriculture (Ed. Pratap S Birthal and O P Sharma), Chandu Press, D-97, Shakarpur Delhi - 110 092.

Raheja, A.K. (1998). Role of crop protection chemicals in IPM. In proceedings of the seminar on Integrated Pest Management. Organized by Indian Crop Protection Association held on 3rd April 1998 at New Delhi. Pp.75-78.

Ranga Rao, G.V., Nandagopal, V., Rameshwar Rao, V. and Reddy, Y.V.R. (2004). Insect Pheromones of Legume Pests in India: Current Status and Future Requirements. Pages 84-95 *in* Proceedings of the National seminar on Trends in Pheromone Research and Technology, 6-7 February, 2004, Junagadh, Gujarat, India.

Ranga Rao, G.V., Rameshwar Rao, V., Prasanth, V.P., Khannal, N.P., Yadav, N.K. and Gowda, C.L.L. (2009a). Farmers' perception on plant protection in India and Nepal: a case study. *International Journal of Tropical Insect Science* 29 (3): 158-168.

Ranga Rao, G.V., Sahrawat, K.L., Srinivasa Rao Ch, Binitha Das, Kirankumar Reddy K., Bharath, B.S., Rameshwar Rao, V., Murthy, K.V.S. and Wani, S.P. (2009b). Insecticide residues in vegetable crops grown in Kothapalli watershed, Andhra Pradesh, India: A case Study. *Indian Journal of Dryland Agricultural Research and Development* 24(2): 21-27.

Ranga Rao, G.V., Visalakshmi, V., Suganthy, M., Vasudeva Reddy, P., Reddy, Y.V.R. and Rameshwar Rao, V. (2008). Relative toxicity of neem on natural enemies associated with chickpea ecosystem: A case study. *International Journalof Tropical Insect Science* 27(3/4): 229-235.

Sharma, H.C., Sharma, K.K., Seetharama, N. and Ortiz, R. (2001). Genetic transformation of crop plants: Risks and Opportunities for the rural poor. *Current science* 80: 1495-1508. US Environmental Protection Agency 2007. Information Published at web site. Info@healthgoods.com Vasantharaj David B 1995. Indian pesticide industry and overview. In Kotharis Desk Book series. Pp. 16-36.

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INSURANCE PEST MANAGEMENT AND ITS EFFECTS ON UNSEEN AND SILENT INSECT

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Abstract:

Insurance pest management is the study or concern about the effect of insecticide on non-target organism, environment and its solutions. The majority of the past two decades have seen a heavy reliance on an insurance-based strategy for managing insect pests in important grain and oilseed crops. This strategy requires a number of control measures both before planting and when there are no pest data available. The majority of producers have adopted this entire set of practises despite accumulating evidence that several of its components do not consistently give benefits. This is because there is little room for applying these strategies independently. The usage of neonicotinoid pesticides has sharply increased as a result of this preventive strategy to insect pest management, and neonicotinoids have subsequently increased in soil and water inside crop fields and elsewhere. Numerous off-target effects that have been most thoroughly researched in pollinators and insect natural enemies have been present along with these increases. Less focus has been placed on how this practise affects the tens of thousands of aquatic insect species, many of which are obscure and provide little to no evident benefits to humans and their commerce. The non-target impacts of neonicotinoids on these aquatic species are frequently as severe as those on terrestrial species, and they are more challenging to treat, according to a review of the literature. We are probably vastly underestimating the effects of neonicotinoids on the wider environment by concentrating on charismatic insect species that offer clearly defined services. Given the growing body of information showing that the benefits of this strategy for pest management and crop output are insignificant, we support a return to the largely abandoned IPM principles as a practical alternative.

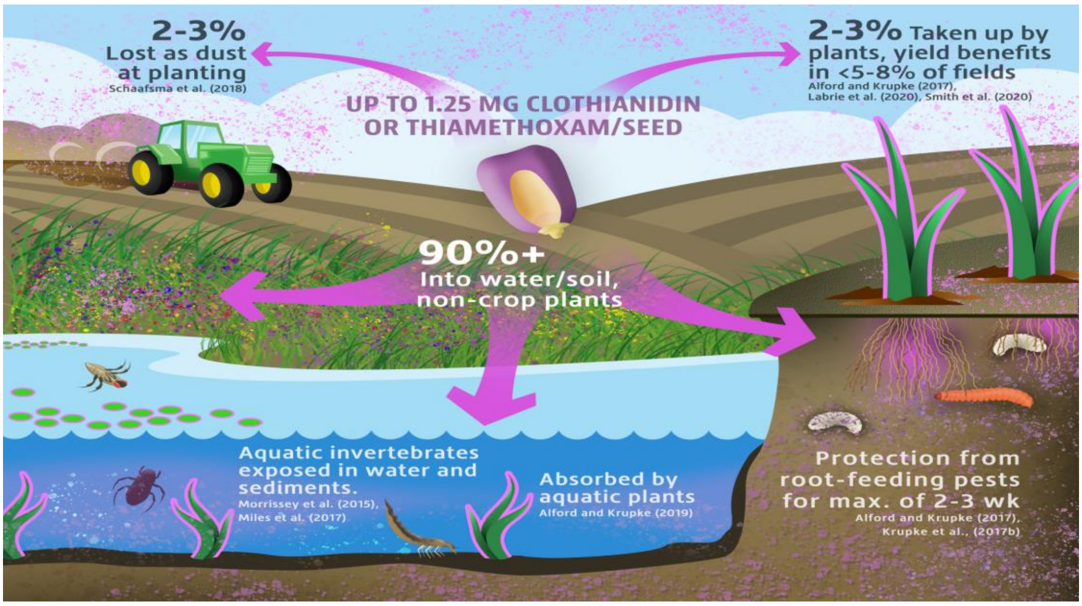
Introduction:

Our chemical insecticides still have a broad range of activity and are non-specific towards both target and non-target organisms. The anticipation of "selective insecticides" that was articulated in one of the initial descriptions of IPM (Stern *et al.*, 1959) mostly remains elusive in contemporary pest management, although some classes of insecticides have evolved that are more selective (e.g., insect-growth regulators, Bt toxins).

