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VOLUME II

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PREFACE

We are delighted to publish our book entitled ***"Sustainable Agricultural Volume II".*** *This book is the compilation of esteemed articles of acknowledged experts in the fields of basic and applied agricultural science.*

The Indian as well as world population is ever increasing. Hence, it is imperative to boost up agriculture production. This problem can be turned into opportunity by developing skilled manpower to utilize the available resources for food security. Agricultural research can meet this challenge. New technologies have to be evolved and taken from lab to land for sustained yield. The present book on agriculture is to serve as a source of information covering maximum aspects, which can help understand the topics with eagerness to study further research. We developed this digital book with the goal of helping people achieve that feeling of accomplishment.

The articles in the book have been contributed by eminent scientists, academicians. Our special thanks and appreciation goes to experts and research workers whose contributions have enriched this book. We thank our publisher Bhumi Publishing, India for taking pains in bringing out the book.

Finally, we will always remain a debtor to all our well-wishers for their blessings, without which this book would not have come into existence.

Editors

CONTENT

RESOURCE CONSERVATION TECHNOLOGIES (RCTS) IT'S USED IN AGRICULTURE

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Abstract:

The current trends and future directions in the use of resource conservation technology in agriculture. The first of all examines the key resource conservation technologies currently in use in agriculture, including conservation tillage, integrated pest management, precision agriculture, and water-saving irrigation techniques. The benefits and challenges of each technology are discussed, along with case studies that illustrate successful implementation. Continuous use of conventional farming practices with conventional tillage and burning crop residues has degraded the soil resource base and intensified soil degradation with a concomitant decrease in crop production capacity. Further, escalating fuel, fertilizers, and other input costs; necessitates the effective use of resources in agriculture. The CA technologies involving no- or minimum-tillage with direct seeding and bed planting, residue management, and crop diversification have the potential for improving productivity and soil quality, mainly by soil organic matter build-up. Conservation agriculture systems appear to be appealing options to achieve sustainable and intensive crop production under different agroecological environments because they use available resources efficiently and maintain soil fertility. However, there is a need for wider scale testing of these new technologies under diverse production systems, as the CA technologies are site-specific, and therefore appraisal of CA is important to have significant adoption.

Keywords: Conventional tillage, Cover crops, Diversification, Precision farming, Zero tillage.

Introduction:

Resource conservation technology refers to a set of tools and techniques that can be used to reduce the consumption of natural resources, minimize waste, and promote sustainable development. With growing concerns about the environmental impact of human activities, there is an increasing need for the development and adoption of resource conservation technologies. Broadcast seeding and harvesting measure yields were common features of ancient agriculture. Whereas, substantial yield gain through greater use of improved seeds, irrigation, chemical fertilizer, pesticides, and mechanization (Foresight, 2011) was the main thrust of modern agriculture. Therefore, today's agriculture is an energy-intensive farming system (Khan *et al.*, 2010). Though the modern technology model succeeded in achieving targeted food demand, it has contributed to environmental problems such as loss of biodiversity and soil fertility, salinization, and water scarcity (McIntyre *et al.,* 2009). Conventional or modern agriculture has largely been characterized by tillage which includes, soil loosening and leveling for seedbed preparation, mixing fertilizer into the soil, weed control, and crop residue management (Hobbs *et al.,* 2008). However, continuous use of conventional farming practices with conventional tillage (CT) and burning crop residues has degraded the soil resource base (Montgomery, 2007) and intensified soil degradation by about 67%, with concomitant decreases in crop production capacity (World Resources Institute, 2000). More recently, yield growth has been diminishing, which is especially true for rice in Asia (Pandey *et al.,* 2010). The current scenario of escalating fuel, fertilizers, and other input costs; necessitates the effective use of energy and other vital resources in agriculture. Without a new and more sustainable boost to productivity, agricultural supply will hardly be able to keep pace with the rapidly rising demand caused by population and income growth and changing consumer preferences (Foresight, 2011). Today's real agricultural challenges are resource fatigue with declining factor productivity, decreasing human resources, and rising costs and socioeconomic changes (Erenstein, 2011; Gathala *et al.*, 2011a). Thus, there is a dire need for energy, water, and labor-efficient alternate system that helps to sustain soil and environmental quality, and produce more at less cost (Jat *et al.,* 2011; Gathala *et al.,* 2011b).

The CA technologies involving no- or minimum- tillage with direct seeding and bed planting, residue management (mainly residue retention), and crop diversification (Gupta and Sayre, 2007) have the potential for improving productivity and soil quality, mainly by soil organic matter (SOM) build-up (Bhattacharyya *et al.,* 2013a, b). The RCTs bring many possible benefits including reduced water and energy use (fossil fuels and electricity), reduced greenhouse gas (GHG) emissions, soil erosion and degradation of the natural resource base, increased yields and farm incomes, and reduced labor shortages (Pandey *et al.,* 2012). CA was originally designed as a response to the

What is conservation agriculture?

Conservation Agriculture (CA) is a farming system that can prevent losses of arable land while regenerating degraded lands. It promotes the maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production. another term of CA principles is universally applicable to all agricultural landscapes and land uses with locally adapted practices. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes

Why choose RCT:

- A resource is any natural or artificial substance or energy which can be used for the benefit of mankind.
- Natural resources are those which exist in the environment naturally, that is, they are not created by humans. They are soil, water, sunlight, the wind, plants, coal etc.
- To support life by supporting ecological balance
- To ensure that future generations will be able to access the resources.
- To preserve biodiversity.
- To make sure the human race survives.

Conservation agriculture (CA) has four principles:

(i) The minimizing mechanical soil disturbance and seeding directly into untilled soil to improve soil organic matter (SOM) content and soil health.

(ii) Enhancing SOM using cover crops and/or crop residues (mainly residue retention). This protects the soil surface, conserves water and nutrients, and promotes soil biological activity.

(iii) Diversification of crops in associations, sequences, and rotations to enhance system resilience that complements reduced tillage and residue retention by breaking cycles of pests and disease (FAO, 2010)

(iv) Controlled traffic that lessens soil compaction. CA avoids straw burning, improves soil organic carbon (SOC) content, enhances input use efficiency, and has the potential to reduce GHGs (Bhattacharyya *et al.*, 2012a, b).

Need for conservation agriculture (CA) in future prospect:

At present, the challenge for agricultural scientists is to increase food production to meet the food security needs of the ever-growing population of the world. However, such production increases must be accomplished sustainably, by minimizing negative environmental effects and, equally important, providing increased income to help improve the livelihoods of those employed in agricultural production. There are several key issues in this equation on which there is almost unanimous consensus. The demand for food is still increasing, not only to meet food security for a growing population but to provide nutritional security as well. Most of the sources of productivity growth viz. improved varieties, fertilizer, and water used in the last 40 Green Revolution years are already being exploited. Future sources of productivity growth will be more complex and harder to find. To maintain ecological balance for supporting life and to make the resources available for the present and future generations. Competition for surface and groundwater resources will be more severe as domestic and industrial needs will compete for them. The shrinking agricultural land is because of urbanization and its use for other purposes. Expansion is possible in some parts of the world, but the quality of the new land may be less than that already in use for agriculture Fossil fuels will be more costly, adding to production costs directly as well as indirectly. GHGs will increase with subsequent effects on climate, especially an increase in severe climatic events such as drought, floods, etc. This will make the challenge more difficult and complex. One obvious way to accomplish this sustainable food production objective is to make more efficient use of the natural resources that are needed to produce food; this includes soils, water, air, inputs, and people.

RCTs for conservation agriculture (CA)

Zero tillage:

No-till farming (also known as zero tillage or direct drilling) is an agricultural technique for growing crops or pasture without disturbing the soil through tillage. Zero tillage (ZT) involves the use of a tillage implement that creates a narrow slot for the seed and does not disturb or turn over the soil in the process of planting the crop. The traditional approaches of ploughing which include 3-4 tillage operations are completely skipped. Hence, the cost of production is reduced and timely planting of crops (wheat) is ensured. Another benefit of earlier sowing under ZT is that Phalaris minor, an herbicide-resistant weed in wheat, is less competitive than when wheat is sown late under conventional tillage (CT), (Malik *et al.,* 2002). Evidence on yield effects of zero tillage is highly variable (Giller *et al.,* 2009). Where zero tillage is combined with mulching, a commonly described pattern is for yields to fall initially (Baudron *et al.,* 2011), and then to increase over the subsequent decade or so, eventually exceeding yields in conventional tillage-based agriculture (Rusinamhodzi *et al.,* 2011). In addition, ZT has a direct mitigation effect as it converts the greenhouse gases like CO2 into O2 in the atmosphere and enriches soil organic matter (Venkateswarlu and Shanker 2009). However, the potential of CA for storing C depends on antecedent soil C concentration, cropping system, management duration, soil texture, slope and climate (Luo *et al.,* 2010).

Crop residue cover:

Crop residues are the parts or portion of a plant or crop left in the field after harvest, or that part of the crop which is not used domestically or sold commercially or discarded during processing. A vast potential is available to efficiently recycle crop residues, especially in the rice-wheat belt of Punjab, Haryana, and western Uttar Pradesh, where it is burnt in situ. CA practices require a critical level of crop residues with the objective, to protect the soil against weather aggressions and water erosion, to maintain soil moisture (Lal 1997), to suppress weed growth, and to provide shelter and food for the soil biota (Blanchart *et al.,* 2006). Crop residues are also an important source of nutrients and maintain or enhance soil chemical, physical and biological properties and prevent land degradation. The importance of crop residue cover as part of the CA system has been emphasized by several researchers (Govaerts *et al.,* 2009; Hobbs *et al.,* 2008). However, the decomposition rate and release of N from residues depend on soil, climatic conditions, and the C: N ratio of plant residues (Prasad and Power, 1991). Nonetheless, there can be negative aspects to crop residue retention. For example, Govaerts *et al.* (2007), in Mexico, found an increased incidence of disease with retained residue, but the benefits from increased infiltration and water availability outweighed the disease factor.

Cover crops:

Keeping the soil covered is a fundamental principle of CA. Crop residues are left on the soil surface, but cover crops may be needed if the gap is too long between harvesting one crop and establishing the next. Cover crops may fulfill additional agronomic, ecological, or economical functions in CA systems that can supplement those performed by the main commercial crops (Hartwig and Ammon 2002; Seguy *et al.* 2003). They may also contribute to the mineral nutrition of the main crop(s) through nitrogen fixation in the case of legumes, mulch mineralization or manure returns from animals that feed on them. Part of the biomass they produce may contribute to farm incomes, e.g. additional grain production for human food or as extra fodder resources. Besides their above-ground functions, cover crops fulfill important functions below the ground. Their root systems contribute to preventing or remediating soil compaction, tapping soil moisture from deeper horizons below the root zone of the main crops or recycling nutrients such as nitrates, K, Ca, and Mg that are easily leached to deeper soil horizons (Barthes *et al.* 2005). There are various crop alternatives to be used as vegetative covers, such as grains, legumes, root crops, and oil crops. The vegetative cover also protects the soil against the impacts of raindrops; keeps the soil shaded; and maintains the highest possible moisture content.

Precision farming:

Precision agriculture refers to the application of precise and correct amounts of inputs like water, fertilizers, pesticides, etc. at the correct time to the crop for increasing its productivity and maximizing its yields. The benefits of so doing are twofold i) the cost of production be possible by combining variable nitrogen application and targeting subsoiling to headlands for a crop of wheat in the UK. An average benefit of £38.60 ha^{-1} was reported by Schmerler and Basten (1999), when wheat was grown on a farm scale trial, where both seed and agrochemical rates were varied.

Use of GPS and GIS systems:

Widespread adoption of SSNM technologies based on soil testing requires extensive soil sampling and analysis which could be a hindrance considering the available infrastructure. The use of the Global Positioning System (GPS) and Geographical Information System (GIS) and mapping can provide the right support as a cost-effective alternative. The GPS makes it possible to record the in-field variability as geographically encoded data. Information collected from different satellite data and referenced with the help of GPS can be integrated to create field management strategies for chemical application, cultivation, and harvest (Liaghat and Balasundram 2010).

However, GIS is a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes (Burrough and McDonnell 1998). These technologies enable the coupling of real-time data collection with accurate position information, leading to the efficient manipulation and analysis of large amounts of geospatial data. Studies conducted under AICRIP in UP, West Bengal, and Assam indicated significant variations in crop responses, soil nutrient supplies, nutrient uptake, rice productivity, and nutrient use of efficiency with sufficient yield gaps between farmers' practices and recommended fertilizer dose. Studies on such spatial variability in farmer's fields are limited. In the coming few years precision farming may help Indian farmers to harvest the fruits of frontier technologies without compromising the quality of the land.

Site-Specific Nutrient Management (SSNM):

The nutrient Management and recommendation process in India is still based on response data arranged over large domains. The SSNM provides an approach for need-based feeding of crops with nutrients while recognizing the inherent spatial variability. It involves monitoring of all pathways of plant nutrient flows/supply and calls for a judicious combination of fertilizers, bio-fertilizers, organic manures, crop residues, and nutrient-efficient genotypes to sustain agricultural productivity. It avoids indiscriminate use of fertilizers and enables the farmer to dynamically adjust the fertilizer use to fill the deficit optimally between nutrient needs of the variety and nutrient supply from natural resources, organic sources, irrigation water, etc. It aims at nutrient supply at optimal rates and times to achieve high yield and efficiency of nutrient use by the crop. SSNM approach involves three steps – establishing attainable yield targets, effectively using existing nutrient sources, and application of fertilizers to fill the deficit between demand and supply of nutrients.

Leaf Color Chart (LCC):

An LCC developed in Japan is used to measure the green color intensity of rice leaves to assess the nitrogen requirements by a non-destructive method (Nachimuthu *et al*, 2007), and is being standardized with a chlorophyll meter. In hybrid as well as inbred rice, N management through LCC proved superior to locally recommended N application in three splits. It was found possible to curtail 20-30 kg of fertilizer N/ha without sacrificing rice yield when N is applied as per LCC values. N application at LCC<3 in Basmati and at LCC<4 in coarse and hybrid rice was found optimum. Moreover, in LCC-based N management, basal application of N can be skipped without any disadvantage in terms of grain yield, and agronomic, physiological or recovery efficiency of fertilizer N.

Laser land leveler:

Laser leveling is a process of smoothening the land surface (± 2 cm) from its average elevation using laser-equipped drag buckets to achieve precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2%. This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level. (Walker *et al.* 2003). showed that the use of RCTs, including zero tillage, laser leveling, and bed and furrow planting, reduced irrigation water applications between 23 and 45% while increasing yield.

Crop rotation and cropping system:

Use of crop rotations or intercropping is considered vital in CA systems (Calegari 2001), as it offers an option for higher diversity in plant production and thus in human and livestock nutrition, and pest/weed management that is no longer realized through soil tillage. Legumes grown in rotation can provide a range of benefits to the agro-ecosystem, including increases in subsequent crop yields and reductions in input costs due to nitrogen fixation and reductions in crop diseases (Pannell, 1995); An effective crop rotation in a cropping system is not only helps to increase the crop productivity and soil fertility but also improve the water use efficiency by reducing weeds, providing conducive micro-climate for plant growth and development, reduction in soil thermal regime and improving physical properties of the soil. An efficient cropping system can contribute to a great extent to sustain agriculture. Saxena 2008 found that weed infestation was least in pearl millet-mustard rotation as mustard residue on decomposition released S-containing volatile compounds, which were effective in controlling weeds.

Diversification/Intensification:

A shift from sole cropping to a diversified/ intensified farming system is highly warranted. The increased cropping intensity/diversification is intended to minimize risk, improve biodiversity and diversify income sources and enhance resource sustainability. It will be a key strategy for future gains in crop production. Short-duration pulses, oilseeds, and other high-value crops will find their definite niche as sequential or intercrops, rather than replacing the major cereal crops having higher yield stability (IIFSR 2015). Hence, an increased cropping intensity will contribute substantially to additional demands for food and cash crops. Pigeon pea, the most important wet-season grain legume crop in south Asia has shown potential for rice crop diversification in Indo-Gangetic Plain (IGP). Similarly, bio-intensive diversified cropping systems would enable small and marginal farmers to utilize limited land and water resources in a more efficient manner.

Integrated Farming Systems:

Integrated Farming Systems hold a special position in conservational agriculture as in this system nothing is wasted, the byproduct of one system becomes the input for the other. For example, crop residues from the field can be used for animal feed, while manure from livestock can enhance agricultural productivity by improving soil fertility as well as reducing the use of chemical fertilizers (Gupta *et al.*, 2012). Moreover, the system helps poor small farmers, who have very small land holdings and a few heads of livestock diversify farm production, increase cash income, improve the quality and quantity of food produced, and exploit unutilized resources. Animals play a key and intercept the runoff. Prolonged retention of rainwater on the land surface increases the amount of water entering the soil. The effective methods of in-situ water harvesting are summer ploughing, broad bed and furrows, ridges and furrows, random tie ridging, and compartmental bunding. In-situ moisture conservation does not confine to land shaping carried out during cropping season, it encompasses off-season tillage and contour farming as well.

Off-season tillage or summer ploughing:

Proper off-season tillage maintains higher stored moisture and thereby secures optimum stand. It is done either by the country plough or by blade harrow during the non-crop season after the harvest of the kharif crop depending on the amount of rainfall. Essentially it is meant to open the soil for more water intake with rain. Enhancing the water-use efficiency of crops Water-use-efficiency by crops can be improved by the selection of crops and cropping systems based on available water supplies and increasing seasonal Evapotranspiration (ET). The latter can be achieved by the selection of irrigation method, irrigation scheduling, tillage, mulching, and fertilization.

Bed planting:

Bed planting, another RCT, has the potential to conserve significant quantities of water (30–50%) (Kukal *et al.,* 2005). Other benefits of bed-planting include, reduced seed rates, conserved rainwater, facilitated mechanical weed control, minimized lodging in the wheat crop (Gupta *et al.,* 2000); cost reduction, and conservation of resources (Lichter *et al.,* 2008). Fertilization application practices are also easily performed by trafficking in the furrow bottoms and the fertilizers can be banded through the surface residues, reducing thereby potential nutrient losses (Limon-Ortega *et al.,* 2002) under permanently raised bed planting. The raised bed planting technique also provides an opportunity for crop diversity through the inclusion of different crops as well as the feasibility of inter or relay cropping, thereby opening avenues for generating alternate sources of productivity growth through efficient use of resource base. Bed planting is widely adopted in the Indo- Gangetic Plains, proved to be a successful conservation technology. In Pakistan, Akbar *et al.* (2007) reported about 36% water saving for broad beds and about 10% for narrow beds compared to flat sowing, and 6% increased grain yield of wheat and 33% of maize. However, the use of direct dry seeding on flat and raised beds while resulting in considerable water savings generally had negative impacts on rice yield (Choudhury *et al.,* 2007; Humphreys *et al.,* 2010).

Direct seeded rice (DSR):

The shortages of labor and water, and soil fertility issues are causing an increasing interest in shifting from puddling and transplanting to DSR. According to Pandey and Velasco (2005), low wages and adequate availability of water favour transplanting, whereas, high wages and low water availability favour DSR. The recent shift from transplanting to DSR in Southeast Asian countries has been caused by labor shortages and rising wages (Pandey and Velasco, 2005). DSR can reduce the labor requirement by 50% compared with transplanting (Santhi *et al.,* 1998). The DSR system provides incentives for saving water (Humphreys *et al.,* 2005). In Northwest India, about 35– 57% water savings have been reported in research experiments in DSR sown into unpuddled soils (Singh *et al.,* 2002). Direct-seeded and transplanted rice grown on raised beds decreased water use by 12–60% when compared with flooded, transplanted rice in the IGP (Gupta *et al.,* 2003).

System of Rice Intensification (SRI):

At present, SRI methods have been adopted in almost 50 countries, including major rice-producing nations such as India, China, Vietnam and the Philippines (Uphoff, 2012). The principles of SRI originate from experiments conducted by farmers in Madagascar to improve rice productivity for resource-poor producers. Today, SRI is usually understood as a package of possible practices, which have to be adapted to local conditions (Stoop, 2011). SRI produces higher yields with less water and seeds (Barah, 2009; Zhao *et al.,* 2009). Moreover, studies found rice under SRI to be more robust against extreme weather events, pests, and diseases due to improved plant vigor and root strength (Stoop *et al.,* 2002). Alternating irrigation aims to tackle various challenges such as the loss of soil quality and water scarcity, whereas early transplanting and wide spacing are both meant to boost tillering (Thakur *et al.,* 2010). However, a few studies identified higher labor requirements of SRI as a constraint to adoption (Senthilkumar *et al.*, 2008). Other studies showed that higher labour inputs occurred only in the early phase of adoption; labour requirements seem to decrease with growing SRI experience (Barrett *et al.*, 2004; Uphoff, 2012).

Drip irrigation:

It is sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 liters/hour) from a system of small-diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only part of the soil in which the roots grow is wetted (Figure 60), unlike surface and sprinkler irrigation, which involves wetting the whole soil profile. Drip irrigation is most suitable for row crops. Drip irrigation is adaptable to any farmable slope. It has 85-90% WUE

Furrow irrigated raised beds (FIRB):

In this method of sowing FIRBs are made and keep 15cm distance rows and 55cm width and 30cm wide furrow between two beds. It saves about 20 –30 % water saving.

Use of Nano fertilizers:

Nano fertilizer refers to a product that delivers nutrients to crops in one of three ways: The nutrient can be encapsulated inside Nano-materials such as nanotubes or Nanoporous materials. Coated with a thin protective polymer film. Delivered as particles or emulsions of nanoscale dimensions. It is Slow, targeted, and efficient release becomes possible. In some cases, the nanoparticles themselves can be used.

Green Seeker:

It is an integrated optical sensing, variable rate application & mapping system that measures a crop's nitrogen requirements. The yield potential for a crop is identified using a vegetative index known as NDVI (normalized difference vegetation index) and an environmental factor. The technology was developed at Oklahoma State University, USA, and licensed to N Tech Industries in 2001 (http://www.ntechindustries.com). It offers a more efficient and precise way to manage crop input i.e. nitrogen.

Happy Seeder Technology:

It is a machine that can sow seeds and fertilizer in a single operation at the right place without any kind of tilling or soil disturbance. This machine can work easily with every type of crop residue with a load of 10-12 tonnes without any problem. It has 9 tines which means that it can seed nine rows in one operation. It needs a minimum of 45HP double clutch tractor and its weight is around 750kg. This machine can cover 10-15 hectares.

Advantages of RCTs

- Saving of resources :- 60-85%
- Yield advantages by :- 3-17%
- Increase in profit by :-11-45%
- Lower specific cost :- 8-27%
- Saving in irrigation water :- 4- 38%
- Reduced weed population :-10-48%

Machinery Development and CA

The real success of CA in South Asia started with the development of second-generation planters including the precise seed metering and furrow opening system in addition to seeding in the loose and standing residue. At present four machines are tested for seeding direct-seeded rice and wheat: double disc colters, punch planter/star wheel, rotary disk drill (RDD), and turbo happy seeder. Though the major emphasis was on CA-based RCTs, *viz.* zero/ reduced tillage, direct-seeded rice, crop residue management, and crop diversification through raised bed planting but for realizing the full potential of the technologies, the other RCTs like new tools and techniques for nutrient management, *viz.* LCC, SPAD, GreenSeeker, etc., nutrient use efficient genotypes, integrated crop (ICM) and pest management (IPM), laser aided land leveling, etc. were also integrated by layer, one above the other to 'divisible in application' such as to provide options to the farmers as per their resource endowments.

Future prospects:

Integrating concerns of productivity, resource conservation, quality, and the environment is now fundamental to sustained productivity growth. CA/RCTs offer a new paradigm for agricultural research and development different from the earlier one, which mainly aimed at achieving specific food grains production targets. A shift in paradigm has become a necessity in view of widespread problems of resource degradation, which accompanied past strategies to enhance production with little concern for resource integrity. However, for realizing potential benefits, the full CA involving all the key elements in a systems perspective is to be developed and adopted at the farm level. The following researchable issues are identified for the future: The availability of machinery/equipment for the promotion of RCTs is a prerequisite for achieving the targets of agricultural production. There is a need to on produce suitable ZT drills for loose straw conditions. Standardization of the metering system for the seeding/planting of pulses, oil seeds, rice, and wheat needs to be worked out to have an accurate seeding rate. Availability of implementation at economical cost is the major constraint in the promotion of bed planting of crops

- Development of low power requiring tools for tillage and crop establishment practices with the least disturbances to soil/ soil cover (*in situ* crop residues), especially under conditions of small farms.
- For alleviation of subsoil compaction due to the indiscriminate movement of heavy traffic in the field, systematic research work on controlled traffic ZT drills needs to be initiated.
- Long-term effects of mechanization and RCTs on crop, soil, biodiversity, and climate in various production systems and agroecology for the profitability and
- sustainability of different cropping systems should be the future agenda of research under the natural resource management programs.
- Designing long-term experiments to study the impact of conservation agriculture on soil health, water, and nutrient use efficiency, C sequestration, GHG emission and ecosystem services.

- Region-specific interventions for crop- diversification through substitution/ intensification and matching production technologies.
- Identification and standardization of new cropping, intercropping, and novel farming system combinations including livestock and fisheries, which can be economically viable.
- Developing complete package of practices for CA for prominent cropping systems in each agro-ecological region, particularly in rainfed and dryland ecosystems.
- Site-specific nutrient management/ balanced nutrient supply systems and precision input management for intensive major cropping systems to optimize resource use and enhance efficiencies.
- Discouraging the burning of residues and utilizing them gainfully for CA in improving soil health and reducing the environmental pollution. In regions where crop residues are used for animal feed, some amount of residues should be recycled into the soil.
- Development of cost-effective technologies for *in-situ* crop residue management and efficient application of different kinds of fertilizers and herbicides.
- Promoting conservation agriculture practices, especially in water harvesting, nutrient, pest, and disease management.
- Developing crop varieties to produce more root biomass to improve the natural soil resource base.
- Evolving efficient water and soil management practices in addition to the identification of crops and varieties with high water use efficiency.
- With the use of herbicide-tolerant crops, weed resistance is becoming a serious problem for many CA farmers worldwide. The development of economically viable strategies to prevent and manage herbicide resistance under such a situation should be a major research area.
- Farmer's involvement in participatory research and demonstration trials can accelerate the adoption of CA. Improvement in coordination among various stakeholders (research, extension service, farmers, service providers, agricultural machinery manufacturers, etc.) for the transfer of technologies will play a pivotal role in accelerating the adoption of new interventions.

Conclusion:

Resource conservation technology has emerged as a potential tool for enhancing resource use efficiency, crop productivity, and profitability. Improvements in land and water productivity are an important interdisciplinary approach and are only possible by choosing the appropriate resource conservation technology depending upon the region. Resource Conservation practices resulted in better soil aggregation, and soil biological health and provided a favorable impact on the rhizosphere for crop growth and productivity. RCT which form the basis for CA has the only solution to save soil, water, and other natural resources. Indian agriculture is likely to suffer losses in long run due to heat, erratic weather, and decreased irrigation availability. Adaptation of laser land leveling direct seeded rice (DSR), bed planting, and zero tillage (ZT) are among the common RCTs and mitigation strategies that can help minimize negative impacts to some extent.

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NATURAL FARMING: WAY TO SUSTAINABLE AGRICULTURE

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Abstract:

There is a tremendous increase of chemicals fertilizers and pesticides in conventional farming from last few decades which has harmful effects on soil, human and animal health. The soil is becoming unfertile day by day. Chemical farming is not good for the environment also and causing economic loss to the farmers, so, there is a need for alternative farming system which not only sustainable but also ensures food security and safety. In such situation, natural farming can be a way to recover from this type of health and environmental problems. Most of the inputs in natural farming are made by the farmers using the residue of their farms and animals. No input is purchased from outside the farm which is also beneficial from economic perspective also. The four main principles used in natural farming are Bijamrit, Jivamrit, Achhadan and Wapsa. In natural farming, different leaf extracts are used for insect pests and disease management. Thus the quality of farm produce is also increased as all the practices in natural farming are completely chemical free.

Keywords: environmental problems, health, natural farming

Introduction:

Agriculture in its prevailing form requires farmers to rely heavily on inorganic external chemical inputs such as fertilizers and pesticides. They contaminate groundwater and other water dependent ecosystems, reduce soil fertility over time and contribute to biodiversity loss in farmlands (Aktar *et al.*, 2009 and Singh, R. (2000). Small holdings are a critical source of livelihoods in developing countries that produce about 80 per cent of the food consumed (The Economics of Ecosystems and Biodiversity, 2015). Agriculture, today, accounts for almost 70 per cent of the world's freshwater consumption (Clay, J. 2004). Prevailing agricultural practices such as mono-cropping decreases soil moisture content, causing tremendous stress on water resources. Alternative low cost farming practices are much needed for sustainable development goals and ensuring food security. Natural farming is one of the low-cost farming practice which cuts off the input costs and yields higher. Masanobu Fukuoka, popularised natural farming. He was a Japanese Scientist. Firstly, he practiced natural farming on his own farm which was situated in island of Shikoku. He was known for his natural farming and re-vegetation of desertified lands. He was a proponent of no-till, herbicide and pesticide free cultivation methods from which he created a particular method of agriculture, commonly referred to as "natural farming" or "do-nothing farming"

Many people think that when we practice agriculture, nature is helping us in our efforts in agriculture production. This is only human-centred viewpoint. Instead of this, we receive only what nature provides to us. In India, noted agriculturist Subhash Palekar has helped popularise natural farming practices across the country for which he was honored with

Padma Shri in 2016 (Anon., 2016). Natural farming has been popularised in southern India. It was firstly evolved in Karnatka (Kumar, N. 2012). Natural Farming is chemical-free farming method that is considered to be an agroecology-based in which integration of crops, trees and livestock is done which promotes functional biodiversity (LVC, 2010; Rosset and Martinez-Torres, 2012).

Role of micro-organisms in improving soil health is well known to us. Microbes provide crucial ecosystem services. The microbiota in the soils in which they grow provide nitrogen, phosphorus and other essential nutrients. Microbes are known to produce 50% of the oxygen and at the same time eliminate same proportion of CO_2. They also eliminate about 90% of methane gas. Nicole *et al* (2015). Beneath the imprint of one's foot, extending down into the soil, are 300 miles of mycorrhizal fungal hyphae. In healthy soil, these fungi together with the full coteries of soil microbes help in regeneration, resilience and revitalization of soil system making all needed nutrients available to the plants through fixation, decomposition, solubilization and mineralization (Michael Phillips, 2017).

The four pillars of natural farming

The four pillars of Natural Farming, like jivamrit, Bijamrit, Achhadan and whapsa aims to enhance nature's efforts and eliminate use of external resources, debt and dependency (Table-1). Jivamrit meaning 'life tonic', jivamrit is made from, cow dung, urine, water, jaggery, legume flour and soil. It is fermented microbial culture. Soil act as inoculum of local micro-organisms. Jivamrit promotes microbial activity and organic matter in the soil. Jivamrit also inhibits fungal and bacterial growth which are known to cause diseases, jivamrit significantly increases earthworm activity. Dung and urine of indigenous cows (*Bos indicus*) is found to be superior microculture compared to that of introduced European breeds (Palekar, 2005).

The practices of Natural Farming include the addition of microbial cultures to enhance decomposition and recycling of nutrients; use of local seeds instead of hybrid ones, multicropping, trees and cows of native breeds); effective spacing of crops, water conservation by mulching, intercropping and crop rotations. Mulching has huge positive effect on Soil Organic Carbon content due to enhanced soil and water conservation, lower average and maximum soil temperatures under mulch than in unmulched soil surface, return of biomass to the soil, increase in soil biodiversity, and strengthening of the nutrient cycling mechanisms (Lal and Kimble, 2000).

Preparation of Jeevamrit: - Put 200 litres of water in a barrel - Add 10 Kg fresh local cow dung - Add 5 to 10 liters aged cow urine - Add 2 Kg of Jaggery (a local type of brown sugar) - Add 2 Kg of pulses flour and - Add a handful of soil from the bund of the farm. Stir the solution well and let it ferment for 48 hours in the shade. Jeevamrit is ready for application. The 200 litres of Jeevamrit is sufficient for one acre of land. During the 48-hour fermentation process, the aerobic and anaerobic bacteria present in the cow dung and urine multiply as they eat up organic ingredients (like pulse flour and jaggery). Jeevamrit can be applied at the time of sowing or with every irrigation or as 10% foliar spray. The preparation is stored up to a maximum of 15 days and used in the field either through spray or mixing with irrigation water.

