ISBN: 978-93-91768-88-1

Agriculture Science: Research and Review Volume X

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Bhumi Publishing

First Edition: 2022

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Bhumi Publishing

2022

First Edition: November, 2022

ISBN: 978-93-91768-88-1

Published by:

Bhumi Publishing,

Nigave Khalasa, Kolhapur 416207, Maharashtra, India

Website: www.bhumipublishing.com

E-mail: bhumipublishing@gmail.com

Book Available online at:

https://www.bhumipublishing.com/book/

PREFACE

We are delighted to publish our book entitled ***"Agricultural Science: Research and Reviews Volume X".*** *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

BACTERIAL BLIGHT OF BEANS (*PHASEOLUS VULGARIS*) CAUSED BY *XANTHOMONAS PHASEOLI* PV. PHASEOLI AND THEIR MANAGEMENT

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Abstract:

In all areas where common beans are grown, common bacterial blight is the most detrimental factor affecting harvest of *Phaseolus vulgaris* (CBB). This analysis's main objective was to examine the biology, economic effects, and management choices of CBB, a common bean crop disease, with an eye on potential future research topics and goals. The largest production bottleneck for beans in both the world and India is CBB disease, which is brought on by the pathogenic gram-negative bacterium *Xanthomonas phaseoli* pv. *phaseoli (Xpp).* Common bean lesions can be seen on the plant's leaves, stems, pods, and seeds due to a lethal bacterial illness that affects them. In sensitive types, yields might drop by up to 45 percent and seed quality suffers. CBB is very challenging to manage due to its seed-borne nature and capacity to produce enormous amounts of secondary inoculum. It goes without saying that effective and sufficient control measures must be developed and put into place because the disease is so crucial in causing financial losses in bean crop yields. Use of resistant varieties combined with chemical seed treatment, the right cultural practises, and cultural methods may be the greatest alternative options for treating common bacterial blight of common bean and preventing yield loss. Integrated disease management is the preferred approach in general due to a better understanding of the residual effects of chemical control on non-target organisms and the environment, as well as the limitations of a single alternative management option to achieve the same level of control and reliability as chemical control. Through suitable breeding techniques and the use of molecular markers to support marker assisted selection, special emphasis should be directed to India's efforts to produce multi-line resistant cultivars.

Keywords: Bacterial blight, Symptom, Disease cycle, Management

Introduction:

A vital source of protein in many impoverished nations is pulse beans. One of them, the common bean (*Phaseolus vulgaris* L.), is eaten all throughout the world as a primary source of protein, especially in the majority of Latin American and African nations. (Reynoso- Camacho *et al*., 2006). *Xanthomonas phaseoli pv. phaseoli* is the cause of common bacterial blight of bean, a serious disease that is difficult to treat over the world (Karavina *et al*., 2011). It was first identified as an uncommon non-destructive disease in Markazi Province in the country's central region, where 17339 hectares of Pinto and kidney bean fields were located, in 2002 from bean farms with furrow irrigation systems (Lak *et al.*, 2002). Farmers were urged to quit using furrow irrigation in the following years and switch to overhead sprinkler irrigation because of its higher efficacy in terms of water use due to the province's inadequate water sources and the neglect of *Xap* presence in the area. About 500 million people in areas of Africa and Latin America rely on common beans as a significant source of nutrients; they account for 32% of their calorie and 65% of their protein intake, respectively Broughton WJ *et al*., 2003. Nutrients and minerals like such as calcium, zinc, phosphorus, magnesium, potassium, iron, and folate. Common beans include (B vitamin) and provide a balanced diet a balanced diet (Blair M *et al*., 2010, Cortes AJ *et al*., 2013). Except in drier tropical climates, CBB is widely dispersed, meaning it may be found in most sites where bean is grown across the Americas, Asia, Africa, and Oceania. Nonquarantine pathogens *Xanthomonas phaseoli* pv. *phaseoli* are regulated in Europe and are listed in the European and Mediterranean Plant Protection Organization (EPPO) Zamani *et al.*, 2011, Karavina *et al*., 2011. Bean bacterial blight was originally described in 1893, isolated characterised, and named the causative bacterium *Bacillus phaseoli* Smith in 1897. (Zaumeyer,1930). Burkholder discovered fuscous strains from beans grown in Switzerland in 1924. Fuscous strains generated a brown pigment on tyrosine-containing media and were thus named. The bacteria that cause CBB were dubbed *Xanthomonas phaseoli* after Dowson described the genus *Xanthomonas* in 1939 to collect gram-negative rods that are motile by a single polar flagellum and form yellow mucoid colonies (Corey and Starr, 1957). The fuscous and non-fuscous strains were combined under the name *Xanthomonas campestris* pv. *phaseoli* after taxonomic changes (Dye *et al*., 1980). The pathovar was then transferred to the species *Xanthomonas axonopodis* as *Xanthomonas axonopodis* pv. *phaseoli* after a genus overhaul (Vauterin *et al*., 1995). CBB is one of the most economically important illnesses affecting common beans globally due to its extensive distribution, ability to impair yield, and seed-borne nature of the disease, as well as the generation of resistance variations. In tropical and subtropical climes, CBB can cause severe losses in common beans. Temperate climates have also suffered significant losses. It also infects various legume crops as a secondary host, causing significant losses. This disease, which can result in output losses of up to 40% (Opio et al. 1996), is still a serious barrier to dry bean production in many countries. The gram-negative bacteria pathogen *Xanthomonas axonopodis* pv. *phaseoli (Xap)* and its fuscans variant *Xanthomonas fuscans* subsp. *fuscans* (Xff) cause the common bacterial blight (CBB), a serious seed-borne disease of common beans (Fourie D 2002, Schaad NW *et al.,* 2006) . While the symptoms of both strains are the same, *Xanthomonas phaseoli* var. *fuscans* has been noted to be more aggressive (Opio AF *et al.,* 1996).

Symptoms of bacterial blight

The symptoms of *Xanthomonas phaseoli* pv. *phaseoli,* which causes common blight of beans, are identical to one another. Any aerial part of a bean plant, such as the seedling, leaf, stem, pod, and seed, can be impacted by common blight of beans. The first signs of leaf disease are wet spots on the limb, usually at the hydathodes, which develop into dry, brown necrotic lesions surrounded by a thin yellow halo. In the worst situations, the plant may get defoliated and even die as a result of these spots merging and giving the leaf a burnt appearance. A systemic infection may result in neighboring interveinal tissues soaking up water and a reddish-brown darkening of the veins. On diseased stems, reddish longitudinal stripes can be seen.

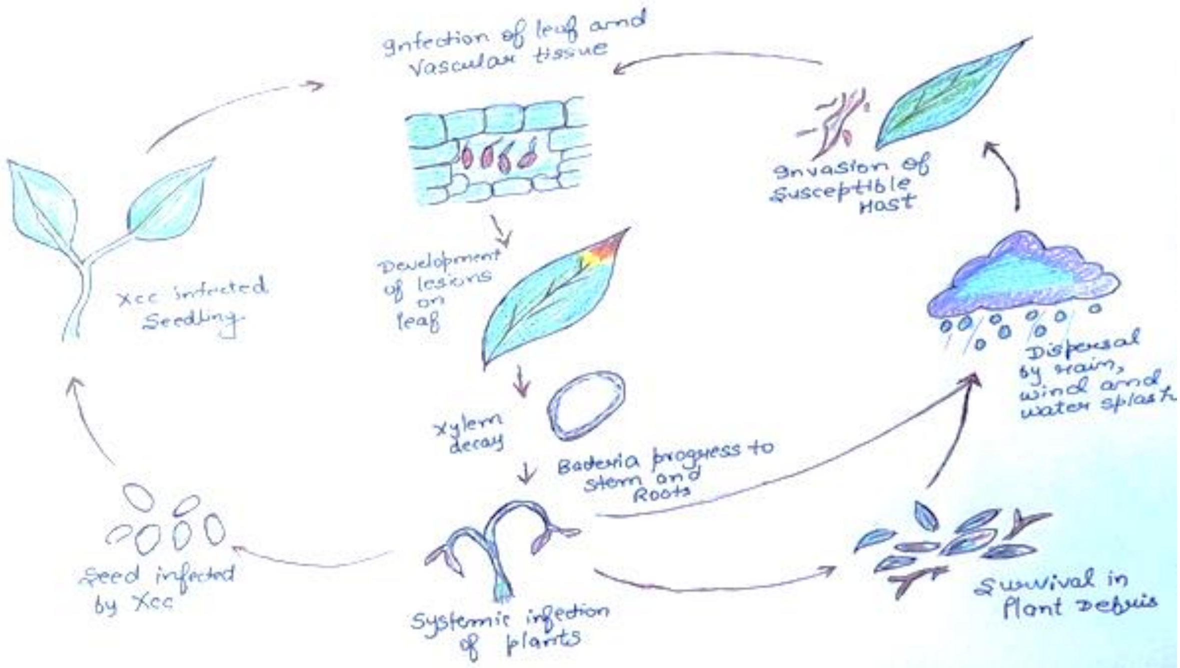
On pods, symptoms start as wet spots that develop into dark reddish-brown lesions with slightly indented circular areas and sometimes bacterial leaking. Pods may contract and perish in the event of a major infection. Butter yellow spots that eventually turn brown and appear on the hilum area of seeds with vascular transmission, the micropyle of seeds with floral infection, and the entire seed coat with contact infection (Darrasse *et al.,* 2010). Large-scale contamination may cause seeds to shrink, which lowers their germination rate and viability (Darrasse *et al*., 2018).

Host range

The common bean is the primary host of *Xanthomonas phaseoli* pv. phaseoli (*Phaseolus vulgaris*). Natural hosts of *Xanthomonas phaseoli* pv. *phaseoli* include the lima bean (*Phaseolus lunatus*) and members of the Vigna genus (*Vigna aconitifolia*, *Vigna angularis, Vigna mungo, Vigna radiata*, and *Vigna umbellata*). Other legumes with natural occurrences of *Xanthomonas phaseoli* pv. *phaseoli* include *Calopogonium sp., Pueraria sp.,* pea (*Pisum sativum*). The natural presence of CBB agents on tepary bean (*Phaseolus acutifolius*) and cowpea is up to debate

(*Vigna unguiculata* subsp. *unguiculata*). CBB symptoms can be found on all parts of the bean's aerial components.

Disease cycle of bacterial blight



Sources of inoculums

The primary source of CBB inoculum is infected seeds. According to Darrasse *et al*. (2018), CBB agents can reside on the surface of the embryo as well as on both sides of the seed coat, enabling contaminated seeds to overwinter and endure for up to 30 years. Temperature and humidity during storage have an impact on seed survival time (Marques *et al.,* 2005). In tropical and subtropical areas, CBB spreads very effectively by surviving on weeds and crop waste. More than seven months of bacterial survival have been seen in trash on or near the soil surface. It is unknown whether CBB agents can endure in crop waste in a temperate climate. In some instances, CBB agents did not last three months among plant detritus.

In both tropical and temperate regions, it has been shown that burying wastes effectively lowers pathogen lifespan to fewer than 5 weeks. Secondary spread between common bean and pigweed (*Amaranthus retroflexus*) or lambsquarters (*Chenopodium album*) was found in the field 12 days after inoculation. These observations are especially crucial in the context of crop rotation. For instance, epiphytic CBB agents were found in onion plants in fields that had previously been used to grow dry beans, but not in non-host plants like maize, sugar beet, or winter wheat (Gent *et al.,* 2005).

Infection process

During the epiphytic phase, CBB agents develop on the plant's surface without penetrating its core tissues and wait for the right circumstances to infect the plant. Epiphytic survival is aided by aggregation in biofilms, where bacterial populations are stable and grow (Jacques *et al*., 2005). After growing on the bean leaf surface, bacteria move into the host tissues through openings like stomata, hydathodes, or wounds. The development and severity of symptoms are enhanced at optimal conditions of 28 to 32 °C and a relative humidity of more than 80%. As the bacteria spread throughout the host, they colonise the vascular tissues, and in the most severe cases, the plant wilts (Vidaver, 1993).

Spread capacity

The propagation of CBB agents occurs in a number of ways. Warm temperatures and high humidity levels promote the spread of disease as well as the occurrence and severity of the condition. The germs that are present on the surface of diseased plants or plant debris can be transported over short distances by wind-blown rain or splashes. As a result, overhead watering is not advised since it mimics rainfall and encourages the growth of secondary germs (Akhavan *et al*., 2013). Transferring farm animals, farm workers, or agricultural equipment can potentially spread bacteria. *Xanthomonas phaseoli* pv. *phaseoli* disperses widely and primarily through human trade of contaminated seed (Zaumeyer and Thomas, 1957). Therefore, it is conceivable that the global spread of CBB is linked to both its capacity to spread through seeds and the growth of international trade, which depends on the global export and import of potentially infected seed lots.

Mechanism of bacterial blight

CBB is one of the most economically significant diseases affecting common beans worldwide due to its extensive distribution, ability to lower yield, seed-born origin, and generation of resistance variations [29,30]. In tropical and subtropical regions, CBB can result in severe losses of common beans. Temperate climates have also seen significant losses. As a secondary host, it also targets several legume crops and suffers respectable losses (Irigoyen ED *et al.*, 1997, Agrios GN 2005). When early plant infection occurs, greater harm is more likely to occur. Premature defoliation is to blame for this, as it lowered the amount of accessible photosynthetic area, hindered translocation, and decreased the size and number of seeds. Quality is decreased by defects on seed and pods. At the primary site for seed multiplication, bacterial blight broke out in Uganda in 1983. According to the paper, there is a yield loss of between 3.5

kg/ha and 11.5 kg/ha for every 1% rise in the incidence of CBB during reproductive growth, depending on the season (Opio *et al.,* 1996; Fourie, 2002). This resulted in the operation being stopped and postponed the distribution of seed to farmers. The main source of inoculum is seeds that are either internally or even externally infected. According to estimates, 1 103 cfu/ ml of inoculum is all that is needed to spread the illness. Darrasse A, et al., 2007. One of the illnesses that has caused significant losses in industrial bean farming and seed production in several parts of the world, including South Africa Fourie D 2002, is the common bacterial blight, which also serves as the primary barrier to exportation. *X. axonopodis pv. phaseoli* also limits bean output in Kenya.Crop losses in percentage terms ranging from 10% to 75% have been reported. According to reports, the two most significant bacterial bean diseases in East and Central Africa are CBB and halo blight (HB). The fourth-most significant bean disease in Africa is CBB, according to (Opio *et al*., 2002). 220,000 t/year are lost in Africa as a result; 146,000 t of these are lost in Eastern Africa and about 70,000 t/year are lost in Southern Africa (Wortmann*et al.,* 1998). *Xanthomonas axonopodis* pv. *phaseoli,* the pathogen, is currently widespread throughout the world, including in Africa [Angola, Burundi, Central African Republic, Congo Democratic Republic, Egypt, Eritrea, Ethiopia (widespread), Kenya, Lesotho, Madagascar, Malawi, Mauritius, Morocco (previously present), Mozambique, Nigeria, Rwanda, Somalia, South Africa (widespread), Sudan, Swaziland The illness, which is generally prevalent throughout Africa's bean-growing regions and is favoured by warm to high temperatures and high humidity (Buruchara *et al*., 2010) is also known as the mungbean disease.

Management practices

CBB management options should include components that reduce initial inoculums, such as field sanitation, weed and volunteer bean elimination, application of a foliar copper bactericide, proper crop rotation whenever possible, planting healthy seed, early incorporation of bean debris into soil, burning of crop residues, and effective seed treatment, as well as the development of resistant cultivars.

Cultural management

Controlling widespread bacterial blight will need cultural activities. CBB is one of the most serious bean diseases in the world because it is extremely difficult to treat due to the bacteria's seed-borne origin. Seed is the most common source of primary inoculum, and germplasm exchange and worldwide seed commerce both domestically and globally transmit bacteria. An effective disease control strategy is the use of pathogen-free seed that does not include a substantial inoculum source. Bacterium-free seed that has been tested and validated for independence from the bacterium that causes CBB is critical for disease outbreak prevention. Pathogen-free seed should be used whenever possible, but there is no guarantee that the crop will be pathogen-free.

Sanitation is another management strategy for reducing the initial CBB inoculum that may survive in the soil when combined with bean waste. Deep ploughing exposes trash to microorganisms, resulting in rapid breakdown and the elimination of CBB from the debris. As a result, while leaving contaminated material in or on the soil surface, use caution. Because contaminated debris is a major source of inoculum, removing it by burning, ploughing, or other methods may be an effective management tactic. This also minimises the amount of infected plants, which furnish the inoculums for disease outbreaks in neighbouring bean fields.

Use of resistance varieties

Planting *Xap*-resistant bean cultivars is the most cost-effective, technically possible, and appealing approach for eliminating CBB. Plant pathologists have attempted and continue to attempt to create resistance commercial varieties of common bean using traditional and molecular breeding methods. They rely on the genetic diversity of the gene pool system and wild populations as a supply of germplasm. Three Phaseolus gene-pools are employed in breeding. The major gene pool consists of *P. vulgaris* and its wild progenitors, the secondary gene pool of *P. coccineus, P. costaricenis,* and *P. polyanthus,* and the tertiary gene pool of *P. acutifolius* and *P. parvifolius*. The best genetic resistance to CBB is seen in *P. acutifolius*, followed by *P. coccineus*, and finally *P. vulgaris*. In addition to the introduction of resistant genes from other species, collection from diverse common bean producing locations across the world has been used as a source of resistance. As a result, a number of somewhat resistant lines and cultivars have been developed. Important interspecific crossings between tepary and common bean were also conducted to generate a number of different breeding lines and cultivars with high levels of CBB resistance, such as HR45, HR67, and VAX 3-6 resistance, and these lines can be exploited as resistance sources in breeding programmes. Negative epistatic interactions between resistance QTL have been documented, in addition to negative connections between agronomic parameters and resistance QTL. Pathogen variety, variability in host-pathogen connections, fluctuating QTL expression, linkage drag, and unique genes impacting resistance in diverse plant tissues all contribute to the difficulty of breeding for CBB resistance in general.