With the insecticides we currently have, it is still difficult to achieve the delicate balance between preserving food production and human health and avoiding negative impacts on the wider environment, which are collectively referred to as "non-target effects." This lecture will examine whether neonicotinoids, the most widely used class of pesticides worldwide, are currently being used in agriculture to achieve this balance. In this review, we primarily concentrate on American agriculture, where the majority of major crops are regularly grown from seed that has been neonicotinoid-treated.

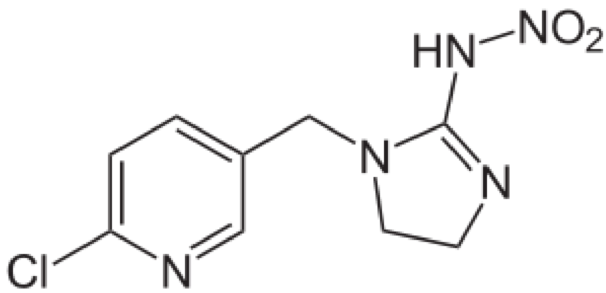
We examine neonicotinoid usage patterns, their potential for efficient pest control, and the ensuing advantages to crop productivity. next go over the likelihood of off-target impacts.

- We go over the likelihood of off-target impacts. Aquatic settings have demonstrated to be an environmental sink for neonicotinoids due to their high water solubility (Figure 1).
- We talk about some of the unintended consequences of neonicotinoids on aquatic communities and if these bad outcomes are significant in a broader sense.

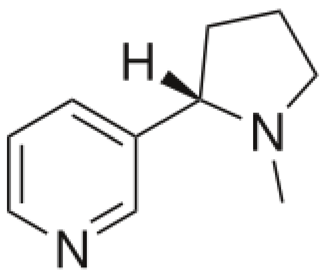


About neonicotinoid

Neonicotinoids are a group of insecticides with a chemical structure that is similar to nicotine.



Imidacloprid



Nicotine

Mode of action

- Similar to that of natural nicotine.
- Act as antagonists at the postsynaptic nicotine acetylcholine receptor (nAChR) In the central nervous system.

Neonicotionoides possess contact and systemic activity

Some example of Neonicotinoids

1st generation- Imidacloprid

Acetamiprid

clothianidin
2nd generation- Thiamethoxam
3rd generation- Nithiazin
Nintenpyram

Neonicotinoid use patterns and potential for targeted pest management

One class of chemicals, the Neonicotinoids, clearly dominates the other classes when it comes to both the frequency of use on the landscape and the potential toxicity to insects (DiBartolomeis *et al.,* 2019; Douglas *et al.,* 2020). This is evident when examining the current insecticide landscape in the United States.

Due to their systemic nature (it was believed that only insects feeding on the crop would be exposed) and apparent lower toxicity to mammals and other vertebrates, neonicotinoids were more selective than prior types of insecticides. According to Douglas et al. (2015) and DiBartolomeis et al. (2019), the majority of application is as coatings on seeds of annual crops, primarily corn, soybeans, cotton, and wheat.

Every hectare of maize planted in the United States contains one of these compounds, and between 2011 and 2014, the amount of active component added to maize seeds more than doubled.

Additionally, they are used on cotton, soybean, and other crop seeds (Douglas *et al.,* 2015, 2020). It is significant to highlight that these tendencies have been verified even in Bt maize and cotton, two transgenic hybrids. The average percentage of corn and soybean acres treated with pesticide from the 1950s to 1990 was about 50% and 10%, respectively. Current insecticide use rates are substantially above those averages.

Earlier the same significant pests that are now largely controlled by transgenic hybrids determined patterns of insecticide use. The majority of the target pests listed for neonicotinoid seed treatments in registration and marketing materials were never common, are not more common now, and typically do not cause significant yield loss when they are present (Bredeson and Lundgren, 2015; Hesler *et al.,* 2018; Sappington *et al.,* 2018; Labrie *et al.,* 2020; Smith *et al.,* 2020); however, longitudinal datasets on pest trends over that time are not available.

In other words, the seed-treatment strategy promoted by neonicotinoids has created an entirely new and incredibly convenient way to deliver insecticides without regard for documentation or monitoring of actual pest infestations on the most widely grown commodities in the U.S., as opposed to "replacing" older insecticide classes.

How and why neonicotinoid rapidly and adopted in every cropping system where insect pest management is required.

Why

- Neonicotinoid extremely water soluble.
- They will readily move “upward” within xylem tissues from roots.

How

- In other words, rather than "replacing" older insecticide classes, the seed-treatment strategy supported by neonicotinoids has created a completely new and incredibly

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convenient way to deliver insecticides without regard for documentation or monitoring of actual pest infestations on the most widely grown commodities in the U.S.

- Neonicotinoids are currently applied to a variety of landscape, garden, and agricultural crops as seed coatings, liquid applications, and infrequently as granular applications.