Jivamrit enhances the available earthworms activity which. Using polycropping and different mulches with trees, crop biomass helps in soil moisture conservation & adds to organic carbon also. Seed treatment with cow dung, urine and lime based formulations. Ensuring soil fertility through cow urine, cow dung, undisturbed soil, pulses flour & jaggery concotion Jeevamrit Beejamrit Mulching Whapsa to the individual plant. Jeevamrit can also be applied through drip irrigation system.

Table 1: Four pillars of natural farming

Sr. No.	**Method**	**Preparation**	**Benefits**
1	Jivamrit	It is made from cow-dung (20kg), urine (5-10 L), jaggery (20kg) and flour (2kg) and is applied to crops with each irrigation cycle.	It provides nutrients, but it also acts a catalytic agent which promotes activity of microorganisms in soil, as well as increases earthworm activity. It also helps to prevent from fungal and bacterial diseases.
2	Bijamrit	It is basically made up of water (20 L), cow dung (5kg), urine (5 L), lime (50g) and a handful soil.	It is a seed treatment, equipped in protecting young roots from fungus as well as from soilborne and seed-borne diseases.
3	Acchadan Mulching	It can be done by soil mulch, straw mulch.	It conserves soil moisture, by reducing evaporation
4	Wapsa moisture	The irrigation should be reduced and irrigation should be practiced at noon in alternate furrows.	It is condition where air molecules and water molecules present in soil.

Proponents of Natural Farming argue that the dung of indigenous cow and small quantity of undisturbed soil has huge number of diverse microorganisms which help in increasing the bio-availability of nutrients to the plants. Soil is a complex ecosystem hosting bacteria, fungi, plants, and animals (Bonkowski *et al.*, 2009; Muller *et al.*, 2016). Soil microbes metabolize recalcitrant forms of soil-borne nutrients to liberate these elements for plant nutrition. In natural ecosystems, most of the nutrients like N, P, and S are in bound in soil. They are minimally available for the plants. Micro-organisms present in the soil help these molecules to depolymerise and be available to the plants. So Jivamrit aims to increase these microbial activities so that the nutrients can be available to the plants (Jacoby *et al.*, 2017). Many different bacterial genera such as *Citrobacter koseri*, *Enterobacter aerogenes*, *Escherichia coli*, *Klebsiella oxytoca*, *Klebsiella pneumoniae*, *Kluyvera* spp., *Morgarella morganii*, *Pasteurella* spp., *Providencia alcaligenes*, *Providencia stuartii* and *Pseudomonas* spp. from cow dung were isolated by Sawant *et al.* (2007). Gupta *et al.* (2016) reported microorganisms present in cow dung have increase soil fertility through phosphate solubilization. 219 bacterial strains were isolated by Lu *et al.* (2014)

from cow dung, out of which 59 isolates showed nematicidal activity against more than 90% of the tested nematodes.

Pest control

Pest control solutions According to natural farming adopter farmers, when chemical fertilizers are applied to the crops, the vegetative growth of the crop is very good and lush green. This attracts the insects/ pests to the crops. While in case of Jeevamritha, the leaves colour is not that much green, and therefore, menace of pests is limited. However, when infestation occurs, the farmers prepare different types of formulations (Kashayam) made up of locally available plant materials to control the pests. Some of these are (Table 2):

1. Neemastra is the most commonly used pest controlling solution which is prepared by the farmers. Cow dung, cow urine, neem leaves, and water are used for preparing the neemastra. The neem leaves are grinded into paste and added with water. The solution is directly applied to plants without any further dilution. For this, 5 kg of neem paste is added with around 2-3kg of dung, 10-20 litres of cow urine, handful of soil. The solution is fermented for about 48 hours. It was found that the farmers are making the solution ranging from 100-200 litres depending upon their usage and crops grown. Committment of State Government Knowledge (Experiential learning) Extension (Champion farmer) Ownership (Women SHGs).
2. Brahmastra is prepared from five types of bitter leaves. Neem leaves are used along with the other bitter-tasting leaves, like custard apple, chillies, etc. these leaves are crushed and added to 20-30 litres of cow urine and boiled for about 2-3 hours. The solution is cooled for about 12 hours and is filtered using fine cloths. The solution is further diluted with about 15 litres of water for every 1 litre of Brahamastra. The farmers are using 10-20 litres of cow urine and 5kg of neem leaves in preparing Brahmastra.
3. Agniastra is prepared by adding 5 kg of neem paste with around 1 kg of tobacco leaves, 0.5 kg of chillies and 0.5 kilo of garlic paste. These are added in about 25- 30 litres of cow urine and is cooled down for about 24 hours. The solution is then filtered and used. The solution is diluted before applying in the field for every half litre of Agniastra about 15 litres of water is added. Agniastra is considered to be effective against insects which live inside plant parts like Leaf Roller, Stem Borer, Fruit borer, Pod borer. The pest controlling solutions were also made available to the farmers at NPM (Nutrients Pest management) shops in Andhra Pradesh. Apart from the abovementioned solutions, there are other pest controlling solutions being used by the farmers. It is being used by the farmers mainly in the paddy crop.
4. Tutikada rasam is prepared from datura leaves and cow urine. The leaves are boiled in cow urine for 2-3 hours and is cooled then it is filtered using a cloth.
5. Dashparini Kashyam It is prepared from ten types of plant leaves. The leaves of Neem, Agele marmelos, Calotropis, Senna auriculata, Papaya, Custard apple, Gauva, Vitex negundo, castor, Pomegranate, Nerium, Ocimum, Aloe vera, Tobacco, Datura, Lantana camara and Pongamia pinnata are used in preparing the solution. Green chilli and garlic are also crushed and added and mixed with 20 litres of cow urine. It is kept up to 45 days for

fermentation. The solution is filtered and sprayed after dilution. In about 8-10 litres of solution 100 litres of water is added for dilution.

Table 2: Pest management in natural farming

Sr. No.	Name of Pest Mgt. Formulae	Composition	Benefits
1	Agniastra	It composed of 10 L local cow urine, 1 kg Tobacco, 500gm of Green Chilli, 500gm of Local Garlic, 5kg Neem leaves pulp (crushed in urine). For spraying, 2 L Brahmastra is taken in 100 L water.	It is effective against the pests like leaf roller, stem borer, fruit borer, pod borer.
2	Brahmastra	It is prepared by neem leaves, custard apple leaves, guava leaves, lantern camellia leaves, pomegranate leaves, papaya leaves and white dhatura leaves crushed and boiled in urine.	It is used to control all of sucking pests, fruit borer, pod borer.
3	Dashparni ark	Neem leaves–5 kg, Vitex negundo leaves-2 kg, Aristolochia leaves - 2 kg, Papaya (Carica papaya)- 2 kg, Tinospora cordifolia leaves- 2kg, Annona squamosal (Custard apple) leaves- 2kg, Pongamia pinnata (Karanja)leaves- 2kg, Ricinus communis (Castor) leaves- 2 kg, Nerium indicum- 2 kg, Calotropis procera leaves-2 kg, Green chili paste2 kg, Garlic paste-250 g, Cow dung-3 kg, Cow urine-5 lit, Water-200 lit.	It can be applied as a foliar spray to control insect pest.
4	Neemastra	It is made up of local cow urine (5 L), cow dung (5kg) and neem leaves and neem pulp (5kg) fermented for 24 hrs.	It is used for sucking pests and mealy bug.

Other principles of natural farming

Vermicomposting:

It is not suggested in natural farming because *Eisinea feotida* which is an exotic species of earthworm, is uded in vermicomposting and there are no quality-control measures in India to test vermicompost. This species is known to carry toxic heavy metals in its body.

Intercropping

This is primarily how Natural Farming gets its “Zero Budget” name. It doesn’t mean that the farmer is going to have no costs at all, but rather that any costs will be compensated for by income from intercrops, making farming a close to zero budget activity. Palekar explains in detail the crop and tree associations that work well for the south Asian context.

Contours and bunds

To preserve rain water, Palekar explains in detail how to make the contours and bunds, which promote maximum efficacy for different crops

Cow dung

Accroding to Palekar, dung from the Bos indicus (humped cow) is most beneficial and has the highest concentrations of micro-organisms as compared to European cow breeds such as Holstein. The entire Natural Farming method is centred on the Indian cow, which historically has been part of Indian rural life.

In natural farming growing of **multiple crops** with very low costs allows the farmers to earn throughout the year (Babu, 2008). This helped them to phase out loans. As one Natural Farming farmer said: In Natural Farming our expenses are very low. It doesn't matter what the yield is, farmers still make a profit because costs are negligible. Plus they have added intercrops to this so they get income from many crops, not just one. Yield is not an important concept for us.

Table 3: Organic farming v/s Natural farming

	Organic Farming	**Natural Farming**
Specific components used	• Farmyard manure • Vermicompost • Biofertilizers • Panchgavya • Hybrid Seeds/High yielding varieties • Management of Insect-pests and Diseases with Biological agents	• Indigenous cows • Jeevamrit and FYM • Ghanajeevamrit • Beejamrit • Mulching • Inter/mixed/polycrops • Seeds of local cultivars • Management of insect-pests and diseases with home made materials
Merits	• Chemical free • Eco-friendly • Assurity of market price	• Regular and better farm income from intercrop • Low production cost • Less use of FYM/Inputs • Improved family health due to no use of chemicals • Improved soil health
Demerits	• Huge quantity of FYM • Yield reduction during conversion period • Products are expensive • Stringent procedure	• Need of indigenous cows, dung and urine • Yield risk • Labour practices • There is no established market for natural products

Conclusions:

Studies on existing farming situation has illustrated a demand for an alternative to current agricultural practices. The high input systems which include chemical fertilizers, pesticides etc. characterize Indian agriculture can lead to negative financial, environmental, and social outcomes. Natural Farming combat these issues by presenting an alternative appraoch to conventional agriculture. There is a need of more field research on natural farming. To our knowledge there are no peer-reviewed studies which examine how natural farming changes soil composition, particularly in the long term. Long-term, peer-reviewed studies to fill knowledge gaps are essential for scaling up of Natural Farming. Preliminary data suggest that Natural Farming will not be a blanket solution that will achieve the same outcomes for everyone, and this is perhaps the most important consideration moving forward.

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RELEVANCE OF SOIL (SOLUM) DEPTH IN AGRICULTURE

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Abstract:

The chapter defines about the importance of soil (solum) depth, its role in controlling the various factors in agriculture. Soil depth is a critical attribute of any soil, and determines rooting, moisture and nutrient storage, mineral reserve, anchorage, and a range of conditions that affect plant growth, or land suitability for any utilization type. In general, soil texture, pH, organic matter and all primary macronutrients observed significant variation with soil depth. The surface layer possesses higher content of majority soil parameters. There is good evidence that in many drought environments, rooting depth is positively related to soil exploration and greater acquisition of water from deep soil strata. Evidence exists that deep rooting is also important in terminal and intermittent drought scenarios that are more common in rainfed agriculture. Deep plant roots directly and indirectly support fauna and microbial communities, and are important for soil water extraction, reducing nutrient loss, and soil carbon sequestration. Understanding the soil fertility on depth-basis is an important management tool in assessing the nutrient requirement of the crops. Soil processes, soil properties, and microbial communities are depth dependent, and for a more complete understanding, soils should be studied to a greater depth.

Keywords: Soil depth, Soil processes, Soil properties, Microbial communities, Effective root zone, Carbon sequestration

Introduction:

Soil depth defines the root space and volume of soil from where the plants fulfil their water and nutrient demands. It is a critical attribute of any soil, and determines rooting, moisture and nutrient storage, mineral reserve, anchorage, and a range of conditions that affect plant growth. Soil structure and texture, infiltration, organic matter, microbial biomass, temperature, soil colour, bulk density and compaction are also affected. Soil depth plays an important role in crop production having influence on seed germination, effective root zone, soil fertility, stable carbon storage, moisture conservation, regulating runoff and soil erosion. Nutrient storage and availability is significantly affected by the depth of the soil, and are important for agricultural production and plant growth (Yost and Hartemink, 2019). Lilienfein *et al.* (2001) found that more than 40% of the total nutrient stored for cropping and pastures were in the top 30 cm of soil. About two-thirds of the nutrient for deep-rooting plants and trees is found in the top 2 m of soil, but there are large differences between soil types. Many soils are deep, yet soil below 20 cm remains largely unexplored. In general, the ability to exploit water in deep soil strata is clearly advantageous and has been posited as a central element of ideotypes for breeding more drought-tolerant crop (Lynch and Wojciechowski, 2015). Exotic plants can have shallower roots than native species, so their impact on microorganisms is anticipated to change with depth. The composition and network structure of both fungal and bacterial communities will change according to increasing depth, and diversity and enzymatic function will decrease. In most soils, the concentration of SOC decreases with depth, and there is potential to sequester SOC with depth. Dissolved organic matter, bioturbation, plant roots, and root exudates are the main sources of organic carbon input into deeper soil horizons (Rumpel and Kogel-Knabner 2011). As SOC inputs move deeper in the soil, the turnover rate decreases. Climate change will thus affect SOC stocks in deeper soils.

Depth of soil profile refers to the top to parent material or bedrock or to the layer of obstacles for roots. It differs significantly for different soil types. It is one of the basic criterions used in soil classification.

Classification of soil depth:

- Very shallow (< 25 cm)
- Shallow (25-50 cm)
- Moderately deep (50-90 cm)
- Deep (90-150 cm)
- Very deep (> 150 cm)

The soil is arranged in layers or horizons during its formation. These layers or horizons are known as the soil profile. It is the vertical cross-section of the soil, made of layers running parallel to the surface. Soil profile helps in determining the role of the soil as well. It helps one to differentiate the given sample of soil from other soil samples based on factors like its colour, texture, structure, and thickness, as well as its chemical composition.

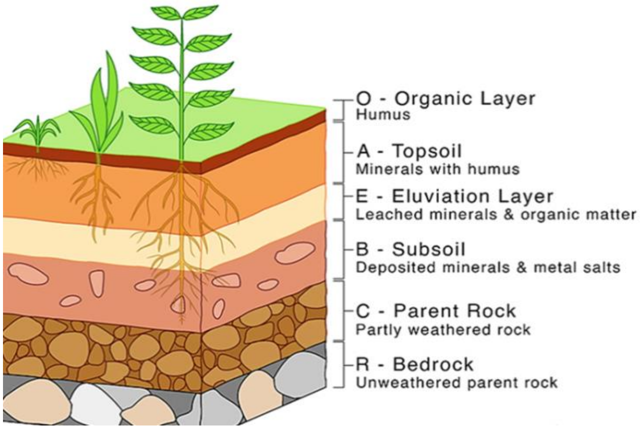

Fig. 1: Soil profile

The soil profile is composed of a series of horizons or layers of soil stacked one on top of the other. These layers or horizons are represented by letters O, A, E, C, B and R.

- **The O-Horizon:** The O horizon is the upper layer of the topsoil which is mainly composed of organic materials.
- **The A-Horizon or Topsoil:** This layer is rich in organic material and is known as humus layer. The topsoil is soft and porous to hold enough air and water. This layer consists of microorganisms such as earthworms, fungi, bacteria, etc.

- **The E-Horizon:** This layer is composed of nutrients leached from the O and A horizons. This layer is more common in forested areas and has lower clay content.
- **The B-Horizon or Subsoil:** It is the subsurface horizon, present just below the topsoil and above the bedrock. It is comparatively harder and more compact than topsoil.
- **The C-Horizon or Saprolite:** This layer is devoid of any organic matter and is made up of broken bedrock. This layer is also known as saprolite. The geological material present in this zone is cemented.
- **The R-Horizon:** It is a compacted and cemented layer. Different types of rocks such as granite, basalt and limestone are found here.

Importance of soil depth in agriculture:

- **Seed germination:** Deeper placement of seeds results in delayed germination, due to lower soil temperatures or result in poor germination or seed injury.
- **Effective root zone:** In a normal soil with good aeration and without restrictive layers, a greater portion of roots of most plants remains within 45 to 60 cm surface.
- **Soil fertility:** Deeper soils generally can provide more water and nutrients to plants than shallow soils.
- **Stable carbon storage:** Most organic carbon is stored in the upper 30 cm of soil because the surface is where biological activity is most active. Soils do contain carbon below this depth, but deeper carbon is generally of inorganic nature in aridic soils.
- **Moisture conservation:** With the increasing depth, the fluctuation of water content decayed gradually or even disappeared.
- **Reduces runoff:** *Areas with deep soil depth will have greater capacity to absorb and store water* thereby reduces runoff.
- **Prevents soil erosion:** *Soil depth decreases as a result of soil erosion* and soil erosion is a serious threat to soil quality and productivity.
- **Soil sampling:** In shallow rooted crops, soil *sampling is done upto 15 cm depth* but in deep rooted crops, it is recommended to collect samples upto 30 cm depth of soil.

Influence of soil depth on various soil parameters:

1. **Soil structure:** Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles when assembled appear as larger particles. These are called aggregates. Aggregation of soil particles can occur in different patterns, resulting in different soil structures. Granular structure is most common in surface soil layers, especially those with adequate organic matter. Columnar structure is often found in soils with excessive sodium, due to the dispersing effects of sodium, which destroys soil structure, rendering the soil effectively sealed to air and water movement. Platey structure has the least amount of pore space and is common in compacted soils.

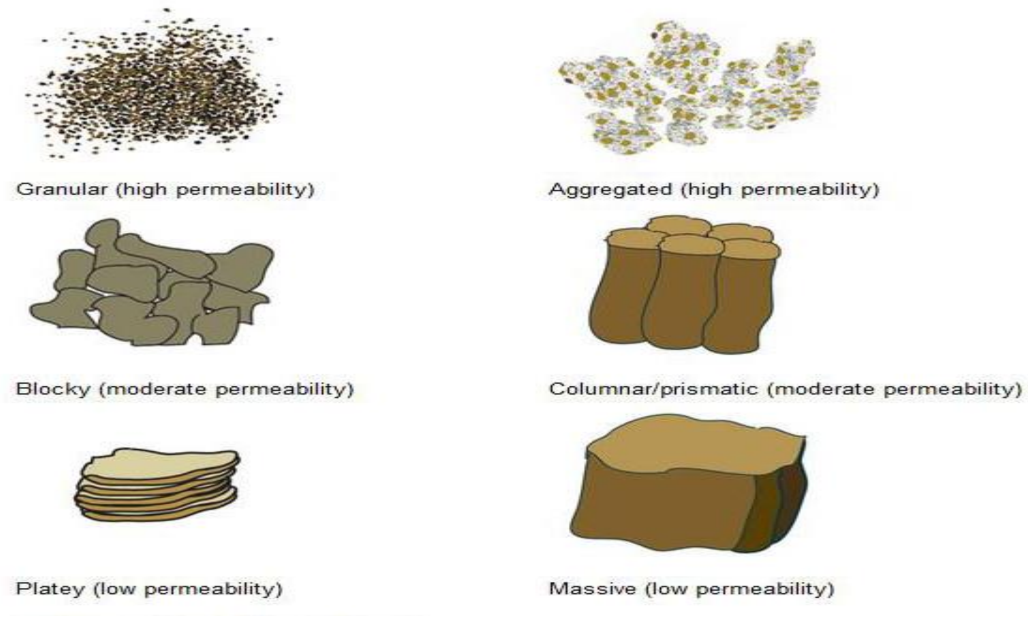

Fig. 2: Types of soil aggregates

2. **Soil texture:** Soil texture (such as loam, sandy loam or clay) refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil. Texture often changes with depth so roots have to cope with different conditions as they penetrate the soil. A soil can be classified according to the way the texture changes with depth. The 2 profile types are:
   - Uniform- same texture throughout the soil profile
   - Texture-contrast- abrupt texture change between the topsoil and subsoil.
3. **Infiltration:** Infiltration is the process of water entry into a soil from rainfall or irrigation. Infiltration capacity is the maximum rate at which a soil in any given condition is capable of absorbing water. The rate of infiltration is primarily controlled by the rate of soil water movement below the surface and the soil water movement continues after an infiltration event, as the infiltrated water is redistributed. Infiltration and percolation play a key role in surface runoff, groundwater recharge, evapotranspiration, soil erosion, and transport of chemicals in surface and subsurface waters. Water moves more quickly through the large pores in sandy soil than it does through the small pores in clayey soil, especially if the clay is compacted and has little or no structure or aggregation. The steeper the slope, the lesser is the infiltration and more runoff occurs. As slope increases, infiltration decreases. Infiltration of soil is rapid near wetting zone before reaching the saturated zone. Beyond saturated zone, it declines.
4. **Water and nutrient storage:** Deeper soils generally can provide more water and nutrients to plants than more shallow soils.

   Globally, the ranking of vertical distributions among nutrients was shallowest to deepest in the following order: P > K > Ca > Mg > Na = Cl = SO_4.

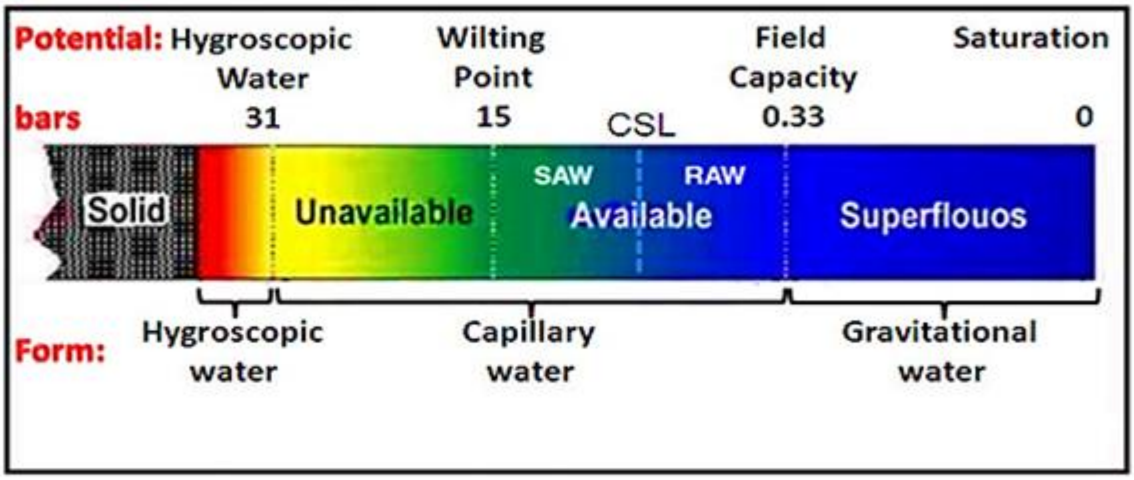

Fig. 3: Physical classification of soil water

On the basis of interaction of water molecules with soil along the depth, soil water can be classified into three types:

- Gravitational water
- Capillary water
- Hygroscopic water

Gravitational water: This is a free form of water which is held loosely in soil. Majorly, these are seen in the soil's macropores. Very little quantity of gravitational water is made available to plants as they quickly drain the water down the table in all, excluding the majority compact of soils. Hence, plants are not able to use this water as much as they move rapidly out of the soil.

Capillary water: It is the water that is contained in the micropores of the soil, in the soil pore spaces precisely. This water, which composes the soil solution, is loosely held around the particles of soil. It is the main water available to plants as they are trapped in the soil solution. Capillary water is retained in the soil by capillary action (force) which is less than the atmospheric pressure. Thus, capillary water is retained in soil as the properties of surface tension (adhesion and cohesion) of the soil micropores are more strong than the gravitational attraction or gravitational force. But, since soil tends to dry out, the size of the pore increases and gravity begins to turn the capillary water into gravitational water, thus moving it down.

Hygroscopic Water: This form of water makes for a fine film wrapping particles of water and is typically not readily available to plants. It is found not only in pores but also on the surface of soil particles. These are tightly held in soil and cannot be eliminated except for over drying at 105 °C. Hygroscopic water is tightly bound to soil by adhesion properties, which causes some water only to be consumed by the roots of plants. As this form of water is seen on the particles of soil and not in pores, only some types of soils composed of several pores (such as clays) will comprise a high percentage of it.

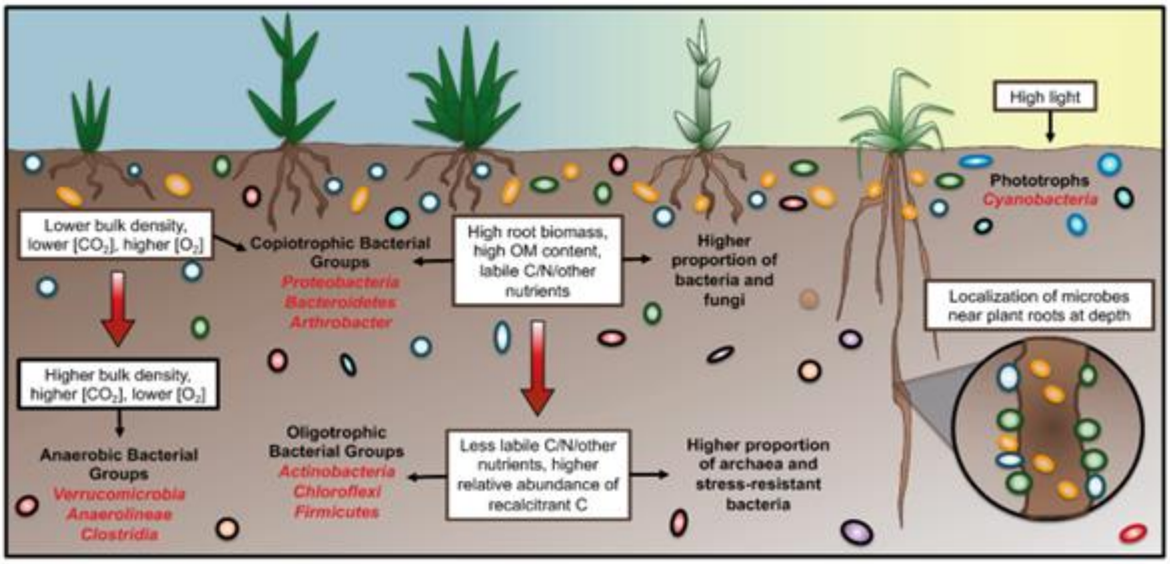

Fig. 4: The effects of soil depth on soil properties and microbial groups

5. **Organic matter:** Soil organic matter (SOM) is largely concentrated in the top 30 cm of the soil, but there is growing evidence that deeper soil horizons have the capacity to sequester high amounts of SOC despite the concentrations in the subsoil. The subsoil carbon sequestration may be achieved by higher inputs of fairly stable organic matter to deeper soil horizons. Generally, organic matter content decreases with increasing depth from the surface.
6. **Temperature:** Soil temperature is an important property that is essential for many soil processes and reactions that may include, but are not limited to, water and nutrient uptakes, microbial activities, nutrient cycling, root growth, and many other processes. Soil temperature properties change by the radiant, thermal and latent energy exchange processes that take place at the soil surface. As the depth of soil increases, amplitude of temperature decreases. After a depth of 0.4 m, there is no diurnal variation of soil temperature. Annual variation of soil temperature with depth. After a depth of 4 m, the soil temperature becomes constant.
7. **Microbial biomass:** The microbial biomass (fungi: bacteria) ratio declined significantly with depth, while the ratio of Gram-positive to Gram-negative bacteria increased with depth in both ecosystems. Microbial community composition showed significant differences among soil depths and between ecosystems. SOM content is highly correlated with bacterial abundance along soil depth. With increasing soil depth, soil aeration and organic matter decreases, thus decrease the microorganism population. This indicates that surface soil is rich in microorganism population since the entire environment such as organic compound, aeration, temperature, etc.
8. **Soil colour:** With depth below the soil surface, colours usually become lighter, yellower, or redder. Colour can be used as a clue to mineral content of a soil. Iron minerals, by far, provide the most and the greatest variety of pigments in earth and soil.

Soil colour is usually due to 3 main pigments:

- Black - from organic matter
- Red - from iron and aluminium oxides
- White - from silicates and salt.

9. **Bulk density and compaction:** Bulk density typically increases with soil depth since subsurface layers have reduced organic matter, aggregation, and root penetration compared to surface layers.

The densification of *soil* mass is commonly known as *compaction.* Soil compaction *can influence plant height by preventing normal root development*. Soil compaction *decreases soil fertility and increases soil erosion*. Soil compaction values increase with the measurement depth when the soil layer being measured is between 0 and a certain depth. When the measurement is carried out for a soil layer of 0.1 m, the soil compaction increases with the increase in soil layer depth upto 0.4 m.

Influence of soil depth on crops:

1. **Germination of crops:** Deeper sowing sometimes ensures crop survival under adverse weather and soil conditions. Planting too shallow may result in poor germination due to low soil moisture retention near the soil surface or seed injury due to insects or disease. Similarly, if placement is too deep, seed may have delayed germination due to lower soil temperatures or result in poor germination or seed injury. Good seed depth 1.5 to 2.0 inches or even deeper is recommended in dry conditions to ensure good moisture availability for successful seed germination. The majority of weed seeds *lying below about 5 cm soil depth* remain dormant and act as source for future flushes of weeds. Weed seeds fail to germinate with increasing soil depth.
2. **Type of crops:** Soil depth can greatly influence the types of plants that can grow in them. Deeper soils generally can provide more water and nutrients to plants than more shallow soils. Furthermore, most plants rely on soil for mechanical support and this is especially true for tall woody plants (e.g., shrubs, trees).

   Depending on the soil depth, crops are classified as follows:

   - **Shallow rooted (12-18 inches)** – rice, onion, potato, radish.
   - **Moderately deep rooted (18-24 inches)** –wheat, groundnut, chilli.
   - **Deep rooted (> 24 inches)** – cotton, maize, jowar.
3. **Effective root zone depth:** The maximum depth in soil strata, in which the crop spreads its root system and derives water from the soil is termed as effective root zone depth. It is the depth within which most crop roots are concentrated, which was estimated as ~50–100 cm for wheat, maize, barley and canola, as ~60–70 cm for peas, as ~120 cm for alfalfa. Some crops, such as irrigated pasture, citrus, bananas, avocados and low-chill stone fruit develop a mass of shallow roots with only a few roots penetrating deeper into the soil. The extraction of water from the root zone is

about 40% in the upper quarter, 30% in the second quarter, 20% in the third quarter followed by 10% in the fourth quarter.

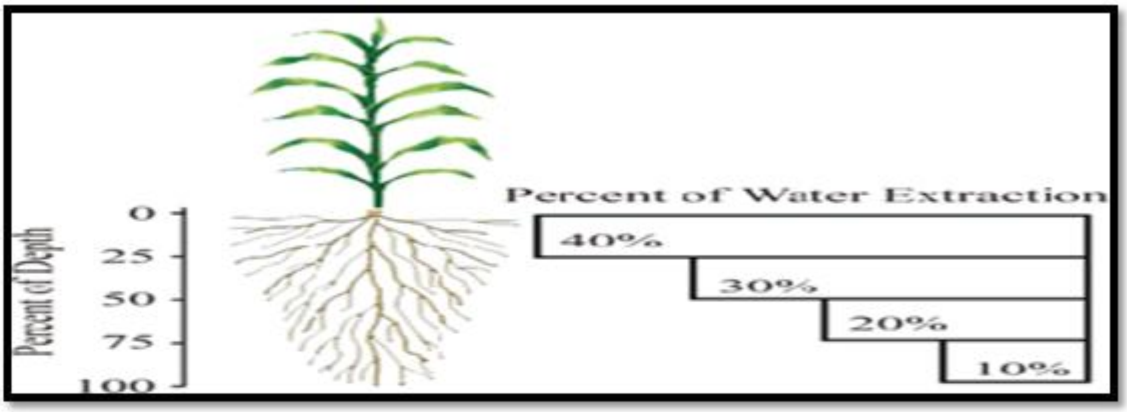

Fig. 5: Effective root zone

Table 1: Effective root zone depth of different crops

Sl. No.	Crop name	Root zone depth (cm)
1	Cabbage	50
2	Rice, potato, small vegetables	60
3	Green beans	70
4	Tobacco, sweet pepper	80
5	Artichoke, banana, dry beans	90
6	Maize, pulses, soybean, sugarbeet, tomato	100
7	Barley	110
8	Alfalfa, spring wheat	120
9	Citrus, cotton, sorghum (grain)	140
10	Table grapes, wine grapes, sugarcane (ratoon)	150
11	Mango, date palm	200

4. **Moisture and nutrient availability:** Moisture is important for root growth and nutrient uptake. Adequate moisture will improve uptake of nutrients by diffusion and root interaction, and will increase organic matter decomposition, which releases N, P, and S. Low moisture can result in the formation of insoluble nutrient-containing compounds. Soil depth, in addition to soil texture and structure, can influence water availability. Shallow hardpans reduce the usable soil depth and enhance the tendency of soil to waterlog in heavy rains and fall below the permanent wilting percentage under drought conditions. Limiting root growth to surface layers also can influence nutrient access. For example, potassium and available phosphorus tend to predominate near the surface, especially in clay soils, whereas magnesium and calcium more commonly characterize the lower horizons. Soils vary in the accumulation of nutrients through their soil horizons. Deeper soils generally can provide more water and nutrients to plants than more shallow soils.