Biological management

Bioassays were carried out in Brazil in attempt to discover a biological control agent for Xap. Isolates from bean-growing soil, isolates from bean pods, and isolates from bean leaves all gave Xap with varied levels of control ranging from 80% to 100%. In an Italian research, 162 isolates of Rhizobacteria from the bean rhizosphere were examined, and 60 of them inhibited CBB development in vitro. Six of them, on the other hand, decreased disease symptoms in in vitro and green house pathogenicity assays when given to seeds prior to planting. Another research in Iran looked at the resistance of Rhizobium leguminosarum *bv. phaseoli* to CBB in a greenhouse and in the field. R. leguminosarum *bv. phaseoli* was used as a seed therapy in this case, and its influence on disease severity was studied.

Chemical management

Many chemicals have been employed as seed treatments and leaf protectants to prevent CBB before it becomes a severe problem. Chemical control of CBB is too expensive for subsistence farms because to chemical scarcity and high chemical prices. Chemicals, on the other hand, can be used sparingly in certain situations such as seed and commercial production as part of an integrated disease control strategy. Limiting bacterial multiplication in appropriate conditions might help lower bacterial populations below the threshold necessary for disease development and prevent pathogen transmission. When paired with the use of moderately resistant cultivars, this strategy has the potential to be quite beneficial.

Integrated disease management

Integrated disease management is a disease-control strategy that employs a variety of techniques. Disease management's purpose is to maintain disease pressure below the economic threshold. Because of increased understanding of the residual effects of chemicals on the environment, as well as the inefficiency of maintaining a single alternative management option, promoting biological, cultural, physical, and mechanical control practises is the preferred strategy for achieving the same level of control and reliability as chemicals. These integrated strategies reduce or postpone disease severity throughout critical stages of vegetative and reproductive plant development. Common bean growers must carefully incorporate the following strategies:

Crop rotation, sanitation, treated or healthy seeds, resistant or tolerance kinds, stress and wound avoidance, and sufficient bactericide scheduling can all help to limit the incidence of bacterial illness on beans. The adoption of resistant varieties in conjunction with appropriate cultural practises and chemical seed treatment may be the best alternative treatments for treating common bacterial blight of bean and reducing yield losses. Combining common bean-sorghum with once and twice foliar spray provided a bigger net benefit with higher marginal net profit, as well as minimising disease outbreaks and boosting production in each sensitive and moderately susceptible cultivar. Combining seed treatment with a single foliar spray provided a superior net benefit with a higher marginal rate of return, as well as reduced disease outbreaks and improving output in two moderately resistant and one vulnerable cultivars. In general, combining host resistance with seed treatment and cultural practises may assist to reduce the severity of common bacterial blight while enhancing bean production and yield components.

Conclusion:

The gram-negative bacterial pathogen *Xanthomonas phaseoli* pv. *phaseoli (Xap*) and its *fuscans* variation *Xanthomonas fuscans* subsp. *fuscans (Xff)* cause common bacterial blight (CBB), a significant seed-borne disease of common bean that has been recorded in many locations throughout the world, including India. The illness is more widespread in hotter climates and can diminish yields by up to 45 percent. The bacterial blight known as common bacterial blight has received a great deal of attention and is a major threat in bean harvests. However, given the large variety of pathogens and identification and diagnostic procedures available, selecting the optimal ones for this pathogen study is crucial. Xap is a gram-negative aerobic bacterium that does not generate spores and grows on a variety of mediums, producing yellow, mucoid, and convex colonies.

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RECENT TRENDS IN DIFFERENT FORAGE PRODUCTION SYSTEMS, QUALITY AND STORAGE

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Abstract:

In the paper the importance of forage crops, new methods in forage crops production aimed at quality forage production, perennial versus annual crops, as well as energy crops were discussed. In comparison to cereals, fruits, and vegetables, forages have received less study attention while being some of the most significant crops on the planet. The literature on the importance of forage crops, current advancements, and some potential future directions for enhancing yield and nutritional characteristics are described in this review. This paper as a whole focused both on the different forage production system in various agro ecosystems and recent approaches in fodder production like hydroponics along with the advanced forage preservation methods like silage and hay. The improved competition between different land use patterns for the arable lands in the nation prevents further growth in the acreage of fodder crops. The only method to supply animals with enough fodder may be to produce high quality and efficiency per unit area per unit time and include fodder crops into the current cropping systems.

Keywords: Fodder, Forage production, Hay, Hydroponics, Livestock, Silage

Introduction:

In India, mixed crop production and livestock raising are an essential part of rural life, and these procedures are entwined with the complex social fabric in cultural, religious, and relative price. Livestock is an important component in our agricultural production system, play a vital role in the economy of the country (Viliana *et al.*, 2020). Draught strength, rural transportation, manure, fuel, milk, and meat are all provided by livestock. Most frequently, livestock is a subsistence farmer's only source of financial income and acts as insurance against crop failure.

Crop byproducts, green feed from yearly basis and herbaceous plant forage crops, some tuber crops, leaves and branches, and grasslands are all sources of food for animals. Forage serves as the primary source of feed on a large scale. The main cause of India's lower animal production is the country's lack of access to high-quality feed, which accounts for nearly 60% of the total cost of milk production. Forage security is ensured by the effective use of both suitable for agriculture and non-cultivable land areas for pasture production. This helps to increase yield and system productivity. Either forage crops are directly nibbled on by cattle or are provided to them after harvest.

Livestock sector accounts for 25.6 per cent of agricultural GDP and about 4.11 per cent of total GDP. India has huge livestock population of 535.78 million (17 % of world's livestock population). If we check the land resources available in the country for growing fodder and forage crops, According to National commission on agriculture, recommended area under fodder production should be 10 per cent of arable land (15.97 m ha). But, present area is decreased to 4.4 per cent (8.3 m ha). National Institute of Animal Nutrition and Physiology (NIANP), Bangalore reports that the deficit is 38%, 45% and 44 % with regard to Green fodder, Dry fodder and Concentrates respectively. Hence, there is need for improved forage agro techniques to enhance productivity and quality of forage.

Twenty-first livestock census: 35.94 % cattle, 27.80 % goats, 20.45 % buffaloes, 13.87 % sheep, and 1.69 % pigs. When combined, Mithun, Yaks, Horses, Ponies, Mules, Donkeys, and Camels account for 0.23 % of all livestock (Fig. 1). The percentage proportion of sheep and goats has grown in contrast with the previous census, whereas the percentage share of cattle, buffalo, and pigs has somewhat decreased.

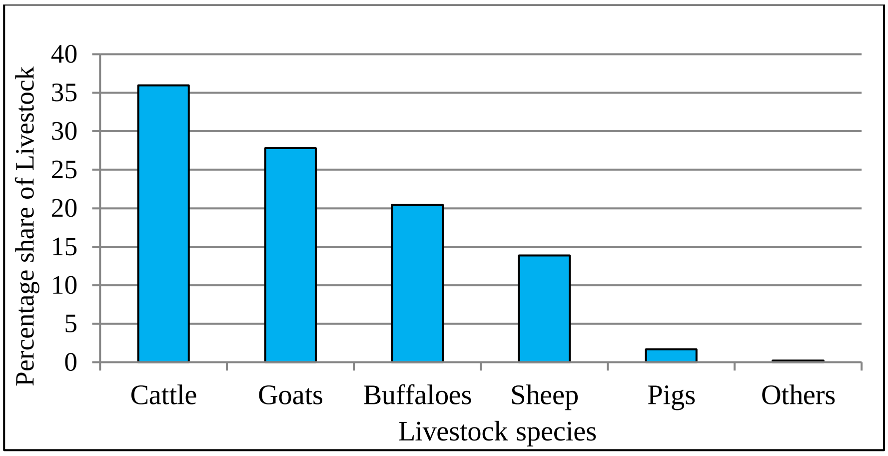

Figure 1: Share of Major Livestock Species in India

Livestock resources in India (20th Census): (Anon., 2019)

- With 535.78 million livestock owners, the world.
- First in the total cattle population in the world – 109.85 million buffaloes.

- 148.88 million Goats make up the second-largest population of goats.
- The second-largest poultry market worldwide.
- Second-largest nation in terms of both fish production and aquaculture in the globe.
- Third in terms of sheep population (74.26 millions).
- Duck and chicken populations are fifth in the world (851.81 million).
- 2.5 lakh camels, ranking tenth in the world.

Fodder and demand supply scenario in India:

The information or estimations of the nation's fodder output vary greatly (Table 1). The type of crops grown, the climate, the socioeconomic environment, and the type of animals all have an impact on the production and use of fodder (Anon, 2013). The estimated shortages for dry feed, green feed, and concentrate in 2020 are 25, 64.6 and 63%, respectively. The table below provides the most likely future prospect of demand and supply in connection to forage in the nation. It demonstrates a significant deficiency in the supply of green fodder in the nation, both currently and in the future. Only half of all animals can be fed with the available feed. Therefore, to face the problem, actions must be taken in appropriate planning and supervision of fodder supplies.

Table 1: Demand and available scenario of forage and roughages in India

Years	Supplies		Demand		% Deficit as of Demand	
	Green	Dry	Green	Dry	Green	Dry
1995	379	421	947	526	568 (60)	105 (20)
2000	384	429	988	549	604 (61)	121 (22)
2005	390	444	1025	569	635 (62)	126 (22)
2010	395	451	1061	590	666 (63)	138 (23)
2015	401	466	1098	610	696 (64)	143 (24)
2020	406	474	1134	630	728 (64)	157 (25)

Fodder scenario in Karnataka

Realizing the importance of dairy farming and providing sufficient quantity & quality fodder to dairy cattle in Karnataka, ICAR New Delhi sanctioned AICRP on Forage Crops was founded in the year 1987 at Tiptur (Zone 4) and shifted to Mandya (Zone 6) in the year 2004 (Shashikanth *et al*., 2013). As other states, Karnataka also facing a deficit in forage and roughages shortage over years of 30 % green fodder, 37 % dry fodder and with a total of 31.32 %.

Fodder scenario in districts of Karnataka

Out of 29 districts of Karnataka, 6 districts belonged to adequately DM available category. Five districts belonged to moderately adequate and 10 districts belonged to deficient DM available categories. One in every four districts belonged to severely deficient DM category with the DM availability of less than 40 % (Table 2). The mean DM availability for the state was 56.46% indicating the deficiency to the extent of 43.54%.

Table 2: Classification of districts as per estimated dry matter (DM) availability in Karnataka

Categories	Criteria	No. of districts	Percentage of districts
Adequate	> 80% DM availability	6	20.69
Moderately adequate	60-79% DM availability	5	17.24
Deficient	40-59% DM availability	11	34.49
Severely deficient	< 40% DM availability	8	27.58

Importance of fodder crops

- Support and provisions for livestock industry.
- Dense stand to smother weeds and avoid soil erosion loss.
- Enhance soil health by increasing the proportion of organic leftovers in the soil.
- Low tillage and regular seeding are required due to the plant's high persistency and regeneration potential.
- Greater flexibility and the ability to grow under pressure.
- A multifaceted nature with the ability to offer a stable source of income and employment.

Constraints in Forage production in India

- ✓ We were driven to plant more grain crops as opposed to fodder crops as a result of the growing human population. Cereal grains and sidetracked feed were the key components of the green revolution.
- ✓ Low productivity is a result of outdated industrial technology being unavailable or not being used.
- ✓ Small (21.75%) and marginal (69.4%) livestock farmers do not give feeding of low-yielding animals any thought.
- ✓ Growing under rain-fed conditions on marginal areas. Lack of qualified and experienced human resources for managing fodder production
- ✓ The lack of high-quality seed and planting supplies.
- ✓ Loss of grazing land as a result of urbanization.

Definition of Forage and Fodder

- Species of plants that are planted for use as animal fodder are known as fodder crops. The term "fodder" usually refers to crops that are harvested and fed to livestock.
- The vegetative matter – whether it's fresh or preserved—used as animal feed may be referred to as forage. Grasses, legumes, crucifers, and other crops that are grown and utilised as hay, grassland, fodder, and silage are examples of fodder crops. Forages are classified based on various features

Classification of forage crops

1. Based on the lifecycle	2. Based on growth habit	3. Based on habitat
▪ **Annuals/Seasonal**: Kharif - Cowpea, Maize, Grasses Rabi - Oat, Berseem, Lucerne Summer - Bajra, Grasses, Sorghum ▪ **Perennial:** Guinea grass, Para grass, Subabul	▪ **Herbs** - Cowpea, Jowar, Oat, Maize ▪ **Shrubs** - Hedge Lucerne, Guinea ▪ **Trees** - Subabul, Sesbania	▪ **Cultivated fodders** - NB Hybrid, Lucerne ▪ **Wasteland fodders** - Rhodes, Marvel grass ▪ **Marshy land fodders** - Paragrass ▪ **Aquatic fodders** - Water hyacinth & algae

Recent approaches of forage production technology

1. Sowing and planting

Seed priming: Seeds priming is the technique of carefully hydrating seeds to a point where pre-germination metabolism can continue but real radical appearance is prevented. When crops sowing delayed and no moisture in that condition, it improves resistance to water and temperature stress. Seed priming can be done through the water, osmotic solution, salt solution and hormones.

Optimizing date of sowing: By optimizing different date of sowing the crops will get favorable climatic conditions like temperature and other climatic parameters which will improve the growth and yield of the crops.

Paired row planting: Utilization of space and time will be done by this which will improve the productivity and production of the system.

Nursery: Various perennial grasses like Napier, guinea, etc. are cultivated by slips and other planting materials that can be prepared earlier in the nursery that will improve the establishment of the crops (Singh *et al*., 2018).

2. Nutrient management

Optimizing the application of major and micro nutrient at optimum levels will help in the crop growth improvement and yield and quality improvement.

Soils which are deficit in some nutrients are added through the agronomic fortification so that crop will agronomically fortified, so that they will get be rich with additional nutrients and their by animals also get nutrition through the fodder and forages that intake.

3. Water management and hydroponics

Use of different micro irrigation methods like drip, sprinkler which improve the use efficiency of water and which also use of poor quality water will also help improve water use. New technologies like hydroponics also help in improvement in production and productivity of fodder crops. The Greek terms hydro, which means "water" and hydroponic, which means "working" were combined to create the English word hydroponics. So-called hydroponic or sprouting grain or germinated fodder is created by growing crops in water or nutrient-rich solutions without the use of soil.

I. Forage production systems in irrigated lands

In India, less than 4.5% of the total land used for agriculture is dedicated to growing fodder. In India, there are now over 8.6 million hectares of fodder crops. Due to rising competition among other land uses for the country's arable land, further growth in the area of fodder crops is not viable (Susheela *et al*., 2015). The only method to supply animals with the necessary fodder may be to boost productivity for every unit of land area and include fodder crops into the current cropping systems.

1. Intensive fodder production systems

The goal of intensive grazing production systems is to use the land and other resources as effectively as possible to produce the most fodder possible per unit area and unit time. For a continual supply of fodder to dairy cows all year long, this production strategy cultivates three to four fodder crops on the same plot of land each year. It is an intensification of the cropping system in both time and space. Intercropping, crop diversification, and sequential cropping are all included.

These crop sequences are designed to provide a large output of healthy, green forage while preserving the soil's fertility. Multiple crop sequences like sorghum + cowpea - Berseem + mustard - maize + cowpea and sorghum (multicut) + cowpea - Berseem + mustard are promising in central India's irrigation-guaranteed regions.

2. Food-fodder production systems

Owing to land constraints small and marginal farmers are not able to grow forage crops in place of food crops. In turn their livestock are not fed adequately. Integrating fodder crops in the existing food crop based cropping systems to enhance forage availability in these areas without compromising with yield of food crops.

Due to their high canopy, substantial contribution of stubble biomass, and effective use of applied nutrients, the contribution of fodder crops to existing sequences increases soil productive in irrigated environments. Since berseem needs more number of irrigations therefore other crop sequences like rice – oat, rice – shaftal and cowpea – wheat may be adopted.

3. Forages in non - food crop production system

Crops like cotton, sugarcane and potato provide room for growing forage plants with small statures (Lucerne, Berseem and Oat) in the inter row spaces without affecting the yield of main crop.

The availability of good quality forage is scarce in all the regions. So, any effort of producing good quality forage may prove more remunerative in present entrepreneurial scenario. Inclusion of forage crops in existing non-food crops (sugarcane, potato, cotton, etc.) may be an important aspect of fodder production.

4. Forage production during lean period

In irrigated situations of northern India, most of the areas lie under double cropping systems, which offer great scope for raising short duration fodder crops during lean periods. This period falls before the start of rainy season in May-June and during winter season in November-December.

Raising short duration fodder crops during lean periods. In maize/ sorghum/ pearl millet (grain)-wheat sequence fodder crops like cowpea, mustard & turnip are could be grown for Forage.

5. Forage production under orchards and grooves

In our country, area under horticultural crops gives ample scope for interspace utilization and system diversification in different regions.

Fodder crops like Signal grass, Congo grass and Guinea grass are either shade loving or tolerant to shade. These crops find scope for growing under or near to the horticultural trees and grooves.

II. Forage production systems in rainfed lands

It is impossible to allocate land just for forages on small and marginal farms. The production of grain, pasture and other agricultural goods may therefore be ensured in a rainfed environment by integrating forages into the current crop layout.

1. Round the year forages production system

At present 60% of the nation's agricultural land is rain-fed and is dispersed throughout the nation. In these regions, July through September is when 90% of the rain falls. therefore allowing growing period 20 to 25 weeks.

The technology includes the appropriate combination of perennial and annual forage species which utilizes moisture and nutrients from different soil layers, thereby insuring higher green fodder availability over a prolonged period.

2. Seasonal crop based forage-food production system

There is possibility of accommodating short duration forage species in sequence with food crops to increase the intensity of cropping in time. This is feasible on black soil consisting of kabar and mar which retain sufficient residual moisture for growing winter crops. In this system, forage crops may be included to precede or succeed the food component depending upon food and fodder needs.