Realized potential of neonicotinoid-treated seeds for pest management and yield protection in field studies

- A certain amount of collateral harm to the environment may be regarded acceptable if a particular pest management method offers substantial advantages to agriculture as a whole. In agricultural systems that heavily rely on massive, dense monocultures and routine application of a variety of pesticides, non-target effects are partially inevitable and probably to be expected.
- The use of neonicotinoids in grain and oilseed crops has not been consistently or convincingly shown to have economic benefits, according to a review of the literature. Numerous small-plot field studies across North America, analyses of soybean trials across several U.S. states (Mourtzinis *et al.,* 2019), and multi-year larger scale trials carried out across dozens of commercial corn and soybean fields have all failed to find any discernible or consistent economic benefits linked to this widely used pest management strategy.
- Neonicotinoids may be able to safeguard production in 5-8% of cases, according to surveys of pest infestations conducted over a number of years in Quebec and Ontario, Canada's primary corn and soybean producing regions. Smith et al. in 2020; Labrie *et al.*, 2020).
- These studies also recorded target pest populations, but they were small (often nonexistent), which led the authors to draw the conclusion that no pest control advantage was attained because the pests were not present in quantities that were harmful.

The fate of neonicotinoids from seed coatings

- Neonicotinoids are mostly applied to crop seeds because of their high water solubility and capacity for xylem transport in plant tissues, which make them perfect for use as seed treatments.
- In the United States, where nearly every non-organic seed cultivated for grain production is treated with thiamethoxam and/or clothianidin, and less frequently, imidacloprid, neonicotinoids are used more broadly and comprehensively than yearly production of maize, or maize (Douglas *et al.*, 2015).
- Neonicotinoids and other active components are removed from the seed coat during the planting of maize seeds using pneumatic planting equipment, which is frequently utilised in contemporary North American planting operations. Due to insecticide drift, this dust disperses over the surrounding landscape and has been linked to reports of honey bee death in numerous jurisdictions (summarised in Krupke and Long, 2015).

- As a result, there is a chance that non-target creatures, in this case foraging honey bees, could be exposed to deadly doses of the active ingredient hundreds of metres beyond each planted field (Krupke *et al.,* 2017).
- Although the authors remark that this percentage may range as high as 12% of the applied active ingredient, planting of treated seeds typically results in 2-3% of the active ingredient applied to seeds being abraded and disseminated during planting (Schaafsma *et al.,* 2018).

Neonicotinoid intersections with aquatic communities

It is hardly surprising given the neonicotinoid pesticides' quick, widespread "adoption"—often without the customers' explicit consent—and the fact that non-target impacts have been reported for a number of organisms and systems. For instance, roughly 30% of farmers were unaware that their seeds included insecticides. The majority of research on non-target effects has focused on honey bees and other pollinators, both in terms of discovering exposure pathways and evaluating lethal and sub-lethal effects. Because honey bees are a highly managed, mobile, and resilient species that live in colonies of tens of thousands, honey bee health metrics are likely to significantly understate the risk to more delicate organisms whose life histories are more easily disrupted by exposure to a water-soluble insecticide. The best place to start when determining the causes of aquatic insect death is probably with water-soluble pesticides. Adoption of neonicotinoids has grown along with other stressors linked to agricultural intensification, such as habitat loss and climate change. There are additional difficulties in determining the impacts of neonicotinoids in aquatic environments, partly because aquatic insects are frequently cryptic (many reside beneath rocks, in leaf litter, or within silt), and because there is a lack of fundamental knowledge about natural history or population data.

The difficulty of quantifying the degree and effects of pulsed neonicotinoid exposures on the variety of organisms living in aquatic environments is made more difficult by the lack of baseline data for species diversity and abundance, relatively scarce quantitative data on aquatic insect sensitivity to neonicotinoids (e.g., Van den Brink *et al.,* 2016; Rico *et al.,* 2018; Macaulay *et al.,* 2019), and a lack of published protocols for rearing and maintaining colonies of

Researchers have advised regulatory bodies and the agricultural community to adopt alternative pest management strategies. These strategies range from the complete ban on the sale of neonicotinoid insecticides to a more thorough adoption of pest control strategies that rely on an IPM framework.

Neonicotinoids have lately been linked to ecosystem-wide effects in Japan. In this instance, neonicotinoid runoff from rice farming into a sizable lake resulted in significant and long-lasting declines in major midge and zooplankton species, which are prey to eels and smelts, essential fish species for nearby fisherman. Neonicotinoids caused a significant decrease in the eel and smelt fisheries' food supply, which had devastating effects on regional economy (Yamamuro *et al.,* 2019).

This story is instructive for at least two reasons.

First, the system's introduction of imidicloprid rapidly reduced zooplankton numbers, which were kept low by the persistence of neonicotinoids in the water and their cumulative toxicity over time.

Second, whereas zooplankton in this example would not have been expected to be extremely sensitive to neonicotinoids, midge populations in this example would have been expected to be sensitive to neonicotinoids in water based on limited toxicity data with aquatic crustaceans.

According to recent studies, many aquatic species are more vulnerable to neonicotinoids than the model toxicological organisms that regulatory agencies frequently employ to evaluate the possible risks to aquatic ecosystems. One notable example is the crab Daphnia magna, which is the most frequently employed aquatic invertebrate for aquatic toxicity testing and regulatory submission packages despite being orders of magnitude more tolerable of neonicotinoid insecticides than many aquatic insects.