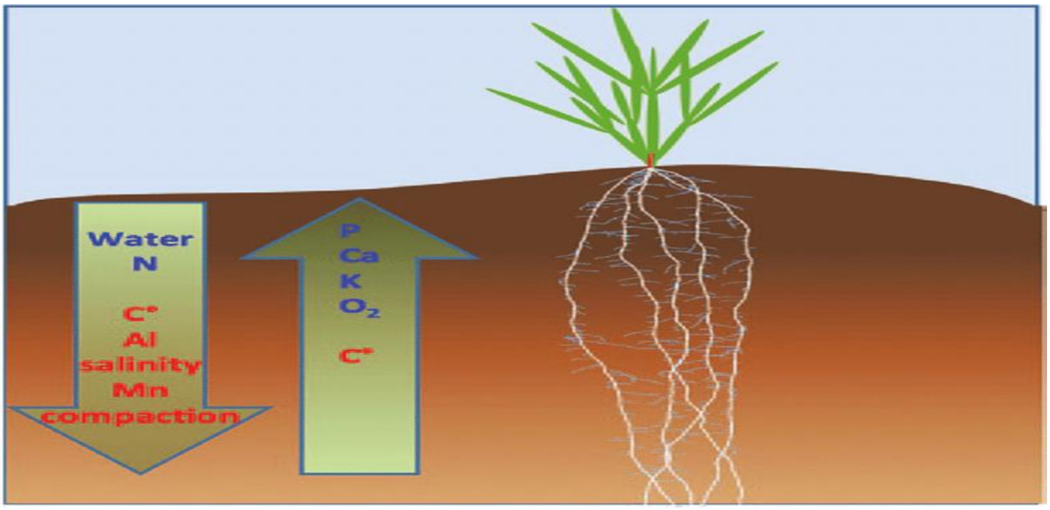

Fig. 6: Depiction of nutrient and physical constraints occurring in deeper soils

5. **Crop yield:** Soil depth can greatly influence the types of plants that can grow in them. Deeper soils generally can provide more water and nutrients to plants than more shallow soils. There is a directrelationship between topsoil depth and yield. The thickness of A horizon had a positive effect on yield up to a certain thickness.The subsoil does not absorb the rainfall as rapidly, leading to more surface water runoff and less available water for crop production.

Conclusion:

Soil depth is a critical attribute of any soil. In general, soil texture, pH, organic matter and all primary macronutrients observed significant variation with soil depth. Soil depth is a key factor in plant growth and it can affect the types of plants that can grow on it. It has a significant effect on soil moisture hydrological processes, vulnerability to erosion and landslides, soil carbon stocks, soil microbial community and crop productivity. Knowledge of soil depth in agriculture can lead to better management of resources in terms of both quantity and quality. Finally, assessing the spatial distribution of soil depth is very important for soil quality, land use management and hydrological and ecological modelling.

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AGRICULTURAL SUSTAINABILITY: INSECT PEST MANAGEMENT STRATEGIES FOR GRAIN STORAGE

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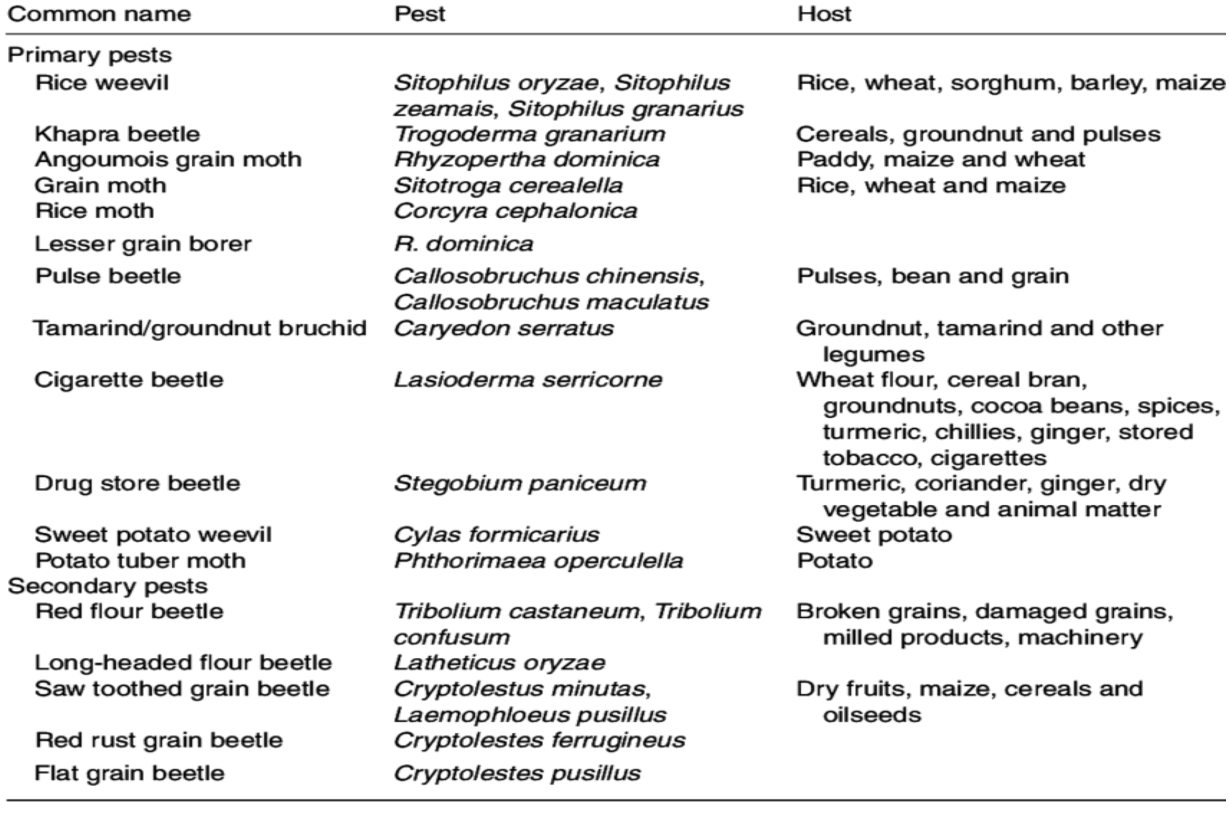
Abstract:

As different insect life stages cause financial harm and degrade the quality of food grains and food products, infestation of stored grains is a highly important issue. Due to uncontrolled environmental conditions and subpar warehousing technologies, there are numerous stored grain insect pests that infest food grains in farmer stores and public warehouses. However, very specific and more suitable current measures should be applied to control the expanding insect population. The use of entomopathogens and a few key techniques including microwave and ionizing radiation, pheromone-baited traps, IGRs, and microwave radiation have all been shown to be particularly successful against stored grain insects. Repellants and oviposition inhibitors extracted from various plant spices are preferred over these approaches because they are thought to be considerably safer than synthetic pesticides. These organic pesticides are safe and biodegradable in a natural setting. However, it is best to employ non-residual, non-persistent, and less hazardous bio-organic pesticides as they might not have an impact on the nutritional value of grains. Additionally, low pressure and low temperature treatments have been shown to be significantly safer pest management methods and a potential substitute for fumigants in the management of coleopteran and lepidopteran insects. However, different parasitoids, predators, diseases, and other living organisms are used in natural settings to limit the pest population in order to effectively control stored grain insects. Computer-based decision support systems should be utilized to forecast damage and operational needs for prompt control in order to improve the protection of stored grain. In order to handle stored grain insects effectively, a few control measures must be combined.

Introduction:

One of the main issues in the modern world is the security and safety of the food supply. Food grains must be preserved and stored safely in order to be delivered to consumers on time. For their use in home or commercial settings, various food commodities such as harvested legumes and grains, processed plant and animal food products, and semi-perishables require safe storage. The majority of the storage section is mostly concerned with grain that is kept at home or in a business [1]. Currently, a variety of facilities, from modest metal bins to substantial grain elevators and silos, assure the secure storage of grains. During the protracted storage period, agricultural commodities are typically vulnerable to contamination and damage from biotic and abiotic agents. The most frequent insects responsible for losses of stored goods of agricultural and animal origin include more than 600 species of beetles, 70 species of moths, and 355 species of mites. There are significant quantitative and qualitative losses in the stored commodities as a result of this large pest arena. Because of the favourable microclimate at the storage site, insect pests that cause harm to storage products frequently arrive from the field. They are then kept around during several channels of processing and storage [2]. By correctly harvesting and drying grains to a safe storage moisture content, which will be provided by grain storage agencies, the initial infection can be reduced. Insects from stored products travel and spread mostly through grain supplies from one place to another during storage activities through the commodity. Since many insects have strong wings, they can occasionally be dispersed via active flight as well [3]. Storage loss evaluation is challenging due to a number of methodological limitations and the need for qualified individuals. They often involve small-scale experiments that extend to bulk storage. The first step is to identify an insect infestation in a product that has been preserved because different insects/species have different harmful signs. This action is essential for stopping the population from growing and for advancing plans for improved storage management strategies. The "primary pests" and "secondary pests" classification system for storage insects is based on how they eat. The complete, undamaged grains are primarily infested and damaged by primary. These can seriously harm the grain lot and are challenging to eradicate if discovered before they form a population. Therefore, monitoring is necessary to stop their invasion and damage. In contrast, secondary feeders and pests settle on grains that have already sustained harm from primary pests or unrelated causes [4]. Numerous insect species can coexist in the same commodity lot because their feeding niches differ and allow for simultaneous survival. The type of grain being stored and the area of the warehouse both affect which insects are present. For instance, khapra beetles and flour beetles are frequent pests of wheat storage in India's northern and southern halves, respectively [5].



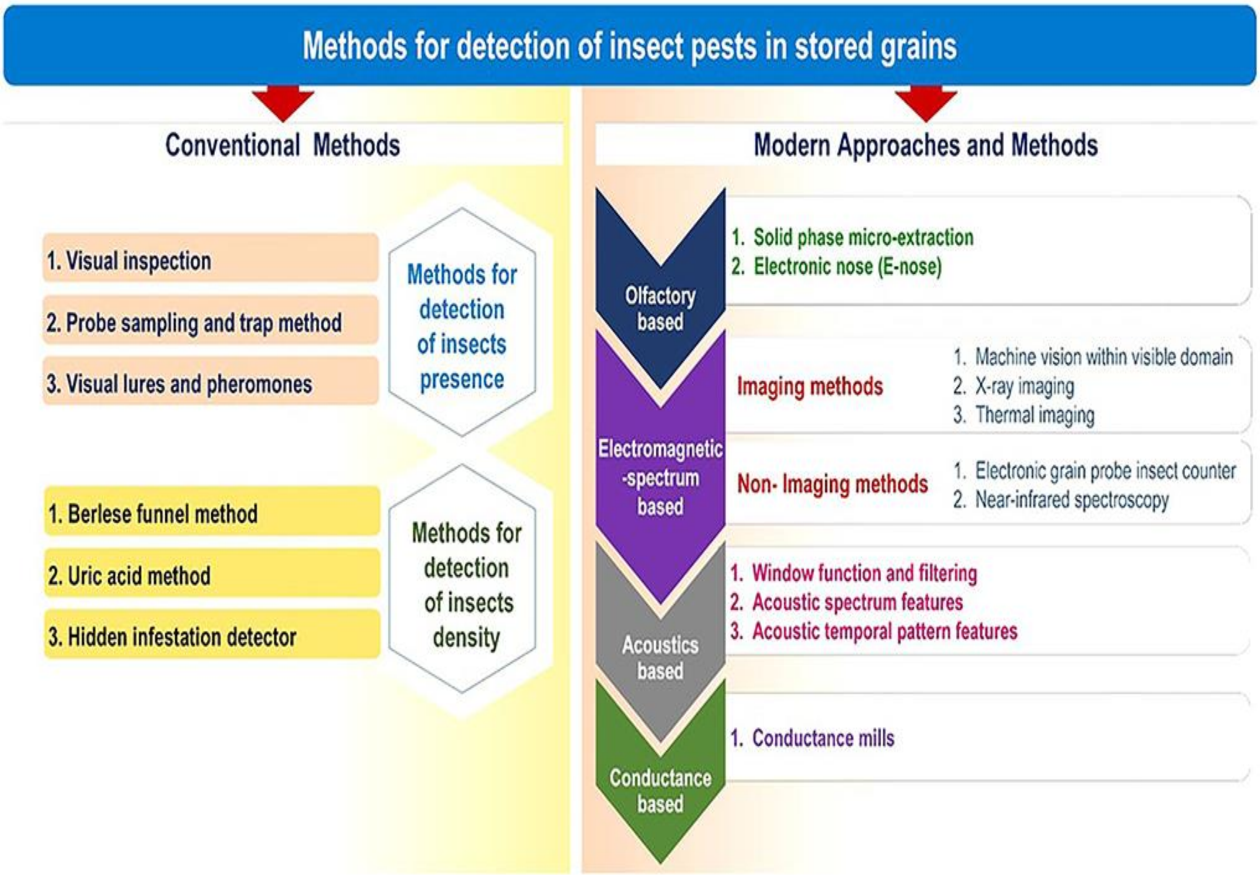
Common name	Pest	Host
Primary pests		
Rice weevil	*Sitophilus oryzae*, *Sitophilus zeamais*, *Sitophilus granarius*	Rice, wheat, sorghum, barley, maize
Khapra beetle	*Trogoderma granarium*	Cereals, groundnut and pulses
Angoumois grain moth	*Rhyzopertha dominica*	Paddy, maize and wheat
Grain moth	*Sitotroga cerealella*	Rice, wheat and maize
Rice moth	*Corcyra cephalonica*	
Lesser grain borer	*R. dominica*	
Pulse beetle	*Callosobruchus chinensis*, *Callosobruchus maculatus*	Pulses, bean and grain
Tamarind/groundnut bruchid	*Caryedon serratus*	Groundnut, tamarind and other legumes
Cigarette beetle	*Lasioderma serricorne*	Wheat flour, cereal bran, groundnuts, cocoa beans, spices, turmeric, chillies, ginger, stored tobacco, cigarettes
Drug store beetle	*Stegobium paniceum*	Turmeric, coriander, ginger, dry vegetable and animal matter
Sweet potato weevil	*Cylas formicarius*	Sweet potato
Potato tuber moth	*Phthorimaea operculella*	Potato
Secondary pests		
Red flour beetle	*Tribolium castaneum*, *Tribolium confusum*	Broken grains, damaged grains, milled products, machinery
Long-headed flour beetle	*Latheticus oryzae*	
Saw toothed grain beetle	*Cryptolestus minutas*, *Laemophloeus pusillus*	Dry fruits, maize, cereals and oilseeds
Red rust grain beetle	*Cryptolestes ferrugineus*	
Flat grain beetle	*Cryptolestes pusillus*	

Source: Ahmad (1983).

[6]

Detection of store grain insect pest

The field-harvested commodities stored food grains are infested with a number of insect pests. The biology, behaviour, ecology, and harmful symptoms of each insect are often unique. Early bug or damage detection is therefore essential for effective control. The most fundamental of all detection techniques is visual inspection and encountering insect life stages. Numerous researchers have developed cutting-edge methods to find insects infesting stored goods. For instance, scientist identified the presence of one infected kernel in 650 g of wheat grains using acoustical detection techniques [7]. Popcorn kernels with Sitophilus zeamais larvae were found by [8] using a modified laboratory roller mill with electrical conductivity. In addition, depending on the roller speed, the detection accuracy varied from 75 to 81% for pupae, 80-91% for medium larvae, and 43-47% for tiny larvae. [9] created a trap using deep learning techniques and a visual analysis program to find *Cryptolestes pusillus, Oryzaephilus surinamensis, Tribolium confusum, Sitophilus oryzae,* and *Rhyzopertha dominica*. Initially, a database of live insects was created using Red, Green, and Blue (RGB) photos, and R-CNN was used to extract these images and categorize the insects.



[10]

Actions for prevention

The difficulty of managing insects throughout later stages of post-harvest processing and storage may be lessened by the successful reduction in the initial build-up of insects from field to storage. These policies are typically traditional or native, and they are primarily founded on the knowledge of our predecessors. Preventive management techniques are required since insects are active and passive fliers in order to eliminate the source of infestation. The management of insects that migrate to stored commodities and those that emerge inside the commodities as a result of pre-infestation are the two ways that preventative measures manage the insect build up. Most notably, it is quicker to dry food grains to moisture content between 10 and 14 per cent (on a wet basis) before storing them.

Storing food grains in storage structure

Farmers and governments frequently store food grains in order to use them later. The grains are typically kept at homes or in sizable storage facilities. The development and adoption of metal bins, automated storage facilities, enormous warehouses, lofty elevators, silos, and other upgraded buildings are seen as a result of the evolution of human knowledge and skills. On the other hand, these buildings sparked the creation of complex microclimates and storage conditions. In due course, insects also adapt to these networks and disperse to numerous regions. Hermetic and low-pressure storage structures are very common in the modern world. Hermetic seals are a result of the idea of putting a barrier between the commodity and the grain. The concept of de-oxygenation inside the storage structure is used in airtight storage to lower aerobic conditions because many conventional structures are internally oxygenated. Because of the increased carbon dioxide (CO_2) due to the decrease in oxygen (O_2) concentration, the insects' metabolic processes are significantly impacted, ultimately resulting in death. An expanding area of agricultural engineering study is storing grains in hermetic seal storages [11]. The gas-tight situation, however, was equally harmful to grains that were being stored. Controlled aeration, changing the gas composition, or adding an insect-proof barrier, however, provide additional benefits and success with hermetic storage structures in modern management techniques. The design and development of various configurationally modified hermetic storages has been the subject of numerous scientific investigations [12]. They are more expensive when made of metals than bags. Even so, they are praised for having contemporary storage facilities. Improved subterranean storage facilities for grains, pulses, and oilseeds were continued in use in Asian and African locations because lower O_2 concentrations report desired insect mortality. However, an efficient and economically feasible hermetic storage structure for field/farm level and/or bulk storage is still lacking.

[13]

Method of Protection from Insect Pest

Physical Method:

Atmospheric air is primarily composed of O_2 (21%), CO_2 (0.03%), and N_2 (78%), and depletion of O_2 (3%) and elevation of CO_2 (>50%) exposure to >24 h significantly distress the insects, which even achieve mortality of residual populations when exposed for prolonged periods. Various gas generators, gas exchange apparatus, and catalytic converters were attached to storage for the insects. However, CO_2 may be used in various ratios with other fumigants depending on their efficacy. As an alternative to chemical fumigation, thorough studies on field-level research on modified structures with standard doses (a combination of gases) may be given priority. Ozone (O_3) is an extremely reactive oxidizing agent. Its ability to enter the grain mass and its quick conversion to O_2 without leaving any residues makes it a potent substitute for fumigants in the protection of stored grains. The treatment of empty bins, the disinfestation of grains, and the treatment of phosphine-resistant populations were the main topics of ozone fumigation research. The phosphine-resistant populations of *T. castaneum*, *R. dominica*, and *O. surinamensis* were controlled by scientists using ozone. Total insect mortality was measured using ozone that was passed at a concentration of 150 ppm in a continuous flow of 2 L/min. Each insect needs a specific set of favourable atmospheric circumstances, namely the right temperature, relative humidity, and gas compositions, for normal growth and development. In general, even a slight temperature change has a significant impact on the growth and development of insects. Insects used to control stored-product insects were known to be fatal under extreme temperatures. In a controlled environment, hot/cool-air/water combinations were traditionally used in grain disinfestation thermal treatments [14]. Grain disinfestation also involved the use of ionizing radiation, such as gamma rays (emitted by cobalt-60 and cesium-137), x rays, or electric beams. The 256 Gy dose was found to be the standard lethal dose and effective in stopping the development of all immature stages. A thorough understanding of gamma and x-ray use for irradiation, integration with other compatible procedures, and safer handling of these radiations are required to be investigated for field-scale and may be employed as a useful alternative to currently practising methods.

Biological methods:

Semiochemicals are chemical signals created by one insect or organism that cause the receiving insect or organism to exhibit certain behavioural or physiological reactions. They are frequently categorized as "pheromones": intra-specific chemical signals as well as inter-specific chemical signals known as "allelochemicals". Pheromones are typically utilized in three types of in-field pest management: monitoring, mass trapping, and mating disruption. Researchers investigated a variety of synthetically produced semiochemicals for *C. ferrugineus* orientation experiments in the field and the lab, and they found that the aggregation pheromones Cucujolide I and Cucujolide II, used either alone or in combination, boosted adult attraction. Utilizing these chemical elements in integrated stored-grain pest management is crucial since semiochemicals change the biology and behaviour of both male and female insects. It is subject to concurrent developments in chemistry, biochemistry, physiology, and genetics. According to the literature evaluation, the best and most sustainable strategy for pest management of stored grains is the use of semiochemicals. The management of stored pests by natural enemies (predators and parasitoids) has been researched for a century. However, the majority of them were concentrated on genetics, toxicity, population and evolutionary ecology, and biology of natural enemies. Biological control emerges as one of the most essential and durable elements of the integrated pest management strategy. The focus on biocontrol was also being boosted by issues with insecticide residues in storage and stored grains, an approach to organic farming, food safety, and other issues. Pteromalids and braconids made up the majority of parasitoids, accounting for 70%, followed by bethylids, ichneumonids, and trichogrammatids (24%), chalcidids, and eulopids (3%). In the past, there were very few applications of predators and parasitoids that were both affordable and field-level inundative. Lab studies make up a large portion of the studies. Furthermore, none of them were considered to be widely utilized due to their host specificity and limited environmental adaptations. Synergists, particularly diatomaceous earth, were tested in combination to increase their potency and wide range of adaptability. *Beauveria bassiana, Metarhizium anisopliae*, and the bacterium *Bacillus thuringiensis* (Bt) are a few examples of the commercially available entomopathogenic fungi and bacteria. These organisms were mostly studied against stored-grain pests, particularly beetles. [15] tested the effect of *Steinernema feltiae* (three strains namely, UK 76, USA/SC, and Hawaii) against *T. confusum*, and *E. kuehniella* in wheat under laboratory condition. They observed 100% larval mortality (after 14 d of exposure) with Hawaii strain against *T. castaneum*, whereas USA/SC strain was found effective against *E. kuehniella* larvae (69% mortality after 14 d exposure). A single nematode strain or species, however, cannot manage a variety of insects since they behave differently depending on the species. While combining different strains can offer the anticipated stored-grain protection. All of these research involve bioassays that are carried out in laboratories, therefore there isn't any field testing of these EPNs on a large scale. Large-scale field trials and mass cultivation could be used to advance EPN technologies in storage management. As a result, just 1% of insecticides sold globally are botanicals [16]. These plant compounds may function as chemical fumigation alternatives in light of human health issues. Studies on the toxicity, screening, effectiveness, sorption, formulation, and fumigation of botanicals, particularly essential oils, are receiving more attention these days.

Chemical methods:

Although sprays are frequently used to prevent the infestation, fumigation is the method used to control infestations that have been found. However, the increased reliance on chemicals has led to problems with both environmental and public health. However, the dependence Insecticides with a unique mode of action are currently being investigated extensively, especially the spinosyn group [17]. Application of insecticide plays a significant part in insect management in several post-harvest management steps/conditions, including mills and processing plants. However, the chemical application in storage was mostly focused on fumigation. Fumigation is the term for treatment delivered using gas. In the 1990s, it was a very popular technique for pest control in bulk storage. The utilization of alternate fumigants and formulations was one of the most recent advancements in fumigation. Future efforts should concentrate on non-chemical methods for safer and long-lasting stored grain protection. Despite the fact that there were more entries, only DE and silica achieved significant results and are the only ones studied by many researchers. Using DE as a sole control method or in combination with other low-risk control methods was shown to be a promising alternative to insecticide sprays in storage . For the management of storage pests, improvements are being made in the creation of newer formulations, their integration with other methods, and their increased treatments using lower doses. In the future, food-grade inert dust might take the place of the contact pesticides currently used to protect stored grains.

Molecular methods:

A unique method of controlling insects is to interfere with an organism's natural gene expression RNA interference (RNAi) and Clustered Regularly Interspaced Short Palindromic Repeats were the two molecular tools used [18] (CRISPR). For these experiments, the rust-red flour, *T. castaneum*, was used as a model insect, and the majority of the information found in the published articles mostly concerned this insect [19]. *T. castaneum* was chosen as the host because to its simpler laboratory growth and robust RNAi response throughout all embryonic stages Normally, CRISPR deactivates Cas9 (a DNA binder) and RNAi targets dsRNA to prevent further gene activation. Only after thorough research are these methods capable of managing stored-grain pests. A necessary first step and a topic of concern is the identification of particular genes in insects infesting grains that have been kept. When compared to other related approaches, such as genome editing and gene modification, these revolutionary technologies seem futuristic.

Conclusion:

One of the main topics of study for post-harvest engineers and entomologists is the safe handling and protection of stored items. Both emerging and developed nations are currently concerned with issues related to food safety and security. Several dryers and controlled storage structures were developed as a result of rationalization in preventive management methods, such as adequate drying and safer storage, which were then used globally. Hermetic and low-pressure storages are particularly popular among them, however there aren't many uses for bulk storage. The benefits of temperature control (heat or cold treatment) inside storage include insect mortality. Exposure to electromagnetic radiations like RF and MW can also be used as a form of heat treatment. Additionally, as alternatives to traditional fumigants, the use of CO2 and ozone as fumigants may become more widespread. Predators, parasitoids, diseases, and EPNs are examples of biological choices that are less harmful to the environment, but their widespread use is constrained by their formulation, mass production, and field-level adoption. Research into the chemical ecology and semiochemistry of stored product insects is necessary to build lure/trap solutions that can both attract and kill pests. In field-crop pest management, chemical control of insect pests is recommended as a last resort; nevertheless, in storage, it is utilized as the first line of defence. The major uses of insecticides are surface applications and de-infestation. Alternatives are required because there are few fumigant choices left and insects have already become resistant to them. Innovative scientific fields like nanotechnology and biotechnology are developing quickly and helping to preserve stored goods. However, the rising concern for secure storage and organic pest control has spurred advancements in a number of disciplines. Modernized and integrated pest management solutions for bulk storage need to be periodically updated in light of the changing post-harvest systems. Since grain must be harvested, dried, handled, packaged, and transported until it is safely stored, pest management measures can significantly lower and avoid grain loss.

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MAJOR INSECT-PESTS OF ROOT CROPS (CARROT, RADISH AND BEET ROOT) AND THEIR MANAGEMENT

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Introduction:

The greatest problem of the 21st century is to sustain a population of 10 billion people with a declining soil resource base in a changing climate. The creation of crops with the potential to produce well with restricted water and nitrogen (N) availability will be a key component of this effort. Plant growth in terrestrial habitats, both natural ecosystems and the low-input agroecosystems typical of developing countries, is primarily constrained by inadequate water and nitrogen availability. Insect pests and phytophagous insect-pests cause a considerable loss to root crops in the field. Many times, modern agriculture has promoted pest population growth at the expense of beneficial arthropod populations. Carrot *Daucus carota*, is an edible biennial herb in the family Apiaceae grown for its edible root. Afghanistan, which continues to be the centre of diversity for *D. carota*, is where the carrot is believed to have originated. Some of the major insect pests, which are limiting the production of carrots, are aster leaf hopper, flea beetle, aphid, carrot weevil, carrot rust fly and cutworm. The information regarding insect pest of carrot is scanty. Therefore, this information will be valuable asset for scientific community.

Beets, *Beta vulgaris*, are herbaceous biennial root vegetables in the family Chenopodiaceae grown for their edible root. The plant is usually erect with a long main root and a rosette of leaves growing on stems. The leaves are oval in shape, arranged alternately on the stem and grow 20–40 cm (7.9–15.7 in) in length. The roots are usually red in color. The plant produces sessile green flowers and can reach 1–2 m (3.3–6.6 ft) in height. Beets are usually grown as annual plants, harvested after one growing season. Beets may also be referred to as beetroot, garden beet or spinach beet and originated from the Mediterranean. The roots are consumed after boiling and may be pickled in vinegar. The leaves of the spinach beet plant are consumed as a herb in Indonesia and Japan. Chemicals in the roots can be extracted and used as food coloring.

The botanical name of radish is *Raphanus sativus.* The enlarged edible roots are fusiform and differ in colour from white to red. There are two distinct genetical groups in radish. The Asiatic varieties, which are primarily for tropical climates, produce edible roots in the first season and seed in the second season as a biennial crop. On the other hand, the exotic or European varieties produce roots in the plains of tropical and subtropical climate and seeds in the hills of temperate climate. Radish originated probably in China. In India, it seems to have been cultivated from ancient times. It was popular among the ancient Egyptians and Greeks.

Insect pests of carrot and their management

Aster leafhopper:

The aster leaf hopper is a noxious pest of carrot because it transmits the aster yellow phytoplasma disease. Adult leaf hoppers are olive green, wedge shaped and about ½ inch long. They are poly phagous in nature. Adults have six spots on the black of the head. Nymphs are similar in shape to the adults, but are cream coloured and lack of fully developed wings. Adults are extremely active and jump, crawl or fly when they get disturb. Nymphs are less active but crawl rapidly.

Biology:

Adult female lay eggs in the leaves of susceptible plants. Nymphs hatch 5-7 days later mature within 20-30 days. They are generally completed 2-5 generations per year. This insect over winters in the eggs tage in northern locations and in the adult stage in warmer climates.Because the generations overlap and are initiated by both over wintering eggs and migrating leaf hoppers, it is difficult to discern the generations.

Nature and symptoms of damage:

Both nymphs and adults feed by inserting piercing and sucking the plant to extract sap. If a leaf hoppers feed on an infested plant, it ingests the aster yellow pathogen. When the leafhopper moves to another plant to feed, it transmits the pathogen inits saliva. In carrots, disease symptoms appear about3 weeks later. Symptoms may appear as early as 10 days after infection or as late as 40 days after infection.

Management:

Aster leafhopper may effectively be controlled by excluding them from the carrot planting with floating row covers. Place yellow sticky card in the field early in the spring when plants are newly sprouted. Remove weeds from the field edges as these may be reservoir for the pathogen.

Flea beetle:

Flea beetle is an occasional pest of carrot. Its larvae are delicate and thread like with white bodies and brown head capsules. They have characteristically large hind legs, which makes them excellent jumpers.

Biology:

Flea beetles overwinter as adults in leaf litter, hedge rows, wind break sand wooden areas. The beetles become active when temperature reaches 500 F and emerge in late April . Feeding on weeds and volunteer plants until the new crop emerges. Adult lay eggs in the soil at the base of host plants in May. Eggs hatch in 7-14 days and larvae feed on various plant parts until full grown. The larvae pupate in earthen cells for 11-13 days before emerging as adults. They have two generations per year.

Nature and symptoms of damage:

They make small holes or pits in leaves that give the foliage a characteristic “shothole” appearance; Young plants and seedlings are particularly susceptible; plant growth may be reduced.

Management:

Early planting will helps to avoid the population of flea beetles while the plants are small and vulnerable, enclosing seed bed with floating row cover to get protection from laying by adults, application of a thick layer of mulch to prevent beetles reaching surface, applications of diamotecoeus earth or oils such as neem oil are effective control methods for organic growers and application of insecticides containing carbaryl, spinosad, bifenthrin and permethrin can provide adequate control of beetles.