3. Perennial crop based forage-food production system

The climatic limitations, erratic rainfall soil heterogeneity and lack of irrigation resources make agriculture difficult in rain fed situation. The holdings are very small and fragmented in rainfed areas. Livestock production is quite important to the local economy in these areas. In such cases, forage crops must be blended with crop production and other agricultural area.

III. Forage production in problem soils

Problem soils are characterized by the excess or deficiency of some properties of soil making it not fit for cultivation under normal condition. These soils are affected by different degree soil degradation problems. The development of additional forage resources is possible only through utilizing these problematic soils having less competition for other land uses. Acid, salt affected waterlogged and calcareous soils offers promise for forage resource development.

1. Forage production in salt affected soils

Soils having unusual high salt content interfering in the cultivation of the crop plants are collectively known as salt affected soils. The type and concentration of salt elements, soil texture and the dispersion of salt in the soil profile, the kind of crop planted, soil-water-crop management, and meteorological circumstances all affect how severe the problem is for crop productivity.

The management needs of the forage crops and grasses are relatively less than the food crops and these soils can be successfully utilized for economic forage production with minimum interventions.

2. Forage production in acid soils

The crop production in acid soils (below pH 5.5) are impaired due to excess activity of lack of P, Ca, Mg, and Mo as well as Al, Mn, and Fe. Low soil biological activity affect nutrient cycling in these soils. Other constraints in these soils are low base status, low CEC and poor soil fertility.

Technology developed for amelioration of acid soil for fodder production needs to be undertaken by sensitizing the stake holders. Grasses are found to be more tolerant than annual crops, like legumes and cereals. In slightly too strongly acid soils (pH 5.5 - 6.0) maize, Deenanath grass, Napier bajra hybrid, guinea grass and Setaria grass performs better than other fodder crops.

3. Forage production in calcareous soils

The production of certain crops is restricted due to $CaCO_3$ induced deficiency of plant nutrients like P, Fe and Mn. The presence of Kankar pan in lower soil layers restricts drainage. It is distinguished by the existence of calcium carbonate in the parent material and by a calcic horizon, which is a layer of secondary accumulating of carbonates (often Ca or Mg) that contains at least 5% more carbonate than a substrate surface and more than 15% calcium carbonate equivalent. The soils are very hard and have aeration problem. Sorghum amongst other cereal fodder crops performs better in these soil conditions.

4. Forage production in waterlogged soil

Waterlogged soils are defined as an area where soil pores in the crop root zone get saturated due to stagnant water on the surface of the ground or a rising water table, it restricts airflow normally, lowers oxygen levels, and raises carbon dioxide levels (Central Water and Power Commission, India). The continuous availability of excess water in root zone causes poor aeration, which in turn results into poor growth and nutrient uptake.

Problematic soils fodder production

Acidic soils: cowpea, oats, Fodder maize, Napier grass

Alkali soil: Jowar, Bajra, Oats, Para grass

Saline soils: Jowar, Lucerne, Rhodes, Para grass

Water logged: Rhodes, Para grass

Eroded land: Stylosanthes, Guinea grass

Dryland or marginal lands: Anjan grass

IV. Forage production systems in new niches

The region used for forages has very little room for growth. Consequently, efforts are being undertaken to use the unconventional locations as new fodder producing niches.

1. Non-competitive forage production system

Feed may be successfully grown on bunds by farmers with marginal or small land holdings and livestock owners with modest forage needs. These regions make use of land that would not otherwise be used for agriculture and do not compete with current crops or cropping techniques. In non-competitive fields of irrigated lands, irrigation channels of various climates, as well as vast bunds of rainfed farms, some fodder species can be planted.

2. Fodder production in rice ecosystem

Field bunds account for around 5-7% of the entire rice acreage, making them an alternate site for hosting parallel pasture species. Similarly rice fallows may be utilized for growing forage legumes like Berseem, oats, lathyrus in residual soil moisture.

3. Non-conventional forages

There are a number of plants and their species which can supply the green herbage to small and large ruminants. These species are either cut or lopped for animal feeding. In different parts of country this is a common practice but species of plant vary among different agro-climatic conditions.

Therefore the crops like wheat, barley possessing dual-purpose characters for fodder and food availability will be greatly helpful for boosting forage production without affecting grain yield of crops. Similarly crops like turnip and sugar beet offers good choice with the development of higher biomass producing genotypes.

Hydroponic fodder production

The Greek terms hydro, which means "water," and ponic, which means "working," were combined to create the English word hydroponics. So-called hydroponic or sprouted grain or sprouted fodder is created by growing plants in water or a nutrient-rich solution without the need of soil (Ghazi and Al-Hashimi, 2011). In a short amount of time, hydroponics are grown in greenhouses with regulated environments.

However, green fodder may be grown with only fresh water. Water, sunshine, and additional nutrients are the only inputs needed for hydroponic seed growing of green fodder because the green fodder is fed to the animals after around 6 to 8 days of plant growth. The crucial cultivars used in hydroponics to generate high-quality, nutrient-rich green feed for dairy cows are maize, oats, barley, wheat, cowpeas, etc.

Hydroponic Technology Principles

Cereal grains are grown hydroponically, which is without a solid growth medium but with the required moisture and nutrients. Within 7 – 10 days, germination – a reaction to the moisture and nutrients supplied - produces a 20 - 30 cm long bright green stalk with intertwined roots. As they develop, many cereal grains, including maize, bajra, millets, horse gram, etc., undergo a variety of chemical and structural changes that can be utilized to produce fodder (Rajesh *et al*., 2019). It has been discovered that breakdown of nutrients into their simpler forms requires enzyme activity. The amount of sprouted and high-quality fodder is influenced by grain type, quality, treatments such fertilizer availability, pH, water quality and soaking duration, among other things.

Precise use of Space

For urban residents having small yards, hydroponic systems take up far less area. Up to 1000 kg of maize fodder may be generated each day using hydroponics technology from 45 to 50 m^2, which is comparable to 25 acres of arable land used to create traditional fodder.

Advantage of hydroponic techniques of green fodder production

1. Nutritional Benefits: Compared to conventional fodder production, hydroponic green fodder is tastier, easily digestible, and of higher quality. Hydroponics Green Fodder (HGF) has a lower crude fibre content (14.1% v/s 25.9%) and a higher crude protein content (13.6% v/s 10.7%) when compared to conventional green fodders.

2. Greater Palatability: The fodder is more succulent, tasty, and nourishing, and cattle consume more HGF than CGF as a result, which increases the output of milk and meat.

3. Hydroponic techniques use only a few litres of water to produce a kilogramme of green fodder, compared to standard cultivation methods that need 55 to 75 litres.

4. A wider temperature range: The technology is cost-effective and environmentally beneficial, with a temperature range of 15 to 35 °C and a relative humidity (RH) of 70 to 80%.

5. Requires the least amount of land possible; with a typical agriculture technique, one hectare of land would be needed to produce the equivalent amount of 600–650 kg of feed each day. With this amount of feed, 20–25 mature cattle may be raised for a year.

6. Readily Measurable: Farmers with just two head of cattle may easily monitor the hydroponics production to meet their demands.

7. Less labour is needed: In the HGF system, a single worker can complete the entire process in two to three hours per day, whereas the traditional system of producing the same amount of fodder requires more labour to complete tasks like clearing the land, planting, watering, harvesting, moving the fodder from the field to the cattle shed, cutting the chaff, and finally feeding the cattle.

8. More fodder in less time: HGF only need 7-8 days when they are between 20 and 30 cm tall.

9. More biomass is converted when: When compared to CGF cultivated for 65 to 80 days, the biomass conversion ratio can be up to 6-7 times higher.

10. Year-round production of green fodder is possible under semi-protective circumstances 365 days a year.

11. Minimal losses: Since the entire plant, including the roots, leaves, grain, and stem, is fed to the animals, losses are kept to a minimum.

12. Organic/natural green fodder: Green fodder is cultivated naturally because no nutrients are added and no soil is used.

13. Faster production and higher growth: Green fodder cultivation results in a high output of fodder.

Fodder grown hydroponically is nourishing, tasty, and digestible and may be produced using cheap procedures and grains that are cultivated at home nearby. In India's many agro climatic areas, hydroponics fodder production is a useful alternative technique for sustainable livestock production in the face of accelerating climate change and decreasing land availability.

Forage Quality and Preservation

The capacity of forage to supply animal nutrients requirements. How much forage has the potential to cause desirable animal behaviors. Animal performance, forage value and ultimately earnings are all directly impacted by forage quality.

Factors that affect animal performance on forage

- Animals choose one type of forage over another based on its palatability. Texture, leafiness, fertilization, dung or pee patches, moisture level, insect infestation, or substances that give forage a sweet, sour, or salty flavour can all affect how palatable a plant is. Forages of good grade are typically quite tasty.
- Animal performance depends on the amount of forage they ingest. Generally speaking, intake increases with forage quality and palatability.
- Digestibility - The amount of fodder that is absorbed as it moves through an animal's digestive system varies significantly. Less than 50% of mature, stemmy material is digested, compared to 80 to 90% of immature, leafy plant tissues.
- Living forage plants often have a water content of 70 to 90%. Forage production and nutrient content are often expressed on a dry matter (DM) basis to standardise studies.
- Anti-quality elements - A variety of substances that might impair animal performance, bring on illness, or even lead to death - may be found in forage. These substances include mycotoxins, cyanoglycosides, alkaloids, tannins, nitrates, and cyanoglycosides.

Forage Crops Preservation

The availability of food is a pressing concern as the population rises. Reducing food losses between harvest and consumption is a crucial but often ignored step in this direction.

Despite technological advancements, tonnes of cereal are lost each year due to various types of rotting. It is of utmost importance to protect food supply through safe storage methods. If storage and marketing are done well, they will significantly help the underdeveloped nations where there is a serious scarcity of food and feed. (Mina *et al*., 2011).

Loss is calculated as a weight decrease in the amount of feed that is available to be consumed. Losses may be quantitative, qualitative, economical, nutritional and germinative.

Essential criteria for safe storage of products

- Completely weatherproof. Gas tight to allow complete contents to be fumigated.
- Equipped with adjustable ventilation. Proof that keeps birds and rats out.

- Free of light-transmitting portions in the ceiling to prevent hot spots on top of product that is being kept.
- Constructed to allow for the inclusion of a few fans in the walls and ducting on the floor for particular storage requirements.

Silage

Silage is a fermented feed that is produced when high moisture crops, often green forages, are stored in a Silo under anoxic environments. Structure that is airtight to partially airtight that was created for the storage and preservation of high moisture feeds like silage.

Ensilage, ensiling, or silaging refers to the fermentation and storage process that is often created from grass crops, such as maize, sorghum, or other cereals, utilizing the entire green plant (not just the grain). Many field crops may be used to make silage, and depending on the kind, different terminology may be used: Outage for oats, haylage for alfalfa (also used to describe high dry matter hay silage (Umadevi *et al*., 2014).

The following techniques can be used to create silage: packing huge circular bales of chopped green vegetation firmly in plastic film; stacking the vegetation in a large heap and compacting it to remove as much oxygen as possible; or putting the vegetation in a large heap and compressing it.

Haylage: When referring to high dry matter silage, which is often derived from hay, the term "haylage" is frequently used. Horse haylage is often formed in tiny bales or bigger bales and contains 60% to 70% dry matter (Keys *et al*., 1984).

Silage making procedure

- ✓ Build a surface/trench silo (silage storage structure). 500–600 kg of green fodder may be stored in a cubic metre of space or a silo.
- ✓ At 30-35 percent dry matter (DM) stage, harvest the crop.
- ✓ Wilt the gathered hay, if necessary, to reduce DM to 30-35 percent.
- ✓ Cut the fodder into pieces that are 2-3 cm in size. Fill the silo with the cut fodder.
- ✓ Press the cut fodder into the silo in 30-45 cm layers.
- ✓ Filling and pressing have to be finished as quickly as feasible.
- ✓ If necessary, add supplements when filling the silo with feed.
- ✓ Seal the silo with a thick polyethylene sheet following the pressing and filling steps.

Benefits of silage production

- ✓ Ensures a consistent supply of high-quality fodder for animals throughout the year, especially throughout the varied seasons.
- ✓ Silage may be produced in practically every kind of weather.
- ✓ Green fodder that is in excess can be saved, reducing waste.

- ✓ Due to the fact that the parasites contained in green feed at various stages are eliminated during ensiling, feeding silage is a successful method for controlling parasitic infections.
- ✓ Increases green fodder output by raising the level of harvesting.
- ✓ Increases cattle production by assuring a source of feed, particularly during the lean season.

Drawbacks of silage production

- Compared to the more straightforward techniques of field curing and hay storage, it necessitates a silo (a permanent structure), which is likely to result in greater expenses for small farmers.
- If silage is not correctly produced, there may be increased wastage.
- Animals won't eat silage that has been improperly prepared.
- It has a lot less vitamin D than hay that has been dried in the sun.
- Preservatives are an additional cost associated with ensiling.
- A greater amount of labour is required for filling silos.

Hay

When grasses or legumes are collected, dried, and stored at 85–90% dry matter, they are referred known as hay. Hay of a high grade is green in colour, leafy and malleable, and musty-free. Hay is a term used to describe grass, legumes, or other herbaceous plants that have been harvested, dried, and stored for use as animal feed, particularly for big grazing livestock like cattle, horses, goats, and sheep. But it's also given to smaller domesticated animals like guinea pigs and rabbits. Hay may be fed to pigs as well, although they do not digest it as effectively as herbivores do.

When there is not enough pasture or rangeland for an animal to graze, when grazing is not possible due to weather (such as in the winter), or when lush pasture alone would be too rich for the animal's health, hay can be utilized as animal food (Buckmaster *et al*., 1989). Additionally, it is fed when an animal is housed in a stable or barn and is unable to reach pasture.

Different hay types: The following groups of hay can be separated based on the various processing methods viz. Sun-dried hay, Barn-dried hay, dehydrated fodders and Jungle hay.

Advantages of hay

- Reduce the cost of transportation to the drying site.
- Drying time is reduced.
- Loss of nutrients due to rains is avoided as the process is performed in a barn.
- Loss of plant parts especially leaves is less to that of field curing.

Recent trends in hay and silage making

In the preparation on hay and silage recent trends were made to avoid the constraints and helps in easy transportation, easy handling, more palatable and nutrition rich and avoiding deterioration of hay and silage content. By the below recent trends hay and silage can be better managed and are best utilized for livestock feeding.

Conclusion:

Growing of superior dual purpose varieties with improved agro techniques like water management, cutting intervals and nutrient management etc., observed higher fodder yield and quality. Green fodder production can be augmented by growing fodder crops with food crops in diversified cropping system as intercrop, mixed crop and grass legume mixture. Forage production can also be maximized by use of new technologies like hydroponics.

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SOIL MOISTURE, NUTRIENT AND CROP CANOPY SENSORS APPLICATIONS IN AGRICULTURE

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Abstract:

Growing concerns about the need to increase crop productivity without causing environmental injury have led to the deployment of site-specific strategies in irrigation and soil nutrient management, where water and nutrients are applied in variable rates to fit local requirements. They provide data that helps farmers to monitor and optimize crops with environmental conditions and challenges. Sensor technology helps farmers and enterprises in efficient input utilization by irrigation scheduling and application of required amount of plant nutrients at proper growth stage. Use of sensors can increase production efficiency, improve product quality, efficient input usage and for soil and ground water protection.

Keywords: Irrigation, Nutrient management, Precision farming, Sensors, Site-specific

Introduction:

The total geographical area of the country is 328.7 million hectares (2.4% world geographical area), of which 139.4 million hectares is the reported net sown area and 200.2 million hectares is the gross cropped area with a cropping intensity of 143.6%. Also second largest populous country with the population of 1.3 billion. According to Food and agriculture organization (FAO), by 2050 the world population is likely to touch 9.8 billion and 11.2 billion in 2100. As we are seeing huge increasing population over years, thereby requirement of food grains also increases. Vertical development is only viable option.

To get a better crop, the most important things that should be there in the land are accurate fertilizer, better irrigation facilities and best methods for cultivation. An adequate amount of fertilizer can help plants to produce better yield and quantity to meet the needs of world economy that is increasing the need of food and its production. Over 58 per cent of the rural population depends on agriculture for their livelihood and it constitutes to 10 per cent of the country's total exports. So, the farmers and even the nation's economy will be reduced if there are no proper yields due to lack of knowledge of the soil nature and unavailability of water. Therefore, the researchers in agriculture are looking for ways to improve crop yield while minimizing the consumption of fertilizer and irrigation water through promising way.

Soil sensors and plant wearables play a critical role in smart and precision agriculture via monitoring real-time physical and chemical signals in the soil, such as plant nutrients, temperature, moisture, pH and pollutants and providing key information to optimize crop growth circumstances, fight against biotic and abiotic stresses and enhance crop yields. "Sensor is an easy and small tool that measures or detects natural world conditions such as motion, heat or light and converts this condition into an analogue or digital representation". We need sensors to increase production efficiency, improve product quality, efficient input usage and for soil and ground water protection (Adamchuk *et al.,* 2005).

The most common types of soil moisture sensors include tensiometer, gypsum blocks, neutron probes, time domain reflectometry, frequency domain reflectometry, capacitance and soil moisture indicator. Most commonly used nutrient and crop canopy sensors in agriculture are green seeker, crop circle ACS-470, crop sensor, SPAD meter, ion electrodes, infrared thermometry, *etc.*

What is the role of sensors in agriculture?

Sensors used in agriculture for smart farming are known agriculture sensors. They provide data that helps farmers to monitor and optimize crops with environmental conditions and challenges. These sensors in agriculture installed and fixed in weather stations, drones, and robots used in the agriculture industry. They can be controlled by mobile apps precisely, which develops for this purpose. Agriculture sensors based on wireless connectivity; they can be controlled directly using Wi-Fi or through cellular towers with the help of mobile phone applications.

Types of sensors in agriculture

1. Optical sensor
2. Electrochemical sensor
3. Mechanical sensor
4. Dielectric sensor
5. Location sensor
6. Electronic sensor
7. Air flow sensor
8. Agriculture sensor IoT

Soil moisture sensors and their applications in agriculture

The world, at present is facing shortage of water which is hampering the development of agriculture and hence the food production. Judicious use of water is therefore necessary and in agriculture particularly, optimum use of water is necessary (Munoth *et al.*, 2016) as there is shortage of water in most parts of India. Soil moisture is primary information in achieving optimum water requirements for the crops.