This suggests that ecological thresholds for neonicotinoid concentrations in water need to be lowered to prevent unexpected effects from acute and chronic exposure (Morrissey *et al.*, 2015). There is also a strong case for including more species, possibly more sensitive ones, in future assessments (Roessink *et al.*, 2013).

Ecosystem-wide effects of insecticide use: what's past is prolog

Similar tales, but with different characters, were being told sixty years ago. Environmentalists, including author Rachel Carson, were horrified by the harm that synthetic pesticides, particularly the organochlorine insecticide DDT, were causing to ecosystems. The link Carson identified between the environment and human health was one of the major ideas that gave Carson's Silent Spring its enormous influence (Carson, 1962).

This connection is vividly demonstrated by a recent case from Africa, which also emphasises the risk of unintended ecological changes when pesticides reach aquatic systems. According to this study, relatively low concentrations of the neonicotinoid imidacloprid and the organophosphate diazinon decreased the abundance of some of the more delicate aquatic insect species, which resulted in larger populations of aquatic snails due to less food competition and insect predation.

When lamenting the "needless havoc" on wildlife caused by careless insecticide use, Rachel Carson wrote in Chapter 7 of Silent Spring: "The entomologist, whose specialty is insects, is not so qualified by training, and is not psychologically disposed to look for undesirable side effects of his control programmes." This portrayal of entomologists from the 1950s and the beginning of the 1960s as dogmatic, narrow-minded researchers who were only concerned with eradicating insect populations without taking into account any unintended consequences is unflattering and one-dimensional.

Synthesis

There is little doubt that post-World War II improvements in chemistry and synthetic insecticides benefited farmers and consumers who were plagued by insect pests. Notably, the

USDA and its entomologists supported and encouraged the use of insecticides, with officials frequently guaranteeing that using the insecticides in accordance with USDA instructions would result in little to no cost to animals.

Like today, back then people believed that using insecticides correctly was safe for the environment. Fortunately, science is progressive by nature, and new theories and the methods to verify them are constantly being developed. Toxicologists, ecologists, wildlife biologists, entomologists, and other scientists have all contributed to our understanding that non-target impacts are not only real, but also pervasive.

We now know that using insecticides indiscriminately, frequently as a preventative measure, can have important off-target impacts. Numerous studies have shown that these effects are pervasive in the contemporary environment and are linked to the extensive usage of neonicotinoids. In fact, there have been no recent reports of an increase in the abundance of aquatic species in American agricultural areas where neonicotinoids are widely used.

We now understand the ecological impacts of food network simplification better than we did in the 1960s. Years of theoretical and empirical research have shown that removing the easily missed, seemingly insignificant species from terrestrial food webs can cause surprising changes in primary productivity and consumer performance. Without a historical counterpart, neonicotinoids present a particularly challenging issue; their persistence, widespread use, and high water solubility have made it logistically challenging to locate really "untreated" reference locations for rigorous experimental study.

The basic principles of ecology ensure that, if current trends continue, undermining the foundations of aquatic systems will eventually materialise in detrimental effects for game fish, birds, and other species that do have an obvious monetary worth.

Conclusion:

The goal of this paper is to consider whether current agricultural use of neonicotinoids, creating this balance is the primary goal of the most widely used class of insecticides worldwide. In this study, we largely concentrate on American agriculture, where the majority of the major crops are regularly grown from seed that has been neonicotinoid-treated. We examine neonicotinoid usage patterns, their potential for efficient pest control, and the ensuing advantages to crop productivity. The risk for off-target impacts is then covered. We explore some of the neonicotinoids' non-target effects on aquatic communities and whether these negative effects matter in a larger context because aquatic environments have demonstrated to be an environmental sink for these chemicals. Finally, we describe corrective actions that can be taken to make the situation better both now and in the future.

References:

Bredeson, M.M., and Lundgren, J. G. (2015). Thiamethoxam seed treatments have no impact on pest numbers or yield in cultivated sunflowers. *J. Econ. Entomol.* 108, 2665–2671. doi: 10.1093/jee/tov249

DiBartolomeis, M., Kegley, S., Mineau, P., Radford, R., and Klein, K. (2019). An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United State. *PLoS ONE* 14:e0220029. doi: 10.1371/journal.pone.0220029

Douglas, M. R., Rohr, J. R., and Tooker, J. F. (2015). Neonicotinoid insecticide travels through a soil food chain, disrupting biological control of nontarget pests and decreasing soybean yield. *J. Appl. Ecol*. 52, 250–260. doi: 10.1111/1365-2664.12372

Hutchison, W. D., Burkness, E. C., Mitchell, P. D., Moon, R. D., Leslie, T. W., Fleischer, S. J., et al. (2010). Areawide suppression of European corn borer with Bt maize reaps savings to non-Bt maize growers. Science 330, 222–225. doi: 10.1126/science.1190242

Krupke, C. H., and Long, E.Y. (2015). Intersections between neonicotinoid seed treatments and honey bees. *Curr. Opin. Insect. Sci* 10, 8–13. doi: 10.1016/j.cois.2015.04.005

Krupke, C. H., Prasad, R., and Anelli, C. (2007). A noisy response to a silent spring: entomology's response to Rachel Carson. *Am. Entomol*. 53, 16–25. doi: 10.1093/ae/53.1.16

Labrie, G., Gagnon, A. È., Vanasse, A., Latraverse, A., and Tremblay, G. (2020). Impacts of neonicotinoid seed treatments on soil-dwelling pest populations and agronomic parameters in corn and soybean in Quebec (Canada). *PLoSONE*15:e0229136.doi:10.1371/journal.pone.0229136

Mourtzinis, S., Krupke, C. H., Esker, P. D., Varenhorst, A., Arneson, N. J., Bradley, C. A., et al. (2019). Neonicotinoid seed treatments of soybean provide negligible benefits to US farmers. *Nat. Sci. Rep.* 9:11207. doi: 10.1038/s41598-019-47442-8

Roessink, I., Merga, L. B., Zweers, H. J., and Van den Brink, P. J.(2013). The neonicotinoid imidacloprid shows high chronic toxicity to mayfly nymphs. Beketov,M. A., Kefford, B. J., Schäfer, R. B., and Liess,M. (2013).