Willow carrot aphid:

Willow carrot aphid is the main aphid pest of carrot crops. Distinguishing features include the presence of cornicles, which project backwards from the body of the aphid and will generally not move very quickly when disturbed, willow carrot aphid will also attack turnip, parsley and celery. The green peach aphid is slender, dark green to yellow, and has no waxy bloom. The wingless form of the green peach aphid is pale green. The winged form has a black head and thorax. It is primarily an early year pest and transmits virus diseases.

Biology:

Most species of aphids have similar life cycles. Aphid females give birth to live off spring all year without mating. When vegetable crops are not available, aphids live on a wide variety of weed hosts. In summer and fall, aphids may produce winged females and later winged males. They mate and produce eggs for overwintering, especially in colder climates. Otherwise, the adult aphids overwinter on crops, weeds or trees. There may be as few as two generations or as many as 16 generations each year, depending on the species and climate.

Nature and symptoms of damage:

Aphids feed on carrot foliage, but they are a key pest because they can transmit diseases such as motley dwarf virus. If aphid infestation is heavy it may cause leaves yellow, necrotic spots on leaves and stunted shoots, aphids secrete a sticky, sugary substance called honey dew, which encourages the growth of sooty mold on the plants.

Management:

Use tolerant varieties, sanitation for curbing the spread of the viruses, ploughing all crop residues under as soon as harvest, use of reflective mulches such as silver colored plastic can deter aphids from feeding, use of predators such as green lacewing larvae, lady beetles, and syrphid fly larvae prey on this aphid, use of insecticidal soaps or oils such as neem or canola oil etc. are followed to control the aphids.

Carrot weevil:

Adult weevils spend over winter in crop debris remaining in the ground, larvae feed for approximately 2 weeks before pupating in the soil, insect undergoes several generations each year. Snout nosed beetles that are about 6 mm long. Larvae are white to pinkish white C-shaped grubs with a yellow-brown head.

Biology:

Adults lay 2-3 eggs in the petioles or crown of the carrots beginning in the first true leaf stage. Eggs hatch in one to two weeks and white in color. There are 2 generations per year.

Nature and symptoms of damage:

Their grub like larvae either tunnel down into the root or leave the stalk and bore into the side of the root from beneath the soil.Larvae may kill young plants. Damage to older plants is typically observed in the upper one-third of the root. Feeding injury may allow entry by pathogens that will cause roots to rot.

Management:

Removing of all debris from Umbelliferous crops to reduce sites where weevil can survive and persist, croprotation, using of Azadirachtin quite effective against carrot weevil.

Carrot rust fly:

The rust fly adult is about 6-8mm long with a shiny black thorax and abdomen, reddish-brown head, and yellow legs. Adult insect is dark colored fly larvae are white maggots approximately 1 cm long.

Biology:

The adult female lays its eggs in the soil at the base of the carrot. Six to ten days later the larva hatches and feeds on the carrot root.

Nature and symptoms of damage:

Their Larva feeds on the carrot root, rendering the carrots impossible to market. Carrot rust flies obtain their common name from the rust colored frass they deposit in the superficial feeding tunnels on the carrot.

Management:

Use of row covers will help to protect plants from damage but they must be installed before adult fly lays eggs on plants.

Cutworm:

Cutworms are the larvae of nocturnal grey moths. They tend to feed at just below the ground surface at night. Cutworms are active feeder of young foliage and stem sand will cut off many young seedlings in an evening. They are large, fleshy larvae curl up into a tight C shaped when disturbed.

Biology:

Few cut worms over winter, beginning in late May, moth migrates into the state. Female moths lay hundreds of eggs either singly or in clusters. Most eggs are laid on low growing, grassy vegetation or plant residue from previous year’s crop. Once the egg hatch, the young larvae feed above ground on the tips of plants. There are three to four generations per year, but first generation is most damaging because it coincides with seedling plants.

Nature and symptoms of damage:

Large larvae may destroy several plants in one evening. The larvae often the pull the stem of the severed plant into the subterranean burrow.

Management:

Deep ploughing and stirring of soil, flooding of fields so that caterpillars are exposed to birds and other enemies. Hand picking and destruction of caterpillars found just under the damaged plant. Soil application (drenching) of chlorpyriphos @0.1 percent. Poison baits containing wheatbran + carbaryl + molasses be spread on the ground to attract and kill larvae and mixing of insecticidal dust are some of the practices to control the cutworms.

Insect pests of beetroot and their management

Leafminers- *Lyriomyza* spp.

Symptoms

Thin, white, winding trails on leaves. Heavy mining can result in white blotches on leaves and leaves dropping from the plant prematurely. Early infestation can cause fruit yield to be reduced. Adult leafminer is a small black and yellow fly which lays its eggs in the leaf. Larvae hatch and feed on leaf interior.

Life cycles

Mature larvae drop from leaves into soil to pupate; entire lifecycle can take as little as 2 weeks in warm weather; insect may go through 7 to 10 generations per year.

Management

Check transplants for signs of leafminer damage prior to planting. remove plants from soil immediately after harvest; only use insecticides when leafminer damage has been identified as unnecessary spraying will also reduce populations of their natural enemies.

Darkling beetle (Rove beetle) *Blapstinus* spp.

Staphylinid spp

Symptoms

Feeding damage on stems; death of seedlings; seeds dug up; insect is a dull blue-black or brown beetle about 0.6 cm (0.52 in) long; tips of antennae are often enlarged, resembling a club. Beetles are generally active at night. during the day beetles hide in organic debris.

Management

Ditches filled with water can prevent spread of beetle to/from adjacent fields; remove all weeds from garden borders. if beetle is problematic then appropriate insecticides can provide control. Insecticides are usually in the form of baits.

Root knot nematode- *Meloidogyne* spp.

Symptoms

Galls on roots which can be up to 3.3 cm (1 in) in diameter but are usually smaller, reduction in plant vigor, yellowing plants which wilt in hot weather. Galls can appear as quickly as a month prior to planting; nematodes prefer sandy soils and damage in areas of field or garden with this type of soil is most likely.

Management

Plant resistant varieties if nematodes are known to be present in the soil, check roots of plants mid-season or sooner if symptoms indicate nematodes, solarizing soil can reduce nematode populations in the soil and levels of inoculum of many other pathogens.

Insect pests of radish and their management

Aphids

Aphids are the most serious pests of radish. They attack both seedlings and mature crops. Cloudy humid weather conditions favour the spread of their infestation. In case of heavy infestation the plant are completely devitalized, leave and shoots curl up, become yellowish and finally die.

Control

Spraying Malathion 50% in the ratio of one litre in 1000 litres of water gives sufficient high percentage of kill with a residual effect of 2- 3 weeks. Nicotin sulphate one litre in 800 litres of water is also effective at higher temperature of about 210 C. Spraying Nuvacron (1.25ml) or Metasystox (2ml) per litre of water is also recommended.

Mustard saw-fly

This is a common pest of radish and turnip. In radish, it appears when the crop is in flowering and at vegetative stage. The damage is done by the group by biting holes in the leaves and fruits.

Control

Mustard saw-fly can be controlled by dusting 10% BHC at the rate of 15-20 kg per hectare at the vegetative growth of the infested crop and 35-40 kg per hectare at the seed formation stage. Spraying of 4 gm Sevin 50 W.P. per litre of water at weekly interval can also control this pest.

Flee beetle

In some areas, it becomes a serious pest on the vegetative parts of the plants which are eaten by this pest.

Control

It can be controlled by spraying with Malathion (0.15%) or Sevin (0.4%) at 10 to 15 days interval.

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MAJOR INSECT-PESTS OF BRINJAL, OKRA AND THEIR MANAGEMENT

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Introduction:

Brinjal (*Solanum melongena* L.) is a solanaceous vegetable also known as "King of vegetables". Being a major vegetable crop in India, brinjal is cultivated in about 7.27 Lakh hectares with an annual production of 123.23 Lakh tonnes during 2016-17. However, kitchen garden cultivation of brinjal is also a common practice in each and every household of India. But the production of the crop is regulated by different biotic and abiotic factors and amongst those factors, insect pests plays a pivotal role for lowering the yield of brinjal, by attacking the crop right from the nursery stage to till harvesting.

Okra (*Abelmoschus esculentus*), also known as lady's finger or bhendi, belongs to family Malvaceae and is an important vegetable crop grown throughout the year. Besides India, it is grown in many tropical and subtropical parts of the world. Tender fruits are used as vegetables or in culinary preparations as sliced and dried pieces. It is also used for thickening gravies and soups, because of its high mucilage content. Matured fruits and stems containing crude fibre are used in paper industry. It has good nutritional value, particularly the high content of vitamin A, potassium, calcium, iron and other minerals like magnesium, sodium and phosphorus, vitamins B and C, fats and carbohydrates. India grows okra on about 4.52 lakh hectares with an annual production of 48.03 lakh tons and productivity of 10.61 t/ha. The productivity of our country is low compared to other countries due to yield losses caused by insect pests, diseases and nematodes. The crop is attacked by more than 72 insect pests and infests the crop from seedling to harvest stage. The shoot and fruit borer (*Earias vittella*), fruit borer (*Helicoverpa armigera*), leaf roller (*Sylepta derogata*), leafhopper (*Amrasca biguttula biguttula*), whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*), solenopsis mealy bug (*Phenacoccus solenopsis*), dusky cotton bug (*Oxycarenus hyalinipennis*), red cotton bug (*Dysdercus koenigii*), red spider mite (*Tetranychus urticae*) and root-knot nematode (*Meloidogyne incognita*) are some of important pests which cause damage in okra crop.

Important pests of brinjal:

Major pests:

i.	Shoot and fruit borer	*Leucinodes orbonalis*
ii.	Hadda / spotted beetle	*Henosepilachna vigintioctopunctata*
iii.	Stemborer	*Euzophera perticella*
iv.	Ash weevils	*Myllocerus subfasciatus, M. discolor, M. viridanus, M. maculosus*
v.	Brown leafhopper	*Cestius phycitis*

Minor pests:

1.	Aphid	*Aphis gossypii*
2.	Sphingid	*Acherontia styx*
3.	Thrips	*Thrips tabaci, Frankliniella schultzei, Scirtothrips dorsalis*
4.	Spider mite	*Tetranychus cinnabarinus*
5.	Whitefly	*Bemisia tabaci, Aleurodicus disperses*
6.	Budworm	*Scrobipalpa blapsigona*

Shoot and fruit borer: *Leucinodes orbonalis*

Distribution:

India, Bangladesh, Malaysia, Thailand, Burma, Sri Lanka, Laos, South Africa, Congo. Damage to even 30 -50% of fruits or more.

Host range:

Brinjal, potato, other wild plants belonging to Solanaceae, peas.

Damage symptoms:

Larva bores into tender shoots & causes withering of terminal shoots / dead hearts. Also bores petioles of leaves, flower buds & developing buds - causes shedding of buds - make fruits unfit for consumption. Attacked fruits are with boreholes plugged with excreta.

Bionomics:

Egg: 3 - 4 days. 150 - 350 creamy white eggs laid singly on leaves, tender shoots, flowers & developing fruits. Larva - stout, pink coloured with sparsely distributed hairs on warts on the body & brownish head. Larval Period: 15 days, Pupal Period: 6 - 8 days – tough grayish boat shaped cocoon. Medium sized adult with white wings, with triangular brown & red markings on forewing. TLC: 17 - 50 days. ETL: 1 - 5% of fruit damage.

Management:

- Avoid continuous cropping of brinjal and ratooning.
- Grow Resistant varieties like **Annamalai, Pusa purple round, Arka Kusumakar, Doli – 5, Pusa purple Long, Pusa Purple Round, SM 67, Pant Samrat.**

- Collect and destroy the damaged tender shoots & fallen fruits. Use light traps @ 1/hato attract and kill the moths.
- Egg parasitoids ***Trichogramma chilonis*** @1.0 lakh/ha.Spray Bt formulations of ***B. thuringiensis*** **var.** ***kurstaki*** such as Dipel @ 1.5 to 2 ml /Lof water.
- Spray any one of the insecticides starting from one month after planting at 15 days interval, Carbaryl 50 WP 2 kg + wettable Sulphur 50 WP 2 kg, Quinalphos 25 EC 1.5 L + Neem oil 1.0 L, NSKE 5%, Azadirachtin 1.0% 1.0-1.5 L or Fenpropathrin 30 EC 250-340 ml or Thiodicarb 75 WP 625-1000 g Flubendiamide 20 WG, 375 g with 500 – 750 L water/ha.
- Avoid using synthetic pyrethroids - cause resurgence of sucking pests.
- Avoid using insecticide at the time of fruit maturation and harvest.
- Uproot & burn old plants before planting new plants since they harbor pest and carry over infestation.

Hadda / spotted bug: *Henosepilachna dodecastigma*, *H. vigintioctopunctata* (Coccinellidae [*Epilachna = Henosepilachna*]: Coleoptera

Distribution and status: South Canada, USA, Mexico, Africa & SEA

Host range: Brinjal, potato, tomato, cucurbitaceous plants, wild solanaceous plants.

Damage symptoms:

Both adults & grubs scrap the lower of leaves in characteristic manner leaving behind stripes of uneaten areas. The leaves give a stifled appearance. In severe infestation all leaves may be off leaving only the veins (Skeletonization).

Management:

- Collect and destroy adult beetles, grubs and pupae.
- Shake plants to dislodge grubs, pupae and adults - kerosenated water early in the morning or collect them mechanically and destroy them.
- Spray carbaryl 50% WP 2 kg + wettable Sulphur 2 kg or malathion 50 EC 1.5L or Azadirachtin 0.03% 2.5-5.0 L in 500 - 750 L of water.
- Emulsify 1 lit of Neem oil with 60 g of soap dissolved in ½ L. of water, dilute emulsion by adding 20 lit of water, then mix about 400 g of well crushed garlic and spray.
- Mix diflubenzuron with chlorpyriphos 1.0 L /ha and spray on the crop - reduces the population by nearly 95%.

Stem borer: *Euzophera perticella* (Phycitidae: Lepidoptera)

Distribution and status: Indian sub-continent

Host range: Chilli, tomato, brinjal and potato

Damage symptoms:

Larva bores into main stem of young & old plants - move downwards. Top shoots of young plants crump & wither. Older plants become stunted. Fruit bearing capacity is adversely affected - thickening of stem at the entry point

Bionomics:

10 days – Creamy & scale - like, laid singly / in batches on young leaves, petioles & branches. LP: 26-58 days - Fully grown larva is creamy white with few bristle-like hairs. Pupa: Pupates within cocoon inside larval tunnel – PP: 9-16 days. Adult: Greyish brown, forewings with transverse line and white hindwings. Life cycle is completed in 35 - 76 days.

Ash weevils: *Myllocerus subfasciatus, M. discolor, M. viridanus, M. maculosus* (*Curculionidae*: Coleoptera)

Damage symptoms:

Notching of leaf margins by adults. Grub's feeds on roots resulting in wilting & death of plants.

Bionomics:

500 eggs laid in soil EP: 6 - 7 days. Grub: 30 - 45 days. Pupa: Pupates in soil in earthen cocoons. Adult: 10 - 12 days. *M. subfasciatus*: Brown; M. *discolor*: Brown and white spots; *M. viridanus*: Small light green weevil.

Management:

- Collect and destroy adult weevil. Apply lindane 1.3 D before planting @ 25 kg/ha.In endemic areas apply carbofuran 3G @ 15 kg/ha, 15 days after planting.
- Spray carbaryl 50 WP 2 kg + wettable Sulphur 2 kg or malathion 50 EC 1.5L.

Damage symptom:

It is a vector of little leaf of brinjal. Nymphs & adults suck cell sap from ventral side of leaf & inject toxins into the plant tissues. Reduction in size of leaves, shortened petioles, excessive growth of branches - stunting of plants, conversion of floral parts into leafy structures & give the plants a bushy appearance. Fruiting is rare.

Bionomics:

The adults are small light brown leafhoppers having bright yellow marks on its thorax.

Management:

- Rogue out infested plants as soon as they appear in the field & completely destroy them. Before transplantation dip the seedlings in 0.2% carbosulfan 25 DS solution to control the insect vectors.
- Spray 3 - 4 times at 10 days interval with methyl parathion 750 ml or dimethoate 500 ml or imidacloprid 125 ml in 500 -750 L of water /ha.

Aphids: *Aphis gossypii* (Aphidiae: Hemiptera)

It can be occasionally serious.

- Release of first instar grubs of Ch*rysoperla zastrowi sillemi* @ 10,000/ha.
- Spraying methyl demeton 25 EC or dimethoate 30 EC 500 ml or Fenvalerate 20 EC 375-500 ml or Phosphamidon 40 SL 625-750 ml.

Egg plant mealy bug: *Coccidohystrix insolitus* (Pseudococcidae: Hemiptera

Host: Pigeonpea, brinjal, other *Solanum* spp., etc.

Old plants usually affected - leaves & tender shoots covered by a large number of mealy bugs - attended by small, brown ants. Leaves become yellow & covered with sooty mould.

Lace wing bug: *Urentius hystricellus (*Tingidae: Hemiptera)

Symptoms of damage:

Yellowing of leaves. Affected leaves covered with exuviae and excreta

Identification of pest:

Eggs are White nibble shaped. Nymphs are yellowish white with prominent spines. Adults are Dorsal side -straw coloured, Ventral side - black coloured, Pronotum & forewings with reticulated markings.

Management:

- Spray dimethoate 30 EC @ 1 lit/ha or methyl demeton 25 EC @ 1 lit/ha

Important pests of okra

Major pests:

1. Shoot and fruit borer	*Earias vittella* and *Earias insulana*
2. Fruit borer	*Helicoverpa armigera*
3. Shoot weevil	*Alcidodes affaber*
4. Stem weevil	*Pempherulus affinis*
5. Leaf roller	*Sylepta derogata*
6. Semilooper	*Anomis flava*
7. Jassids	*Amrasca devastans*
8. Whitefly	*Bemisia tabaci*
9. Aphid	*Aphis gossypii*
10. Red cotton bug	*Dysdercus cingulatus*

Shoot and fruit borer: *Earias vittella & Earias insulana* (Noctuidae: Lepidoptera)

Distribution and status: Cosmopolitan. Major pest

Host range: Cotton, bhendi, holly hock, *Hibiscus cannabinus, Abutilon*

Symptoms of damage:

Terminal shoots wither and droop. Shedding of buds and flowers. Bore hole in fruits & feed inside. Deformed fruits.

Identification of pest:

E. vitella:

Egg: Sculptured egg and sky blue in colour - EP 3 days **Larva:** Brownish with white streaks dorsally and pale yellow ventrally – LP 10-12 days. **Adult:** Forewings are pale with a wedge-shaped green band in the middle.

E. insulana:

Larva: Brown with dorsum showing a white median longitudinal streak; Finger shaped processes on larval body. **Pupa:** Outside the fruit in a tough, brown and boat shaped cocoon; PP: 7 – 10 days. **Adult:** Forewings are uniformly silvery green

Management:

- Set up pheromone trap @ 12/ha.
- Collection and destruction of affected fruits.

- Release of egg parasite *Trichogramma chilonis* @ 1.0 lakh/ha.
- Release of 1st instar larvae of green lacewing predator *Chrysoperla zastrowi sillemi* @ 10,000/ha.
- Spray *Bacillus thuringiensis* @ 2 g/lit. Spray any one of the following insecticides
- Azadirachtin 0.03% WSP (300 ppm) 5.0 g/lit
- Azadirachtin 5% Neem Extract Concentrate 5.0 ml/1 lit
- Emamectin benzoate 5 % SG 3.0 g/10 lit
- Phosalone 35 % EC 1.5 ml /lit
- Pyridalyl 10 % EC 1.0 ml/lit
- Quinalphos 25 % EC 8.0 ml/10 lit

Bhendi fruit borer: *Helicoverpa armigera (*Noctuidae: Lepidoptera)

Distribution and status: Cosmopolitan, Major pest

Host range: Sorghum, lablab, soybean, peas, sunflower, safflower, chilies, groundnut, tobacco, bhendi, maize, tomato.

Symptoms of damage:

Feed on the flowers. Circular boreholes on fruits. Larva thrust only part of their body inside the fruit feed

Bionomics:

Eggs: Spherical in shape & creamy white in color, laid singly EP: 7 days. **Larva:** Shows colour variation from greenish to brown, LP: 14 days **Pupa:** Brown in color, occurs in soil, leaf; PP: 10 days **Adult:** Female brownish yellow stout moth, Male is pale greenish in colour with V shaped markings.

Management:

- Collect and destroy the infected fruits and grown-up larvae.
- Install pheromone trap with Helilure at 15/ha.
- Six releases of *T. chilonis* @ 50,000/ha per week coinciding with flowering time. Release *Chrysoperla zastrowi sillemi* at weekly interval at 50,000 eggs or grubs/ha from 30 DAS.
- Spray HaNPV at 1.5 x 10^{12} POB/ha along with cotton seed oil 300 g/ha to kill larvae.
- Spray carbaryl 50 WP 2 g/lit or *B. thuringiensis* 2 g/lit.Do not spray insecticides after maturity of fruits.

Shoot weevil: *Alcidodes affabe*(Curculionidae: Coleoptera)

Symptoms of damage:

Grub feed on stem & galls are formed in the stem & petiole. Adults feed on leaf buds and terminal shoots

Identification of pest:

Grubs - creamy yellow, apodous. Adults - dark greyish brown with pale cross bands on elytra

Stem weevil: *Pempherulus affinis (*Curculionidae: Coleoptera)

Symptoms of damage:

Swellings on the stem just above the ground level. Young plants are invariably killed. Older plants that survive lack vigor and strength, breaks at the nodes due to strong wind

Identification of the pest:

Larva - Grub, white in colour without leg (apodous). Adult - Very small weevil, dark in colour with two small white patches on the elytra. ETL: 10% infestation

Management:

- Soil application of Carbofuran 3 G at 30 kg/ ha on 20 DAS and earthed up.Basal application of FYM 25 t/ha or 250 kg/ha of neem cake.

Leaf roller: *Sylepta derogate* Pyraustidae: Lepidoptera

Distribution and status: Africa, Australia, Burma, Sri Lanka, Japan, Java & China. It is considered as minor pest

Host range: Cotton, bhendi, Abutilon indicum and other malvaceous plants.

Damage symptoms:

Young larvae feed on epidermis on the under surface. Rolls the leaf in the form of trumpets and remains inside . More than one larva can be seen inside the roll. It is fastened by silken threads on marginal portion. In severe cases - defoliation occurs

Bionomics:

Egg: 2 - 4days, green – round, 250 - 300 eggs/female laid on the ventral surface of the leaves. Larval period: 2- 3 weeks, glistening green with dark head. Pupal Period: 6 - 12 days. Pupates within the roll or ground or fallen leaf. Adult - medium sized cream coloured moth with wavy markings.

Management:

- Collect and destroy rolled leaves.Spray carbaryl 50 WP 2 g/lit or phosalone 35 EC 2 ml/lit

Semiloopers: *Anomis flava; Xanthodes graelsi; Tarache nitidula (*Noctuidae: Lepidoptera)

Distribution and status: India, Africa, Asia & Australia.

Host range: Cotton, tomato, bhendi and other malvaceous plants.

Damage: Defoliation

Whitefly: *Bemisia tabaci (Aleyrodidae; Hemiptera)*

Distribution and status: India, Sri Lanka, Nigeria, Congo, West Africa, Japan & Europe

Host range: Cotton, tomato, tobacco, sweet potato, cassava, cabbage, cauliflower, melon, brinjal and bhendi.

Symptoms of damage:

Chlorotic spots on the leaves which latter coalesce forming irregular yellowing of leaf tissue. Severe infestation results in premature defoliation. Development of sooty mold. Vector of yellow vein mosaic virus. ETL: 5-10 nymphs / leaf.

Management:

Timely sowing with recommended spacing & avoid alternate host. Remove & destroy alternate weed hosts-*Abutilon indicum, Solanum nigrum.*Follow judicious irrigation management

& nitrogenous fertilizer application to arrest the excessive vegetative growth and pest the buildup. Setting up yellow pan traps & sticky traps at 1 foot height. . Collect and remove whitefly infested leaves from the plants. Spray NSKE 5% and neem oil 5 ml or fish oil rosin soap at 1 kg / 40 L of water. Avoid repeated spraying of synthetic pyrethroids. Spray any of the following insecticides with 500 L water/ha.

- Phosalone 35 EC @ 2.5 l/ha
- Quinalphos 25 EC @ 2.0 l/ha
- Triazophos 40 EC @ 2.0 l/ha

Jassids: *Amrasca devastans* (Cicadellidae: Hemiptera)

Host range: Cotton, potato, brinjal, castor, bhendi, tomato, hollyhock and sunflower

Symptoms of damage:

Tender leaves become yellow. Margin of the leaves start curling downwards &reddening.In severe infestation leaves get a bronze which is typical "hopper burn" symptom.The margins of the leaf get broken and crumble into pieces when crushed.ETL: 50 nymphs / adults per 50 leaves or yellowing and curling from the middle to upper portion of the plants in 25 % of plants in the field.

Nymph: Light green, translucent, wingless found between the veins of leaves on the under surface

Adult: Green, wedge-shaped leafhopper

Management:

Install light trap to monitor leaf hopper - to attract & kill.Spray any one of the following insecticides (spray fluid 500 l/ha). Imidacloprid 200 SL at 100 ml/ha. Methyl demeton 25 EC 500 ml/ha Dimethoate 30 EC 500 ml/ha.40 SL 600 ml/ha Release predators viz., *Chrysopa zastrowi sillemi*. NSKE 5%.

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VIRTUAL WATER: EXPLORING THE HIDDEN COSTS OF GLOBAL WATER FOOTPRINTS

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Introduction:

Water is an essential resource for all living beings and that is why it is known as elixir of life of earth. The availability of water resources plays a crucial role in the economic growth of a country (Allan, 1997). However, there is an uneven distribution of water across the world, with some nations having an abundance of water while others do not. This has resulted in several poor countries still struggling to acquire water resources. If a water-rich nation produces and exports water-intensive products to a water-scarce nation, the importing country can save the water that would have been used for the production process. This saved water can be utilized for other water-intensive processes, thus helping to improve global water usage efficiency and achieve water security in regions of the world that lack water resources. In this way, countries can support one another in their water needs.

Virtual water:

The concept of virtual water, also known as water foot print or embedded water, was first introduced by Professor John Anthony Allan in the 1990s (Allan, 1993, 1998; Chapagain and Orr, 2009; Ridoutt, 2015). It involves quantifying the amount of water needed to produce a particular product or service, and serves as a tool to measure its water footprint. For instance, the virtual water of a cup of coffee includes the water utilized in growing, transporting, roasting the beans, and making the coffee. Similarly, the virtual water of a cotton t-shirt encompasses the water required in cultivating, processing, and manufacturing the t-shirt from cotton.

Understanding the concept of virtual water is crucial because it enables us to recognize the hidden water usage associated with products and services, allowing us to make informed decisions about consumption. This understanding also aids in the identification of water-intensive products and services. Importing low virtual water content products is beneficial for water-scarce regions, allowing them to preserve their own water resources for essential purposes.

Moreover, comprehending the virtual water concept is significant for water management. By having an awareness of the virtual water content of products and services, water managers can make informed decisions about water allocation. For instance, if a crop necessitates a large amount of water, water managers can allocate water resources to crops with a lower virtual water content. This can assist in the conservation of water resources and ensure efficient water allocation.

The virtual water concept is useful in evaluating the environmental impact of goods and services. According to a study by the Water Footprint Network, a kilogram of beef has a higher virtual water content compared to a kilogram of vegetables. Hence, a shift towards a plant-based diet could significantly contribute to water conservation and environmental sustainability.

Virtual water trade:

World virtual water trade refers to the movement of water, embedded in traded commodities, from water-rich to water-scarce regions. This trade is driven by the increasing demand for water-intensive goods, such as crops, livestock, and industrial products, in water-scarce regions (Allan, 2003). Virtual water trade allows water-scarce regions to import water-intensive products, thereby reducing their dependence on local water resources. However, it also raises concerns about the sustainability of water use in water-rich regions and the potential for water conflicts between trading partners (Hoekstra, 2009). The concept of virtual water trade highlights the interdependence of global water resources and the need for integrated water management strategies to ensure water security for all (Oki and Kanae, 2004).

Virtual water trade is a concept that has gained increasing attention from individuals concerned with water management, particularly in relation to water-intensive food production. It refers to the water utilized in the manufacturing process of industrial or agricultural goods. The implications of virtual water are significant for international trade because regions with water scarcity may import water-intensive products from water-rich regions. This implies that water-rich regions are essentially exporting water. For instance, the virtual water content of one kilogram of beef is approximately 15,000 liters, implying that when a water-scarce region imports one kilogram of beef, it effectively imports 15,000 liters of water ((Chapagain and Hoekstra, 2003). Similarly, the virtual water content of one kilogram of grain is between 1,000-2,000kg, while the production of a 32-megabyte computer chip of 2 grams requires 32kg of water. When a country exports one metric ton of wheat to another country, it loses 1,500 cubic meters of water, while the importing country gains the same amount of water (Zimmer and Renault, 2003). Consequently, there is a hidden flow of water when countries trade agricultural or industrial goods. This flow of water is referred to as virtual water trade, and it has sparked a debate about its fairness. While some argue that water-rich regions should receive compensation for the virtual water they export, others contend that virtual water trade is a natural consequence of globalization.

Significance:

Water is essential for the survival of all living organisms, and while humans require 2-4 liters of water daily for drinking, food production requires a much larger amount. As the global population grows and water resources become increasingly scarce, policymakers are looking for ways to efficiently manage water to meet the needs of everyone on Earth. Virtual water trade has emerged as a potential solution to this problem. The importance of virtual water trade is likely to increase as food trade grows, especially for water-intensive products like cereal and meat. When one country exports a water-intensive product, it is essentially exporting virtual water, which can help support the water needs of other countries. This is particularly important in regions where water is scarce, and virtual water trade has become a key component of water management at both the global and regional levels.

Virtual water trade refers to the water required to produce goods and services that are traded between countries. It is a concept that was first introduced by Tony Allan in 1993 (Allan, 1993) and has since gained significant attention in the field of water resource management, international trade, and environmental sustainability. The significance of virtual water trade can be understood from the following points:

Water scarcity mitigation: Virtual water trade allows water-scarce countries to import water-intensive goods instead of producing them domestically, thus reducing their water footprint and mitigating water scarcity

Economic benefits: Virtual water trade can provide economic benefits by allowing countries to specialize in the production of goods that are water-efficient and trade them with countries that are water-intensive This can lead to increased efficiency and productivity, and generate economic growth and development (Kumar and Singh, 2012).

Environmental benefits: Virtual water trade can also have environmental benefits by reducing the amount of water required to produce goods, thus reducing the overall water footprint and the associated environmental impacts (Chapagain and Hoekstra, 2011).

Global water security: Virtual water trade can contribute to global water security by allowing water-scarce countries to import water-intensive goods, thus reducing the pressure on their own water resources and promoting sustainable water use.

Political implications: Virtual water trade can have political implications as countries may use it as a tool for geopolitical influence and power.

Tony Allan proposes a political argument that highlights the potential of net import of virtual water in water-scarce nations as an alternative source of water, which can ease pressure on the nation's own resources. This approach can effectively address geographical challenges and help prevent conflicts over water, as stated in Allan's work in 1998. Moreover, the concept of virtual water also has an economic argument rooted in the International Trade Theory. The theory suggests that nations should export products in which they have a comparative or relative advantage in production and import products in which they have a comparative disadvantage. Therefore, trading virtual water between nations could enhance global water use efficiency.

Compared to other natural resources like land and energy, research on water resource use in relation to consumption patterns has been limited. However, some studies have examined the impact of different diets on water usage. For example, a survival diet necessitates 1 cubic meter of water per person per day, while an animal-based diet requires about 10 m3/cap/day. Diets commonly consumed range from 2.5 m3/cap/day in regions with low animal product consumption, such as North Africa, to 5 m3/cap/day in regions with high animal product consumption, such as Europe or the USA.