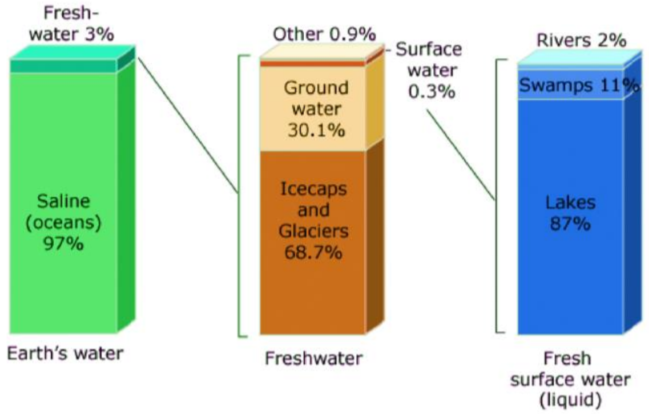


Figure 1: Distribution of earth's water

There are generally two methods of measuring soil moisture, which are *Direct inspection* (Feel and appearance method, Hand-push probe, and Gravimetric method), and *Meters and Sensors* (Soil moisture blocks, TDRs, FDRs, etc.) (Evans *et al.*, 1996). The soil moisture sensors are very productive instruments in measuring soil moisture to assess crop growth. Soil moisture sensors measure the water content at the root zone and is useful in irrigation scheduling (Clarke *et al.*, 2008), precision agriculture and hydrology, residential gardens, landscapes, rainfall monitoring, environmental testing etc. There are various types of soil moisture sensors available in the market.

Sensor-based irrigation scheduling

- There are a number of sensor systems now available that provide valuable information on when a field is ready to be irrigated.
- Wireless data transmission and improved software interfaces are now making these sensors practical for farm use.
- An affordable way to gain experience with sensor-based scheduling is to monitor a field for a season and review the data over the winter to see how your irrigation decisions matched the sensor readings.

The procedures often used to employ soil moisture sensing devices for irrigation scheduling include:

1. Determine the irrigation application amount to apply.
2. Determine which type of sensor to use.
3. Decide whether to collect sensor data manually or involve automation. There are two levels of automation. One, the sensors automatically turn the irrigation system on (and possibly off)

and two, only data is collected automatically (through hard-wiring or telemetric signal) but the irrigation is turned on/off independently of sensor readings.

4. Decide at what depths to install the sensors and at how many locations in the field.
5. Determine the sensor value which will serve as the – trigger point to start irrigation.
6. Decide how often sensor measurements will be taken.
7. Convert numerical data into graphical representations.

Need for soil moisture sensors

- Out of the India's water usage 70 % is solely used for irrigation in the crop production.
- Declining per capita water availability, over years as the population is increasing the availability of water for individual person is reduced to 1486 m^3 in 2021. By 2050 it will reach to scares level *i.e.* less than 1000 m^3.
- Increasing water requirement of different sectors. Among the different sectors, over years from 1999 to 2050 the estimated annual water requirement for various uses in India increased more than 2 times (Fig. 2).

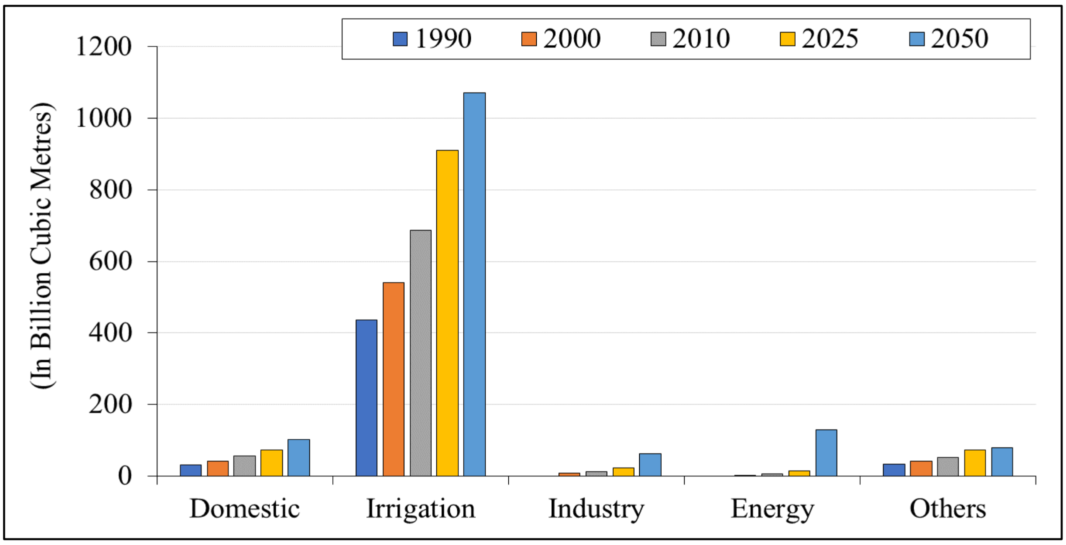


Figure 2: Estimated annual water requirement for various uses in India

Role of sensors in irrigation scheduling

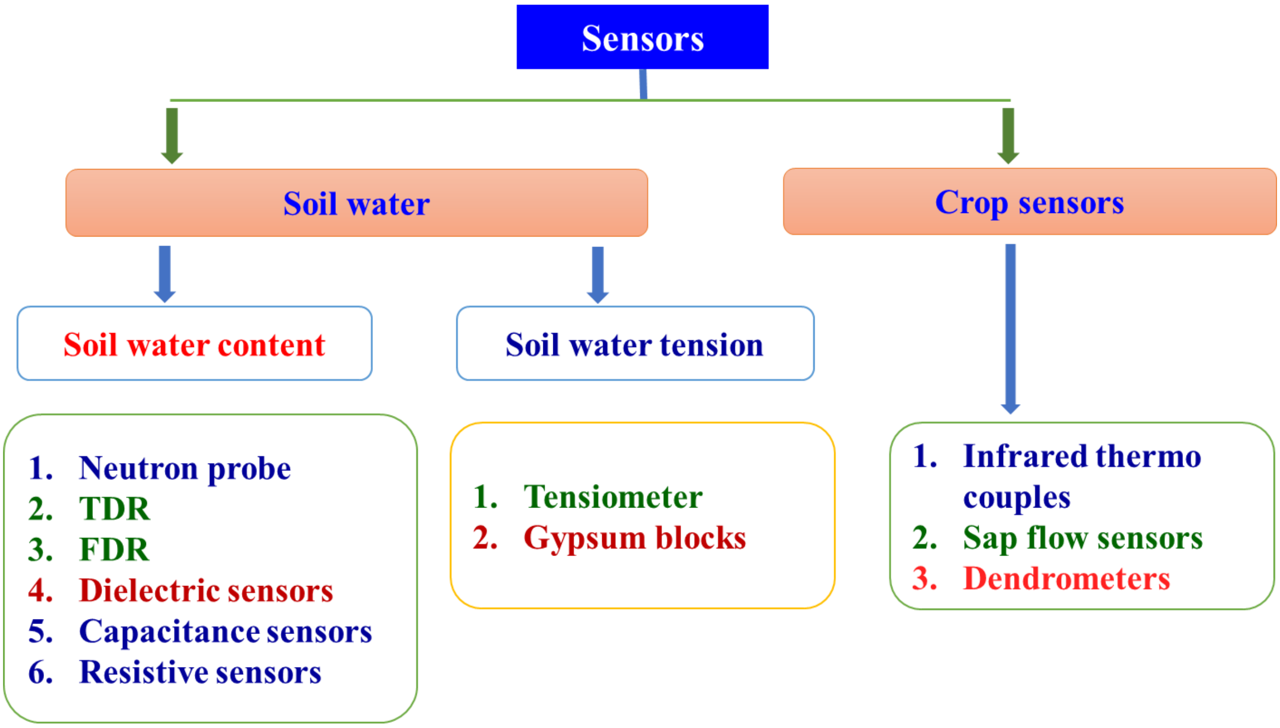
A sensor that will sense the moisture level in the land (sand) is called soil moisture sensor. For determining the soil moisture content (in volumetric and gravimetric forms), various techniques can be employed, which can be categorized into

(i) Classical and

(ii) Modern techniques for both the laboratory and in situ measurements.

Different types of soil moisture sensors

There are numerous types of sensors available today, each having variable performances (Francesca *et al.*, 2010). Some measure soil moisture content while other measure soil water potential and dielectric constant (volumetric content). Although there are numerous techniques available for soil moisture sensing, but in this review the soil water tension based sensors (tensiometers and granular matrix sensors) and soil water content based sensors (TDR, FDR and VH400) are discussed. The nuclear scattering and gamma ray attenuation techniques have not been discussed here as they use radioactive material which may prove to be hazardous.



1. Tensiometers

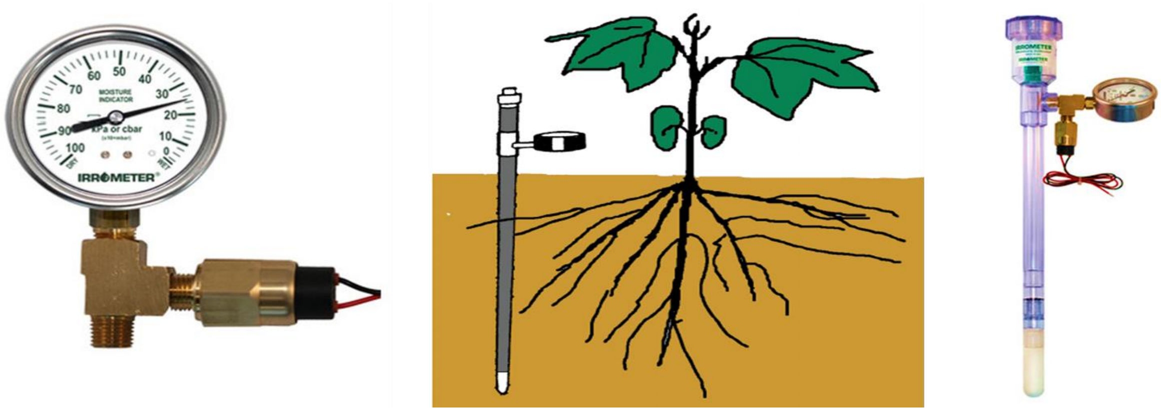
Tensiometers are simple soil moisture tension measuring devices used frequently in irrigation scheduling. The figure shows a typical tensiometer which consists of a porous ceramic tip connected to vacuum gauge through a PVC tube. The tube consists of water which should be free from air. The porous ceramic cup is installed into the soil in such a way that soil water pressure is transmitted to the tensiometer which is read by pressure sensing devices mounted on the tensiometer. This instrument do not measure soil moisture content directly, instead it measures soil water tension (Freeman *et al.*, 2004). Generally, the response time of a tensiometer is 2 to 3 hours (Zazueta *et al.*, 1994). There are tensiometers available which can be automated with the irrigation system with the help of pressure gauge.

Advantages

a) Tensiometers are simple, rapid, inexpensive and easy to use (Enciso-Medina *et al.*, 2007).

b) Different types of liquid like ethylene glycol solution can be used to obtain data during freezing and thawing conditions (Schmugge *et al.*, 1979).

c) A tensiometer is ideal for sandy loam or light textured soils (Alam *et al.*, 1997).



Disadvantages

a) Periodic maintenance is required as air bubbles accumulate under normal use (Hensley *et al.*, 1999).

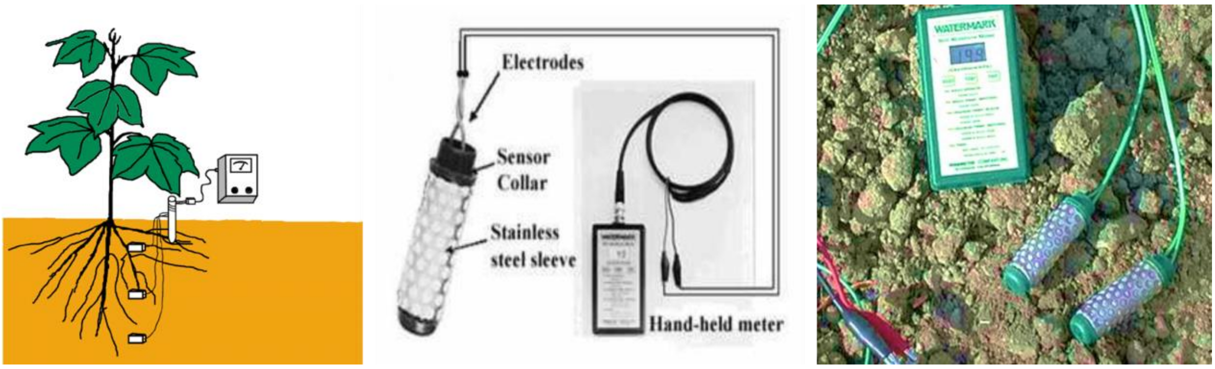
b) It is prone to damage due to freezing temperatures (Alam *et al.*, 1997).

c) Several tensiometers are required for measurement because they measure soil water potential only in the vicinity of the tensiometer (Goodwin, 2009).

d) The usable range is only between 0-85 centibars of tension above which the gauge will malfunction (Werner, 2002).

2. Granular Matrix Sensor (GMS)

The granular matrix sensor is made of a porous ceramic external shell with an internal matrix structure containing two electrodes as shown in figure 3. The electrodes inside the GMS are imbedded in the granular fill material above the gypsum wafer. The water conditions in the granular matrix change with variation in corresponding water conditions in the soil and these changes are continuously indicated by difference in electrical resistance between two electrodes in the sensor (Berrada *et al.*, 2014). This resistance between the electrodes is inversely related to soil water.



Advantages

a) GMS is cheaper and requires less maintenance compared to tensiometer (Shock *et al.*, 1998).

b) Automation of irrigation in fields can be achieved (Muñoz-Carpena *et al.*, 2005).

c) Negligible change in sensor performance with variation in soil temperature (Irmak*et al.*, 1990).

Disadvantages

a) It shows different response to different soil types (Enciso-Medina *et al.*, 2007).

b) Sometimes, poor contact between the soil and the sensor occurs which could cause high readings which is most likely to occur in heavy soils (Berrada *et al.*, 2014).

c) It is less responsive to small rains (<0.5 in.) (Berrada *et al.*, 2014).

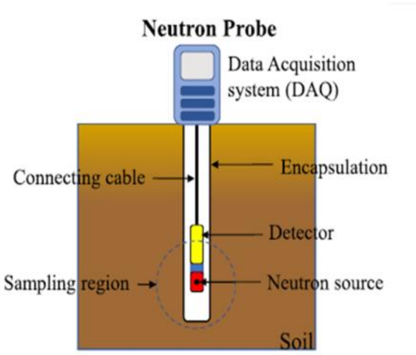
d) It is low accurate in sandy soils because of their larger particle size (Zazueta *et al.*, 1994).

Applicability

The GMS is used for assessing soil moisture in crops like cotton, onion, potato, urbanized landscapes (Muñoz-Carpena *et al.*, 2005), corn (Irmak *et al.*, 2006), drip irrigated vegetable crop (Thompson *et al.*, 2005). The GMS has good accuracy in medium to fine soils because the soil particle size will be similar to that of the transmission material which has a consistency close to that of fine sand that is wrapped in porous membrane of the GMS.

3. Neutron Probe Method

The neutron probe (NP) method for SMC determination uses the characteristic property of hydrogen nuclei in water molecules to scatter and/or slow down neutrons. Based on the energy transfer, scatter cross-section and having the similar size as a neutron, hydrogen nucleus has greater thermalization (collision) effect with neutrons than any other element. High energy neutrons from a radioactive source, such as radium-beryllium or americium-beryllium slow down or change direction due to elastic collisions. The thermalized neutron density can easily be measured by a detector and if the capture cross-section of soil media remains fairly constant i.e. the chemical composition remains fairly constant except the variation due to water, the measurements from neutron probes can be calibrated to represent the SMC.



The high energy neutrons are released by the radioactive source that collide with hydrogen atom nuclei of water in soil and are captured by the detector. Neutron probes are available commercially where, with good calibration based on soil make up (metal content and density) and proper installation (sampling region completely buried in soil and minimal air gaps around the probe), precision between 1% to 5% can be achieved. Some advantages of NPs include high accuracy, and relatively less dependence on soil temperature and salinity. Some limitations of this method include radiation hazard, the requirement of a skilled operator to properly install and take measurements making the method labor as well as cost intensive.

4. Time Domain Reflectrometry (TDR)

In time domain reflectrometry, a pulse of radio frequency energy is injected into a transmission line and its velocity is measured by detecting the reflected pulse from the end of the line. This velocity depends upon the dielectric constant. It measures the moisture content by measuring how long it takes for the reflected pulse to come back (Cepuder *et al.*, 2008 and Haman *et al.*, undated). The response of a TDR is very quick (≈ 28 sec) (Zazueta *et al.*, 1994).

Advantages

a) TDR respond quickly to varying soil moistures (Marenghi, 2013).

b) It measures moisture quite accurately (± 2%) in any type of soil (Cepuder *et al.*, 2008).

c) Soil moisture from multiple depths can be obtained from a single probe (Pitts, 2016).

d) There is little or no disturbance to the test site during the testing process (Skierucha *et al.*, 2012)

Disadvantages

a) They need to be carefully calibrated to precisely measure the amount of time it takes for the pulse to come back (Paige *et al.*, 2008).

b) This instrument is costlier than other measuring methods (Zazueta *et al.*, 1994 and Heiniger, 2013).

c) TDR applications are limited due to high costs (Blonquist *et al.*, 2005).