Schaafsma, A. W., Limay-Rios, V., and Forero, L. G. (2018). The role of field dust in pesticide drift when pesticide-treated maize seeds are planted with vacuum-type planters. *Pest Manag. Sci*. 74, 323–331. doi: 10.1002/ ps.4696

Yamamuro, M., Komuro, T., Kamiya, H., Kato, T., Hasegawa, H., and Kameda, Y. (2019). Neonicotinoids disrupt aquatic food webs and decrease fishery yields. *Science*, 366, 620–623. doi: 10.1126/science. aax3442.

CONTRIBUTION OF CROP DIVERSIFICATION IN SUSTAINABLE AGRICULTURE

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Abstract:

An expansion of methodologies are used in sustainable farming practices. Crop diversification is the most vast method for lengthy-term agriculture improvement. It permits farmers to apply organic cycles to lessen inputs, conserve natural assets, boom yields, and reduce threat from ecological and environmental worries. It gives a sizable opportunity for rural communities to generate additional money and employment. Crop range decorate beneficial soil micro- organism to engage, pauses the disease cycle, and reduce the number of weeds. Agricultural variety improves the bodily and chemical properties of soil, inspire land-use efficiency and crop productivity. Crop diversification has a whole lot of ability for addressing troubles which includes insect-pest and weed revival, soil degradation, pollution, soil salinity, declining farm profit, and weather trade. Crop diversification progressed a farm's net returns, B:C ratio, and ordinary system productivity thru a crop intensification machine. Farmers are transitioning from low-value, low yielding plants to high-cost, excessive-yielding vegetation so one can gain the income of crop diversification. Crop diversification for this reason offers a terrific danger of engaging in the goals of dietary security, profits increase, meals protection, task introduction, and lengthy-term agriculture development.

Keywords: Crop Diversification, Sustainable Agriculture, Nutritional Security, Food Security

Introduction:

A growing global populace, specifically in many growing nations, needs extra food, fibre, and oil supplies, providing an extreme mission to agricultural scientists to produce extra from constrained, declining, and degraded land and water sources. By using 2050s, the worldwide population is expected to have elevated with the aid of 50%, and worldwide grain call for might have doubled. The pressure introduced on through weather change, in addition to extreme climate and urbanization, adds to the load. In its present day kingdom, international agriculture poses a severe risk to agricultural sustainability. The finest full-size threat to food security and the environment is the depletion and reduce the exceptional of natural sources consistent with capita. Present intensification technologies are beginning to reveal signs of deterioration. Groundwater scarcity, fossil water exploitation, groundwater contamination, and growing CO_2 levels within the surroundings are all serious threats to sustainability. In sustainable production, a ramification of approaches are hired. The web page specific and particular nature of sustainable agriculture need to be taken into consideration in specific plans. Reduced reliance on monocultures can enhance resilience and lower the threat of total device failure, both of that are important for long-time period agricultural success. Adjusting to moving occasions can be a dynamic and steady system.

The diversification of agriculture is an alternate manner now not only for the regeneration and conservation of land but additionally for enhancing its productivity. Furthermore, it may bring about holding the most important useful resource that is water. National Agricultural coverage (NAP), 2001, emphasised the want for efficient use of soil, water, bio-assets to meet the growing requirement at domestic and face the opposition in world marketplace effectively. Crop diversification in India means a shift from traditionally grown much less remunerative plants to greater remunerative vegetation. It depends on geo- climatic, socio-economic conditions and technological development in a vicinity. Due to various agro climatic situations in the United States, a massive quantity of agricultural products are produced in our country. Crop diversification designed to a shift from the regional dominance of 1 crop to regional manufacturing of a number of vegetation and to fulfil ever increasing call for of coarse cereals, pulses, vegetables, fruits, oilseeds and sugarcane. It targets to enhance soil health and to keep dynamic equilibrium of the agro atmosphere. Crop diversification is supposed to sell technological improvements for sustainable agriculture and allow farmers to select crop options for extended productivity and profits.

Crop diversification refers to bringing suited alternate in the current cropping gadget in the direction of extra balanced and lucrative device to fulfil the ever growing demand of meals, feed, fibre and fuel on the only hand and maintenance of soil fertility and agro- surroundings on the opposite.

Crop diversification inside the Indian point of view

With the appearance of modern-day agricultural era, especially for the duration of the period of the inexperienced Revolution within the past due Nineteen Sixties and early Nineteen Seventies, there may be a non-stop surge for diverse agriculture in terms of plants, frequently on financial issues. The crop sample changes, however, are the final results of the interactive impact of many elements which may be widely classified into the subsequent five agencies:

a. Resource related elements overlaying irrigation, rainfall and soil fertility.
b. Generation related elements protecting no longer best seed, fertilizer, and water technology however also those associated with advertising and marketing, garage and processing.
c. Household associated elements overlaying food and fodder self-sufficiency requirement as well as investment potential.
d. Fee associated factors covering output and input fees as well as trade policies and other financial rules that have an effect on these charges either immediately or in a roundabout way.
e. Institutional and infrastructure associated factors protecting farm size and tenancy arrangements, research, extension and advertising structures and authorities regulatory guidelines glaringly, those elements aren't watertight however inter-associated. As an instance, the adoption of crop technologies is impact now not most effective with the aid of useful resource associated elements but also by using institutional and infrastructure

elements. In addition, government guidelines - both supportive and regulatory in nature - affect both the input and output expenses.