A comprehensive study to calculate the water footprints of nations has been conducted, which shows that Belgium and the Netherlands have a relatively high-water footprint per capita of around 2000 m3/yr. Japan, Mexico, and the USA have an average water footprint of around 1000 m3/yr. per capita. On the other hand, China, India, and Indonesia have a relatively low water footprint of around 500 m3/yr. per capita. (Shiklomanov, 2000).

The experts in virtual water trade predict that it will become increasingly important and widely used to alleviate water scarcity issues at both local and global levels. To achieve this, it is necessary to develop and disseminate standard procedures for virtual water accounting and references. Furthermore, understanding a nation's virtual water trade balance is crucial for developing a rational national policy regarding virtual water trade. It is imperative to conduct further research to investigate the natural, social, and economic implications of utilizing virtual water trade as a strategic instrument in water policy. Additionally, instruments should be developed to analyze the impact of virtual water on local socio-economic and cultural conditions, while considering a nation's broader objectives such as promoting economic growth, creating employment, reducing poverty, and providing national security. When analyzing trade in food and other water-containing products, it is important to consider not only virtual water trade but also virtual labor, virtual land, and other non-water factors. To expand virtual water analysis, countries like China, where there is a significant issue of domestic virtual water trade, should include internal trade within their virtual water accounting.(Hoekstra and Hung, 2002)

Table 1: Virtual water content of a few selected products

Sl. No	Products	Virtual Water Content (m^3/ton)*
1	Wheat	1150-2000
2	Rice	1400-3600
3	Maize	450-1900
4	Potatoes	105-160
5	Soybean	2300-2500
6	Beef	13500-20700
7	Pork	4600-5900
8	Poultry	2900-4500
9	Eggs	2700-4600
10	Milk	560-870
11	Cheese	5290

Conclusion:

The concept of virtual water is an important tool for understanding the hidden water use behind products and services. It allows us to make informed choices about what we consume and helps water-scarce regions to conserve their water resources. Virtual water also has significant implications for international trade, water management, and the environment. As the world’s population continues to grow and water resources become scarcer, the concept of virtual water will become increasingly important for sustainable water management.

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MULTIGENE ENGINEERING IN PLANTS

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Abstract:

Through conventional breeding methods, it is rarely possible to incorporate all types of resistance genes governing different biotic and abiotic stresses into a single plant. There is a need for novel transgenic technology to achieve Multi Gene Transfer (MGT). The various methods followed to achieve this include crossing transgenic lines, sequential transformation, co-transformation, chloroplast transformation and site-specific integration by homologous recombination. Essentially all these methods aim to achieve the creation of a SMART locus, *i.e.* one containing *stable multiple arrays of transgenes*. Through the MGT approach we can also achieve nutritious food supply by incorporating various genes governing nutrient biosynthesis pathway.

Keywords: Multigene, co-transformation, vector, chloroplast, Agrobacterium

Introduction:

Off late trend of rapidly increasing human population all over the globe, there is a need of increased food production to meet the food requirement coupled with the major constraints of decreased cultivable area, increased land degradation, changing climatic condition and major threats in crop production like insects, diseases and abiotic stresses. To mitigate these problems there is a demand for the crop varieties and hybrids that can yield much better with increased productivity even in all types of unfavorable conditions and also there is a need of nutritious food supply to the hunger world.

Multigene engineering means incorporating various multiple gene governing resistance against different stresses and gene governing various quality traits into a single plant.

Multigene engineering enables us to transfer different genes governing resistance against different diseases and insects to a single outstanding genotype to achieve a resistant variety, to change the entire metabolic pathway for the biosynthesis of required nutrients, to express multimeric proteins or protein complexes, and to study complex genetic control circuits and regulatory hierarchies.

Importance of multigene engineering

The complete metabolic pathway can be altered through multiple gene transformation, includes multimeric proteins or protein complexes and analyse complex regulatory networks and genetic control circuits. Plant genetic engineering will need to manipulate complicated metabolic or regulatory networks involving several genes because the majority of agronomic traits are polygenic in nature. The integration of many transgenes into the plant genome is necessary to redirect complex biosynthetic pathways and alter polygenic agronomic characteristics while assuring their permanent inheritance and expression in subsequent generations. Multiple genes must also be introduced and expressed in plants in order to manipulate secondary metabolisms and produce multimeric proteins of biological or pharmacological value. Combining the production of antifungal proteins with several mechanisms of action, which also necessitates the incorporation of numerous transgenes into the plant genome, can result in a more resilient antifungal resistance. So the transfer, stable integration and expression of multiple genes into the plant genome is known as multiple gene transformation. Naqvi *et al.* (2010)

Methods for multigene engineering

1. Nuclear genome transformation
2. Chloroplast genome transformation

1. Nuclear gene transformation

In nuclear gene transformation there are 2 types

I. Conventional stacking methods

a. Crossing transgenic lines
b. Sequential transformation

II. Co-transformation

a. *Agrobacterium* mediated
b. Direct method

I a. Crossing transgenic lines

In this, two plants are crossed to produce offspring with characteristics from both parents. In the case of transgenic plants, one parent receives a first gene and the other parent receives a second gene. When the two transgenic parental lines are crossed, the progeny either contain the two transgenes in 25% (if both parents are hemizygous for the transgenes) or in all cases (if both parents are homozygous for the transgenes). For instance, Datta *et al.* (2002) developed disease and pest resistance rice by crossing plants expressing the *Xa21* gene (resistance to bacterial blight) with plants expressing both a *Bt* fusion gene and a chitinase gene (confers resistance to yellow stem borer and tolerance to sheath blight respectively).

Advantages and limitations of iterative strategy

This is a simple technique and includes transfer of pollens from one parent to the other, but precautions should be taken to avoid the self-pollination. The main disadvantage is only applicable to sexually propagated crops and obtaining homozygous plants is difficult. Also, introduced transgenes are not linked and can integrate at random locus of plant genome. This indicates that they will segregate apart again in subsequent generations.

I b. Sequential transformation

Sequential transformation, or repeated transformation or re-transformation, is defined as the repetitive insertion of transgenes into a plant. For example, Single-preek *et al.* (2003) introduced two-gene glyoxalase pathway into tobacco that led to enhanced salinity tolerance.

Advantages and limitations

This approach can also be used for vegetatively propagated organisms, and it prevents recombination from causing the loss of traits that make up a desirable combination. However, it is labor-intensive, takes a lot of time, needs one selectable marker for each transgene, and can silence genes.

II. Co-transformation

It is the simultaneous introduction of multiple genes in a cell followed by the integration of genes in cell genome. Genes are either present on the same plasmid that is single plasmid co-transformation of linked genes or on separate plasmids that is multiple plasmid co-transformations of unlinked genes. Single plasmid co-transformation is the robust strategy for small number of input genes, but as number increases, the vectors become unstable. In this, the genes to be introduced are linked as a single piece of DNA, with each gene having its own promoter and terminator. Daniell and Dhingra (2002)

This method has advantage over the other methods that the integration of linked genes will take place on a single locus. So, the transgenes will be inherited stably to the next generations. Other multiple plasmids co-transformation involves several plasmids each carrying a different transgene. It has the benefit of making the assembly of the various expression cassettes technically simpler. The main drawback is that T-DNA integration can take place at any chromosomal locus, which will make further breeding difficult. Technically challenging aspects of co-transformation include the problem of gene silencing, the challenge of linking together complicated plasmids with multiple gene cassettes, and undesirable insertion of complex T-DNA molecules from many sources. Dhanoa *et al.* (2019)

Steps involved in co-transformation

1. **Selection of desirable genes with their promoters**
2. **Selection of suitable vector and transformation vectors systems**
3. **Transfer of desirable genes into suitable vector**
4. **Transfer of vectors into the plant genome**
5. **Screening of transgenic plant**

Desirable genes or biotic and abiotic stress resistance genes can be obtained through NCBI or gene banks. They provide desirable genes for the transformation work, for this many procedures has to undergo and as well as information regarding the work should be provided to the gene banks.

2. Selection of suitable vector and transformation vector systems

Vectors

- A vector is a circular DNA capable of independent existence and replication.
- Examples: plasmid and viruses

In case of plants, Agrobacterium plasmids Ti and Ri are most commonly used vectors

Structure of Ti plasmid

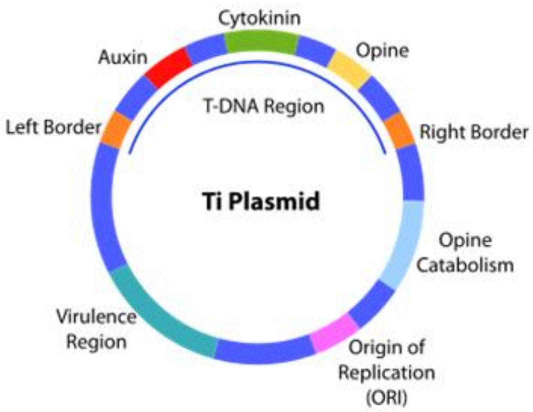


Fig. 1: Structure of Ti plasmid

Types of modified DNA vectors:

- ✓ Co-integrate vector
- ✓ Binary vector

Co-transformation (linked genes):

Agrobacterium, standard binary vectors:

- Multiple genes can be incorporated within a single T-DNA.
- It is efficient for a small number of small transgenes having single transgenic locus.
- Not suitable for large genes or large numbers of genes because the binary vectors become unstable and they undergo spontaneous deletions.
- Upper limit size is 50 kb.

Direct transfer, conventional vectors:

- Multiple genes assembled within a single transforming DNA segment.
- It is also efficient for a small number of small transgenes having single transgenic locus.
- Ineffective for very large genes or large numbers of genes due to the likelihood of fragmentation.
- Upper limit size is 80 kb

Agrobacterium, high-capacity binary vectors (BIBAC, TAC):

- Multiple genes inserted within a single T-DNA housed on a high-capacity vector.
- It carries large genes or larger numbers of small genes effectively.
- Upper limit size is 200 kb carrying single transgenic locus.
- The cumbersome cloning more numbers of genes in series, although Gateway vectors address this to some extent.

Assisted direct transfer (high-capacity transfer):

- With the help of protective structures such as bioactive beads ease the direct transfer of large DNA fragments.
- It enables the introduction of very large DNA fragments, up to size of 200 kb.
- Single transgenic locus.
- Incompatible with particle bombardment thus less effective in large-scale experiments.

Artificial plant chromosomes:

- Transgenes which is attached to DNA vectors containing the minimum components are required to act as plant chromosomes.
- The Upper limit is unknown, likely to be in the Mb range, and potential for tens or hundreds of transgenes to be transferred simultaneously.
- Early-stage technology currently is available in maize only.
- Technically challenging.

Operon system:

- The genes arranged in tandem in a bacterial operon and expressed as a polycistronic mRNA.
- It allows the coordinate regulation of multiple genes.
- It is only suitable for plastid transformation.
- The plastid transformation only applicable in a limited number of species.
- The maternal inheritance of transgene.

Co-transformation (unlinked genes):

Agrobacterium, standard binary vectors:

- Multiple T-DNAs included on a binary vector or (more usually) multiple bacterial strains each carrying a different transgene used for simultaneous infection of plant tissue.
- It is simple and convenient for a small number of transgenes.
- The two different T-DNAs often integrate back-to-back at the same locus depending on the strain.
- It is unsuitable for more than two transgenes if single transgenic locus is required.

Direct transfer, conventional vectors:

- Multiple genes on the multiple plasmids transferred to plant simultaneously.
- Effective for many transgenes.
- Regardless of transgene number, this method tends to generate a single transgenic locus.
- It tends to generate complex loci

Plant Multigene Transformation Vector Systems

- Restriction Enzyme-Based Assembly
- Homologous Recombination in Yeast
- Gibson Assembly
- Cre Site-Specific Recombination
- Gateway recombination

Although the assembly and transformation of a large transformation construct carrying multiple genes have been a challenge, various multigene vector systems using a variety of approaches have been developed to facilitate the stacking and delivery of different numbers of genes into plants. Currently, these approaches have employed the use of rare cutting homing endonucleases and zinc-finger nucleases type IIS restriction enzymes (Golden Gate cloning), Cre/loxP recombination, Gateway recombination, Gibson Assembly, and homologous recombination in yeast Shih *et al.* (2016). The multigene vector systems with easy manipulation and large DNA-carrying capacity (e.g., using artificial chromosomes as vector backbone) have more advantages. An example is the recently developed Trans-Gene Stacking II (TGS II) system.

Chloroplast transformation

In this technology, Genes can be introduced into chloroplast genome via homologous recombination. As opposed to nuclear genes in plants, which transcribe singly, chloroplast genes are often present in operons. First chloroplast transformation was done by Boynton and gillham in 1988 in alga *Chlamydomonas reinhardti* and in higher plants, first chloroplast transformation done in 1990 by Pal maliga and coworkers in tobacco. Chloroplast transformation requires a robust method of DNA delivery into chloroplast, presence of active homologous recombination machinery in the plastid, and the availability of highly efficient selection and regeneration protocol. Daniell *et al.* (2005)

Characteristics of chloroplast engineering

1. Maternally inherited
2. Multi gene transfer can be conveniently carried out
3. High level of gene expression
4. Not linked with gene silencing
5. Single promoter can control the expression of genes

Conditions to be full filled to achieve plastid transformation

- A robust method of DNA delivery into chloroplast
- The presence of active homologous recombination machinery in the plastid
- The availability of highly efficient selection and regeneration protocols for transplastomic cells.

Approaches in chloroplast transformation

- Biolistic method
- PEG-mediated
- Carbon nanotubes carriers
- UV-laser microbeam
- Agrobacterium-mediated transformation

1. **Biolistic approach steps**

Steps:

- E.coli plasmid in which selectable marker gene and gene of our interst introduced into chloroplast of detached leaves using biolistic approach.
- Leaf is then cut into pieces grown on appropriate regeneration medium containing the appropriate antibiotic depending on the selectable marker used
- After two rounds of selection the regenerated plants transcribed into transplastomic plants.

Methods/ Techniques of Plastid Transformation:

Transformation refers to the process of introducing DNA into the genome of an organism. For genetic transformation two approaches have been applied to stable genetic modification of plastids: integration of transforming DNA by homologous recombination/targeting and introduction of independently replicating shuttle vectors. Stable genetic transformation in plants consists of three phases: 1) Transfer of cloned DNA to the appropriate target tissue; 2) Selection of cells that have taken up the transforming DNA and integrated it into the genome 3) Regeneration of transformed plantlets capable of continued propagation or sexual reproduction. For the majority of plants of agricultural relevance, this procedure is currently standard practice for producing nuclear transformants. However, each step of the transformation process faces a unique set of difficulties due to the distinctive structural and metabolic properties of plastids. (Fig.2.)

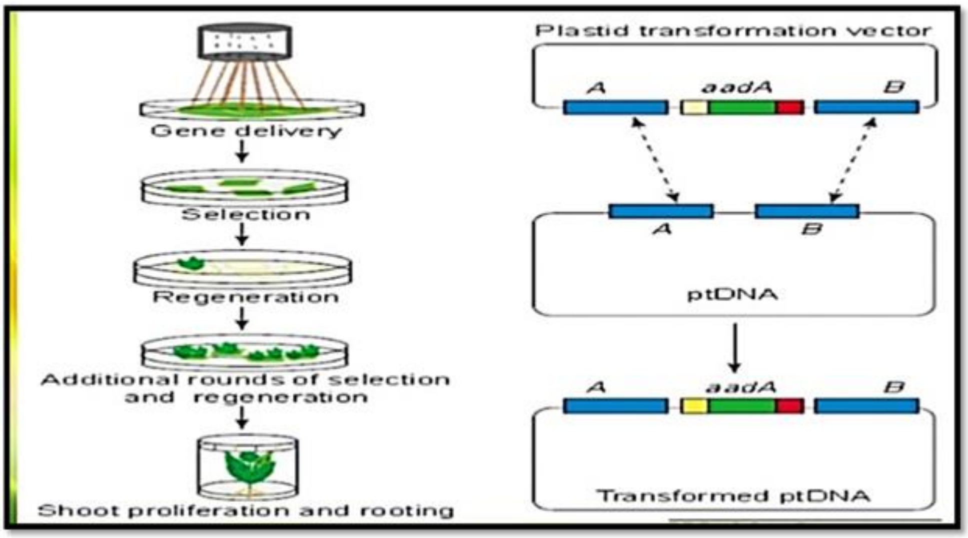
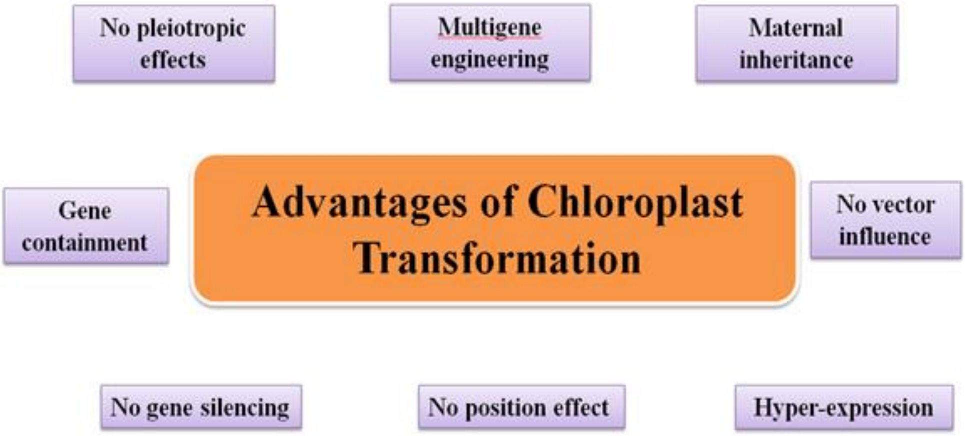


Fig. 2: Chloroplast transformation

Challenges faced by chloroplast transformation

- Applicable to limited plant species
- Unavailability of genome sequence
- It requires homologous flanking regions for recombination and insertion of genes
- Phenotypic alterations of transplastomic plants
- Gene expression in non-green plastids
- Degradation of target gene product
- Low success rate of gene insertion into chloroplast genomes

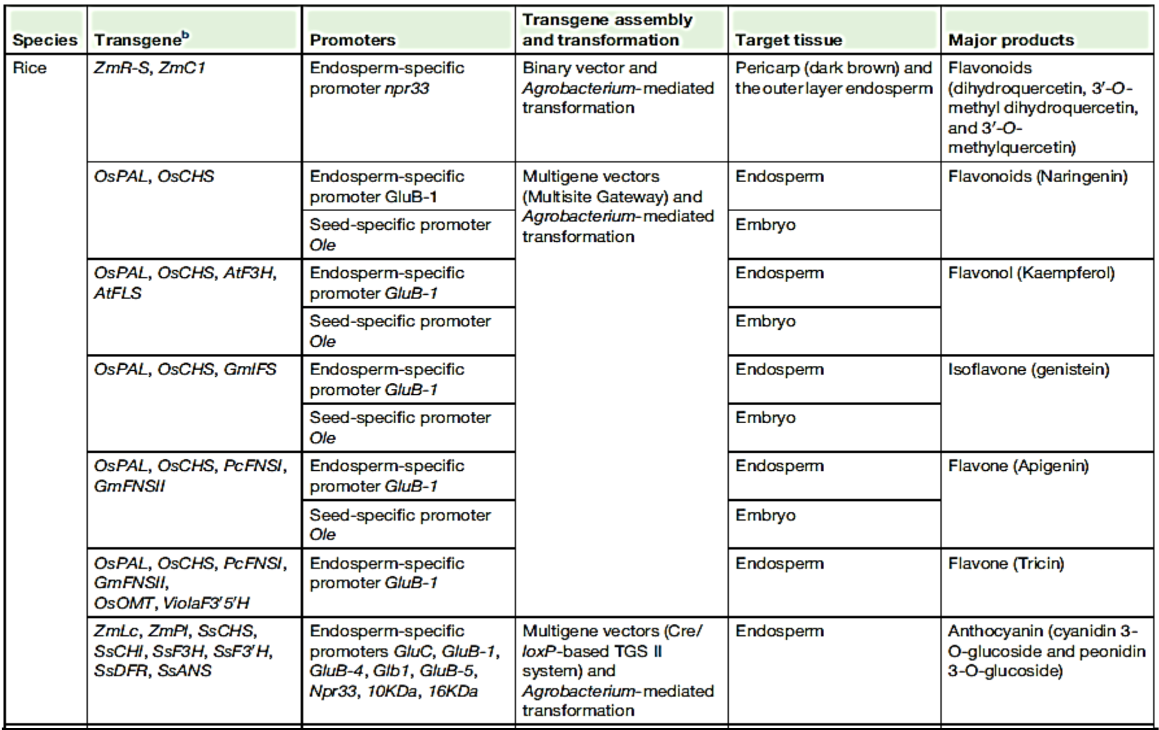


Applications of multiple gene transformation

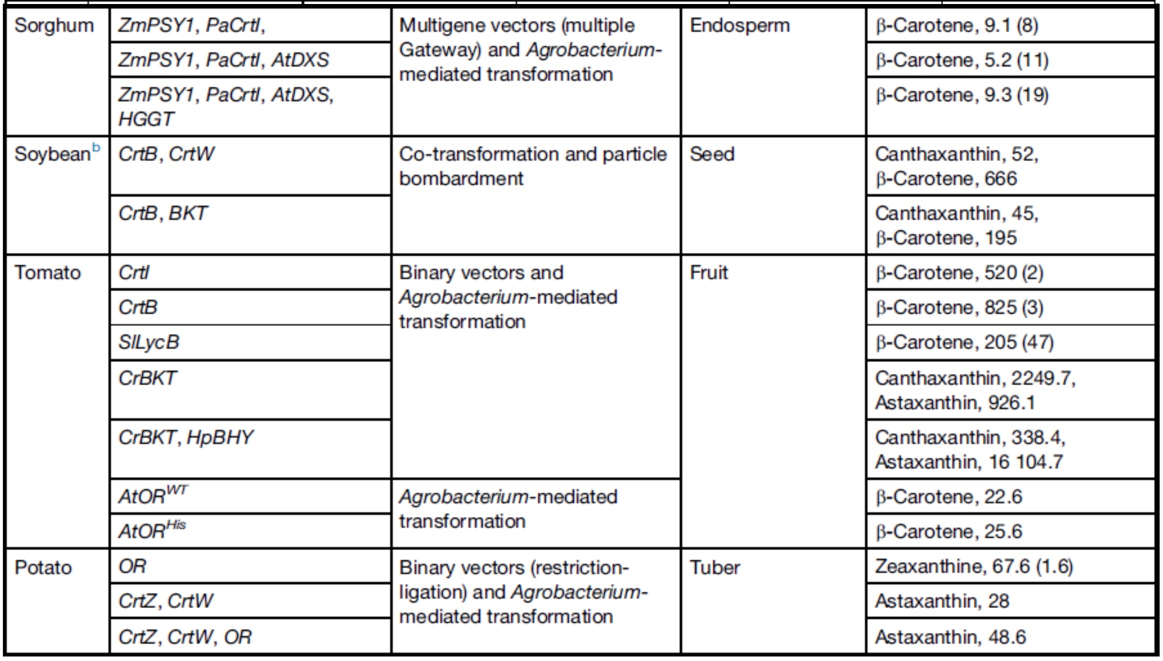
- Enhancement of nutrition

  Ex: Carotenoids and Vitamin E in Canola Fujisawa *et al.* (2009)
- Resistance to biotic and abiotic stress Datta *et al.* (2002)
- Development of super nutritious maize Naqvi *et al.* (2009)

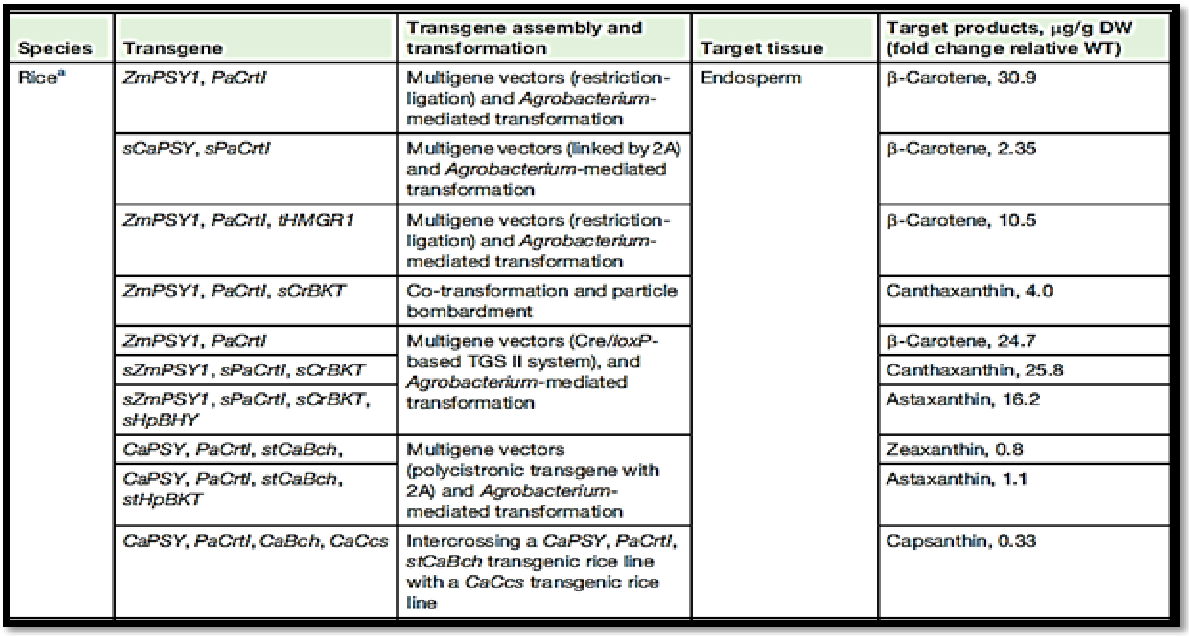
Achievements in multigene transformation



Species	**Transgene**[b]	**Promoters**	**Transgene assembly and transformation**	**Target tissue**	**Major products**
Rice	*ZmR-S, ZmC1*	Endosperm-specific promoter *npr33*	Binary vector and *Agrobacterium*-mediated transformation	Pericarp (dark brown) and the outer layer endosperm	Flavonoids (dihydroquercetin, 3′-*O*-methyl dihydroquercetin, and 3′-*O*-methylquercetin)
	OsPAL, OsCHS	Endosperm-specific promoter GluB-1	Multigene vectors (Multisite Gateway) and *Agrobacterium*-mediated transformation	Endosperm	Flavonoids (Naringenin)
		Seed-specific promoter *Ole*		Embryo	
	OsPAL, OsCHS, AtF3H, AtFLS	Endosperm-specific promoter *GluB-1*		Endosperm	Flavonol (Kaempferol)
		Seed-specific promoter *Ole*		Embryo	
	OsPAL, OsCHS, GmIFS	Endosperm-specific promoter *GluB-1*		Endosperm	Isoflavone (genistein)
		Seed-specific promoter *Ole*		Embryo	
	OsPAL, OsCHS, PcFNSI, GmFNSII	Endosperm-specific promoter *GluB-1*		Endosperm	Flavone (Apigenin)
		Seed-specific promoter *Ole*		Embryo	
	OsPAL, OsCHS, PcFNSI, GmFNSII, OsOMT, ViolaF3′5′H	Endosperm-specific promoter *GluB-1*		Endosperm	Flavone (Tricin)
	ZmLc, ZmPl, SsCHS, SsCHI, SsF3H, SsF3′H, SsDFR, SsANS	Endosperm-specific promoters *GluC, GluB-1, GluB-4, Glb1, GluB-5, Npr33, 10KDa, 16KDa*	Multigene vectors (Cre/*loxP*-based TGS II system) and *Agrobacterium*-mediated transformation	Endosperm	Anthocyanin (cyanidin 3-O-glucoside and peonidin 3-O-glucoside)



Sorghum	*ZmPSY1, PaCrtI,*	Multigene vectors (multiple Gateway) and *Agrobacterium*-mediated transformation	Endosperm	β-Carotene, 9.1 (8)
	ZmPSY1, PaCrtI, AtDXS			β-Carotene, 5.2 (11)
	ZmPSY1, PaCrtI, AtDXS, HGGT			β-Carotene, 9.3 (19)
Soybean[b]	*CrtB, CrtW*	Co-transformation and particle bombardment	Seed	Canthaxanthin, 52, β-Carotene, 666
	CrtB, BKT			Canthaxanthin, 45, β-Carotene, 195
Tomato	*CrtI*	Binary vectors and *Agrobacterium*-mediated transformation	Fruit	β-Carotene, 520 (2)
	CrtB			β-Carotene, 825 (3)
	SlLycB			β-Carotene, 205 (47)
	CrBKT			Canthaxanthin, 2249.7, Astaxanthin, 926.1
	CrBKT, HpBHY			Canthaxanthin, 338.4, Astaxanthin, 16 104.7
	AtOR^{WT}	*Agrobacterium*-mediated transformation		β-Carotene, 22.6
	AtOR^{His}			β-Carotene, 25.6
Potato	*OR*	Binary vectors (restriction-ligation) and *Agrobacterium*-mediated transformation	Tuber	Zeaxanthine, 67.6 (1.6)
	CrtZ, CrtW			Astaxanthin, 28
	CrtZ, CrtW, OR			Astaxanthin, 48.6



Species	Transgene	Transgene assembly and transformation	Target tissue	Target products, μg/g DW (fold change relative WT)
Rice[a]	*ZmPSY1*, *PaCrtI*	Multigene vectors (restriction-ligation) and *Agrobacterium*-mediated transformation	Endosperm	β-Carotene, 30.9
	sCaPSY, *sPaCrtI*	Multigene vectors (linked by 2A) and *Agrobacterium*-mediated transformation		β-Carotene, 2.35
	ZmPSY1, *PaCrtI*, *tHMGR1*	Multigene vectors (restriction-ligation) and *Agrobacterium*-mediated transformation		β-Carotene, 10.5
	ZmPSY1, *PaCrtI*, *sCrBKT*	Co-transformation and particle bombardment		Canthaxanthin, 4.0
	ZmPSY1, *PaCrtI*	Multigene vectors (Cre/*loxP*-based TGS II system), and *Agrobacterium*-mediated transformation		β-Carotene, 24.7
	sZmPSY1, *sPaCrtI*, *sCrBKT*			Canthaxanthin, 25.8
	sZmPSY1, *sPaCrtI*, *sCrBKT*, *sHpBHY*			Astaxanthin, 16.2
	CaPSY, *PaCrtI*, *stCaBch*,	Multigene vectors (polycistronic transgene with 2A) and *Agrobacterium*-mediated transformation		Zeaxanthin, 0.8
	CaPSY, *PaCrtI*, *stCaBch*, *stHpBKT*			Astaxanthin, 1.1
	CaPSY, *PaCrtI*, *CaBch*, *CaCcs*	Intercrossing a *CaPSY*, *PaCrtI*, *stCaBch* transgenic rice line with a *CaCcs* transgenic rice line		Capsanthin, 0.33

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RICE FOODBORNE DISEASE DETECTION USING MACHINE LEARNING

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Rice is considered a staple food in many parts of the world, particularly in Asia, where it is a primary dietary component for a large portion of the population. Here are some reasons why rice has become a staple food:

Availability: Rice is one of the most widely cultivated and produced crops globally. It can be grown in diverse climatic conditions, ranging from wetlands to upland areas, making it accessible to a wide range of regions and populations.

Nutritional Value: Rice is a good source of carbohydrates, which provide energy for the body. It also contains essential nutrients such as vitamins, minerals, and dietary fiber. While it may not be as rich in protein and certain other nutrients compared to other crops, it still plays a significant role in meeting caloric and nutritional needs, especially when combined with other food sources.

Caloric Efficiency: Rice is a calorie-dense food, meaning it provides a relatively high amount of calories per unit of weight or volume. This makes it an efficient source of energy, particularly in regions where access to food may be limited or where people engage in physically demanding work.

Versatility: Rice can be prepared and consumed in various ways, such as steamed, boiled, fried, or ground into flour. It can be the main component of a meal or used as an accompaniment to other dishes. Its versatility allows it to be incorporated into different cuisines and adapted to local tastes and preferences.