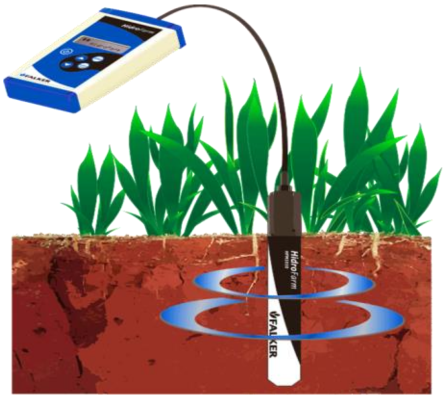
d) TDR read soil moisture only in the vicinity of the sensor (Wolpert *et al.*, 2013).

Applicability

TDR is mostly used in fields having mineral crops and crops grown on organic soils. Dukes *et al.*(2010) have listed sweet corn, green bell pepper, and the crops grown on sandy soils for which TDR can be used.

5. Frequency Domain Reflectrometry (FDR)

FDR sensor consists of a pair of metal rings which are formed as a capacitor and the soil sample acts as a dielectric. The electrical sensor capacitance is a direct measure of soil volumetric content. Its principle is similar to TDR sensor (Prichard, undated).



Advantages

a) It is very accurate (± 1%) if calibrated properly (Muñoz-Carpena *et al.*, 2004).

b) Unlike TDR, it can be used with soil having high salinity (Muñoz-Carpena *et al.*, 2004).

c) With FDR, measurements can be made at several depths at the same location (Abouatallaha *et al.*, 2011).

d) It is expensive as compared to TDR (Maughan *et al.*, 2015).

Disadvantages

a) It requires soil specific calibration (Linmao *et al.*, 2012).

b) In FDR, good contact between soil and the sensor is to be ensured to avoid the formation of air gaps (Muñoz-Carpena *et al.*, 2004).

c) It can sense moisture content only in the vicinity of the sensor (Wolpert, 2013)

6. Impedance/Capacitance-Based sensor

Impedance/capacitance-based SMC measurement methods rely on the effect of moisture content on the overall dielectric permittivity of soil, similar to TDR-based SMC sensors. Where TDR sensors use the time delay measurement to determine the permittivity of soil, the impedance/capacitance sensors measures the impedance or the capacitance of a buried probe or planar structure which depends directly on the permittivity of the soil. These sensors operate in comparatively lower frequency ranges (10s of MHz) which makes the application specific circuit design simpler than the TDR-based method. There are two main component of an impedance-based SMC sensor, (i) the sensing element or the probe, and (ii) the impedance or capacitance measurement circuit. Numerous strategies involving single as well as multi frequency impedance measurements have been explored in literature. Some of the key recent sensing systems built in the past decade for in field determination of the SMC are discussed here.

7. Infrared thermocouples

It is a sensor which measures leaf temperature. When it is compared to air temperature, it is used to predict the health status and transpiration activity of the plant. It works based on leaf-air temperature differential condition.

8. Dendrometers

These sensors measure daily shrinkage/swelling and radial growth of the stem, and are successfully used to detect stress condition.

9. Soil Moisture Indicator (SMI)

A devise to assess soil moisture status and schedule irrigations. In an effort to save water and to facilitate irrigation scheduling, ICAR-SBI has developed this gadget a handy and user friendly electronic moisture indicating device, named “Soil Moisture Indicator’.

This device was developed with the active participation of farmers and sugar factory personnel across three agro-climatic zones of Tamil Nadu through the Farmers’ Participatory Action Research Project (FPARP) during 2008-10. This device was tested by the farmers’ in their fields, comparing with the already known irrigation scheduling device 'tensiometer'. From farmers experience, it was found that tensiometer has many inherent problems like permanent installation of multiple units in different places of the field, blocking of ceramic cup, regular filling of water in the reservoir tube immediately after irrigation, vacuum leakage problems, chances for breaking the ceramic cup of the field installed tensiometer, expensive (each unit costing about Rs. 6500/-) . Soil moisture indicator was found better than tensiometer in assessing the moisture status of their fields and helped them to decide when to irrigate. Based on the farmers’ experience, it was found that scheduling irrigations based on soil moisture status considerably reduced the number of irrigations required for cultivating crops, thereby saving precious water without affecting productivity.

Working principle of Soil Moisture Indicator

Field capacity and permanent wilting point are two levels of moisture that are used to calculate available water for plant. This soil moisture indicator has been designed to objectively indicate soil moisture status. The device works based on the principle that electrical conductivity of the soil is directly proportional to soil moisture or soil electrical resistance is indirectly proportional to soil moisture content (similar to gypsum block technique),

How to use?

SMI has two metal sensor rods. When these rods are properly inserted in soil and on pressing the switch, the electronic circuit translates conductivity or resistance and indicates soil moisture level through a colour glow of light emitting diode (LED). Three LEDs are provided for approximation and to suit different soils. The device indication is as follows.

- Moisture status slightly above permanent wilting point is indicated by red or orange LED light glow. This status indicates immediate requirement for irrigation.
- Soil moisture status sufficiently above wilting point and less than field capacity (sufficient soil moisture) is indicated by Green glow. No need to go for immediate irrigation; can wait for few more days.
- Soil moisture at field capacity is indicated by Blue glow. Excess or more than sufficient soil moisture.

There is no need to install the unit permanently in the field. It is portable and whenever required it can be used in any place in the field to ascertain the soil moisture level.

Table 1: Reading soil moisture status from SMI

LED	Soil Moisture Status	Inference
Blue	Ample moisture	No need for irrigation at all
Green	Sufficient moisture	Immediate irrigation may not be necessary
Orange	Low moisture	Irrigation advisable
Red	Very low moisture	Immediate irrigation necessary

10. Cotton App – Smart irrigation in Cotton

Cotton application works on the principle of evapotranspiration (ET) and soil water balance mechanism. The app uses estimated daily crop water use and precipitation data to track daily available soil moisture. The app tracks available soil moisture in all registered fields and sends push notifications when irrigation is recommended or when the crop is approaching a new growth stage.

III. Nutrient and crop canopy sensors applications in agriculture

Enhanced management of essential soil nutrients is a vital goal in achieving sustainable agriculture and maintaining necessary increases in food production while minimizing economic losses and environmental impacts (Goulding *et al*., 2008). Technology plays a catalytic role in striking a common ground between environmental and economic goals. Conventionally, the spatial and temporal variability of nutrients in soils are assessed based on a rigorous field sampling followed with laborious soil testing, both of which can be time-consuming and costly. More often than not, soil sampling is performed destructively.

At present, development of sensors suited to quantify soil properties at the scale required for accurate mapping of within-field variability is a necessity. Ideally, sensor devices are fitted with a global positioning system to allow for soil data to be captured on-the-go and instantaneously converted into distribution maps. This would facilitate real-time monitoring and intervention of soil nutrient

Different nutrient and crop canopy sensors:

- SPAD meter
- Green seeker (NDVI)
- Crop circle
- Infrared thermometry
- Fiber optic sensors
- Ion electrode sensor (ISM) – Electrochemical method

1. SPAD meter

An alternative to the tissue test is a chlorophyll test, using chlorophyll meter to estimate N in the plant and aid in determining fertilizer N recommendations. The Minolta chlorophyll meter (model SPAD 502) can be used to make quick and easy measurements of leaf greenness, which is positively related to leaf chlorophyll content.

2. Green seeker – NDVI Sensor

The sensor emits brief bursts of red and infrared light and then measures the amount_of each type of light that is reflected back from the plant. The sensor displays the measured value in terms of an NDVI reading (ranging from 0.00 to 0.99) on its LCD display screen.

3. Crop circle Sensor

The instrument similar to green seeker in working principle with wide measurement range – 0.25 m to 2.5 m and fast data output rate. It works on low power operation, make measurements day or night and also provides 3D NDVI measurement.

Figure 3: (a) SPAD meter, (b) Green seeker and (c) Crop circle

4. Infrared thermometry

Heat is transferred from one body to another through conduction, convection, or radiation. Radiation is a process where heat energy in a form of electromagnetic waves is emitted by a hot object and absorbed by a colder object. Most of this radiation is in the infrared (IR) region of the electromagnetic spectrum, but some also spread into the visible light band. The IR wavelength band stretches from 0.7 to 1000 microns, however, practical IR measurement systems use only certain wavelength bands between 0.7 and 14 microns because the radiation is the strongest in this range.

5. Fiber optic sensor

Multimode plastic fiber optic based color sensor has been developed to determine N, P and K values in the soil sample. Colorimetric measurement of aqueous solution of soil has been carried out. The instrument works with the principle of light gets reflected from solution depending upon its absorbent coefficient of soil. Reflected light is received by another optic fiber which is converted into electrical signal.

6. Ion-selective membrane (ISM)-based electrochemical methods

Sensors like ion selective electrodes (ISEs) and ion selective field-effect transistors (ISFETs) use ion selective membrane (ISM) for selectivity and are the most common electrochemical sensing methods studied and applied for the determination of inorganic ions in soil. ISMs can be classified into 3 broad categories: (i) glass membrane (primarily used for pH measurement), (ii) inorganic salt crystal-based solid state membranes, and (iii) polymer membranes containing ionophores. This last kind (a polymer ISM) is typically made from a mixture of the ionophore/ligand, a high molecular weight polymer matrix as the base material for ionophore immobilization, and a platicizer that imparts flexibility as well as enhances dissolution of the ionophore in the polymer. Often an anion or cation exchanger is added to the mix which may improve the selectivity of the membrane. Synthesis of ISMs developed for detecting various anions and cations can be found in. A general procedure for fabricating ISMs includes pouring the prepared recipe in a glass mold, kept in an air permeable enclosure, until the solvent evaporates and the ISM is left behind for use.

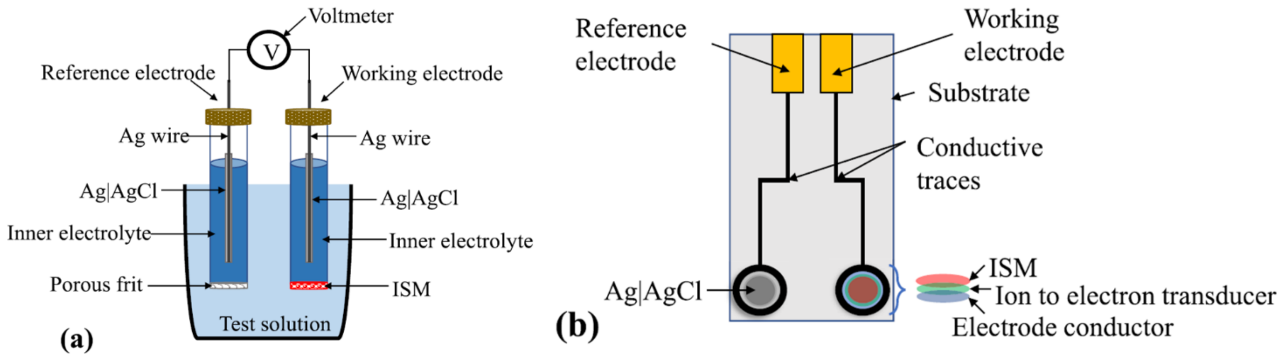


Figure 4: (a) Schematic of a conventional ISE and (b) Schematic of a planar all solid state ISE

The detection principle of an ISE is based on a potentiometric electrochemical (EC) cell where instead of direct analyte redox reactions, selective binding of the analyte ion to a membrane generates an electric potential. An ISE sensor is composed of a complete galvanic cell with two electrodes, a working electrode (WE) and a reference electrode (RE), where an ISM specific to a particular analyte/ion is integrated with the WE, and the potential difference between the WE and the RE varies depending on the concentration/activity of the analyte in the test solution/electrolyte.

7. Bhu-Parikshak: IIT, Kanpur

This first-of-its-kind novel device is capable of detecting soil health in just 90 seconds through an embedded mobile application. It would assist individual farmers in obtaining soil health parameters of agricultural fields with recommended dose of fertilizers without having to go to a laboratory. The device is based on Near Infrared Spectroscopy technology that provides real-time soil analysis reports on smartphones with an embedded mobile application named Bhu-Parikshak available on Google Play Store. The portable soil testing device that can detect soil health in just 90 seconds. Based on 'Near Infrared Spectroscopy' technology that provides real time soil analysis report on smart phones with an embedded mobile application. "Bhu Parikshak" is transferred to an agritech company named AgroNxt Services Pvt. Ltd. The device can detect six important soil parameters namely – Nitrogen, Phosphorus, Potassium, Organic Carbon, Clay contents and Cation Exchange Capacity.

Conclusion:

The general need for innovation in the 21st century is served by the application of soil sensing, which can help to unleash people's innovative capacities. The use of soil sensors in agriculture allows individualized, innovative 'bottom-up' procedures, helping farmers to fine-tune enterprise management and balance production with environmental quality, including the preservation of soil. The use of soil moisture and nutrient sensors helps growers with irrigation scheduling by providing information about when to water the crops and supply of required plant nutrient based on the analyzed available soil status. Sensing can provide soil information at different spatial scales so that it can also be used in the dialogue to develop new science and policy to better articulate the potential of soil to sustainably meet the world's needs for food, fiber, climate adaptation and environmental quality.

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BOTANICAL EXTRACT ACT AS POTENTIAL INSECTS PESTS CONTROLLER IN OKRA AT BALAGHAT DISTRICT MP

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Introduction:

Okra is an annual vegetable belonging to malvaceae family; it is also known by different names viz., ladies finger, bhindi, bamia, okro or gumbo in different parts of the world. Okra is cooked in avariety of dishes and its seed, leaves, stem and fruits each one is utilized as the all parts of plants contain important content. Its medicinal properties has also reported in curing ulcer and haemorrhoids (Mehta, 1959; Adams, 1975). In India, it is grown in an area of 0.50 million ha with an annual production of 5.98 million tones (Subbireddy, 2018). Now a day one of the most important global problems is protecting crops from insects and one of the important limiting factor in the cultivation of okra is insects pest. As high as 72 species of insects have been recorded on okra (Srinivas and Rajendran, 2003), among them fruit borers like Earias species and helicoverpa armigera cause significant damage to crop (Iqbal, 2015). For the control of insects, synthetic chemicals are continuously used and their toxicity endangers health of farmers or farm operator (including labour), animals and food consumers. The negative effects on human health led to a resurgence of interest in ITK methods due to their low cost, no ecological side effects and easily degradable. In this we review the use of plant compounds (essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids) having anti insect effects and their importance as an alternative to the chemical compounds used in the elimination of insects in different way, namely repellents, feeding delterrents, antifeedents, toxicants, growth retardants, chemosterilants and attractants. Botanical insecticides affects only target insects, not destroy beneficial natural enemies and provide residue-free food and safe environment. Cleistanthus collinus (Euphorbiaceae) is a medium size tree, commonly called as garari. Traditionally the farmers used these leaves extracts for control of insects in different crops as a ITK methods (Bharti *et al.*, 2011). Garari leaves is an extreamly poisonous due to presence od diphylline (lignan) lactose and its glycoside cleistanthin A and B the leafe, roots and specially fruit act as a violent gastrointestinal irritant (Chopra *et al.*, 1996; Sastry 1983). We, therefore, recommend using botanical insecticides as a ITK methods to control many insects pests in vegetables which can greatly reduce the use of synthetic insecticides and also reduces the health problems arises due to insecticide residue in vegetables. Hence this study aims at evaluating different botanicals and their efficacies in the management of insects pests in okra vegetable production.

Materials and methods:

The present field study was performed in 2018 at the farm of Agriculture College Balaghat, MP. The land was ploughed twice and ridges were prepared with tractor and before sowing garari leaves compost was spread in the field and mixed it properly. 21 plots were prepared (including control) with plot size2.5mx2.5m, with spacing of 30m (Row x Row) and 23cm (Plant x Plant). The distance between the replication was maintained at 90cm. The weeds were removed manually to avoid any competition for space, water, nutrients and light with the crop. Six treatments were replicated three times in Randomized complete block design (RCBD). 5% concentration of 6 different plants extract (leaf or fruits) were used as indegeneous technical knowledge to control major insects pests of okra at Balaghat district. At regular interval of 15 days these extracts were sprayed with the help of hand knapsack sprayer.

Preparation of plant extracts:

The targeted plant parts (Table 1) were collected from the local area washed and dried under shade for 7 days. The dried material of each plant parts was grinded separately with pestle and mortar into fine powder. 10% stock solution of each plant extract was prepared by mixing 100g powder in water in a conical flask to make the final volume of 1L. The mixture was thoroughly shaken, left for 24h and filtered through muslin cloth to remove the impurities (Mochiah *et al.,* 2011). 5% concentration for field application was prepared from the stock solution.

Population of sucking insects:

The data regarding population of sucking insects pests was recorded in the morning time by taking upper, middle and lower leaves of ten randomly selected plants of each plot. The population was recorded up to 7 days after each spray.

Percentage fruit damage:

The percentage fruit damage caused by chewing insects (borers) was also monitored by observing the damage fruits per plot. The data was taken from five randomly selected plants and counting the damaged and undamaged fruits at weekly interval. Percentage fruit damage was calculated by the following formula (Rahman *et al.*, 2013).

Result and Discussion:

The current experiment was conducted to evaluate six plants leaf and one fruit extracts (garari leaf, garari fruit, garlic, dhatura, aloe vera and custard apple) against major insects of okra like jassids (*Amrasca bigutulla bigutulla*), Whitefly (*Bemisia tabaci*), thrips (*Thrips tabaci*) fruit borers (*Helicoverpa armigera*).

Effect on jassids, whitefly and thrips:

Our data revealed that the plant extracts possess significant potential toxicity against jassid, whitefly and thrips. However Garari leaves extract and garlic leaf extract showed comparatively better results as compared to all other tested extracts. The data in table 2 revealed that minimum population of jassid (6.214), Whitefly (7.311) and Thrips (11.886) was observed in garari leaves treated plots followed by garlic fruit extracts with values 6.756, 8.311, 12.628 respectively. The highest mean population of these insects was noticed in control.

Fruit damage:

The data of fruit damage was observed at weekly interval to check the impact of plant extracts on fruit damage caused by borers. Three weekly observation till harvesting were taken regarding fruit damage and mean fruit damage was calculated. It was found that there was highly significant difference between the fruit damage of all plots. The minimum percentage fruit damage was observed in garari (3.268) followed by garlic (6.577) and maximum in control (17.533) (fig. 1).