Which includes, special authorities programmes also have an effect on location allocation and crop composition. greater importantly, each the financial liberalization regulations as well as the globalization process also are exerting strong pressures at the location allocation selection of farmers, basically through their effect on the relative costs of inputs and outputs. Although the elements that impact the vicinity allocation selection of farmers are all important, they manifestly fluctuate in terms of the relative significance both across farm organizations and resource regions. At the same time as factors such as food and fodder self-sufficiency, farm size, and funding constraints are essential in influencing the vicinity allocation pattern among smaller farms, large farmers with a capacity to bypass resources constraints generally move extra via monetary concerns based totally on relative crop fees than by means of other non-economic issues. Further, monetary elements play an exceedingly stronger position in influencing the crop pattern in areas with a better irrigation and infrastructure potential. In such regions, commercialization and marketplace networks co-evolve to make the farmers extra dynamic and rather conscious of economic impulses.

What is maximum exquisite is the alternate in the relative significance of those elements over the years. From a completely generalized attitude, Indian agriculture is more and more getting prompted increasingly more by financial elements. This want not be sudden because irrigation enlargement, infrastructure development, penetration of rural markets, development and unfold of quick period and drought resistant crop technology have all contributed to minimizing the position of non-economic elements in crop desire of even small farmers. What's greater, the reform tasks undertaken inside the context of the continued agricultural liberalization and globalization regulations also are going to in addition give a boost to the position of price related financial incentives in determining crop composition both at the micro and macro ranges. manifestly, any such changing financial environment may even make certain that authorities charge and change guidelines becomes nonetheless greater effective units for directing place allocation choices of farmers, aligning thereby the crop pattern changes in step with the changing demand-supply conditions. In a circumstance where agricultural increase outcomes greater from productiveness development than from place enlargement, the increasing role that fee related economic incentives play in crop preference also can pave the way for the next degree of agricultural evolution wherein increase originates more and more from fee-delivered manufacturing.

Crop diversification is an idea

Crop diversification, as contrasted to specialized farming, is described as a try and growth crop range by way of crop rotation, more than one cropping, or intercropping, with the reason of boosting ecological gadget productivity, sustainability, and deliver. It could be a first step towards greater sustainable agricultural structures, minor crop price chains, and social benefits. Agricultural diversification tasks encompass advanced agricultural range, higher various crop rotations, blended cropping, cultivation of grain legumes in typically cerealdominated structures, perennial leys or grassland, and regionally suitable varieties or variety combinations. Crop diversification is defined because the substitution of one or greater agricultural crops for another in developing international locations. In agriculture, diversification is described because the making an investment of a few farm effective sources, along with land, capital, farm device, and labour, into new companies. Diversification is the manner of switching from a much less profitable farming gadget to a greater profitable cropping system. Agriculture diversification refers back to the move from an unmarried crop's regional or temporal dominance to the production of more than a few crops to fulfil the ever-increasing want for cereals, pulses, oilseeds, fibres, gas, and feed. Crop diversification is a dynamic and iterative belief that encompasses spatial, temporal, value addition, and useful resource-complementary techniques, as well as a shift away from conventional and much less-profitable plants.

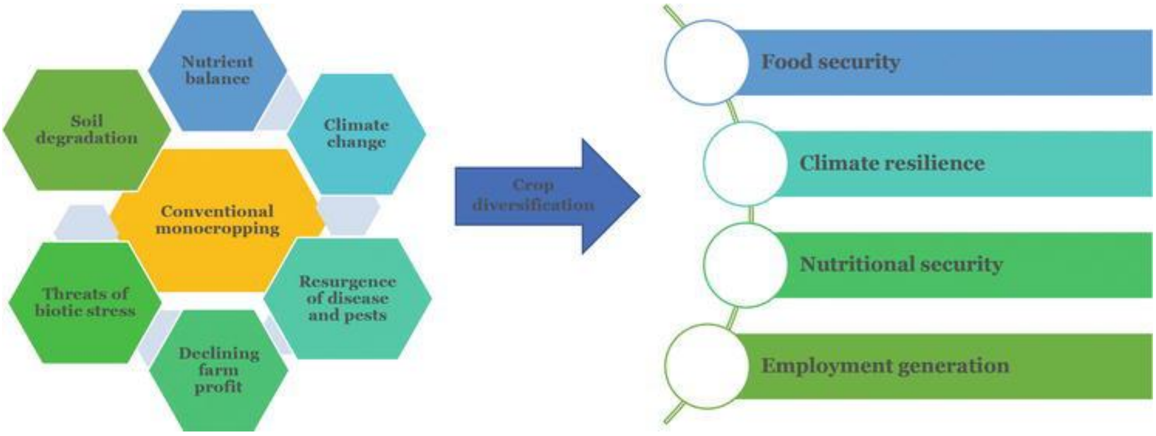

Figure 1: Basic Concept of Crop Diversification

Crop diversification approaches:

Horizontal diversification:

Crop substitution and crop intensification are the 2 essential methods for doing so. The two simple techniques of agricultural diversification had been these ways. Crop substitution refers back to the substitute of any crop that is developing as a monoculture crop or has a tendency to specialise. For the duration of the green revolution, for example, there has been a fashion towards cultivating completely cereal plants. In current years, the tendency in growing countries has shifted dramatically. Farmers are transitioning far from monoculture cereals as a staple food and closer to high-cost plants which includes veggies, spices, and different excessive-value vegetation. Crop substitution has diverse benefits, inclusive of increased net returns, progressed useful resource use efficiency (land and labour), and a break within the pest and ailment cycle. Crop intensification, on the other hand, is the addition of extra high-fee crops to a current cropping machine in order to improve the farm's total productivity. We want to transport away from simple crop rotation and toward in depth structures like more than one cropping, intercropping, relay cropping, and so on if we need to acquire the blessings of agricultural diversification. Crop intensification contributes to elevated task possibilities, profitability, and electricity efficiency.

Vertical diversification:

Vertical crop diversification, on the other hand, is a degree of the degree and quantity to which agricultural manufacturing has turn out to be industrialized. Farmers and others use this strategy to enhance the marketable really worth of vegetation by way of adding price to them via packing, processing, regional branding, and merchandising. food crop vertical diversification can also be described as the growth of submit-harvest activities, together with the processing and transformation industries, to allow meals vegetation to be taken care of, graded, processed into both meals and commercial merchandise, packed, stored, and transported to home or export markets. In terms of producing cash and jobs in rural regions, the growth of processing and transformation groups seems to be the maximum critical detail.

Both types of diversification (i.e., multiple cropping or horizontal diversification and agri-business or vertical diversification) could be vital to enhance crop yields and earnings advent on the local, regional, and countrywide ranges.

Others approaches

1. Land based totally method – in this method enhance structural range consisting of makes vegetation inside the greater structurally numerous given benefit in pest suppression.
2. Water-primarily based approach - Integration of crop with different farming components for year spherical earnings and employment technology, except sustaining soil and surroundings fitness. Capability gain – insect, pest and sickness suppression, climate change buffering and multiplied production, employment and income.
3. Varietal diversification
4. Diversification for dietary safety
5. Diversification for nutrient management
6. Diversification for pest control
7. Diversification for mitigation and adaption of climate exchange.

Need of crop diversification - Crop diversification has emerged as a crucial option to reap numerous goals viz.

1. For raising farm income
2. Natural resources sustainability- inclusive of cultivable land, water shortage, and soil.
3. Ecological stability,
4. Output increase,
5. Employment generation- in agriculture business
6. Risk coverage: mono cropping, excessive upward push etc
7. Decreased or plateaued yield of rice-wheat cropping structures.
8. Reduced level of natural carbon in soil in Indo-Gangetic Plains (IGP).
9. Deficiency of vitamins such as nitrogen, phosphorus, potassium, sulphur, Boron, and so on in soil (rather, in rice primarily based cropping systems).
10. Meals and nutrient safety,
11. Promotion of export

Advantages of crop diversification

Crop diversification has validated to useful now not just due to the fact it's a contemporary new farming method, but also as it manages to triumph over quite a few farming problems resulting from changing surroundings, panorama, disorder and pest conduct, authorities policies, deliver and demand and tendencies.

SDG 1 = Sustainable improvement aim. The above flowchart describes how crop diversification undoubtedly influences one of the sustainable improvement desires set by United countries. It depicts how agricultural diversification performs a critical function in removing poverty from the society. Source: Diana Feliciano, an evaluation at the contribution of crop diversification to Sustainable improvement goal 1 "No poverty" in exceptional global areas

- Greatly reduces farmers danger as the farmer now does now not rely upon simply one crop for profits. In contrast to the traditional farming strategies wherein failure of the crop ended in entire exit of that farmer from the marketplace.
- Small farmers are majorly empowered as the overall yield of the multiple business flora and crop will increase.
- a couple of cropping device or multi-tier cropping systems greatly boom employment possibilities.
- Increases earnings of small farms.
- Crop diversification facilitates in balancing and pleasant food demand Crop diversification also allows in increasing manufacturing of top exceptional fodder for cattle animals.

Reduces the capacity of pests, bugs and weed to become immune to insecticides and herbicides.

- Agricultural diversification facilitates in maintaining the nice of natural resources (soil vitamins / soil fertility and water).
- It additionally helps in minimizing environmental pollutants which is because of immoderate use of herbicides and insecticides.
- It opens up new agribusiness opportunities for budding marketers (who want to step into the arena of meals processing) and additionally opens up new frontiers for exports of crops, greens and fruits.

Challenges in adopting crop diversification

- The implementation of crop diversification is facing many problems in its implementation. These problems may be climatic, geographical, monetary or human.
- Extra than 60% of the United States of America's cultivated area is rain-fed and is dependent on rainfall. Therefore, areas with less rain have fewer alternatives for vegetation for crop diversification.
- Suboptimal and excessive use of assets such as land and water, inflicting terrible results on the surroundings and sustainability of agriculture.
- In India, in a few cases, the landownership can be divided into more than one parties (consisting of siblings and spouse and children). The difference of opinion and private hobbies additionally hampers the implementation of crop diversification method.