Economic Accessibility: Rice is often affordable and widely available, making it accessible to people across different socioeconomic backgrounds. It can be grown and purchased at relatively low costs, contributing to its widespread consumption and affordability as a staple food.

Cultural Significance: Rice has deep cultural and historical significance in many societies. It is often an integral part of traditional rituals, celebrations, and culinary traditions. Its cultural importance further reinforces its status as a staple food.

It's important to note that while rice is a staple food for many, dietary patterns can vary significantly among different regions and individuals. Other staple foods, such as wheat, maize, potatoes, or cassava, are consumed in different parts of the world, depending on local agricultural practices, cultural preferences, and dietary habits.

To reduce rice diseases and improve production, here are some strategies that can be implemented:

Crop Rotation: Implementing crop rotation practices can help break the disease cycle by alternating the cultivation of rice with other non-host crops. This reduces the buildup of pathogens and pests in the soil, minimizing the risk of disease outbreaks.

Genetic Resistance: Breeding and cultivating rice varieties that are resistant or tolerant to specific diseases can significantly reduce the impact of diseases. Plant breeders work on developing disease-resistant varieties through traditional breeding techniques or genetic engineering.

Proper Field Management: Good agricultural practices, such as maintaining proper water management, adequate nutrient supply, and effective weed control, can contribute to healthier rice plants and reduce the likelihood of disease development.

Disease Monitoring and Early Detection: Regular monitoring of rice fields for signs of disease can help detect outbreaks early. Prompt identification and diagnosis of diseases enable timely implementation of control measures to limit their spread.

Integrated Pest Management (IPM): Adopting IPM strategies can help manage pests and diseases effectively while minimizing the use of chemical pesticides. IPM includes techniques such as biological control, cultural practices, and judicious pesticide application.

Seed Treatment: Treating seeds with fungicides or bio control agents before planting can protect young seedlings from soil-borne diseases and promote healthy plant establishment.

Proper Crop Nutrition: Providing balanced and optimal nutrition to rice plants enhances their overall health and resilience to diseases. Soil testing and appropriate fertilization practices ensure that plants receive essential nutrients.

Awareness and Education: Promoting awareness among farmers about common rice diseases, their symptoms, and control measures is crucial. Providing training and access to information on disease management practices can empower farmers to make informed decisions and take proactive measures.

Collaboration and Research: Collaboration between farmers, researchers, and agricultural extension services is essential for sharing knowledge, conducting research, and developing innovative solutions to address specific rice diseases and production challenges.

Sustainable Farming Practices: Implementing sustainable farming practices, such as organic farming, conservation agriculture, and agro ecological approaches can promote a healthier agro ecosystem and reduce the reliance on synthetic inputs, leading to improved long-term disease management and overall sustainability.

It's important to note that the specific strategies for disease management and production improvement may vary depending on the region, climate, and specific rice diseases prevalent in a given area. Local agricultural extension services and experts can provide tailored advice and guidance based on the specific conditions and challenges faced in a particular location.

Convolutional Neural Networks (CNNs) can be used to reduce and detect rice plant diseases through their ability to analyze and classify images. Here's how CNNs can be applied:

Dataset Collection: A large dataset of rice plant images is collected, containing both healthy plants and plants affected by various diseases. These images are annotated with labels indicating the presence of specific diseases.

Data Preprocessing: The collected images are preprocessed to ensure uniformity and enhance the training process. Preprocessing steps may include resizing the images, normalizing pixel values, and augmenting the dataset through techniques like rotation, flipping, or adding noise.

Model Architecture: A CNN model is designed to extract meaningful features from the rice plant images. The architecture typically consists of multiple convolutional layers, pooling layers, and fully connected layers. The convolutional layers apply filters to the input image, capturing local patterns and features. Pooling layers downsample the feature maps, reducing their spatial dimensions.

Training: The CNN model is trained on the preprocessed dataset. The images and their corresponding disease labels are fed into the model. During training, the model adjusts its internal parameters (weights and biases) to minimize the difference between the predicted disease labels and the ground truth labels. This process involves forward propagation, where the input images pass through the network, and backward propagation (backpropagation), where the model updates its parameters based on the calculated errors.

Disease Detection: Once the CNN model is trained, it can be used to detect diseases in rice plants. New, unseen images of rice plants are fed into the trained model. The model processes the images through its layers, extracting relevant features. The output layer provides predictions of the presence and type of diseases in the input images.

Disease Diagnosis: The predictions made by the CNN model can be used to diagnose rice plant diseases. By comparing the predicted disease labels with a predefined set of disease classes, the specific disease affecting a plant can be identified. This information can then be used for further actions, such as implementing targeted disease management strategies.

The key advantage of using CNNs for disease detection in rice plants is their ability to automatically learn and extract discriminative features from images, enabling accurate classification. By training the model on a diverse dataset, it can learn to recognize patterns associated with different diseases, helping in their detection. The CNN model can be a valuable tool for farmers, agronomists, and researchers, providing early detection and timely intervention to mitigate the impact of diseases, reduce crop losses, and optimize resource allocation in rice production.

Introduction to deep learning and convolutional neural networks (CNNs):

- Overview of deep learning and its applications in image recognition and classification
- Introduction to CNN architecture and its suitability for image analysis tasks
- Explanation of convolutional layers, pooling layers, and fully connected layers in CNNs
- Training CNN models to automatically learn discriminative features from rice plant disease images:
- Preprocessing and augmentation techniques for preparing rice plant disease images for training
- Designing CNN architectures specific to rice plant disease diagnosis
- Training CNN models using labeled image datasets of rice plant diseases
- Optimization techniques such as gradient descent and backpropagation for training CNNs

- Transfer learning and fine-tuning pre-trained CNN models for improved accuracy and efficiency:
- Overview of transfer learning and its benefits in limited data scenarios
- Utilizing pre-trained CNN models, such as VGG, ResNet, or Inception, for rice plant disease diagnosis
- Adapting pre-trained models to the rice plant disease dataset through fine-tuning
- Techniques for freezing and unfreezing specific layers during fine-tuning
- Evaluation and validation of deep learning models for rice plant disease diagnosis:
- Metrics for evaluating the performance of deep learning models, including accuracy, precision, recall, and F1 score
- Strategies for cross-validation and validation set selection to ensure robust model evaluation
- Handling imbalanced datasets and addressing biases in model predictions
- Interpretation of model performance and trade-offs between accuracy and computational complexity
- Advanced techniques and considerations in deep learning for rice plant disease diagnosis:
- Multi-class classification and handling multiple diseases in a single image
- Localization and segmentation of diseased regions in rice plant images
- Interpretability and explainability of deep learning models in rice plant disease diagnosis
- Model deployment and integration with other agricultural systems for real-time diagnosis

A CNN: What is it?

Similar to conventional supervised learning techniques, convolutional neural networks receive input images, identify each one's features, and then drag a grader over it.

Deep learning is a subfield of machine learning that focuses on training artificial neural networks to learn and make predictions from complex data representations. It has gained significant attention and achieved remarkable success in various fields, including computer vision, natural language processing, and speech recognition.

Convolutional Neural Networks (CNNs) are a specific type of deep learning model commonly used for image classification and object recognition tasks. They are designed to automatically learn and extract hierarchical features from input images, allowing them to understand the spatial relationships and patterns within the data.

However, features are automatically picked up! The laborious task of extracting and describing features is handled entirely by CNNs: during the training phase, the classification error is minimised to optimise both the classifiers and the features' parameters!

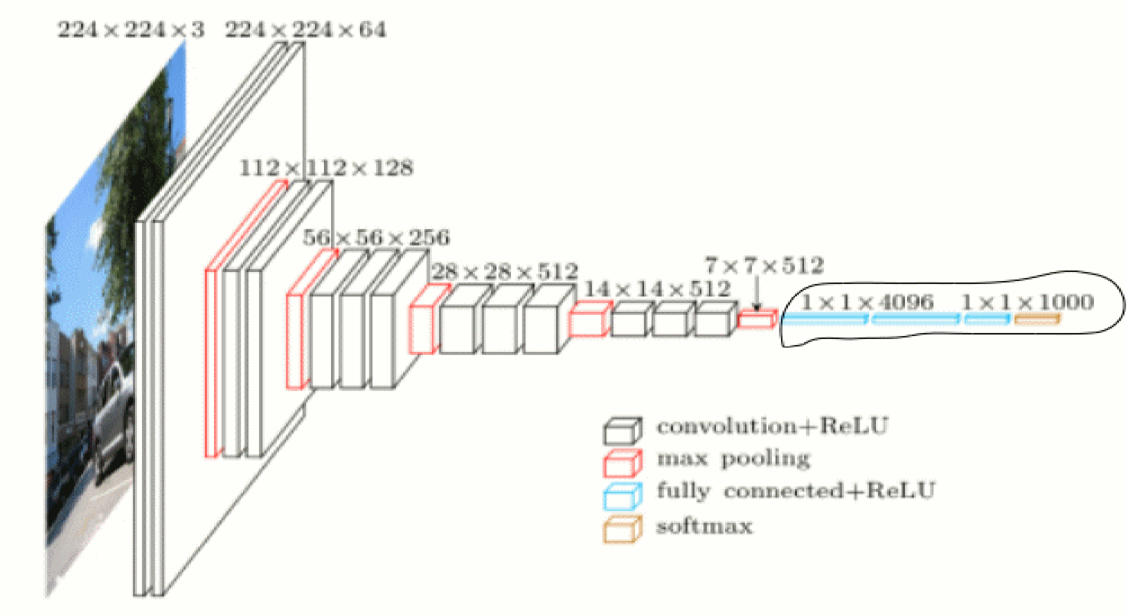

Fig.1: VGG 16 Architecture (CNN Model)

Although this is a type of neural networks, convolutional neural networks exhibit all the traits of neural networks. CNN, on the opposite hand, was created expressly to process input images. Therefore, their architecture is more detailed and is made up of two primary fundamental components.

Since it serves as a feature extractor, the first block defines the uniqueness of this kind of neural network. It accomplishes this by doing template matching through the use of convolution filtering processes. The first layer applies numerous convolution kernel filters to the image to produce "feature maps" that are then normalised (using an activation function) and/or scaled.

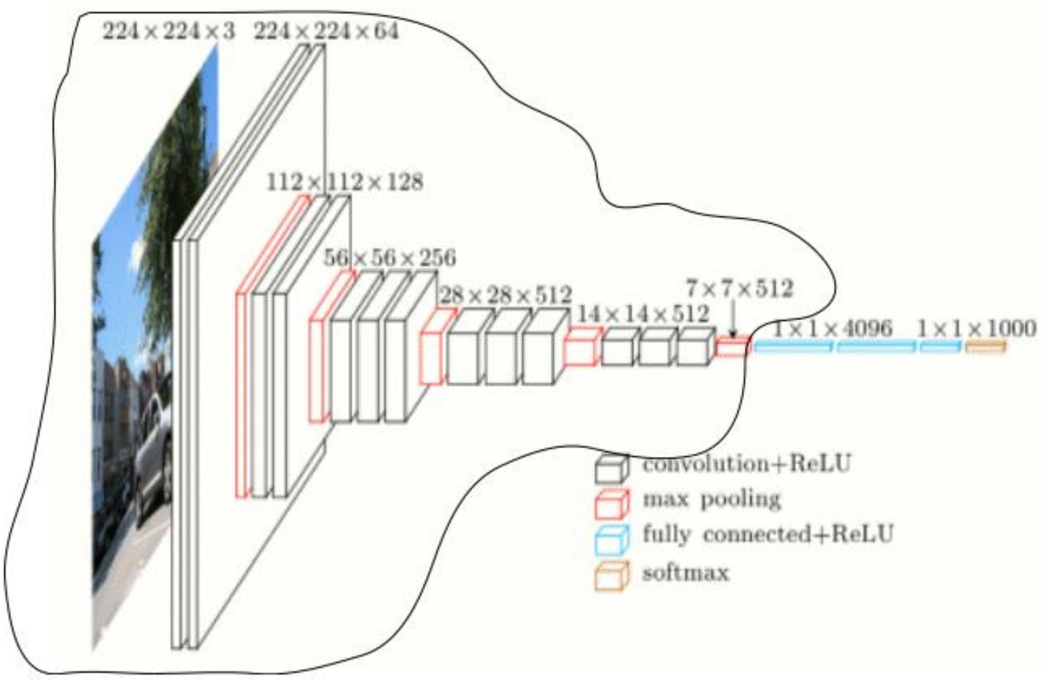

Fig. 2: The first block has a black border around

In fact, the second block occurs at the end of all classification neural networks and is not a hallmark of a CNN. To produce a new vector at the output, the input vector values are converted (using a number of linear combinations and activation functions). The chance that the image corresponds to class i is represented by element i in the final vector, which has as many elements as classes. As a result, each component has a value between 0 and 1, and the total is 1. The network's last layer, which uses a logistic function (binary classification) or a softmax function (multi-class classification) as an activation function, calculates these probabilities.

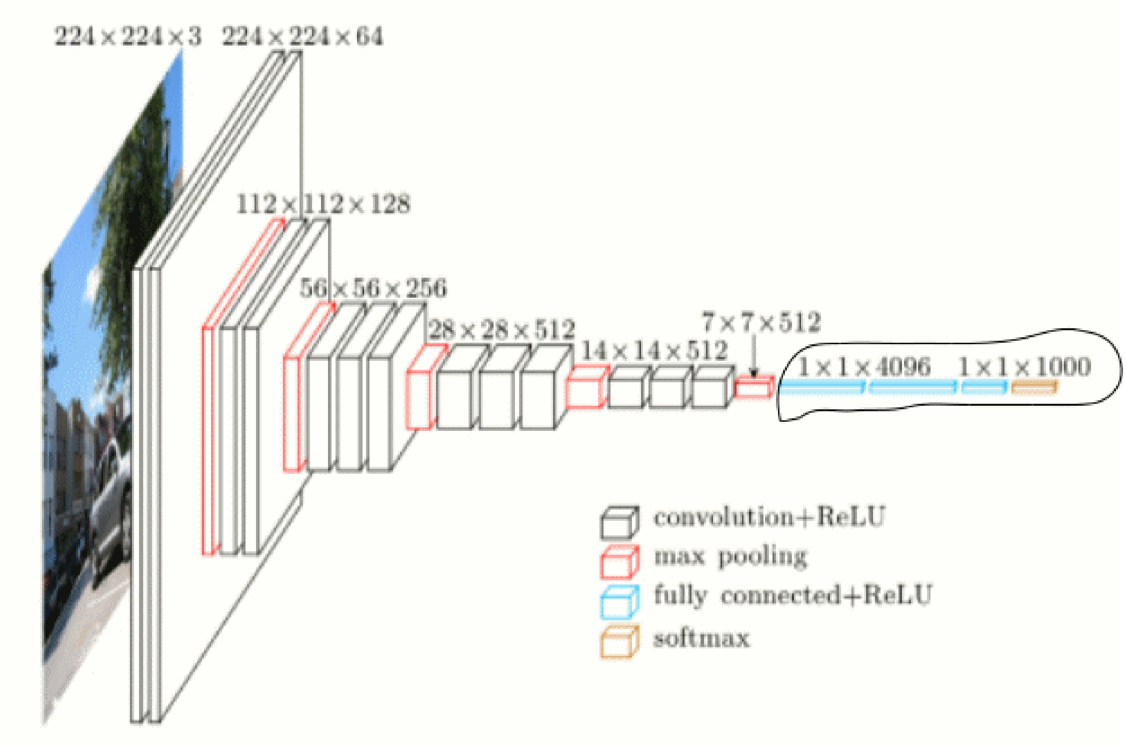

Fig. 3: Black surrounds the second block

Similar to conventional neural networks, gradient backpropagation is used to determine the parameters of the layers since it minimizes cross-entropy during training. These criteria, however, specifically correspond to the visual features in the instance of CNN.

The different CNN layers: The convolutional layer, the pooling layer, the ReLU correction layer, and the fully-connected layer are the four different types of layers that make up a convolutional neural network.

Input Layer: The input layer represents the raw input image. Each image is typically represented as a grid of pixels, where each pixel contains numerical values representing the intensity or color information.

1. Convolutional Layer: The convolutional layer consists of a set of learnable filters (also called kernels) that convolve across the input image. Each filter detects specific local patterns or features, such as edges, corners, or textures. The filters slide over the input image in small strides and perform element-wise multiplications and summations, generating feature maps or activation maps that highlight the presence of those features.

2. Activation Function: After the convolution operation, an activation function is applied element-wise to introduce non-linearity. The most commonly used activation function in CNNs is the Rectified Linear Unit (ReLU). ReLU sets all negative values to zero and keeps the positive values unchanged.
3. Pooling Layer: The pooling layer helps to reduce the spatial dimensions of the feature maps generated by the convolutional layer. It performs down sampling by partitioning the feature map into non-overlapping regions (e.g., 2x2 or 3x3) and taking the maximum (max pooling) or average (average pooling) value within each region. Pooling helps to extract the most important features while reducing computational complexity and controlling overfitting.
4. Fully Connected Layers: The output from the last pooling layer is flattened into a vector and connected to one or more fully connected layers. Each neuron in the fully connected layer is connected to all neurons in the previous layer. These layers perform high-level reasoning and learning of global patterns in the image. The fully connected layers have weights that are learned during the training process to make predictions based on the learned features.
5. Output Layer: The final layer of the CNN is the output layer. It consists of neurons equal to the number of classes in the classification problem. The activation function used in the output layer depends on the task at hand. For binary classification, a sigmoid activation function is commonly used, while for multi-class classification, a softmax activation function is used to produce class probabilities.

Overall, the diagram of a CNN would show the flow of information from the input layer through the convolutional layers, activation functions, pooling layers, fully connected layers, and finally to the output layer. Each layer performs specific operations to extract meaningful features and make predictions based on those features.

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OPTIMAL ALLOCATION OF FERTILIZERS AND IRRIGATION FOR MAXIMIZING FARM INCOME

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Introduction:

Agriculture plays an important role in ensuring food security and sustaining livelihoods around the world. In view of population growth, changing climate patterns, and the need for sustainable agricultural practices, it is important to optimize the allocation of inputs in farming involves strategic decision-making to maximize farm income while using available resources efficiently. Optimizing the allocation of inputs such as fertilizers and irrigation to maximize farm income involves considering various factors such as crop requirements, soil conditions, water availability, and economic considerations. By adopting efficient and effective strategies, farmers can increase productivity, reduce costs and promote environmental sustainability. Optimum use of fertilizers and allocation of irrigation is important to maximize farm income while ensuring environmental sustainability. Fertilizers provide essential nutrients to crops, while irrigation ensures an adequate water supply. However, improper allocation of these resources can result in economic losses, environmental degradation, and decreased productivity. On the other hand, irrigation is important to ensure the availability of water for crops, especially in areas with erratic rainfall. Inefficient irrigation practices can result in water wastage, waterlogging, salinization and increased production costs. The optimal allocation of fertilizers and irrigation practices is a complex task involving a variety of factors including soil conditions, crop type, climate and economic considerations. Optimum allocation of fertilizers and irrigation techniques are essential for sustainable agricultural practices, increasing crop yields and increasing farm income with minimized environmental impacts. Thus, the need for an integrated farm management system has emerged. Crop allocation, crop combination, and operational activities involved for better productivity are some of the most important decision variables that need to be optimized.

Role of fertilizers in maximizing farm income:

Fertilizers play an important role in modern agricultural practices by replenishing soil nutrients and enhancing crop growth. They replenish nutrients that are depleted through plant absorption, leaching and erosion. Optimum fertilizer allocation involves consideration of factors such as soil nutrient content, crop nutrient requirements and environmental considerations. Soil testing and analysis are fundamental tools for determining nutrient deficiencies and formulating an appropriate fertilizer plan. By applying the right types and amounts of fertilizers, farmers can optimize the availability of nutrients to crops, resulting in improved yields and increased farm incomes. Consequently, efficient fertilizer allocation can have a significant impact on farm income.

The following points outline the importance of fertilizers: -

1. Soil fertility: Fertilizers supply essential nutrients to the soil, promoting plant growth and crop yield. Understanding soil nutrient levels through soil testing helps farmers determine specific nutrient requirements and design a targeted fertilization plan.

2. Crop nutrient demand: Different crops have different nutrient requirements at different growth stages. Adapting fertilizer applications to meet these specific demands can help optimize nutrient intake, minimize wastage, and maximize productivity.

3. Nutrient balance: Maintaining a balanced nutrient profile is critical to crop health and yield. An optimal fertilizer allocation strategy ensures an appropriate ratio of nutrients, thereby preventing deficiencies or toxicity.

4. Environmental impact: Improper use of fertilizer can lead to nutrient runoff, causing water pollution and ecosystem damage. By allocating fertilizers efficiently, farmers can minimize environmental impacts while maximizing crop yields and farm income.

Role of irrigation in maximizing farm income:

Water is a critical resource for agricultural productivity. Water scarcity and changing climate patterns pose significant challenges to agricultural productivity. Irrigation is an important solution to reduce the effects of water scarcity and ensure consistent crop growth. Optimum irrigation allocation involves consideration of factors such as crop water requirements, soil moisture levels and irrigation efficiency. Various irrigation techniques, including surface irrigation, sprinkler irrigation, and drip irrigation, offer varying levels of water use efficiency. Implementing the most appropriate irrigation method for specific crops and soil conditions can significantly increase water availability, crop yield, and ultimately farm income.

The following points underline the importance of optimum irrigation allocation: -

1. Crop water requirements: Different crops have different water requirements during their growth cycle. By understanding crop water requirements and implementing efficient irrigation techniques such as drip irrigation or precision sprinklers, farmers can provide the right amount of water at the right time, ensure optimum growth and maximize yield.

2. Water availability and management: Water scarcity is a growing concern in many regions. Appropriate water allocation strategies, such as water-efficient irrigation methods and water storage systems, can help farmers make the most of limited water resources while maintaining crop productivity and farm income.

3. Water use efficiency: Efficient use of water reduces costs and conserves resources. Technologies such as soil moisture sensors and weather-based irrigation scheduling enable farmers to apply water precisely when and where it is needed, preventing water waste and maximizing irrigation efficiency.

4. Climate change adaptation: Changing climate patterns, including erratic rainfall and rising temperatures, require adaptive irrigation practices. Optimum allocation of irrigation resources helps farmers mitigate the effects of climate change on crop production, maintain farm income stability and ensure long-term sustainability.

Effect of fertilizer and irrigation on optimum allocation:

The combined effect of optimal fertilizer and irrigation allocation can lead to significant increases in agricultural productivity and farm income. Fertilizers provide crops with essential nutrients, enabling them to use water efficiently and optimize photosynthesis. Properly fertilized plants are better prepared to deal with water stress, resulting in improved drought tolerance and higher yield potential. In addition, adequate soil fertility through optimal fertilizer allocation increases water-holding capacity, thereby reducing the demand for irrigation water. This synergy between fertilizers and irrigation leads to increased crop growth, improved water use efficiency and increased farm income.

1. Strategies for optimizing fertilizer allocation:

To maximize farm income, the optimal allocation of fertilizers is critical. This includes understanding the nutrient requirements of different crops, the nutrient content of soils, and the interactions between fertilizers and soil properties. Soil testing and analysis provide valuable insight into nutrient deficiencies and help farmers tailor fertilizer applications accordingly. Precision agriculture technologies, such as remote sensing and geographic information systems (GIS), enable farmers to map the variability of soil nutrients and apply fertilizers precisely where they are needed. By adopting such methods, farmers can reduce nutrient waste, reduce environmental impacts and achieve higher crop yields, which can increase farm income.

2. Strategies for irrigation optimization:

Effective irrigation management is essential for sustainable agriculture and increased farm income. Various strategies can be employed to optimize irrigation allocation. First, farmers must accurately estimate crop water requirements considering factors such as transpiration rates, crop growth stages, and climatic conditions. Using weather forecasts and soil moisture sensors can help farmers make informed irrigation decisions. Secondly, implementing water-efficient irrigation techniques, such as drip irrigation and precision sprinklers, can reduce water loss through evaporation and ensure that water is delivered directly to the root zone. Additionally, adopting irrigation scheduling based on soil moisture monitoring can prevent both under- and over-irrigation, ensure efficient water use, and enhance crop yields.

Factors influencing optimal allocation:

Many factors influence the optimal allocation of fertilizers and irrigation to maximize farm income. Understanding and considering these factors is important for farmers to make informed decisions.

The following factors should be considered: -

1. Soil analysis: Performing regular soil tests helps determine the nutrient content, pH level and organic matter of the soil. This analysis provides valuable insight into soil fertility status and enables farmers to tailor fertilizer application to effectively meet crop requirements.

2. Crop selection and rotation: Different crops have different nutrient demands and irrigation needs. Selecting suitable crops based on soil type, climatic conditions and market demand and practicing crop rotation helps optimize fertilizer and irrigation allocation. Rotating crops with different nutrient needs can prevent nutrient deficiencies and reduce the risk of diseases and pests, ultimately maximizing farm income.

3. Market demand and economic considerations: Understanding market demand for specific crops and their profitability is essential for making informed decisions about resource allocation. Farmers should consider the cost of fertilizers and irrigation methods in relation to the potential benefits. Strategic planning and market analysis can guide farmers in selecting crops that have high demand and better economic prospects.

4. Water sources and management: Assessing water availability in terms of both quantity and quality is important for efficient irrigation allocation. Farmers should consider factors such as rainfall patterns, access to water sources and water storage capacity. Additionally, implementing water-saving technologies and practices, such as rainwater harvesting, drip irrigation, or mulching, can optimize water use and maximize farm income.

5. Technology and Innovation: Advances in agricultural technology provide new tools and techniques for optimizing resource allocation. Precision agriculture equipment, remote sensing and data-driven decision-making platforms can provide critical information about crop health, soil moisture levels and nutrient requirements. Integrating these technologies into agricultural practices can increase efficiency and profitability.

6. Environmental Sustainability: Promoting sustainable agricultural practices is essential not only for long-term productivity but also to meet environmental regulations and consumer demands. Optimum fertilizer and irrigation allocation aims to reduce environmental impacts such as nutrient runoff, water pollution and soil erosion. Practices such as precision farming, organic farming and conservation tillage can contribute to sustainable resource allocation and long-term farm income stability.

Challenges of fertilizers and irrigation for optimum allocation:

While the optimal allocation of fertilizers and irrigation has great potential to increase farm income, there are some challenges and considerations that need to be addressed. First, farmers must carefully monitor and manage nutrient runoff and leaching to reduce environmental pollution and protect water bodies. Second, the cost of fertilizers and irrigation infrastructure can pose financial challenges, especially for small-scale farmers. Access to credit and government assistance programs can help reduce these barriers and promote sustainable agricultural practices. In addition, continued research and development is necessary to identify improved fertilizer formulations, irrigation technologies and agronomic practices that maximize farm income while minimizing environmental impacts.

Conclusion:

The optimal allocation of fertilizers and irrigation is critical to increasing farm income, ensuring sustainable agricultural practices, and meeting growing global food demand. By understanding crop nutrient requirements, analyzing soil, and using precision agriculture techniques, farmers can optimize fertilizer allocation. Similarly, water use efficiency can be increased by assessing crop water requirements, implementing water-efficient irrigation techniques, and adopting accurate irrigation scheduling. The synergy between optimal fertilizers and irrigation allocation leads to improved crop yields, increased drought tolerance, and ultimately, higher farm incomes. Addressing challenges related to environmental impact and financial constraints is critical to the widespread adoption of these practices. As we strive for sustainable agriculture, optimizing fertilizer and irrigation allocation is an important step toward supporting rural economies in achieving food production and meeting growing global challenges. By doing so, farmers can maximize their farm income, ensure food security and contribute to a sustainable agricultural future.

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ROOT CROPS AGRICULTURE AND SUSTAINABLE LIVELIHOOD OF TRIBAL PEOPLE IN ODISHA

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Introduction:

Dense forest coverage, remote hilly areas of Odisha support the inhabitants of ethnic tribal communities. From centuries, vary far away of civilization, the most tribal settlements are established on hills or close to river yards flowing nearer to forest. These are almost 645 different tribes in India, out of which Odisha hosts approximate 62 vibrant tribes residing in the state (Rajkishore, 2007). The cultural identity and vitality of Odisha state is mostly influenced by their rich heritage of ancient groups of tribal diversity. Each tribe has its own characteristic; some are common but greatly varies in their culture, lifestyle, traditional outfits, religious beliefs, folk language and physical appearance. Basically, their economy is derived by various activities around the nearby forests. They mainly survive on agriculture, farming, fishing, hunting and animal rearing. Despite of all activities, poverty and struggle for existence, they still retain their essence of heritage with inclination towards folk music and dance, and live with natural harmony.

Tribal community in India:

According to Indian constitution, there are approximately 645 tribes scattered throughout the country. They are predominated in the states like Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Gujarat, Jharkhand, Karnataka, Telangana, Uttar Pradesh, West Bengal and Odisha. The states of North East India, Chhattisgarh, and Madhya Pradesh are most tribal states of India where Mizoram and Lakshadweep, both headed highest tribal population as per last census 2011.

Indigenous tribal people are the native inhabitants of India are also called as Adivasis or Vanvasis, is a collective name used for ethnic tribal groups. Most common tribes found in India are Bhils, Gondas, Santhal or Santal, Munda, Gora, Khasi, Angari, Chenchu, Bhutia, Kodaba and Great Andamanese. Bhil is the largest tribe among them where Santals are the largest and oldest tribe of India.All the tribes are unique in their own cultures, languages, and traditions.

Tribes and tribals of Odisha:

Odisha is the native to approximate 62 vibrant tribal groups including 13 primitive tribal communities (PVTG) distributed all over the state, namely DongriaKandha, KutiaKandha, LangiaSaoras, Birhor, Bonda, Didayi, Juangs, Kharias, Lodhas, Bhuinyas, Soura, Mankidias, ChuktiaBhunjia. Mayurbhanj, Keonjhar, Kandhamal, Sundargarh, Gajpati, Koraput, Malkangiri, Nabarangpur, and Rayagada are the nine districts where tribes dominate 50% of the population, among them Mayurbhanj has the highest density of the tribal population. Green hills of Koraput, serves as the home to oldest tribe called as Bonda tribe. Kondha tribes are the indigenous tribal group and Sabor people are one of the Adivasimunda group predominates in the state. While Kondha and Santal are the most widespread tribal group, but other tribes like Munda, Oram and Ganda also are the inhabitants, mainly survive on agriculture, fishing, hunting, and on forest products. All Adivasis are 22.85% of the state population and commonly speaking 21 languages. Major and most spoken language by tribals is Santhali and then Ho language is the second widely spoken language. Tribals having extremely low level of literacy but survive by their one ideology, ethos, values and the rich essence of cultural heritage, varied from one another.

Tribal livelihood:

Tribals basically like to be united always with their community with 'jal, jangal and jameen' in their habitats. Many plants are conserved in natural habitats by tribals due to their religious belief as plants are God and Goddess.Forest as major resource to fulfill the basic needs and acted as their livelihood too. They perform traditional agriculture mostly shifting or Jhum cultivation, fishing, hunting, farming and living in gatheringsfor their means of subsistence. The main source of their livelihood is to collect natural forest products such as fuel wood, timber, bamboos and number of minor forest products such as Canes, Sal, Tendu and Siali leaves, Termarind, Chaar, Amla, Harra, Behera, gums, broom grasses, waxes, dyes, resins, lac, fodders, Mahua flowers and foods including wild fruits, honey, herbs, nuts, roots, tubers and medicinal plants. Between 20-50% of annual income of tribal households comes from Non-Timber Forest (NTF) products (Naresh,2018).

Some tribes are nomadic moving one place to another without permanent abode, leaving in different locations. They move according the seasons in search of their livelihood such as food, water, and grazing land. Pastoral nomads move periodically to different locations, do not settle continuously in the same place. They are tribes, migrate to find fresh pasturage for their domestic animals. Mainly they herd cattle and trade their products such as milk, ghee, wool, leather etc and also exchanged items for grain, cloth, utensils and fulfilling other needs. When change the place they bought and sold these goods as per their requirement and transporting them on their animals.