Table 1: Detail of plant extracts used

Native Name	Scientific Name	Plants Parts	Concentration (%)
Garari	*Cleistanthus collinus*	Leaf	5%
Garari	*Cleistanthus collinus*	Fruits	5%
Garlic	*Allium sativum*	Fruits	5%
Datura	*Datura innoxia*	Leaf	5%
Custard apple	*Annona reticulata*	Leaf	5%
Aloe vera	*Aloe barbadensis*	Leaf	5%

Table 2: Effect of plant extracts on the sucking insects pest population and pod yield of okra

Sr. No.	Treatments	Jassids	Mean population Whitefly	Thrips	Pod yield (Kg/ha)
1.	Garari leaf	6.214	7.311	11.886	3268.5
2.	Garari fruit	7.155	9.734	13.557	3001.1
3.	Garlic fruit	6.756	8.311	12.628	2870.4
4.	Datura leaf	7.213	9.111	14.666	2899.1
5.	Custard apple leaf	8.234	9.112	13.600	2225.4
6.	Aloe vera leaf	8.332	11.331	13.888	2323.0
7.	Control	11.654	14.333	18.432	1750.7

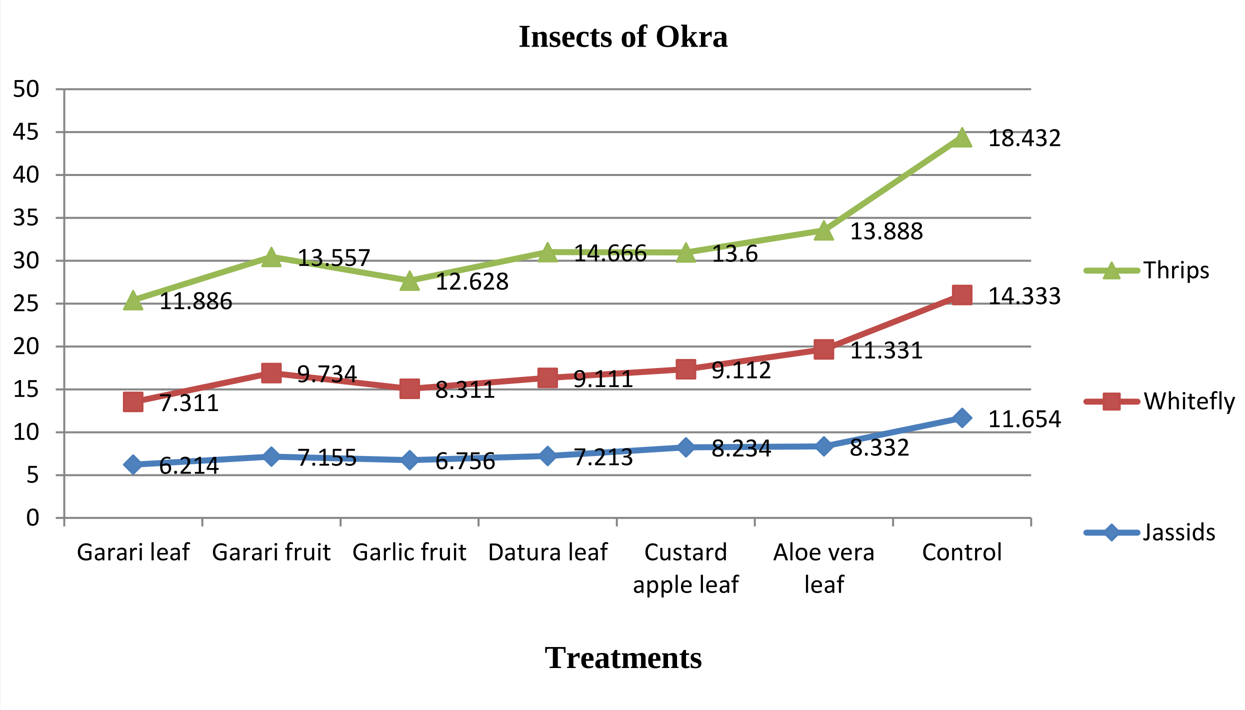

Table 3: Effect of plant extracts on percentage fruit damage of okra

Sr. No.	Treatments	Concentration	Fruit damage		Yield(q/ha)
			Number basis	Weight basis	
1.	Garari leaf	5%	12.09	11.95	118.23
2.	Garari fruit	5%	12.25	12.07	111.84
3.	Garlic fruit	5%	11.82	11.56	116.41
4.	Datura leaf	5%	16.22	16.02	74.56
5.	Custard apple leaf	5%	16.13	15.32	73.78
6.	Aloe vera leaf	5%	14.44	13.55	93.02
7.	Control	-	17.17	17.72	57.33

Conclusion:

It was concluded that all plant extracts were effective against major insects of okra. These ITK methods control insect levels below ETL level and also promote the growth and increase the yield. However, garari and garlic extracts were proved to be the most promising plant extracts with minimum population of sucking insect pests and minimum fruit damage. Thus, this indigenous knowledge could be the better alternate of conventional insecticides for the management of insect pests attack. These techniques are eco-friendly having no side effect on environment and human beings. So for the sustainable agriculture these techniques must be used and promoted.

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SUSTAINABLE AGRICULTURE PRACTICES WITH VERMICOMPOSTING

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Abstract:

Organic wastes are becoming a serious threat to the environment. The tremendous economic growth, industrialization and urbanization during the last couple of decades are resulting in the generation and accumulation of organic wastes in huge amounts which is also playing havoc with the environment severely. Another globally important issue is the use of agrochemicals with high costs because of the high demand for food, through their use has boosted food productivity but at the cost of environment and human health all over the world. Increasing world population has resulted in higher consumption of goods and services that has driven a substantial increase of organic wastes originating from households, industry and agriculture. Much of the organic wastes are highly infectious as they contain a variety of pathogenic microorganisms. Dumping of organic wastes in open areas generates serious environmental issues such as the accumulation of heavy metals in soil, pollution of ground and surface waters due to leaching and run-off of nutrients. These organic wastes when applied directly to agricultural fields cause soil environment-related problem including phytotoxicity. However if handled properly, these organic wastes can be used for vermicomposting, it is an effective recycling technology that improves the quality of the products which is disinfected, detoxified and highly nutritive. It is a low cost, eco-biotechnological process of waste managements in which earthworms are used to cooperate with microorganisms in order to convert biodegradable wastes into organic fertilizer. In demands for safe and sustainable strategies to treat organic wastes includes best known practices of composting and vermicomposting for biological stabilization of solid organic wastes by transforming them into a safer and more stabilized material that can be used as a source of nutrients and soil conditioner in agricultural applications. Thus, vermiculture not only results in management of solid waste but also produce excellent nutrient. Vermicompost is beneficial for sustainable organic agricultures and maintaining balanced ecosystem.

Key words: Agriculture, Vermicompost, Earthworms, Organic waste

Introduction:

All activities of animals, including humans result in residual materials which are not of immediate use where they originate, and which are released into the three receiving media, namely air, water and land as waste (Wilson, 1981). Each person throws out his daily quota of newspapers, garbage, cans, bottles and other waste- large and small without a second thought. No one seems to care much where the waste goes, as long as it goes away. Waste anywhere in the world, is known variously as an annoying headache, an unending problem or more correctly as an evergrowing pile of garbage. But gradually the perception is changing and waste is now being looked upon as a "resource" or "urban ores" which contain recoverable material and energy. In nature, such of this waste which is biodegradable is being treated all the time, the waste is converted to useful and/or harmless products by the action of microorganisms, annelids, insects, solar radiation etc. But in the natural scheme of things there is a certain quantity of waste that can be handled effectively in this manner.

When the quantity of waste exceeds these limits, nature is unable to handle the excess pollution load. The MSW (Municipal Solid Wastes) generated in India contains mainly garbage, with minimal quantities of combustibles likes papers, plastics etc. India spends about Rs. 230 millions per year for waste disposal alone which comprises the cost of collection, transportation and disposal. Despite spending large sum of money on waste disposal, air and water pollution remain unabated in India due to inefficient and improper disposal. Proper disposal of MSW can not only give a high return on investment but also result in a hygienic atmosphere. In India, the common methods of disposing of municipal wastes are: 1) Dumping the wastes in low-lying land 2) Incineration 3) Land filling 4) Dumping the wastes in low-lying land.

Composting of organic wastes has been practiced for a long time. Where in biodegradable materials undergoes decomposition and the end product is a material rich in nutrients called as organic manure or farmyard manure. Decomposition is the natural process of biological degradation and composting is the process of sanitary disposal and reclamation of organic material is termed as composting (Dash and Senapati, 1985). Infact, the term vermicomposting is used to describe the bioconversion of organic waste materials through earthwormic consumption. Vermi-technology is the application of earthworms in producing useful products like vermifertilizer, worm tissue for animal feed etc. for protein supplement. Monitoring of the environment for soil fertility, organic contents, heavy metal, non-biodegradable toxic material pollution and maintenance of environmental quality (Senapati, 1993).

There are mainly two approaches of vermitechnology, one is the process of vermicomposting resulting in the production of organic manure and aiding in waste management. The other is its application in the conservation processes of land or reclamation of waste lands; especially when one talks about organic farming, the former stresses on the importance of the earthworm, with regard to its effects the fertility of the soil. Compared to traditional composting method, vermicomposting also results in mass reduction, shorter processing time, and high levels of humus with reduced phytotoxicity. Thus, vermicomposting is considered an ideal manure for organic agriculture as it is nutrient rich and contains high quality humus, plant growth hormones enzymes. Moreover, vermicompost has high porosity, aeration, drainage and water-holding capacity (Edwards and Burrows, 1988). In addition to increased N availability, C, P, K, Ca and Mg plant nutrient availability in the earthworm cast are also found (Orozco *et al.,* 1996). Plant growth hormones namely cytokinins and auxins are found in organic wastes processed by earthworm (Krishnamoorthy and Vajrabhiah, 1986). Thus, earthworms accelerate the mineralization rate and convert the manures into casts with higher nutritional value. Vermicompost is popularly called as black gold and has become one of the major components of organic farming system (Crescent, 2020).

Earthworms are invertebrates belonging to the phylum Annelida, Class Oligochaeta and Family Lumbricidae. Earthworms are long, thread-like, elongated, cylindrical, soft bodied worms with uniform ring like structures all along the length of their body. These bodies consists of segment, arranged in linear series (i.e. metamerically segmentation) and outwardly highlighted by circular grooves called annuli. Body segmentation is not only an external feature but it exists internally too. At the sides of the body on the ventral surface of each segment are four pairs of short, stubby bristles or setae. The setae provide traction for movement. There is no well-marked head but a preoral called the Prostomium is present. Earthworm does not have any specific organ of sight, hearing of olfaction, but special cell exist all along the length of the body to take up these sensory functions. The order to which earthworms belong have families which are aquatic as well as terrestrial, members of seven families that are aquatic and rather small in size are termed Microdriles (Microdrili). The worms in the other 10 families are mostly terrestrial, comparatively larger and are called Megadriles (Megadrili).

On the basis of morphological characteristics, earthworms have been classified into three categories (Bouche, 1977). 1) Anecic- These are burrowing worms that only come to the surface at night to drag food down into their permanent burrows deep within the mineral layers of the soil. 2) Endogeic- These are also burrowing worms but their burrows are typically more shallow and they feed on the organic matter inside the soil, so they come to the surface only rarely. 3) Epigeic- These worms live on the surface litter and feed on decaying organic matter. They do not have any permanent burrows. Two tropical species *Eudrilus eugeniae* (Kingberg) and *Perionyx excavates* (Perrier) and two temperate ones, red earthworm, *Eisenia Andrei* (Bouche) and tiger earthworm, *Eisenia fetida* (Savigny) are extensively used in vermicomposting (Graffo, 1981). Most vermicomposting facilities and studies are using the worms *E. Andrei* and *E. foetida*, due to their high rate of consumption, digestion and assimilation of organic matter, tolerance to a wide range of environmental factors, short life cycles, high reproductive rates and resistance during handling (Lavelle *et al.*, 1999).

Results:

Composting is the process of converting organic residues of plant and animal origin into manure rich in humus and plant nutrients. It can also be defined as the bioconversion of organic wastes into an amorphous dark brown to black colloidal humus like substance under condition of optimum temperature, moisture and aeration. It is largely a microbiological process based upon the activities of a host of bacteria, actinomycetes and fungi. Vermicompost is the process, when soil entering the mouth of the earthworms is processed and then excreted through the anus in the form of compact, concentrated mass known as vermicasting. Vermicasting are a highly enriched kind of biofertilizer. It is more chemically neutral than the surrounding soil. Earthworm casts contain more micro-organisms, inorganic minerals and organic matter in the form available to plants. Casts also contain enzymes such as proteases, amylases, lipases, cellulases and chitinases; which continue to disintegrate organic matter even after they have been excreted. Comparison of vermicasts with the surrounding soils, have invariably indicated that casts have a higher base-exchange capacity and are generally richer in total organic matter i.e. Potassium, Phosphorous, Manganese and Calcium. The most important effect of earthworms may be the stimulation of microbial activity that occurs in casts. The beneficial influence of worms cast has been related to the biological factors like gibberellin, cytokinins and auxins released due to microbial activity of the microbes harboured in the cast. There are reports that certain metabolites produced by earthworms may be responsible for stimulating plant growth.

Vermicompost is better than chemical fertilizers in economical and ecological aspects. Replacing costly yet deadly chemicals with cheap yet friendly vermicompost will ensure sustainable food production. The mechanism of formation of vermicompost by earthworms occurs in following steps i.e. organic material consumed by earthworm softened by the saliva in the mouth of earthworms. Food in oesophagus is further softening and neutralization by calcium and physical breakdown in muscular gizzard results in particles of size 2u, thereby giving an enhanced surface area for microbial processing. This finally ground material is exposed to various enzymes such as protease, amylase, lipase, cellulose and chitinase secreted in lumen by stomach and small intestine (Dominguez, 2010). Moreover, microbes associated with intestine facilitate breaking down of complex biomolecules into simple compounds. Only 5-10% of the ingested material is absorbed into the tissues of worms for its growth and the rest is excreted as vermicast. The vermicast is a good organic fertilizer and soil conditioner. High-quality vermicast can be produced by worms such as the Red wrigglers (*E. foetida*) as it contains humus with high levels of nutrients that has good potential for the production of organic fertilizer. Vermiwash is a liquid fertilizer and used as a foliar spray produced by passing water through columns of vermiculture beds. Vermicomposting may be carried out at different scales and with different objectives for a household, a community or a city, and for just disposing solid waste to run a commercial enterprise. Accordingly different types of vermicomposting system are in use across India. For vermicomposting, carbon and nitrogen rich organic material, ground space, stakes, hollow blocks, plastic sheets, water (according to the season), shading materials, nylon net, water sprinklers and composting earthworms are required. Vermicompost production can be done at any place which is having shades, cool and has high humidity. For instance, abandoned cattle shed or poultry shed or unused buildings or artificial shading could also be provided.

Three methods are commonly used for vermicomposting like **1) Bin composting, 2) Pit composting and 3) Pile composting**. Bin composting the most common method for small scale composting. The bin can be constructed of several materials such as wooden/plastic/recycled containers like bathtubs and barrels. A vermicompost bin may be in different sizes and shapes, but its average dimensions are 45x30x45 cm. Around 10 holes with 1-1.5 cm in diameter in bottom, side and cap of bin is useful for aeration and drainage. **Pit composting** is large scale composting method. Pits of sizes 2.5mx1mx0.3m under thatched sheds with sides left open are advisable. The bottom and sides of the pit should be made hard with a wooden mallet. **Pile method** is mostly used for vermicomposting in large scale. The piles can be made in porch place like green house or in a floor with some facilities for drainage in warm climate. The pile size may vary in length and width, however, it's height is average height of bin used for bin composting.

Vermicomposting is the process by which epigeic earthworm species are used for the conversion of organic wastes into vermicompost, an excellent organic manure or it is the degradation of organic waste by earthwormic consumption (Ashok Kumar, 1994). Regular inputs of feed materials for the earthworm can be in the form of agrowastes and kitchen wastes, nitrogen rich material like cattle dung. By processing waste into organic fertilizers, organic solid wastes can be treated. Almost any agricultural, urban or industrial organic material can be used for vermicomposting, but may need some form of preprocessing to make them acceptable to earthworms. Such preliminary treatment can involve washing, precomposting, macerating or mixing. The species of earthworms used for the process of vermicomposting must possess a few basic characteristic, like occurrence in high percentage, wide adaptability for environmental variations, high metabolic demand, high assimilation and production efficiency, high fecundity, low incubation period, short development period with high growth rate. Composting can be done either in pits or concrete tanks or well rings or in wooden or plastics crates appropriate to a given situation. It is preferable to select a composting site under shade, in the upland or an elevated level, to prevent water stagnation in pits during rains.

Vermicomposting is set up by first placing a basal layer of vermibed comprising of broken bricks or pebbles (3-4cms) followed by a layer of coarse sand to a total thickness of 6-7 cms to ensure proper drainage. This is followed by a 15 cm moist layer of loamy soil. Into this soil are inoculated about 100 locally collected earthworms (about 50 surface and 50 subsurface varieties). Small lumps of cattle dung (fresh or dry) are then scattered over the soil and covered with a 10cm layer of hay. Water is sprayed till the entire set up is moist but not wet. Less water kills the worms and too much chases them away. The unit is kept covered with broad leaves like coconut or palmyrah. Old jute bag can also be used for covering. Watering the unit is continued and the unit is monitored for 30 days. The appearance of juvenile earthworms by this time is a healthy sign. Organic refuse is added from the thirty-first day as a spread on the bed after removing the fronds. The spread should not exceed 5 cms in thickness at each application. Though addition of this amount of matter can be done everyday, it is advisable for a beginner to spread only twice a week watering to requirement. After a few application, the refuse is turned ones without disturbing the bed. The day, enough refuse has been added into the unit, watering is done and 45 days later the compost is ready for harvest. As the organic refuse changes into a dark brown compost, addition of water is stopped (42^{nd} day). This moves the worms into the vermibed. The compost is harvested and the harvested compost is placed in the form of a cone on ground in bright sunlight. This will facilitate worms present in the compost to move to the lower layers. The compost pile is spread for about 24 to 36 hours, the worms are removed from the lower layers of the compost (Ismail 1996). Moistening of the pit should cease 3 to 4 days prior to harvesting, thus allowing the compost to dry and the earthworms to retreat to their vermibed for fresh culture. Since vermicompost contains high levels of nitrogen, phosphates, potassium, carbon and organic matter, all of which are essential for the growth of microbes. This property of vermicompost makes it an ideal medium for growth of microbial populations.The application of organics helps the microorganisms to produce polysaccharides, nitrogen fixation and phosphorus solubilization due to improved microbiological activity. Vermicompost is rich in digested organic matter, thus providing a good substrate for growth of microorganisms.