- Every so often the scale of the landholding by a farmer isn't sufficient to reap agricultural diversification.
- Inability to finance also performs a chief component in not being capable of adopt this farming technique.
- Loss of simple infrastructure such as roads, power, transportation, and communications in rural regions.
- The post-harvest dealing with of perishable horticulture products such as milk, meat, end result and veggies, is inadequate due to inadequate technologies and infrastructure.
- The agro-based totally industry (consisting of processing devices, cold storage, dry garage, authority's garage, packaging gadgets etc) is vulnerable. Farmers and nearby markets aren't properly linked to the agro-enterprise.
- The linkage between farmers and studies-extension is negative and subsequently farmers do no longer have the know-how of this practice or lack steerage on a way to implement it successfully.
- Low farmer illiteracy and insufficiently educated human resources.
- Most crop flora are being laid low with new species of diseases and pests.
- There are insufficient investments in the agricultural area and a bad database of horticultural vegetation.

Key strategies in crop diversification

1. Changing low yielding and coffee yielding fee crops with high yielding and excessive yielding price plants which have a longer shelf lifestyles.
2. Together with legume farming in agricultural diversification. Legume farming saves water within the land for the subsequent crop.
3. Substitute of excessive-water-the use of plants with plants that require less water. Which include power-green plants and flora.
4. Planting intercrops in rain-fed areas. The inclusion of locally and internationally demanded vegetation.
5. Farming drought-resistant oilseed vegetation to update high-risk vegetation.
6. Adopting crop structures which can be greater productive, worthwhile, and sustainable.

Government coverage and aid in crop diversification

Numerous significant and nation government schemes were launched or introduced when it comes to agricultural improvement, and crop diversification especially.

1. Watershed development fund (established in 2002 to increase rainfed lands country wide).
2. In 2014-15, the NMSA (national task for sustainable agriculture) was released with the intention of enhancing the efficiency of farming, the use of water, and soil fitness management. It additionally ambitions to synergize useful resource conservation across all parts of the US.
3. Seed crop coverage: The government has released a pilot program for seed crop insurance, which covers the hazard issue related to the production of seeds.

4. PKVY (Paramparagat Krishi Vikas Yojna): In 2015, the central authorities released a software to sell natural farming in India.
5. Seed financial institution scheme: approximately 7-eight% of seed produce will be kept in buffer shares to meet any situations at some stage in a drought, flood, hailstorm, and so on
6. Gramin Bhandaran Yojna: A application created in 2001 to provide garage centers for agricultural products in rural India and to sell grading, standardization, trying out and first-rate manipulate to make the goods greater marketable.
7. Mera Pani Meri Virasat: Haryana country authority's initiative with a view to provide beneficiaries Rs 7000 per acre in the event that they switch from rice to low water-use field plants and Rs 10000 in the event that they plant 400 hundred bushes consistent with acre.
8. Pradhan Mantri Fasal Bima Yojana (PMFBY): significant government scheme to offer useful resource and financial surety to the farmer.

Conclusion:

Diversification is one of the most efficient techniques to decorate agricultural sales, ensuing in multiplied meals, nutrients, and environmental security, in addition to a reduction in poverty in developing nations. It has a massive effect on agro-socio-economic benefits. It led to a 12 months-over-12 months growth in revenue. Let's in for the manufacturing of plants primarily based on marketplace want. rate fluctuation is smoothed out. boom the grain equivalent yield, system production performance, relative production efficiency and land use performance.

References:

Bhattacharyya, B. (2008). Crop Diversification: A Search for an Alternative Income of the Farmers in the State of West Bengal in India. *International Conference on Applied Economics*, 83-94.

Brenda, B. Lin. (2011). Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. *Bio Science*, 61(3): 183-193.

Chand R, Chauhan S. (2002). Socio economic factors in agricultural diversification in India. *Agricultural Situation in India*. 58(11):523-530.

Garbach K, Milder JC, De Clerck FA, Montenegro de Wit M, Driscoll L, Gemmill-Herren B. (2017). Examining multi-functionality for crop yield and ecosystem services in five systems of agroecological intensification. *International Journal of Agricultural Sustainability*. 15(1):11-28.

Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF. (2010). Food security: The challenge of feeding 9 billion people. *Science*. 327(5967):812-818.

Hedge DM, Tiwari SP, Rai M. (2003). Crop diversification in Indian agriculture. *Agricultural Situation in India*. 60:255-272.

Kalaiselvi, V. (2012). Patterns of Crop Diversification in Indian Scenario. *Scholar Research Library*, 3(4): 1914-1918.

Kamalika, M. (2014). Nature and Pattern of Crop Diversification in West Bengal. *International Journal for Research in Management and Pharmacy*, 3 (2): 33-41.

Kremen C, Miles AF. (2012). Comparing biologically diversified with conventional farming systems: What is known about environmental benefits, externalities and trade-offs among crop productivity and ecosystem services. *Ecology and Society*. 17:40.

Nishan, M.A. (2014). Crop Diversification for Sustainability. *Popular Kheti*, 2 (2): 20-24: ISSN: 2321-0001.

Patel, S.J. (2014). Crop Diversification: A Paradigm for Sustainable Agriculture. Online Available: http://www.authorstream.com/as Guest 76584-680952-Crop Diversification (13 July 2014).

Singh, S., Park, J., Litten-Brown, J. (2011). The Economics Sustainability of Cropping Systems in Indian Punjab: A Farmers Perspective. EAAE 2011 Congress, Switzerland.

Wezel A, Casagrande M, Celette F, Vian JF, Ferrer A, Peigné J. (2014). Agroecological practices for sustainable agriculture a review. *Agronomy for Sustainable Development*. 34(1):1-20.

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