Forest, farming, wage migration and business were the major livelihood patterns of the tribes with a very low annual income. Poor education, low research base, insufficient farm technology, lack of advanced skill of agriculture, small-scale production and no capital investment, drive their livelihood towards a poor, unproductive, economic status. Shifting agriculture on unproductive terrains, hardly raise only one crop, isalways depending upon the monsoon. Due to low rate of production, the consumption rate is also limited to the family, which enhances subsidiary activities to supplement their economy. The livelihood strategies of tribes determined by their social, economic, demographic and cultural settings (Chhotray, 2004). Tribal economy is affected by the poverty; therefore, lack of food security is a major problem for their community. So it is deserved to put special attention for strengthening their livelihood by developing and implementing government supports with sustainable approaches. State and central government are taking various steps for sustainable livelihood of tribal communities in various sectors through vocational training, formal technical education and skill development initiatives for tribal youths.

Climate change, agriculture and traditional farming:

The ethnic and indigenous people have conserved several plants and endangered cultivars of agricultural crops such as rice, maize, millets, grains, legumes, fruits and vegetables. In rice 150 wild cultivars are conserved by Santal, Munda, Birhor and Gond tribes of Madhya Pradesh, Chhattishgarh, Odisha, Jharkhand, and Bihar (Arora,1997).The major Agricultural tribes are Gadaba, Paroja, Bhumia,Bhottadas, Kondh, Bondo and Juangresides in Odisha. DungariaKondha tribe in Odisha follows traditional farming practices to combat climate changes that includes various diverse cropping systems. From last ten years, Odisha subjected to climate change effects resulted crop loss due to increased period of dryness, pest attacks and erratic raining. Without causing harm to the nature, they prefer to perform traditional farming practices for their crops.

The monsoon delays very often in Odisha which created drought-like situations in the summer cropping seasons during early Kharif stage. Eccentric rainfall during October and November severely disrupts the winter humid temperature, results in increased crop diseases, pests and weed problems. Rise in temperature, floods, drought and humidity changes also reduce crop yield and affect disease management. Tribes usually raise their crop on lower hill slops. Crops like millets, leaves, legumes, tubers, vegetables, pulses, sorghum and rice are cultivated throughout the cropping season and are harvested sequentially from October to February end in their forest-based farms called Dongor. Due to these climatic variations indigenous tribal farmers prefer traditional farming to overcome the distress. Earlier slash and burn agriculture was the main process of raising crops traditionally by the tribals of hilly regions.

In shifting agriculture jhum practice or poduchaas, a forest land is cleaned, plant biomass is burnt and then the ashes collected which are applied in the field as the source of nutrients to the crops. From the next year the field is abandoned for many years (10-15 Years) to resume the soil fertility again. During this period tribes move other places for cultivation.

Owing to pressure of increasing tribal population the Jhum cycles become shorter for the period of 4-7 years, which fails to replenish its lost fertility and reduces crop yield. But the practice of traditional cultivation is responsible, for degrading soil and environment natural sources, leading to the destruction of green cover and triggering soil erosion.

Food security through tuber crops:

Food security is most deficient among the tribal population for which tubers offer ample scope for sustainable food production and livelihood means to tribal communities. They traditionally grow tuber crops varieties such as Yams, Yam bean, Sweet Potato, Topoica, and Taro which are promising in the hilly and plateau regions of Odisha. Root and Tuber Crops play significant role in the improvement of livelihood security and economy of tribal farmers (Naskar, 2006). Government lunched various program and plans to ensure the livelihood, food and nutritional security of tribals through introduction of tuber crop technologies. It is pronounced that the food security of the tribal is in danger due to climate change, un-seasonal rains, rise in temperature, depleting ground water and lack of facilities in agriculture.

Tuber crops like yam, taro and yam bean mostly grown in backyards and sometimes collected from forests. Now a day they are cultivating Arrowroot and Paluas sources of starch. Farming of this crop is very much enhancing as it grown in west lands, hilly areas, needs less agricultural management, less post-harvest storage maintenance with low cost of production, which improve the food security in tribal communities and generate a source of additional income through direct sale providing livelihood security too.

Farming of tuber crops:

Undoubtedly Root Tubers are most climate resilient food crops (Nedunchezhiyan, 2013). Cassava or Tapioca grows in all type of well drained soils in warm climate. Main season for plantingof the setts is April-May before the onset of monsoon. Ideal planting materials are the mature, healthy stems. Sweet potato is a crop, having wide adaptability of tropical and sub-tropical region.Under rainfed condition, the vines of the crop are planted in June-July, which performs better in well drained loamy soils.Cuttings of apical portions of the vine are mainly used as the planting material. Yams are grown in warm and humid conditions with approximate mean temperature of 30^{o}C and a well distributed annual rain fall of 120-200cm. Well-drained fertile soil is very suitable for cultivation of yams. Tuber pieces of 200-300 gm size are the best planting material and March to April is the ideal time for planting of the crop. Elephant foot yamor Amorphophallusis a tropical as well as sub-tropical crop grown well under warm humid climate with a mean annual temperature of 30-35^{o}C and a rain fall of 100-150cm spread over a period of 6-7 months. It grows well on well drained sandy loam soil. Whole or cut tubers with skin of approximate 500gm weight are used as planting materials and planted in pits during March to May. Colocasia commonly known as Taro grows well in warm and humid conditions with mean temperature of 21-27^{o}C and a well distributed rainfall of about 100cm during growth period. It can be cultivated in all types of soils. Cormels weighing 20-25gm can be used as good planting materials. It can be grown in all the seasons but under rainfed conditions colocasia generally planted during April to June. Arrowroot grown for quality starch native to tropical America is widely cultivated in Odisha as well as north eastern states of India with an average temperature 20-30^{o}C and planted during May-June before unset of rain. It can be cultivated in deep well drained slightly acid loam soils under partial shade. Rhizomes of 4-7cm and suckers are used as planting materials.

Production of tuber crops are comparatively much more than other crops. Cassava can yield 35-40 t/ha with proper cultivation practices. Elephant foot yam also can produce tubers of 40-45 t/ha. Besides these crops Sweet potato, yam, taro and arrowroot also yield 20-25t/h, 25-30t/h, 15-20t/h and 40-45t/h respectively which can meet the needs of tribes.

Tuber crops and its nutritional value:

Root and Tuber crops play a vital role in securing nutritional security of all tribes. Tuber crops serves as secondary staples, next to rice in Odisha, substitutes cereals and vegetables during lean period, Sivakumar *et al.* (2014). Besides fulfilling food and nutritional values, it also contributes significantly towards curing of various diseases.

Tuber crops arethe prime food-medicinal substitute and one of the important food crops of rural, tribal and local people of Odisha. Earlier tribal people used to consume different type of wild tuber varieties which are locally known as Kanda. These are collected by them from the forest and stored to secure the food security of the family for two to three months in unavailability of food situations. These are mostly different species of wild tuber genus *Dioscoria* (with their local names) like *Dioscoriaalata*(khamba/desi),*D. bulbifera* (Pita), *D.*

pentaphylla (Mitni), *D. hispida* (Kulia), *D. puber* (Kasa), *D. wallichi* (Cherenga), *D. tomentosa* (Taragai), *D. hamiltonii* (Sika) etc. Besides these Sweet potato (Kandmul), Yam(Oluo) and *Colocasia*(Saru) are also cultivated. But due to lack of modern cultivation practices the yield is very low. But according to the soil quality, soil texture, the improved varities can be cultivated with better yield. Greater yam *(Dioscoria),* Elephant foot yam (*Amorphophallus), Colocasia* (Taro), Sweet potato (*Ipomoea*), Cassava or Tapioca (*Manihot*),Arrowroot(*Maranta*) are the most common tuber crops which can be cultivated and consumed by the tribal people of Odisha. These tuber crops can play key role on the livelihood, food security and economy of the tribal people due to the market demand, nutritional and medicinal value of the above tuber crops.

Elephant foot yam (*Amorphophallus*) is one of the most important tuber crops which can cultivated as a cash crop in the tribal areas of Odisha. Its tuber contains adequate phosphorus (34mg/100gm), calcium (50mg/100gm) and vitamin A (434 IU/100gm). The other components are protein 9.81 to 12.4%, carbohydrate 25.5 to 32.2%, fat 1.5 to 2.5%, fiber 5.7 to 6.9% and water content of about 68%. It is rich in primary and secondary metabolites and can be used as staple food. Elephant foot yam has high medicinal value. It is used in the treatment of emesis, dysmenorrheal fatigue, constipation, piles, dyspepsia, inflammation, tumors, elephantiasis, rheumatism and many other diseases.

Taro or *Colocasia* resembles potato and often replaces the same. It is mainly used as vegetable. The leaf also used for treatment of various ailments includes asthma, arthritis, diarrhea, internal hemorrhage, neurological disorders and skin disorders. The corm is widely used for treatment of body ache and baldness. Taro is an excellent source of fiber and starch, antioxidants and polyphenols that protect against free radical damage and cancer. *Colocasia* leaves are a very good sources of Vitamin A which help in improvement of vision and prevent molecular degeneration associated with ageing.

Greater yam *(Dioscoria)*, is an important source ofdietaryfiber, carbohydrates, protein, antioxidants and also high in minerals like potassium and manganese, magnesium, calcium and many vitamins including vitamin C.

Sweet potato (*Ipomoea*) root is rich in starch, sugar (glucose, fructose, maltose), dietary fiber, vitamins and some compounds like phenolics, anthocyanin, conjugated phenolic acids and minerals, chlorogenic acid which is an antioxidant compound.

Cassava (*Manihot*) is principally used as a food source. Cassava also abundantly used as food ingredient in place of cereal grain in animal food industries. Fresh cassava tubers contain about 7%moisture and high carbohydrate and amylase up to 90.77% and 29.45% respectively depending on crop variety, soil texture and climatic conditions. Cassava containsfewer amounts of fat 0.45-2.67% and protein up to 31%. The fiber content in cassava is nearly 2%.

Arrowroot flour is a good source of dietary fiber, starch, protein, low fat content, also reach in vitamins B complex (riboflavin, niacin), folic acid and minerals like Ca, K, P, Mg, Fe, etc, with lots of medicinal benefits.

All types of tubers are often used as food and a source of raw material for production of starch, alcohol, animal food and various economically sustainable value added products for human consumption. They are also important due to their medicinal value and industrial use. Root and tuber crops are receiving attention because they could be grown on marginal or difficult land. Diverse agro-climatic conditions varied soil, temperature range of 25-35°C, rain fall with wide regional variations tribal areas of Odisha is highly suitable for cultivation of tuber crops. Due to growing population pressure in tribal areas of Odisha they move to grow such type crops that can be adopted to marginal lands with difficult soil, dry land, erratic weather as well as other environmental conditions. These tuber crops can provide promising food and nutritional security to many people of tribal area of Odisha state.

Conclusion:

Tribals are ethnic and indigenous communities live in areas, are immensely rich in biodiversity. Tribal life and economy are driven essentially by activities around the forests. Despite of poverty and struggle for survival they still retain their heritage and know to live with harmony in nature. But from last few years due to climate change, environmental fluctuations and recently pandemic drive the tribal communities into food and nutritional insecurity. During these unfavorable deficient situations Tuber Crops somehow play important role as alternative food source. Root and tuber crops are cheap source of carbohydrates and energy, hence occupy a special niche in the tribal food habits. These crops possess very reliable simple cultivation practices, management and post-harvest storage. Government took number of initiatives to enhance their income, food and livelihood security by introducing tuber crops technologies among tribal farmer communities. High mortality among infants and serious health concerns drives the tribals to adapt this crop as 'secondary staple' food. Besides these its rich nutritional and medicinal properties are made this crop as crucial, play a substantial role to overcome food and nutritional insecurity from their households during scarce period which leads a secure and sustainable life.

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WASTE MANURE AND ENVIRONMENT PROTECTION

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Abstract:

Today agriculture is one of sector which may fetch good foreign currency in the Economy through the agriculture export but for it many amendments reforms and methods of agriculture should be implemented thorough government machinery and social Compiegne like way of good agriculture produce with capability of export with protecting environment as well as with natural ingredients and manure and less use of chemical as, chemical used Produce are not acceptable to many countries as well as it has many bad health issues so waste manure and environment protection and environment Protection is best option for increasing export for foreign currency increase which have high demand for agriculture produce to UAE , some European countries and Asian countries as well as will conserve and beneficial for sustainable agriculture.

Introduction:

Agriculture is main occupation in India of largest people as far as 70% peoples engaged in this occupation from decades to decades many advances taken place still the traditional method of production is going on now a days some new generation educated farmers are making the new experiments with technology and high yields production and chemical fertilizers and pesticides and medicines and modern seeds and modern process but the modernization brought some drawbacks also it reflected some huge production but with the defective produce many chemical used produce are dangerous for human kind specially it for children and old people increasing the chances of cancers and other diseases. The modern age is age of globalization and marketing all over the world so that our country would earn foreign currency but the modern chemical used produce are rejected at the international platform so the natural manure natural pesticides and natural seeds and process with technology is today’s demand for economic development of India.

Objectives:

1) Development with Environmental Protection: The seasonal changes indicates that the environment is showing their bad effect of earth so draught in some are and floods and typhoons and natural calamity indicates that there is utter need of Protecting environments the rivers are dumped with city sewages and dirty chemicals of industries and garbage’s of households. Trees are cut for urbanization and earth water level lowering so the trees plantation not surviving longer which reflect the draught flood typhoon natural calamities we must clean our climate and protect the earth from degradation by utilization all waste and dirt converting into manure for agriculture so that the agriculture development will take place with environment protection.

2) Planning for Next Generation: The modern age is developing fast but the available natural resources also decreasing fast and natural resources is very valuable and important as well as it is limited so securing future and next generation its misuse must be stopped as like the coal, minerals, natural chemicals , patrols , drinking water as well all valuable it should survive for nest generation so that the next generation people will utilize it with best use and save mother earth from calamities and natural disaster on earth as well will take maximum economic development with cleanliness and modern agriculture with natural ingredients with natural manure.
3) Preference for Natural Process Conservation: The traditional process of agriculture is day by day vanishing due to modernization and technological advancement again this is the time to turn over the old tradition of natural production with natural ingredients and modern technology and modernization so that we will get the quality produce from agriculture for international market and globalization for all traditional process of manure making , waste management, dirty waste water utilization and households and other waste conversion into manure for agriculture is the old tradition is very important for this modern age except that the chemical use and modern technological medicine process.
4) Sustainable Agriculture Productivity & Quality: Sustainable agriculture is nothing but its ingredient ,potential ,quality ,process , Nutrition and productivity preserve so that in future it will remain quite good and as it is and increased and it is important also in future the population will be double or triple and agriculture land will reduce double & triple at that time the agriculture productivity & quality is very less then it will be dangerous for country so sustainable agriculture is very important.
5) Environment Accounting & Audit: The environment pollution, degradation, and destruction is taken place day by day so how much it affected and how many destruction and pollution taken into figure and amount should be noticed and recorded so that its accounting will disclose how many loss is suffered to us and it should be audited so that we can learn from it and would apply measure to repair it and amend it or government may plan for protecting the environment.
6) Mortality rate and Waste Management: The corona impact shown the lot of debris of dead due to virus so from that time the mortality rate is high in India prior to corona impact what is factor influencing the corona and other viral diseases India whatever reason it may be but the most dangerous reasons is uncleanliness over everywhere as in public places households travelling places school colleges market places roads and tour camp hotels and vacation destination and public and private hospital everywhere we can observe the dirt and garbage’s which directly attract to the worms insects and animals and diseased birds and insects and such animal when comes into cat act with any reason by pet or nearby or eating or water bodies river and air it release so bacteria or viruses which is main reason of dangerous diseases this is the reason of increasing mortality rate in India.
7) Waste Manure and Cleanliness: The best measures over uncleanliness all over is use of waste like dirty water, garbage, households, hospital waste and other sanitation waste is recycled

and turned into useable manure which may be used for agriculture purposes or government plantation and other land fertilization and in this way cleanliness with plantation will save lot of life of animals and biodiversity, water bodies, human, diseases, and other sanctuary also. So the manure or natural fertilizer not only for animal dung but for all waste is the one solution for cleanliness and environment protection.

8) Waste management for Other Purposes: The waste is not only for converting into manure but may be used for other use of agriculture purposes like in rainy season flood can swan lot of crop as well as the land soil which may create the danger for agriculture process and filling up gap of soil so avoiding swapping away of soil waste material Bhandara or small waste material protecting wall may be created and other waste may be used for natural fertilizers another use is creating ramp for farmers or animals or travelling of agriculture goods up to the road from land for transporting it to the markets etc.

9) Ecological balance and Sustainable Agriculture: The ecological balance is very necessary for reestablishment of natural habitat. The biodiversity are affecting the small creature and various environmental problems created danger for small species which is important for reestablishment of nature, but the many man made pollution of air water soil and notice degrading the ecological balance which are reflecting with drawbacks like Tsunami, corona, earthquake and global warming like problem which is devastating many countries economy due to social and atmosphere condition.

10 Economic Growth & development and Sustainable Agriculture: Agriculture is oldest factor of economic booster many agro based industry and self-sufficiency are depended on the agriculture production and its resources so economic growth and development are main for sustainable agriculture which is correlated with each other sustainable agriculture and economy and economy with sustainable agriculture. Because each one is depended on each factor 80 % population engaged in agriculture in India which provide them employment and food also and provide raw material for industries also, also food processing plants and laborers and seller mediators and transporter and many depended upon agriculture and economy each which should be durable for future and next generation also this is the reason that sustainable development is needful for economic growth and development of India.

Importance of environment and sustainability:

1) Dirtiest cities and river in worlds list include India also so we must vanish our India’s name from dirtiest cities and rivers we must take some measures as like new york city and japan where priority given to garbage management and renewable energy and agriculture.

2) The largest tourist visit in world is Thailand , Amsterdam, Switzerland because of cleanest cities and country this is the main source of foreign currency to them we have also opportunity to grab such foreign currency cleaning our cities with waste management.

3) Extra employment and foreign currency and globalization are todays demand so natural product production and export is modern demand for economic development and growth.

4) The agriculture problems, suicides , profitability and highest cost of production than prices for produce in market these all can be solved by applying natural manure , pesticides, and other material for agriculture and save extra expenses and remain cleanliness.
5) Waste management is need of modern time so that the future of this country and sustainability and agriculture rehabilitation remain quite good otherwise the population explosion will create more problem in India

Conclusion:

Waste manure and environment protection is very important concept in modern age every country are going on globalization of every sector so why not the agriculture of India every experiments of agriculture in point of global market we must think upon so that employment , economic development, natural product, foreign currency with export, sufficiency in food production, Sustainable agriculture is modern need subject The resources are limited and it has ample limitation of durability for next generation or for future generation such productivity , water , fuel, nutrients, minerals should be remain available for various new experiments and development. That's why cleanliness movement, pollution eradication, waste and manure management, sanitation water body rivers management is must for next top & beautiful country in the world.

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INTEGRATING NANOTECHNOLOGY INTO AGRICULTURAL SYSTEMS FOR SUSTAINABILITY

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Abstract:

The integration of nanotechnology into agricultural systems has the potential to transform sustainable agriculture by improving crop yields, reducing environmental impacts, and enhancing food security. This chapter provides an overview of the current state of research on nanotechnology in agriculture and explores the potential applications of nanotechnology for sustainable agriculture. The chapter begins by discussing the challenges faced in agriculture, including climate change, soil degradation, and limited water resources. The chapter then outlines the potential of nanotechnology to address these challenges by improving crop productivity, enhancing nutrient uptake, and reducing the use of agrochemicals. The chapter also highlights the potential of nanomaterials for use in crop protection, seed treatments, and food preservation. Further chapter also explores the potential of nanotechnology for soil remediation and water treatment. Nanoparticles can be used to remove pollutants from soil and water, reducing environmental impacts and improving the quality of these resources. Nanosensors can also be used to monitor soil moisture levels and nutrient availability, optimizing crop growth and reducing the need for water and fertilizer. The challenges associated with the development and implementation of nanotechnology in agriculture, including potential environmental and health risks, ethical and social implications, and regulatory frameworks will also be a part of discussion. The work emphasizes the importance of stakeholder engagement and interdisciplinary research in addressing these challenges and developing nanotechnology-driven solutions for sustainable agriculture. Overall, this chapter highlights the potential of nanotechnology to transform agriculture and promote sustainable development. The chapter provides insights into the opportunities and challenges associated with the integration of nanotechnology into agricultural systems and identify key research needs and opportunities for future research and innovation in this field.

Introduction:

Agriculture is a critical sector that plays a vital role in the food security and economy of any nation. However, agriculture is facing numerous challenges such as climate change, soil degradation, water scarcity, and pests and disease outbreaks. These challenges highlight the need for innovative and sustainable solutions to enhance the resilience and sustainability of agricultural systems (Usman *et al.*, 2020). Nanotechnology is one such solution that offers promising avenues for addressing these challenges and promoting sustainable agriculture.

Nanotechnology involves the manipulation of matter at the nanoscale to create materials, structures, and devices with unique physical and chemical properties. The unique properties of nanomaterials can be harnessed for a wide range of applications in agriculture, including crop protection, nutrient management, soil remediation, and food preservation (Alprol *et al.,* 2023; Chaud *et al.,* 2021). One of the most significant applications of nanotechnology in agriculture is in crop protection. Nanomaterials can be used to develop nanocarriers for delivering biopesticides and biocontrol agents, which can be more effective and environmentally friendly than conventional agrochemicals. Nanocoatings can also protect seeds from pests and disease (Hamzah *et al.,* 2023), improving crop yields and reducing the need for chemical inputs. Nanotechnology also offers solutions for nutrient management in agriculture. Nanofertilizers can enhance nutrient uptake by plants and improve crop productivity (Jakhar *et al.,* 2022). Nanosensors can also be used to monitor soil moisture levels and nutrient availability, optimizing crop growth and reducing the need for water and fertilizer (Umasankareswari *et al.,* 2022). Moreover, nanotechnology can be used to remediate soil and water resources (Hatti *et al.,* 2020). Nanoparticles can be used to remove pollutants from soil and water, reducing environmental impacts and improving the quality of these resources. Nanotechnology can also be used to develop water treatment systems that are more effective and energy-efficient than conventional systems (Kamali *et al.,* 2019). However, the development and implementation of nanotechnology in agriculture present several challenges, including potential environmental and health risks, ethical and social implications, and regulatory frameworks. The safety of nanomaterials and their potential impacts on the environment and human health require further investigation and regulation to ensure their responsible use in agriculture (Rezvani *et al.,* 2021).

The integration of nanotechnology in agriculture also raises ethical and social implications, including issues related to the ownership of intellectual property, access to technology, and its potential impact on smallholder farmers. Despite these challenges, the integration of nanotechnology in agriculture presents significant opportunities for promoting sustainable agriculture practices. The use of nanotechnology in agriculture can improve resource efficiency, reduce environmental impacts, and enhance food safety and security. Nanotechnology can also enable the development of novel products and processes that can transform the agricultural sector and create new business opportunities.

In conclusion, the integration of nanotechnology in agriculture has the potential to transform the way we produce and consume food, promoting sustainable agriculture practices and enhancing food security and economic development. However, the responsible development and implementation of nanotechnology in agriculture require interdisciplinary research, stakeholder engagement, and appropriate regulation to ensure their safe and effective use. The integration of nanotechnology in agriculture is an exciting area of research that offers significant opportunities for innovation and sustainable development in agriculture (Singh *et al.,* 2021).

Sustainable agriculture: A necessity

Sustainable agriculture refers to a farming system that can meet the needs of present and future generations while ensuring the sustainability of natural resources, environmental health, and economic viability. It involves the production of food, fiber, and other agricultural products in a way that balances economic, social, and environmental considerations. Sustainable agriculture seeks to minimize negative impacts on the environment, protect biodiversity, conserve natural resources, and promote social and economic equity. It also aims to enhance the resilience of agricultural systems to climate change and other environmental stresses, while ensuring the long-term productivity and profitability of agricultural systems. Sustainable agriculture is essential for several reasons:

- **Environmental Protection:** Sustainable agriculture practices protect the natural environment, soil, water, and air quality by minimizing the use of synthetic fertilizers, pesticides, and other harmful chemicals. This promotes biodiversity and preserves natural resources for future generations.
- **Economic Benefits:** Sustainable agriculture practices promote the long-term profitability and economic viability of farming systems by conserving natural resources and reducing production costs. This leads to increased farm productivity and reduced economic risks associated with overreliance on costly external inputs.
- **Food Security:** Sustainable agriculture practices enhance the resilience of agricultural systems to climate change and other environmental stresses, ensuring the availability and accessibility of food for present and future generations.
- **Social Benefits:** Sustainable agriculture practices promote social equity by providing equitable access to resources, creating employment opportunities, and improving the livelihoods of rural communities.
- **Climate Change Mitigation:** Sustainable agriculture practices reduce greenhouse gas emissions, increase carbon sequestration, and promote climate-smart agriculture, helping to mitigate the impacts of climate change on agriculture.

Thus sustainable agriculture is necessary to protect the environment, ensure food security, promote economic development and social equity, and mitigate the impacts of climate change on agriculture.

Various strategies for sustainable agriculture

Strategies for sustainable agriculture involve practices that promote soil health, biodiversity, efficient use of resources such as water and fertilizers, and reducing reliance on synthetic inputs.

There are several strategies that can be employed to promote sustainable agriculture**:**

- **Conservation Agriculture:** Conservation agriculture involves minimum tillage, crop rotation, and residue retention to improve soil health, reduce soil erosion, and increase water infiltration.
- **Agroforestry:** Agroforestry involves the integration of trees, shrubs, and crops to promote biodiversity, improve soil fertility, and provide economic benefits such as timber and fruit production.

- **Integrated Pest Management (IPM):** IPM involves the use of natural pest control methods such as crop rotation, biological controls, and the use of resistant crop varieties to reduce the reliance on synthetic pesticides.
- **Precision Agriculture:** Precision agriculture uses technology such as GPS, sensors, and remote sensing to optimize inputs such as water and fertilizer, reducing waste and increasing efficiency.
- **Organic Farming:** Organic farming avoids the use of synthetic fertilizers and pesticides, promoting natural soil health, biodiversity, and reducing environmental impacts.
- **Water Management:** Sustainable agriculture practices promote efficient water use through technologies such as drip irrigation, rainwater harvesting, and water recycling.
- **Crop Diversification:** Diversification of crops promotes resilience in agricultural systems by reducing the risks associated with dependence on a single crop and improving soil fertility.
- **Crop Rotation:** Crop rotation involves growing different crops in a sequence to improve soil health, reduce pest and disease pressure, and increase productivity.
- **Cover Cropping:** Cover cropping involves planting non-harvested crops to improve soil health, prevent erosion, and provide nutrients to subsequent crops.
- **Reduced Tillage:** Reduced tillage involves minimizing soil disturbance to improve soil health, reduce erosion, and increase water retention.
- **Livestock Integration:** Integrating livestock into farming systems can promote soil health, reduce waste, and provide additional sources of income.
- **Nutrient Management:** Nutrient management practices involve optimizing the use of fertilizers and manures to minimize nutrient loss and reduce environmental impacts.
- **Sustainable Forest Management:** Sustainable forest management involves managing forests for multiple purposes such as timber production, wildlife habitat, and carbon sequestration.
- **Agroecology:** Agroecology involves the application of ecological principles to agriculture, promoting biodiversity, resilience, and social equity.

The above mentioned strategies promote sustainable agriculture by minimizing environmental impacts, improving soil health, and promoting social and economic equity.

Application of nanotechnology for advancements in sustainable agriculture

Nanotechnology is a field of science and engineering that involves the study and manipulation of materials at the nanoscale level, which is typically defined as being between 1 and 100 nanometers in size. At this scale, materials exhibit unique properties and behaviors that differ from those at the macroscopic level. Nanotechnology involves designing, creating, and manipulating materials and devices at the atomic and molecular level. It involves the use of various techniques to manufacture and assemble nanoscale materials, including top-down approaches, where materials are broken down from larger structures into smaller ones, and bottom-up approaches, where materials are built up from individual atoms and molecules. Nanotechnology has many applications across a range of fields, including electronics, medicine, energy, and agriculture. It has the potential to revolutionize many industries by offering new materials, devices, and systems with unique properties and functionalities. However, the field of nanotechnology also presents some challenges and potential risks, including environmental and health concerns, which require careful consideration and management.

Nanotechnology being a dynamic and advanced technology/discipline, can contribute to sustainable agriculture and do wonders. The present section of the chapter explores adoption of nanotechnology in agriculture, and highlight various applications where in nanotechnology is been used for the advancement in sustainable agriculture

Nanotechnology has the potential to revolutionize sustainable agriculture by offering new solutions to challenges such as crop productivity, pest management, soil health, and nutrient management. Here are some examples of how nanotechnology can be used to advance sustainable agriculture**:**

- **Nanofertilizers:** Nanotechnology offers the potential for more efficient and targeted delivery of nutrients to crops. Nanofertilizers can improve nutrient uptake, reduce nutrient leaching and runoff, and reduce fertilizer application rates, which in turn can reduce environmental impacts such as eutrophication.
- **Nanopesticides:** Nanotechnology can be used to develop more effective and targeted pesticides that can reduce the use of traditional chemical pesticides. Nanopesticides can also reduce the risks of pesticide resistance, and minimize negative impacts on non-target organisms.
- **Nanosensors:** Nanosensors can be used to monitor soil and crop conditions, such as nutrient levels, moisture content, and disease outbreaks. This information can be used to optimize crop management practices, reduce inputs, and minimize environmental impacts.
- **Nanobiosensors:** Nanobiosensors can be used to detect pathogens and toxins in food and water supplies. This can improve food safety and reduce the risk of outbreaks of foodborne illness.
- **Nanomaterials for soil remediation:** Nanotechnology can be used to develop materials that can remove pollutants from contaminated soils. This can improve soil health and reduce the risks of environmental contamination.
- **Nanotechnology and precision agriculture:** Nanotechnology can be integrated into precision agriculture technologies to create more efficient and sustainable farming systems. This can involve using nanosensors to gather data on soil and crop conditions, and using nanofertilizers and nanopesticides to apply inputs more precisely and efficiently.
- **Nanocarriers for crop protection:** Nanotechnology can be used to develop smart delivery systems for crop protection agents, such as biopesticides and biocontrol agents. These nanocarriers can protect the agents from degradation and release them at specific times and locations, which can improve their effectiveness and reduce environmental impacts.
- **Nanomaterials for seed treatment:** Nanotechnology can be used to develop coatings for seeds that can improve germination rates, protect against pests and diseases, and enhance

nutrient uptake. These nanocoatings can reduce the need for chemical seed treatments, which can be harmful to the environment and human health.

- **Nanomaterials for food preservation:** Nanotechnology can be used to develop materials that can extend the shelf life of food products, such as antimicrobial nanocoatings and nanosensors that can detect spoilage. This can reduce food waste and improve food security.
- **Nanomaterials for animal feed:** Nanotechnology can be used to develop materials that can improve the digestibility and nutrient uptake of animal feed. For example, nanoparticles can be used to encapsulate nutrients or enzymes that can enhance feed efficiency and reduce environmental impacts.
- **Nanotechnology and plant-microbe interactions:** Nanotechnology can be used to study and manipulate the interactions between plants and microorganisms, such as rhizobia and mycorrhizae. This can lead to the development of more effective and sustainable crop management practices that promote plant growth and nutrient cycling.
- **Nanomaterials for water treatment:** Nanotechnology can be used to develop materials that can remove contaminants from water sources, such as nanoparticles that can absorb heavy metals or pathogens. This can improve water quality and reduce the risks of waterborne illness in plants.

Table 1 shows different references where in nanoparticles have been used for various purposes mentioned.