Discussion:

Sustainable agriculture is one in which the goal is permanently achieved through the utilization of renewable resources. Basic elements of sustainable agriculture are conservation of energy, soil and water. Moreover it avoids the use of synthetic fertilizers, pesticides, growth regulators and live-stock feed additives. It has been demonstrated by many workers that earthworms have beneficial effects on soils leading to increased yield of crops. Some of the effects of earthworms on soil take much time to show perceptible influence on plant growth. Earthworms added to the soil in large numbers doubled the dry matter yield of spring wheat; the yield of grass and clover increased 4 and 10 folds respectively. The addition of live worms to a garden soil was reported to increase yields of peas and oats by 70% (Kahsnitz, 1922). Vermicompost has a positive effect on vegetative growth, development and yield, especially at germination and seedling stages, stimulating shoot and root development, stimulate plant flowering, increasing the number and biomass of the flowers produced as well as increasing fruit yield. Furthermore, the application of vermicompost in the field enhances the quality of soils by increasing microbrial activity and microbial biomass which are key components in nutrient cycling, production of plant growth regulators and protecting plants soil-borne disease and arthropod pest attacks. Therefore it must be used cautiously for agricultural and horticultural activities. It has been demonstrated by many workers that earthworms have beneficial effects on soil leading to increased yields of crops. Some of the effects of earthworms on soil take much time to show perceptible influence on plant growth.

The physical communication of organic particles, the amelioration of soil PH, the enhancement of microbial decomposition activity, all these results of earthworm activity contribute to soil fertility. All these effects are reinforced by mixing of the soil from different strata in the profile. The burrowing and casting activities of earthworms can affect the porosity, aeration, water dynamics, structural stability and the formation of the soil profile (Lavelle, 1988). Earthworms that burrow deeply into the mineral strata and return, periodically to cast faecal material at the soil surface may facilitate the transport of certain elements to the surface litter from deep in the profile,. There is abundant evidence that concentrations of exchangeable calcium, sodium, magnesium and phosphorous are higher in earthworm casts. Earthworms always participate in soil forming process in five ways like 1) Through their influence on soil PH, 2) As agents of physical decomposition, 3) By promoting humus formation, 4) By improving soil texture and 5) By enriching the soil.

Vermicompost products confer plant nutrient elements, various hormones, enzymes, humic substances and especially organic matter to the soil. Thus it improves the soil structure while preparing a suitable environment for plant growth as well. It is a material with high water holding capacity and cation exchange capacity. It also has a positive effect on the ventilation of the soil. It also helps plants to more efficiency utilize plant nutrients in the soil. The fact that vermicompost is an effective plant nutrition product was first noticed at the beginning of 1970's (Forgate and Babb, 1972). The positive effects of vermicompost products are seen on a large plant population. It is stated that the vermicompost encourage the development of the plant in vegetable plants such as Tomatoes (Atiyeh *et al.,* 1999, 2000a, 2000b, 2001), Pepper (Aracon *et al.,* 2004a), Garlic (Argiiello *et al.,* 2006), Eggplant (Gajalakshmi and Abbasi 2004), Strawberry (*Aracon et al.,* 2004b), Sweet corn (Lazcano *et al.,* 2011) and Green beans (Karmegam *et al.,* 1999). Vermicompost products have also been shown to be effective in the production and yield of certain medical aromatic plants (Anwar *et al.,* 2005), Cereals, such as Sorghum and rice (Bhattacharjee, 2001).

Earthworms play a crucial role in 1) Tilling the soil 2) Orienting its chemical and biological characteristic to suit agriculture 3) Help in retention of water in the soil and movement of water through the soil to enhance its availability to plants. Earthworms affect the soil structure by ingesting the soil, partially breaking down organic matter, mixing these fractions and ejecting this material as surface or subsurface casts. They also brings subsoil to the surface by burrowing through the soil. During these processes, they thoroughly mix the soil, form water stable aggregates, aerate the soil and improve its water holding capacity. It has been demonstrated by many workers that earthworms have beneficial effects on soil leading to increased yields of crops.

Sustainable agriculture is one in which the goal is permanently achieved through the utilization of renewable resources. Basic elements of sustainable agriculture are conservation of energy, soil and water. Moreover it avoids the use of synthetic fertilisers, pesticides, growth regulators and live-stock feed additives. Vermicompost is a nutrient –rich organic fertilizers which promotes plant growth and improves soil quality. Vermicomposting is an economicaaly feasible and environment friendly technology. Organic fertilizers are alternative to chemicals used in agriculture which enhance soil quality, prevent harmful chemicals entering into food chain, improve health and contribute to sustainable future socially, economically and ecologically. Organic fertilizers are always considered more sustainable practice of agriculture rather than chemical fertilizers. In current time the demands of food is very high due to rapid increase of population all over the world specially the developing countries. The non-availability of land for growing crops led to the higher demand for application of chemical fertilizers, which increased the crop production fulfill the demand. But various adversities are associated with these chemical fertilizers and have shown direct impacts on soil, water and air. Organic farming relies on efficient utilization of local resources and application of advanced sustainable technologies. The various management practices like vermicomposting adopted in organic farming helps in soil improvement and better nutrient supply. Vermicomposting is a technology for the production of organic manure with the help of earthworm. The sustainable development to secure future generation is based on the concept of organic farming. Organic farming has various potential including soil fertility restorage, sustainable agricultural produce, biodiversity maintenance, food security and economic benefits to the marginal farmers.

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(ISBN: 978-93-91768-88-1)

PLANT BREEDING

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Introduction:

In the world population are increase rapidly due to the action of increase the population it is very essential improved the variety of grain or crop plant in different methods especially wheat and rice are improved. In Mexico the wheat production increased by about 10 times between 1950 to 1970 during this period even in India government appointed a commission in 1960 possibility to increase crop yield under Indian climatic and soil condition. From India Nobel Prize winner Dr. N. E. Boaring with his team of scientists evolved many high yielding dwarf varieties of wheat in Mexico. In the world was mainly successful because plant breeding experiments research in various branches of Agriculture as well as new methods to improve, the plant breeding according to soil condition and increase the crop yield.

From ancient time man started cultivation of plants by agriculture methods, he is improved the yield and other desirable characters of crop plant essential knowledge for improve the variety. From early days the man mainly used selection as a important method of crop plant with scientific method and knowledge of genetics. Selection is only important method of improve the food production than any other branch of agriculture science. Many new disease resistant varieties is the main outcome of plant breeding programme during last 50 years.

The science of plant breeding exhibit rapid development after rediscovery of Mendelian laws in 1900. These laws discovered and explained how characters are passed on form one generation to next generation. Increasing knowledge about plant from there reproduction, hereditary and genetics the developed and more useful method of selection and hybridization come into improvement in crop plants.

Aim and objectives of plant breeding:

Plant breeding consists of the principles and the methods required for favourable changes in the genetical characters of the crop plants. Variety is produced through different methods of plant breeding. This indicates the main aim of plant breeding is to improve the characters of plants so they are economically with more desirable characters. As plants breeding is a science base on cytogenetics and it aims to improve the genetic make up of crop plants essential for the increase agricultural production. Proceeding of crop plants is carried out by with the aim to comboine as many desirable characters as possible in a single individuals. The important objectives of the plant breeding that are as fallows.

1. To evolved high yielding varieties: One of the objectives of plant breeding to evolve high yielding varieties for increasing the agricultural production. In India taken to increase per hectre yield in the crop like Maize, Paddy, Wheat, Jawar and Bajra.

2. Imrovement in quality of commercial product: To improve the quality of agricultural product is another important objectives of plant breeders. The characters determining the quality of commercial product varies from species to species.

3. Disease resistance with hybrid vigour: To produce disease resistance varieties with greater vigour is always useful for a plant breeders. It is an important achievement because various disease of crop and other economically important plants cause heavy losses in quality and quantity of commercial important products.

4. Production of varieties suitable for local condition: The climatic condition exhibit great variation from region to region. To obtain a variety suitable for the regional condition is always useful because the variety shows resistance to adverse condition in the region. Variety resist to alkaline and saline soil condition have been evolved and supplied for cultivation in coastal areas with such type of soil.

5. Change or modification in duration of crop maturity: The important objectives of plant breeding programme is to obtain early maturing variety. Wheat variety suitable for late sowing is useful for cultivation in the field after harvesting Rice.

6. Production of exotic: In many horticulture plants a totally new variety combining different character is produced as a novelty plants have great demand from other countries and one of exports value such varieties are exotic varieties and obtain by breeding method.

7. Change in agronomic characters: In some plants change in certain agronomic characters is essential to make the plants more study and resistant i.e. tall variety are susceptible to logging while dwarf varieties exhibit to logging resistance.

8. Synchronous maturity in all plants: If all the crop plants do not nature simultaneously harvesting become expensive i.e. in case of important leguminous crops like green gram and black gram harvesting requires several picking in such plants variety showing synchronous maturity i.e. very useful to harvest the crop with less expenditure.

9. Elimination of toxic substance: In case of some seeds some toxic substances get accumulated i.e. *Lathyrus sativa* (lakh) seeds removal of toxic substance is essential and it can be obtained by plant breeding methods.

10. Change in cultivation season: Maize is a kharif crop but in certain region Rabi condition are more suitable so variety has been produced to grow maize in rabi season. Similar varieties in many legumes have been produced i.e. Mung to grow them during summer in addition to kharif season.

11. Varieties with increasing response to fertilizers: By adding fertilizers increase in the yield is obtained the variety which show positive response to fertilizers are very suitable because by increasing fertilizers does within the limit increase crop yield can be obtained.

12. Change in dormancy: Dormancy in seeds is an important characters. In some varieties it is essential while in some it is not required. The necessary changes in the nature of seed and period of dormancy can be obtained plant breeding method.

Scope of plant bredding: Aim and objective of plant breeding clearly indicates that there is tremendous branch and therefore it has a wide scope for improvement of many crops and horticultural plants. The improvement achieved in different crops plants are relatively few as compared to remaining possible improvement and therefore still considerable scope for modifying the present day crop plants. The following are the important aspects in scope of plant breeding are as fallows.

1. Scope for increase in productive capacity: From utility point of view perfect variety developed for obtaining such variety redesigning and restructuring of genetic make up is essential by involving in different varieties in a cross better and better variety can be obtained with increasing productive capacity. This by a plant breeding technique a variety can be obtained i.e. a) Greater responsiveness to fertilizers. b) Resistance to lodging. c) Resistance to disease and pest. d) High chlorophyll contents. e) Desirable growth habits. f) Fruits and seed many with high nutritive value and g) Leaf show slow rate of senescence.

2. Scope for upgradation of qualities in commercially important products: Different species of plants are cultivated for different types of products of commerecial importance i.e. crop plants for cereal grains and pulses etc. sugarcane for sugar and fruits trees for fruit production. In all these plants along with higher productivity, high quality is also important. In all the improvement process of qualities main important given to nutritional value in all edible products. The quality in the products of commercial importance in different plant species can be increasing by altering different character by plant breeding i.e. a) In pulse and cereals the protein, vitamin and amino acid can be increased. b) Fruit size, shape and taste can be increased. c) Produce long fibres from plants. d) High starch and malting capacity is rich i.e. barley. e) Vegetables have more nutritional value and f) Fodder, grasses and plants with many green.

3. Scope for improving the disease and pest resistance: The natural resistance through the genetical characters is stable and it is the cheapest method to produce many crop varieties of crop plants. For greater crop yield plants must be healthy and it is possible only when plant can resists various diseases and pest under natural conditions. Therefore disease resistance breeding should be continuous process of crop improvement. In this field also plant breeding has wide scope in many species of economic importance there are no disease and pests resistant varieties.

4. Scope for inducing adaptibility to different atmospheric condition: Some plants are tropical, some are temperate, some require specific soil, temperature and humidity condition such type of plants can be cultivated only under specific atmospheric conditions. In this field there is still tremendous scope for plant breeders to develop varieties which can grow under diverse environment conditions.

5. Scope for application of tissue culture in breeding methods: The developments in bio-technology are very useful in plant breeding. The technique like tissue culture has revolution the scope of plant breeding. The tissue culture techniques is very useful in rapid multiplication of desired variety of a species for breeding purpose tissue culture technique is very useful in supplying a) Disease free plants. b) Haploid plants produced through anther culture c) Mutants d) Somatic hybridization of desired qualities e) Protoplast fusion for combining different qualities. Tissue culture reduces the time factor which is important in breeding methods. Since the technique of tissue culture is most important in scope of plant breeding.

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BUCKWHEAT: AS AN IDEAL CROP FOR HUMAN, ANIMALS AND SOILS HEALTH IN NATURAL FARMING

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Abstract:

Buckwheat (*Fagopyrum spp*.) shows a great potential for cultivation in Himachal region as its better response to an equitable fertilizer program, but it is not regarded as an extreme nutrient user. Buckwheat considered as a smart crop in intercropping systems and is intercropped with potato, soyabean, sun hemp, millet, safflower, sunflower, and other warm season annuals. Many farmers who have used buckwheat as a cover crop refer to its ability to “mellow” the soil, leaving it in a friable and fertile state, ready for planting. Buckwheat acts as a smother crop because of its allelopathic effect to crowd out obnoxious weeds. It has also been reported that buckwheat contains higher concentrations of calcium, potassium, magnesium, and phosphorus than other plants like sorghum, maize, wheat, and clover. Buckwheat is considered as an efficient green manure crop because it produces high growth rate and biomass, enhances soil nutrient quality especially nitrogen, and has a phosphorus mobilization, high decomposition rate, and high litter quality. Thus incorporating buckwheat into the soil improves soil health by enhancing the soil texture of the top soil, improving its tilth and porosity. Increased interest has recently been shown for its human consumption due to health benefits. These all qualities of buckwheat make it an ideal crop for natural farming, which is a chemical free method of profitable crop production. In hilly region as we know all farmers are mainly small holdings with cattle production and non-mechanized farming which shows buckwheat as an ideal crop for them with high production and return.

Basic concept of buckwheat

Buckwheat is a moist-loving grain that is considered one of the most versatile crops for fodder and food, as well as having various health benefits. Buckwheat is a plant grown for its grain-like seeds, and its name comes from the Anglo-Saxon words *boc* (beech) and *whoet* (wheat). The word beech was chosen because the plant's fruit resembled that of the beechnut.

Buckwheat is grown in a variety of species all over the world. Common buckwheat, perennial buckwheat, and Tartary buckwheat are the three types of buckwheat. Buckwheat is a member of the Fagopyrum genus in the Polygonaceae family, which is divided into two monophyletic groups: cymosum and urophyllum.

Common buckwheat (*F. esculentum* Moench) has been cultivated in all corners of the world because it can easily survive and grows well, even under adverse environmental conditions. Buckwheat is known in India by a variety of names, including ogal, phaphar, bresha, mittahe dyat, dro, and brotitae. The flour is known as kuttu ka atta in India's northern and western states, and it is consumed on fasting days, especially during Navaratri (religious days according to Hindu mythology). Buckwheat is a versatile grain that may be eaten as a grain or as a green and is highly regarded for its nutritional content.

Origin and domestication history of buckwheat

Buckwheat, sometimes known as common buckwheat, is one of Asia's oldest domesticated crops. It is thought that it was domesticated from a wild Asian species in Western and Central China (*Fagopyrum cymosum*). The species *F. esculentum spp. ancestrale*, according to scientists, is the wild ancestor of common buckwheat. Cultivated buckwheat was introduced to Asian countries by two pathways; the first route passed through the Himalayan region and Tibet, while the second route passed through North China and ended up in Japan.

Plant description

Buckwheat is an annual plant with broad heart-shaped leaves, reddish stems, and blooms varying in colour from white to pink that grows 0.6–1.3 m tall. Buckwheat has a shallow tap root system with multiple laterals that reach depths of 3–4 feet. Flowers can be pure white or pink-tinged white. The blossoms of *F. esculentum* are exquisite, however they are missing something. They don't have petals, but the calyx is made up of five sepals that look like petals and are usually white, pink, or dark pink in colour. The blooms are spectacular and thickly grouped in racemes at the branches' ends or on short pedicles that emerge from the leaf axils.

It is a suitable species for genetic research into the biosynthesis and accumulation of flavonoids due to its diploid nature (2n = 16) and short life cycle (70 days). Plants in this species are dimorphic, with one of two floral forms. Long pistils and short stamens distinguish pin flowers from thrum flowers, which have short pistils and long stamens. Flowers with similar-length pistils and stamens some scientists have been described, as have lines with only one floral type. A one-celled superior ovary and a three-part style with a knob-like stigma surround the pistil, which is surrounded by eight stamens.

Site preparation and seed sowing

Buckwheat is a short-season crop that thrives in acidic soils (pH less than 5) and enjoys a damp, mild environment. It is typically planted on well-drained sandy soil, but it also thrives in acidic soils (pH 5). Buckwheat is a cover crop that does not necessitate substantial site preparation and can thrive even in badly tilled soil. Its cultivation necessitates weed clearance many weeks ahead of time in order to maximize the porosity of the soil. Furthermore, drainage should be designed to prevent seeds from being submerged, as water lodging will affect germination and consequently crop output.