Table 1: Application of Nanoparticles in different ways with specific application in agriculture

S. No.	Application	Reference
1.	Nanofertilizers	Abbasifar *et al.,* 2020; Gosavi *et al.,* 2020; Bala *et al.,* 2019;
2.	Nanopesticides	Yin *et al.,* 2023; Dangi & Verma 2021
3.	Nanosensors/ Nanobiosensors	Bhattacharya 2023; Pandey *et al.,* 2023; Jagtap *et al.,* 2021; Joshi *et al.,* 2019
4.	Soil remediation	Vu & Mulligan 2023; Azeez *et al.,* 2022; Pasinszki & Krebsz, 2020; Sarkar *et al.,* 2019;
5.	Precision agriculture	Ndaba *et al.,* 2022; Presti *et al.,* 2022; Verma & Kumar 2022
6.	Crop Protection	Li, *et al.,* 2023; Mathur & Srivastava 2022;
7.	Seed Treatment	Cao *et al.,* 2021; Nandhini *et al.,* 2019
8.	Food Preservation	Jadhav *et al.,* 2023; Zhang *et al.,* 2023
9.	Animal Feed	Krishnani *et al.,* 2022; Rahman et al.., 2022
10.	Plant-microbe interactions	Feregrino Pérez *et al.,* 2023; Gauba *et al.,* 2023
11.	Water treatment	Jabbar *et al.,* 2022; Nguyen *et al.,* 2022

Challenges and associated ethical considerations

While the integration of nanotechnology into sustainable agriculture has the potential to offer significant benefits, there are also some challenges associated with this field. Here are some of the challenges that need to be addressed for the safe and effective use of nanotechnology in sustainable agriculture**:**

- **Environmental impact:** The impact of nanoparticles on the environment, including soil, water, and air quality, is not fully understood. It is essential to evaluate the potential risks and benefits of using nanoparticles in agricultural systems to avoid unintended consequences. It is one of the most significant ethical considerations associated with the use of nanotechnology in sustainable agriculture is its potential impact on the environment. The use of nanoparticles in agriculture could have unintended and unforeseen consequences for ecosystems, and it is important to ensure that the environmental impact is carefully evaluated before any widespread use.
- **Regulation:** The use of nanotechnology in agriculture is a relatively new field, and there are currently no specific regulations in place to govern its use. It is crucial to establish appropriate regulations and guidelines to ensure the safe and responsible use of nanotechnology in agriculture.
- **Cost:** Nanotechnology research and development can be expensive, and the cost of producing nanomaterials can be high. It is important to assess the cost-effectiveness of using nanotechnology in agricultural systems and ensure that the benefits outweigh the costs.
- **Public perception:** The general public may have concerns about the use of nanotechnology in agriculture, particularly regarding its safety and impact on the environment. It is important to address these concerns through education and communication with stakeholders.
- **Intellectual property:** The development of new nanotechnology-based products and applications in agriculture may lead to intellectual property issues. It is important to establish clear policies and regulations regarding intellectual property to promote innovation while ensuring that the benefits of nanotechnology are widely accessible.
- **Food safety:** Nanoparticles used in agriculture could potentially contaminate food and water supplies. There is a need to evaluate the potential risks and benefits of using nanoparticles in food production to ensure that they do not pose any health risks to consumers.
- **Access and equity:** There is a concern that the use of nanotechnology in sustainable agriculture could create inequities in access to food and resources. The development of new technologies often requires significant investment, and there is a risk that these benefits may only be accessible to large agribusinesses, while small-scale farmers may be left behind.
- **Social and economic impacts:** The use of nanotechnology in sustainable agriculture could have significant social and economic impacts. It is essential to ensure that the adoption of new technologies does not have a negative impact on rural communities and small-scale farmers.

The use of nanotechnology in sustainable agriculture presents significant ethical considerations that need to be addressed. It is essential to evaluate the potential risks and benefits of using nanoparticles in agriculture and ensure that any potential negative impacts are minimized. A responsible and sustainable approach to the development and implementation of nanotechnology in agriculture is required to maximize its benefits while minimizing its risks.

Conclusion:

In conclusion, the integration of nanotechnology into agricultural systems has the potential to revolutionize sustainable agriculture. Nanotechnology can provide innovative solutions for various challenges facing agriculture, such as nutrient management, disease and pest control, and water scarcity. Furthermore, the use of nanotechnology in agriculture can reduce the environmental impact of agricultural practices, enhance crop productivity, and improve food security. However, there are also significant challenges and ethical considerations associated with the use of nanotechnology in agriculture, such as the potential risks to human health and the environment. Therefore, it is essential to address these concerns and develop responsible and sustainable applications of nanotechnology in agriculture. Overall, the future of nanotechnology in sustainable agriculture is promising, and with proper research, regulation, and management, it can contribute significantly to achieving the goal of sustainable agriculture for the benefit of present and future generations.

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IMPROVING NUTRIENT-USE EFFICIENCY (NUE) THROUGH PLACEMENT OF FERTILIZERS

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Abstract:

The worldwide consumption of major fertiliser nutrients (N, P_2O_5, and K_2O) was 162 million tonnes (Mt) in 2009, 186.6 Mt in 2015, and is projected to be more than 200 Mt by 2025. Understanding the interconnections between soil, plant, and the environment is required to ensure optimal nutrient availability through appropriate nutrient management practices. Nutrient utilisation efficiency (NUE) can be defined as yield per unit fertiliser input or in terms of fertiliser recovery. Fertiliser placement methods often involve surface or subsurface treatments prior to, during, or after planting. The crop and crop rotation, degree of deficiency or soil test level, nutrient mobility in the soil, permitted soil disturbance, and equipment availability all influence crop placement practises. Experiments have demonstrated that root/rhizosphere management is an effective technique for increasing fertiliser usage efficiency and crop yield for long-term crop production. Improving nutrient efficiency is a laudable aim and an essential difficulty with crop improvement that may be targeted at the roots and canopy. Specific fertiliser formulations placed close to seed or plant roots increase nutrient availability and result in increased NUE. Agronomic P and K fertiliser rates used in the band can enhance usage efficiency and be a useful approach in minimising the negative effects of climate change. Localised fertiliser placement might be an efficient alternative for increasing NUE by resolving restrictions, particularly for nano-formulations.

Keywords: Fertilizers, Placement, Nutrient use efficiency, Nutrient demand,

Introduction:

Fertilizers account for about half of the global crop output, giving food, feed, fibre, and fuel to a world population predicted to exceed 9 billion by the middle of the twenty-first century. The majority of fertiliser ingredients originate from concentrated quantities of naturally existing minerals mined or collected from diverse ore deposits. One exception is nitrogen (N), which is created by mixing N_2 from the air with natural gas (most often), coal, or naphtha to form anhydrous ammonia, which may be used directly as a fertiliser or transformed into various other N fertilisers. Maintaining sufficient crop output relies on a profitable and effective fertiliser business throughout the world to assist give the appropriate nutrients, at the right rate, at the right time, and in the right location. In recent years, one of the primary elements assuring global food security has been the extensive use of commercial mineral fertilisers as depicted in fig 1. More than 48% of the world's more than 7 billion people are alive today as a result of improved food output made possible by the use of nitrogen (N) fertilisers. The amount to which global food production is dependent on fertiliser use will certainly expand in the future. Without fertilisers, the globe would produce around half as much basic food, and more wooded lands would be required for production. Understanding how plants utilise each nutrient, as well as the supply, rate, time, and positioning of each, is critical for nutrient management and crop production optimisation. The Chemical and biological activities in the rhizosphere not only regulate soil nutrient mobilisation and acquisition, as well as microbial dynamics, but also control crop nutrient use efficiency, and hence have a significant impact on crop production and sustainability (Zhang et al., 2002, 2004). Technology is a crucial component of good nutrition management. Various additions or coatings aid in nutrient availability during the growing season. Other technologies aid farmers and their advisors in establishing and implementing nutrient management programmes. Global positioning systems (GPS) direct fertiliser applications and other field operations, while geographic information systems (GIS) allow farmers and their consultants to physically reference information about the fields. Monitors and sensors for real-time application rate adjustments, as well as numerous analytical methods to measure soil and plant nutrient content, are all part of the suite of technologies used to improve fertiliser usage efficiency. Fertilisers are an extremely vital resource for crop production. Fertilisers provide nutrients that are critical to the life of plants, animals, and people. Nutrient management is critical for making the most use of available resources while also protecting the environment and ecosystem services. This problem must be solved in a way that is affordable for all parties involved, from mine to fertiliser plant to field, is environmentally responsible, and takes into account social considerations in order to preserve diverse ecosystem services for the general population.

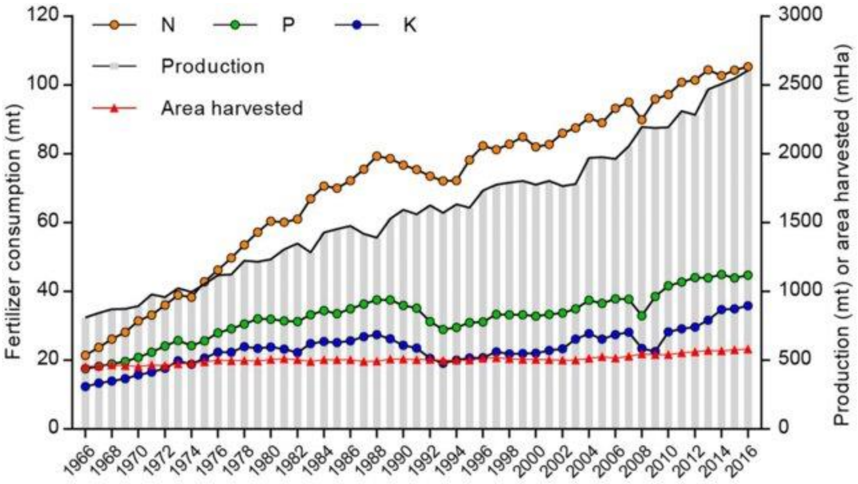
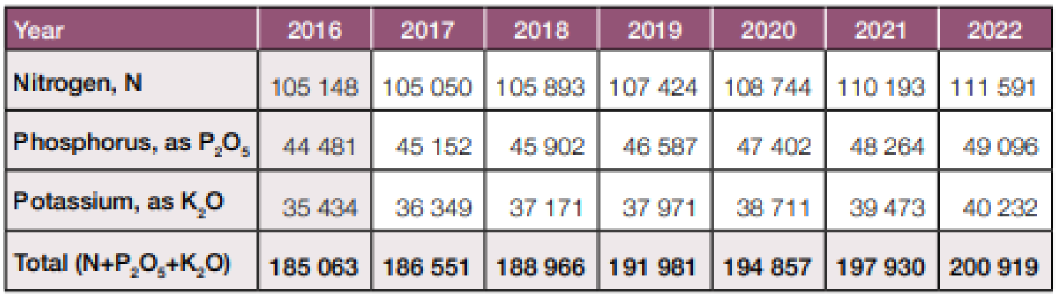


Fig. 1: Global production and area harvested of three major crops (maize, rice, and wheat), fertilizer (N, P, and K) consumption annually from 1966 to 2016. Annual fertilizer consumption worldwide was from the IFA (2009)

In the period 1966 and 2016, global nitrogen (N) fertilizer usage about fivefold rose, while phosphorus (P, in the form of P_2O_5) and potassium (K, in the form of K_2O) fertilizer consumption nearly tripled as depicted in Fig.1. In 2030-2040, worldwide N and P fertilizer demand is expected to surpass 120 million tonnes and 50 million tonnes, respectively. These fertilizers were ingested by rice at rates of 15%, 13%, and 11%, respectively in Table 1. Summarizes the global demand for fertilizer nutrients (N, P_2O_5, and K_2O) in 2016 as well as demand prediction estimations from 2016 to 2022. Total fertilizer nutrient consumption was predicted to be 185.06 million tonnes in 2016, rising to 200.91 million tonnes by 2022.

Table 2: World demand for nitrogen, phosphorus and Potassium for fertilizer use 2016-22



Year	2016	2017	2018	2019	2020	2021	2022
Nitrogen, N	105 148	105 050	105 893	107 424	108 744	110 193	111 591
Phosphorus, as P_2O_5	44 481	45 152	45 902	46 587	47 402	48 264	49 096
Potassium, as K_2O	35 434	36 349	37 171	37 971	38 711	39 473	40 232
Total ($N+P_2O_5+K_2O$)	**185 063**	**186 551**	**188 966**	**191 981**	**194 857**	**197 930**	**200 919**

Source: FAO (2019)

Nutrient Use Efficiency (NUE)

NUE measures how well plants utilize available mineral nutrients. It is defined as the amount of biomass produced per unit of input (fertilizer). Nutrient utilization efficiency can be defined in terms of outputs relative to inputs or as input recovery. Using nitrogen as an example, NUE is often defined as grain yield relative to the quantity of nitrogen accessible to the crop from all sources, such as fertilizer, mineralization in the soil, and atmospheric deposition.

- NUE is the product of two main terms: nitrogen uptake efficiency (NUpE) and nitrogen utilization efficiency (NUtE)
- NUE can be expressed as yield per unit fertilizer input or as fertilizer recovery. On the surface, this looks to be a straightforward word. Complexity stems from the large number of available fertilizer sources and the numerous factors that influence crop nutrient needs.

  The mobilization and acquisition of soil nutrients, as well as microbial dynamics, affect NUE by crops and so have a significant impact on cropping system productivity and sustainability (Zhang *et al.*, 2004, 2010).

Reasons for low nutrient use efficiencies

a. Intense cropping
b. Low soil organic carbon status and soil degradation
c. Imbalanced and insufficient fertilizer usage, mostly urea
d. Emerging multi-nutrient deficits
e. Inappropriate rate, duration, and technique of application
f. Failure to implement INM practices

Strategies to improve NUE

a. Soil test-based balance use of fertilizers
b. Retention of agricultural wastes and use of organic nutrient sources
c. Utilization of enhanced crop genotypes with a robust root system.
d. Nutrient collection and partitioning efficiency contribute to crop quality components

e. Deep application of urea in paddy
f. Incorporation of legumes into cropping system

Nutrient interactions in the plant–rhizosphere–soil continuum

The rhizosphere is the major region of interaction between plants, soils, and microorganisms in the plant-soil system. As a result, it is an incredibly essential and active region in controlling nutrient bioavailability, plant communities, adaption processes, and the growth environment. Physical processes during root mechanical penetration (e.g., physical extension of the root system and water and nutrient flow towards root surface), root exudation of carboxylates (e.g., carboxylates such as citrate, malate, and oxalate, flavonoids, and other substances), enzyme secretion (e.g., phosphatases and phytases), and proton release into the rhizosphere to mobilize sparingly available nutrients (e.g., phosphorus (P), zinc (Zn), and iron (Fe)) through changing the rhizosphere environment chemically or biochemically, such as chelation, enzyme catalyzed hydrolysis and acidification, and biological interactions between plant roots and microorganisms (e.g., mycorrhizal and rhizobia associations) in P mobilization and N fixation. Plant-rhizosphere-soil continuum nutritional interactions and nutrient transport from soils to plants via rhizosphere activities as a connection between plant and soil processes.

The 4R's of nutrient stewardship

4R Nutrient Stewardship as it provides a framework for achieving cropping system goals of greater output, increased farmer profitability, improved environmental protection, and improved sustainability. It is offered here to provide a comprehensive life cycle view on nutrient management, encompassing economic issues, environmental effects of nutrient management practice, and social implications of various practices (Fixen, 2007; Roberts, 2007; IFA, 2009)

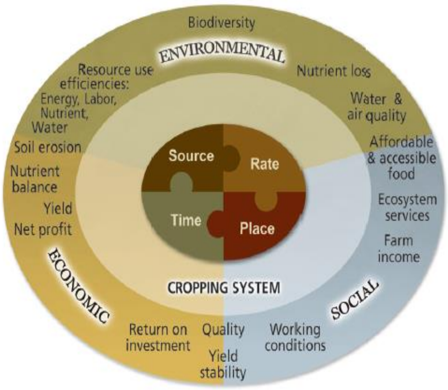


Fig. 2: 4R's Nutrient Stewardship Global Framework

The approach is based on the four interconnected R's, which are dictated by economic, social, and environmental goals related to nutrient management (IFA, 2009).

a. 4R nutrient stewardship can help improve agricultural productivity:

i. Optimizing nutrition management is simply excellent business when dealing with swings in fertilizer and other input prices, as well as crop selling processes.
ii. Higher agricultural yields have been linked to improved crop and soil management.
iii. Improved fertilizer efficiency increases the quantity produced per acre for each unit of nutrient supplied without compromising yield potential.

b. ***4R nutrient stewardship can assist to reduce environmental impact*:**

i. By growing more on less land, nutrient stewardship helps to preserve natural ecosystems.
ii. Retaining nutrients inside a field's boundaries and in the crop rooting zone considerably minimizes the quantity that is not used by plants and hence escapes into the environment as pollution.

Components of the 4 R'S nutrient stewardship system

Component	**Goal**
Right source	Provide plant-available forms of all critical nutrients in a balanced supply. Take advantage of diverse formulations that boost efficiency while reducing environmental impact
Right rate	Ensure that all vital nutrients are available to fulfil plant demand.
Right time	Adapt nutrient treatments to crop absorption, soil supplies, environmental concerns, and field operating logistics
Right place	Consider root-soil dynamics and nutrient movement, and manage spatial variability within the field to meet site-specific crop needs and minimize potential losses from the field.

Fertilizer best management practices (FBMPs) are a component of an integrated farming system, which encompasses crop management as well as other soil and plant nutrient management components. Based on the concepts of nutrient stewardship, FBMPs not only meet the four management objectives of production, profitability, cropping system sustainability, and a favourable biophysical and social environment. Specific and universal scientific principles in the development and implementation of FBMPs have been described and discussed in order to improve nutrient efficiency through a variety of fertiliser materials and new technologies, not only to increase crop production but also to reduce the negative effects of fertiliser use on air and water resources.

Rhizosphere management to optimize nutrient inputs

Nutrient inputs in intensive farming systems should be optimised to maximise root/rhizosphere nutrient mobilisation and acquisition efficiency while also producing high crop yield. Rhizosphere management conceptual model for optimising nutrient inputs for high crop yield and high nutrient utilisation efficiency by maximising root/rhizosphere efficiency in nutrient mobilisation and absorption, as shown in Fig. 3. At low or excessive input, the effectiveness of root/rhizosphere activities in enhancing nutrient acquisition and crop development is limited, but there is a maximum root/rhizosphere efficiency in attaining high nutrient utilisation efficiency and high crop output at optimal nutrient supply.

Model of root/rhizosphere management based on (Zhang et al., 2010) for increasing crop yield and nutrient utilization efficiency while lowering environmental risk by maximizing root/rhizosphere efficiency in nutrient mobilization and acquisition. When there is a robust root system and efficient rhizosphere processes in boosting nutrient absorption and crop yield, the efficacy of the root/rhizosphere may be controlled to an optimum level by regulating nutrient input. Root/rhizosphere management in cropping systems throughout the crop growth period for promoting soil nutrient mobilization after root system establishment at rapid growth stages from shooting to anthesis (transformation from vegetative to reproductive growth), and delaying root senescence at late growth stages.

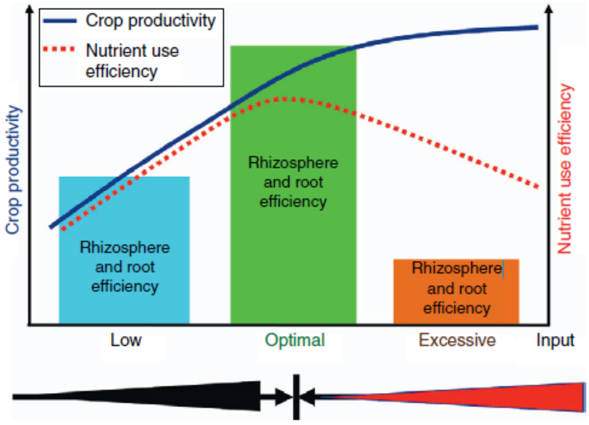


Fig. 3: Conceptual model of rhizosphere management for optimizing nutrient inputs toward both high crop productivity and high nutrient use

Root/rhizosphere management in cropping systems

Researchers have been studying root and rhizosphere dynamics and management in intensive cropping systems for many decades, but the underlying strategy of root/rhizosphere dynamics and management in intensive cropping systems remains mostly unknown. Improved grain production has been heavily reliant on chemical fertilizer input to meet the food demand of an expanding population, based on the traditionally assumed notion of 'high input, high output,' which results in fertilizer overuse but ignores the biological potential of roots or rhizosphere for efficient soil nutrient mobilization and acquisition. Exploration of soil nutrient resources by roots, as well as root-induced rhizosphere activities, are crucial in managing nutrient transformation, appropriate nutrient absorption and utilization, and, ultimately, crop yield. The root/rhizosphere's efficiency in terms of increased nutrient mobilization, uptake, and usage can be completely realized by:

(1) Root growth control (includes root development and size, root system design, and root system dispersion).

(2) Rhizosphere process management (for example, organic anion and acid phosphatase exudation, localized nutrient delivery, rhizosphere interactions, and crop genotype efficiency).

(3) Improving root zone management to match agricultural system nitrogen requirements with root development and soil nutrient delivery. Experiments have revealed that controlling the root/rhizosphere is an efficient long-term approach for increasing fertilizer usage efficiency and crop productivity.

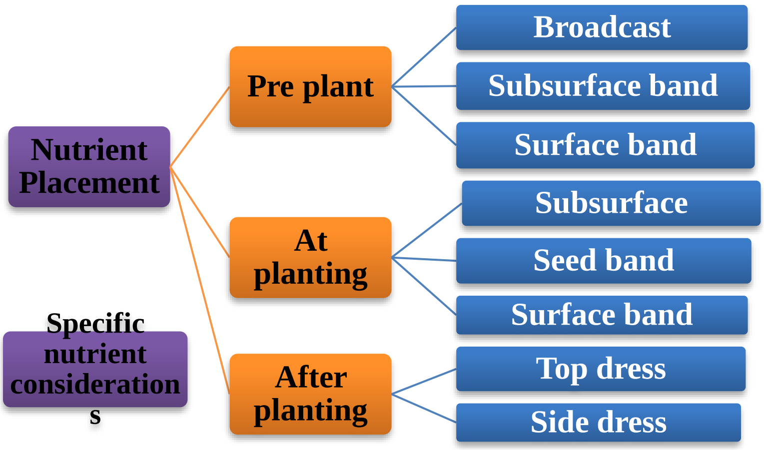


Fig. 4: Fertilizer placement techniques

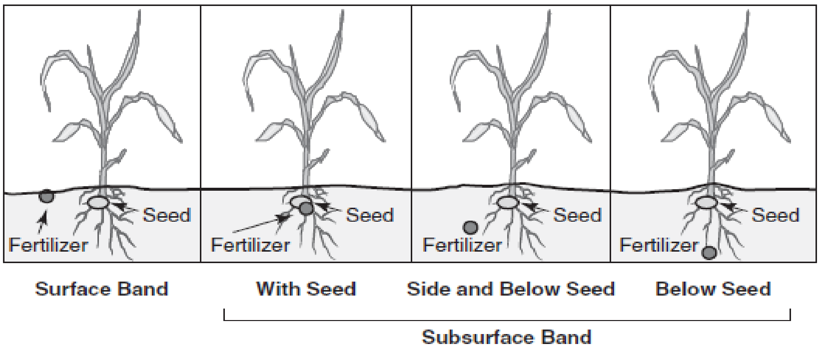


Fig. 5: A schematic comparison of the various conceptual frameworks used to analyse plant nutrient usage efficiency from the plant to the field size is shown

(a) Plant-level concepts in which soil nutrients (including those from fertilizer) are viewed as part of the environment as depicted in Fig. 4.

(b) Plant-soil-level strategies that integrate biomass and nutrient pools from soil and plants

(c) Field-scale difference approaches that include biomass and nutrient pools from soils and plants cultivated in various environments as shown in Fig. 5.

Research findings on increasing NUE

Experiments have demonstrated that root/rhizosphere management is an effective strategy for increasing fertilizer usage efficiency and crop output for long-term crop production (Shen *et al.*, 2013).

Nayak *et al.* (2021) studied the impact of Three N placement methods were used, namely NPM$_1$: both N splits were surface band placed, NPM$_2$: the first split of N was sub-surface point placed and the second N split (late vegetative stage) was surface band applied, and NPM$_3$: both N splits were sub-surface point placed, under four long-term tillage and residue management (+R) options, namely permanent raised bed (PB+R), zero-till flat (ZT+R), conventional till flat (CT+R) in an on-going long-term study (since 2008) in maize for three consecutive years (2018–2020). Under CA-based PB, ZT, and FZT plots, sub-surface point placement of both N divides (NPM$_3$) enhanced maize grain yield by 4.7, 7.0, and 6.0% (3-years mean basis) compared to NPM2. CA-based plots enhanced cob length and grain per cob by 4.8-8.7 and 8.6-12.8%, respectively, as compared to CT+R plots. Similarly, the contribution of reproductive stage N intake to grain in CA-NPM_3 plots was 9-12% greater than in CT-NPM_1 plots. Under CA-based maize, sub-surface point placement of both N divides (NPM_3) enhanced maize grain production by 4.7, 7.0, and 6.0% above previous placement strategies.

Ma *et al.* (2015) conducted two-year field experiment with maize grown on calcareous soil was carried out, using localized applications of NH_4^+-N, P (superphosphate), P plus either NO_3-N, NH_4^+-N, or NH_4:NO_3 (1:1) at sowing and jointing, as well as no N and P as a control (CK). The results showed that when compared to CK, localized supply of NH_4^+-N + P as starter fertilizer and as side-dressing at jointing increased shoot dry weight, N and P accumulation at different stages, grain yield and N concentration in grain increased by 10-48% and 4-27%, respectively, in localized NH_4^+-N, NH_4:NO_3 (1:1) + P and NH4+-N + P treatments in two years.

Rochette *et al.* (2013) The band applied urea at 5 cm depth to a silty loam soil (pH=5.5) at rates of 0, 6.1, 9.2, 13.3, and 15.3 g N m^{-1} and discovered that volatilization losses increased exponentially with urea application rate to 11.6% of applied N for the highest urea rate, indicating that as more urea N was added to the soil, a greater fraction was lost as NH_3.

Rehim *et al.* (2012) revealed with study that was Phosphorus (P) application strategies were evaluated under varied irrigation levels in order to maximize wheat production and phosphorus usage efficiency (PUE). P was administered as band placement or broadcasting at rates of 0, 61, 104, and 142 kg P_2O_5 ha^{-1} on wheat irrigated at four irrigation regimes (0, 2, 3, and 4 irrigations). Increasing the P rate to 104 kg P_2O_5 ha^{-1} (0.2 mg P L^{-1} in soil solution) enhanced wheat grain production, yield-related characteristics, grain and straw P content, total P absorption, net income, and benefit-cost ratio (BCR). P treatment at 61 and 142 kg P_2O_5 ha^{-1} (0.1 and 0.6 mg P L^{-1} in soil solution, respectively) resulted in increased PUE and Olsen P. Band placement proved to be more efficient and cost-effective than broadcasting.

Farmaha *et al.* (2011) found that compared to no-till, strip-till can offer improved seedbed conditions with deep band placement at 15 cm beneath the planted row. The objective of this study was to quantify the effect of rate and placement of P and K in no-till and strip-till systems on soybean [*Glycine max* (L.) Merr.] seed yield. A 3-yr field experiment was conducted near Urbana, IL, on Flanagan silt loam and Drummer silty clay loam soils, with soybean planted following corn (*Zea mays* L.). The main plot had no-till/broadcast (NTBC), no-till/deep band (NTDB), and strip-till/deep band (STDB) tillage/fertilizer placement, with deep band placement 15 cm under the planted row. The subplot was phosphorus fertilizer rate (0, 12, 24, and 36 kg P ha^{-1} yr^{-1}) while the sub-subplot was K fertilizer rate (0, 42, 84, and 168 kg K ha^{-1} yr^{-1}). Soil water, soil P and K, and seed yield were all measured. Overall, STDB yielded 3.1 Mg seed ha^{-1}, 10% more than NTBC and 7% more than NTDB. P fertilization increased seed yield, number of pods $plant^{-1}$, and trifoliate P concentration and accumulation uniformly across tillage/fertilizer placement, indicating that fertilization cannot be reduced with deep band applications relative to broadcast applications without a reduction in seed yield, but deep banding increased subsurface soil test levels.

Sidhu *et al.* (2019) from this study was therefore, planned to evaluate effects of residue mulch, different spacing and depths of laterals for SSDF on crop yield, irrigation water productivity (WPi), nitrogen use efficiency (NUE) and net returns for CA based RW system in a silt loam soil in northwestern India. Drip laterals were spaced either at 33.75 cm or 67.5 cm, and installation depths were 0, 15 or 20 cm beneath the soil surface and compared with conventional and zero tillage-based flood-irrigated RW systems. Grain yield and irrigation water input in rice and wheat were generally similar under different SSDF treatments. Irrigation water savings were 48–53% in rice and 42–53% in wheat under combination of SSDF and CA compared to flood irrigation system. A similar trend in WPi was recorded in both the crops. Residue mulch contributed to higher irrigation water savings, wheat yield and WPi compared to no mulch. Both rice and wheat needed 20% less N fertilizer under SSDF system to obtain grain yields similar to that under flood irrigated crops. Net returns from SSDF system with 67.5 cm lateral spacing were significantly higher compared to flood irrigation system. In conclusion, SSDF system having laterals spaced at 67.5 cm and installed at 15 cm depth provides tangible benefits for substantial saving in irrigation water and energy and increasing NUE and net income for CA based RW system in South Asia.

Wu *et al.* (2017) reported that the grain yield and apparent NRE significantly increased for N deep placement and NPK deep placement as compared to N broadcast. Although there were no significant changes in grain yields between deep placed and broadcast prilled urea (PU) treatments, deep placement of 30% less N relative to broadcast PU considerably boosted N recovery (Islam *et al.,* 2016).

Constraints:

- **a.** Non-availability of suitable, low-cost machinery for proper placement of fertilizer
- **b.** Lack of skilled man power
- **c.** Lack of soil moisture under rainfed conditions offers challenges in appropriate utilizations of nutrients in deep placement
- **d.** Fertilizer placements in CA based system become cumbersome under certain situations.
- **e.** The relative effects of fertilizer placement to broadcasting on crop nutrient acquisition and yield enhancement needs proper quantification.
- **f.** Non-applicability of nano-fertilizers for localized placement remains a challenge.
- **g.** Reflect a shift in emphasis away from conventional nutrient management with increasing soluble inorganic nutrient inputs and towards controlling root shape and managing rhizosphere activities to improve NUE and crop output.

Future thrust:

- **a)** Fertilizer consumption is increasing and factor productivity is declining which ultimately affect the NUE
- **b)** Placement of specific fertilizer formulations close to seed or plant roots ensure higher nutrient availability and improves higher NUE
- **c)** Inadequate and imbalanced use of N fertilizers provides evidence that agronomic P and K fertilizer rates applied in a band can result in improved yields and higher NUE
- **d)** Use of improved crop genotypes with efficient root system ensures optimum crop nutrient acquisition and higher product quality
- **e)** Appropriate fertilizer placement could be an effective tool in mitigating negative consequence of climate change including high temperatures and drought.

f) The successful tactics, as well as the unavoidable frustrations of discovering and practising rhizosphere management for boosting NUE and sustainable crop production in China, are likely to contribute to the development of solutions that will be beneficial in other regions of the world.

g) Future research should concentrate on molecular, cellular, individual, and ecosystem-level investigations of rhizosphere processes related to crop nutritional improvement, as well as the establishment of integrated rhizosphere management.

Conclusion:

Achieving high fertilizer usage efficiency, high crop output, and environmental preservation all at the same time has become a key problem in intensive agriculture. The demand for agricultural sustainability necessitates the optimisation of inputs such as fertilisers as well as the preservation of soil fertility. There are challenges to increasing productivity, ensuring sustainability, optimising production, and delivering safe nutrition to people. To achieve the efficient use of mineral nutrients essential for yield and quality, an integrated approach is required encompassing agronomy, breeding, biotechnology and whole system nutrient budget analysis. Reproducing step changes such as seen in the green revolution that involved a combination of These major advances are only likely to be achieved in the long term and may not be practically applied in many production systems. NUE is becoming increasingly important as farmers strive to obtain high yields while maintaining profits as fertiliser prices rise. The pattern of irrigation and environmental conditions also have an effect on the absorption of available nutrients from the soil. Crop rotation might raise crop output and improve the viability of dry land agriculture in semiarid zones. In agricultural-based countries, NUE improvement is critical. It is also an admirable objective for the fertilizer industry. Furthermore, our goal should be to reduce fertilizer application rates while increasing crop production. Global food production needs have more than doubled. This rise in demand is directly tied to a seven-fold increase in fertilizer application. Many research has been published in the last few decades to enhance NUE and minimize fertilizer overuse while maintaining sustainable crop yield.

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