Seed sowing

Late May, as opposed to late April, early, and late June, is the optimal sowing date for buckwheat, with a maximum yield of 2059 kg/ha. Seeds should be sown 4–6 cm deep, although in dry climate; seeds should be sown deeper to ensure appropriate moisture. Deep sowing, on the other hand, delays seeding emergence and reduces crop uniformity.

Seed rate

When used as a grain crop, seeds are normally sown in rows about 10 cm apart or distributed randomly in the fields at a rate that ranges from 35 to 40 kg/ha, but is around 50 kg/ha when used as a smoother crop, vegetable crop, or fodder crop, and thinning can be done after 20 days. Seeding rate should be kept to a minimum because it impacts plant growth and productivity.

Nutrient requirement

Buckwheat, in comparison to cereals, is more productive on low-nutrient soils. Buckwheat can get its phosphorus (P) from a stable inorganic pool, primarily calcium-bound P, that is used by other crops. Buckwheat cultivated in plots with low quantities of plant-available P was compared to plants grown in P fertilized plots, which revealed that buckwheat did not influence soil-P availability but did increase tartrate concentration in the rhizosphere. In comparison to P-fertilized plots, these alterations were much higher in plots with little available P. This shows that tartrate is exuded into the rhizosphere by the roots of the plants, altering the availability of P.

To achieve a yield of roughly 1600 kg/ha, the suggested fertiliser requirements for buckwheat production are 47 kilogramme nitrogen, 22 kg phosphorus, and 40 kg potassium (Campbell and Gubbels, 1978). According to Phogat and Sharma (2000), a greater yield is produced under Indian conditions by applying roughly 50 kg nitrogen, 20 kg P_2O_5, and 40 kg K_2O, or 1500–2000 kg farmyard manure per acre.

Environmental conditions

Buckwheat grain quality is significantly influenced by environmental factors. Protein accumulation is aided by dry, sunny conditions. Weather conditions have a considerable impact on the amount of amino acids, in addition to the overall protein content. Buckwheat grains produce more amino acids when there is less rainfall paired with high air temperatures during flowering and maturity. Furthermore, the characteristics of proteins in buckwheat grains are affected by weather conditions. Plants manufacture new proteins or modify their proportion and amino acid composition in response to drought stress. The amount of albumins and globulins in buckwheat nuts is not considerably impacted by soil moisture, nevertheless, soil moisture had a considerable effect on prolamin content in buckwheat nuts. Drought stress caused a decrease in prolamin levels, primarily gliadin content, from blooming through harvest time.

Rutin accumulation in buckwheat is also linked to drought and cold stress responses. A higher rutin concentration in buckwheat grains is linked to adequate soil moisture during the growing season and the occurrence of water shortages of 30 percent ppw from flowering to grain setting.

Harvesting

Green seed coat grains are thought to have a better scent and taste than white/brown grains. When the blackened husk ratio approaches 80%, grains are usually harvested (ie, when 20 percent of total grains are still immature). Some farmers, however, harvest 1–2 weeks sooner, when the blackened husk ratio is barely 40–70%. Although the grains have a higher water content, the early harvest results in more green grains with high rutin content and antioxidant benefits, as well as a favourable sensory evaluation.

Although the colour tone of buckwheat flour does not change significantly until 180 days at room temperature, scent and taste may be lost over time, as previously observed in research. Domestically made and even locally sourced buckwheat flour is preferred for these reasons.

Crop diseases and pests

Buckwheat is usually free of major pest and disease infestations, but there have been reports of many pathogenic issues. Several scoop caterpillars, such as *Euxoa segetum, Euxoa tritici, Phytometra gamma, Trachea atriplicis,* and *Barathra brassicae,* harm the buckwheat stalks. Polyphytophages cause damage to subsurface parts, hence some of these pests are polyphytophages. Several phytophages cause harm to buckwheat stalks and leaves, including *Chaetocnema concinna,* which attacks immature leaves. Buckwheat blooms are also used as food by *Meligethes aeneus*. Ramularia causes leaf spot, Rhizoctonia causes root rot, *Peronospora ducometi* causes downy mildew, and *Botrytis cinerea* causes Botrytis rot. Aphids, wireworms, birds, and rats, as well as one nematode (*Ditylenchus dipsaci*), all attack buckwheat. Buckwheat planted earlier than the recommended times is more vulnerable to aphid attack and stunting in mid-June, according to research. Furthermore, buckwheat plants are a home for approximately 20 viruses, including cucumber and tobacco mosaic viruses, as well as some bacteria. The most dangerous pests are beetles and their larvae. Beetles appear in late May or early June and begin munching *F. esculentum* shoots.

Products

Buckwheat proteins, unlike those of other cereal crops, do not contain gluten. This explains why buckwheat flour is utilised in the manufacture of various thin cookies. It is utilised in the creation of some types of chocolate when combined with soya bean flour. Buckwheat flour is used in the manufacturing of vermicelli in China, Korea, and Japan.

Animal feed

Buckwheat is also an important feed crop. In pig and poultry farming, defective grains and waste products from processing are utilised as feed. These items provide 57 g of protein per kilogramme. It has a feed value of 0.5 units. Buckwheat grows quickly, producing up to 2 tonnes of biomass per hectare in 50–60 days. It can be utilised as green fodder in this manner. However, the crop's flowers and fruit coatings contain a fagopyrin pigment, which can cause fagopyrism in white animals. This is something to consider.

Green manure

In addition, a sufficiently large biomass of buckwheat with a high content of potassium, phosphorus, magnesium, and other chemical elements, which improves soil fertility, can be used as green manure.

Weed control

Buckwheat grown under good technological circumstances eliminates weeds like wheatgrass and sow thistle. It has a lot of phosphate and potassium in its roots and after-harvesting remnants. Buckwheat is a good forage crop for most winter and spring crops because of this. Buckwheat's role as a precursor has increased considerably in modern crop rotations with heavy saturation by cereal crops. Buckwheat is one of the most promising crops for multiple sowings. Fallow can be modified and after-harvesting sowing attempted in places where the aggregate of active temperatures (>10°C) after harvesting winter wheat reaches 100°C (90–100 warm days), allowing early and mid-ripening types to be grown.

It is especially important to grow buckwheat as a soil-reclamation crop in rice crop rotation. It helps to purify fields from weeds and diseases and improves the yield of rice by 0.5–0.7 tons/ha.

Nutritional value

Buckwheat grains contain 12.6% of proteins. This is much more than other cereals and bread (rice 7.0%, millet 12.0%, oats 11.3%, pearl barley 9.8%, rye bread 5.0%, and white bread 8.6%). The majority of buckwheat proteins (up to 80%) are soluble and easily absorbed by the human digestive system. The diversity of amino acids (17) and high prevalence of essential amino acids (tryptophan, lysine, and methionine), which are in short supply in other cereals and breads, contribute to their high dietary value. Buckwheat includes a high level of histidine, which promotes child growth and development. Buckwheat proteins have a biological value that is similar to that of dry milk (92.3%) and chicken eggs (81.4–99.8%). The presence of tiny amounts of organic acids (citric acid, oxalic acid, malic acid) in the grains, which improves the activity of the human digestive system, explains the high assimilation rates of buckwheat proteins.

Phosphorus, calcium, iron, copper, manganese, and zinc are all essential minerals found in boiled buckwheat. Buckwheat has 2.6 times the zinc concentration of other cereals. Vitamins PP (nicotinic acid), B1 (thiamine), B2 (riboflavin), and E (tocopherol) have all increased in concentration. All these factors make buckwheat an essential nutritional product and explain the ongoing interest in the use of biomolecular technologies in the breeding process of buckwheat.

Buckwheat's calorie content is dictated by its high carbohydrate content (85%) and low gluten level (1%), which does not absorb in the human digestive system. Buckwheat grains have a fat content of 3.8 percent. Buckwheat has a low iodine number (94.2–96%), indicating a high quantity of nondrying oils (linoleic and lanoline acids), as well as a low oxidising number, indicating a high resistance to oxidation. The existence of significant amounts of vitamin E, which possesses antioxidant capabilities, suggests the presence of oxidising resistance. Buckwheat can be stored for a long time without losing its nutritional and dietetic qualities due to all of these factors. Buckwheat products are extremely beneficial due to their particular vitamin and enzyme makeup. Rutin (vitamin P), nicotinic acid (vitamin PP), thiamine (B1), riboflavin (B2), folic acid (B9), cyanocobalamin (B12), and the enzymes proteinase, aminase, maltase, glucosidase, and phytase can all be found in them.

Medicinal properties

Buckwheat has recently sparked interest as a potential medicinal herb. It is used to preserve the functioning features of the vascular system due to its high rutin (vitamin P) concentration. Buckwheat has a beneficial effect on blood circulation problems, cardiovascular collapse, vasospasms, and edemas. A buckwheat diet is also utilised to prevent and treat arterial sclerosis caused by lipidemia. The plant possesses radioprotective qualities due to its high cysteine content (300 mg/100 g of buckwheat).

Nicotinic acid (vitamin PP) is found in all organs of the buckwheat plant, but the seed coat has the highest quantity. The nicotinic acid concentration in the grains is 4.4 mg per 100 g. Animal creatures are known to use vitamin PP in redox processes. The synthesis of pigments can be harmed in the absence or deficiency of these vitamins, resulting in liver damage and vasoconstriction. Nicotinic acid lowers cholesterol and improves the fraction ratio. This is why it's used to treat lipidemia-related arterial sclerosis, ulcer disorders, and other conditions.

The high vitamin B content of buckwheat is the most essential element of its nutritional benefits. Vitamin B1 is abundant in pollen and buckwheat grains, and it has a role in synaptic activation control. Buckwheat is therefore beneficial in the prevention and treatment of neuritis, neuralgia, radiculitis, paralysis, and syncopes. It's also used to treat dermatoses and mercury, methyl alcohol, and arsenic toxicity. Vitamin B6 aids in glucose metabolism and protects pregnant women and children from vitamin deficiency. Buckwheat meal is also recommended for patients with vascular and radiation disorders, children's hepatitis and dermatitis, intoxications produced by tuberculosis medications, and other ailments because it is a natural source of the vitamin.Folic acid (B7) and cyanocobalamin (B12) take part in the synthesis of amino acids. They play an important role in the treatment of anemia, gastric diseases, and leukemia caused by nuclear irradiation. Riboflavin (vitamin B2) affects protein and carbohydrate metabolism, as well as haemoglobin synthesis and vision.

Buckwheat has the right quantity of copper to help red blood cells use iron more efficiently for haemoglobin formation. Anemia can be caused by a lack of copper in the body. Copper concentration in 100 g of buckwheat is 21.8 mg, compared to 11.1 mg in fine powdered barley, 8.68 mg in oatmeal, 7.24 mg in semolina, and 18.8 mg in millet. Buckwheat has special qualities for lowering body temperature, curing major problems of the digestive system, mucous and lymphatic systems, and regulating lipid, protein, and carbohydrate metabolism under ionising irradiation.

Status in H.P

In the Sangla valley in Kinnaur district, Himachal Pradesh, India, buckwheat was a staple food crop. Planting of apple and offseason vegetables has nearly eliminated buckwheat cultivation in the valley during the last two decades. Over the last three to four years, the NBPGR has held food fairs and awareness initiatives on the nutritional value of buckwheat in collaboration with nongovernmental groups, state tourism offices, and health departments. During this time, many farmers and local political bodies became convinced and advocated for its cultivation, passing a resolution (obligatory order) through the Panchayat (a local political body) that stated that every household must serve at least one buckwheat recipe at any religious or family functions (eg, marriage). Every household was required to raise at least some buckwheat crops on their fields, and those who were unable to do so were required to acquire seed from others. Buckwheat cultivation has returned to Sangla Valley as a result of this. Buckwheat is now one of the valley's cash crops. We've also planned community seed banks in Kinaur's Sangla and Spiti's Losar to assure a steady supply of these crops' seeds.

Reason for less cultivated area

a. **Changing cropping patterns:** Buckwheat was once an important part of the hills' cropping systems, but as a result of modernization and development activities, particularly the road network, traditional buckwheat farming was phased out in favour of new cash crops such as apple, green pea, cabbage, hops, potato, and so on. Buckwheat was displaced from many traditional growing areas by these high-return crops.

b. **Low yields:** Until date, the majority of buckwheat production has come from farmers' own cultivars, which are often low yielders.

c. **Changing eating habits:** The food supply has become limited, consisting solely of wheat, rice, and maize. Buckwheat eating is observed to be less popular among the younger generation than among the elder age. To learn about people's preferences for consuming buckwheat, a survey was done in both a large buckwheat growing area (Kinnaur) and a partially buckwheat growing area (Kangra). In 1997–1998 and 1977–1978, the figures were calculated based on the number of days in a year that persons ate buckwheat. Over the last 20 years, there has been a 76 percent decline in Kangra and a 37 percent reduction in Kinnaur (Rana and Sharma, 2000).

d. **Limited alternate uses/products:** The crop is mostly grown for grain and greens. There is a lack of value addition for making alternative food and medical items, like Japan, China, and Russia have done. In Japan, 90 percent of the flour is utilised to make the popular "Soba" noodles.

e. **Lack of knowledge about its nutritional and medical worth:** People who grow buckwheat, in general, and younger generations in particular, are unaware of its medicinal and nutritional value. Most individuals who consume buckwheat believe it is a poor man's diet with minimal nutritional value when compared to rice and wheat.

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(ISBN: 978-93-91768-88-1)

A STUDY ON PRODUCTION AND PRICE VARIATION IN AGRICULTURE COMMODITIES FOR FINANCIAL SECURITY OF FARMERS IN SANGLI DISTRICT

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Introduction:

India has famous for agriculture .Agriculture has been the backbone of the Indian Economy and it will continue to remain so for a long time. The agricultural economic reforms, initiated in the country during the early 1990's, have put the economy on higher growth trajectory Agriculture market are hub of rural economy. Agriculture Marketing today means more than linking the producer with consumers includes creation of favorable economic Environment for farmer to enthuse him to grow more and Get proceeds from transactions. Sangli is our home city. Most of the farmers prefer Cash crops like soyabin, gram, and urid. Here we are interested to suggest to farmer that which crop is more beneficial to them. For the purpose of testing the profitable crop for Farmer we have decided to study of price and quantity Variation of crops like soyabin, urid and gram. Hence we collected the data of last 12 years of three crops from "SANGLI KRUSHEE UTPANNA BAJAR SAMITEE, SANGLI" Now a day the cash crop price is increasing in Market. So we want to study the price variation of the three crops.

Objectives:

1. To analyse Trend of production and price of the crop in the period 2008 – 2019.
2. To compare the production and prices of the crops by graphical representation.
3. To analyse correlation between production and price of the crops.
4. To construct percentage increase or decrease of crops with respect to production and price by using index number.

Methodology:

Statistical tool

1. Graphical representation: Trend Line, time series, scatter diagram
2. Analysis by using Index Number
3. Correlation by using R-software

Source of data: Secondary data is taken from the record of SANGLI KRUSHEE UTPANNA BAJAR SAMITEE, SANGLI Agriculture products are: Soyabin, Gram & Urid Quantity & Price rate during Year 2008-2019.

Year	Soyabin		Gram		Urid	
	Quantity (in 100kg)	Price	Quantity (in 100kg)	Price	Quantity (in 100kg)	Price
2008	43727	1800	7085	2200	10526	2000
2009	71993	1500	26135	2000	6387	2200
2010	60822	2118	19240	2164	1219	3355
2011	61653	1950	22602	2148	6902	3521
2012	68477	2235	16206	2891	3669	3204
2013	37183	3435	8524	4030	728	3001
2014	35852	3433	20096	3022	3969	3016
2015	38874	3574	26408	3411	2858	4500
2016	74914	3500	53674	4315	7744	7612
2017	28296	3383	50561	6710	22016	7187
2018	6714	3165	30917	5091	30375	5499
2019	711	3679	8886	4500	410	5700

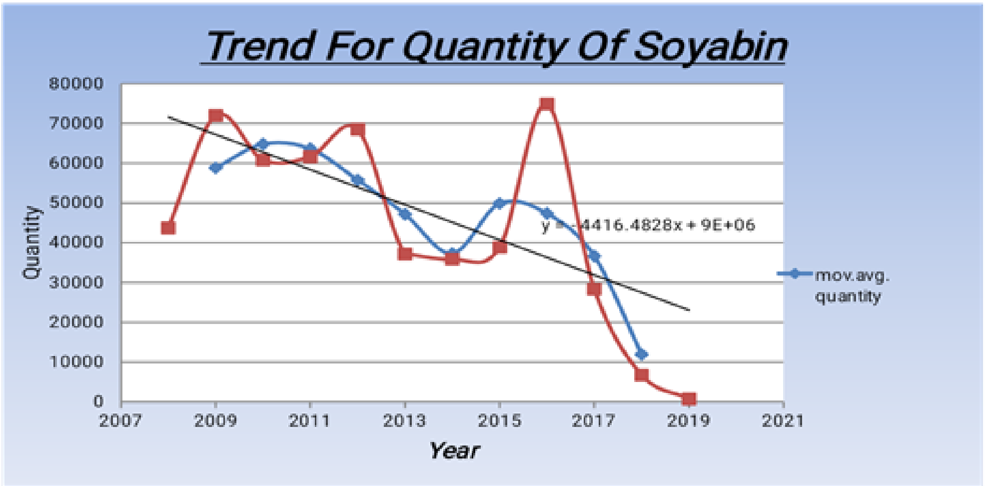
Data analysis:

1. Analysis of Soyabin: Soyabin is one of the most important crop in Sangli district. Generally the season of this crop is here we study of the trend for price and trend for Quantity by moving average method. Then we have considered three months moving average.

Year	Quantity (In 100kg)	Price	Moving Average Quantity	Moving Average Price
2008	43727	1800		
2009	71993	1500	58847.33333	1806
2010	60822	2118	64822.66667	1856
2011	61653	1950	63650.66667	2101
2012	68477	2235	55771	2540
2013	37183	3435	47170.66667	3034.333333
2014	35852	3433	37303	3480.666667
2015	38874	3574	49880	3502.333333
2016	74914	3500	47361.33333	3485.666667
2017	28296	3383	36641.33333	3349.333333
2018	6714	3165	11907	3409
2019	711	3679		

Graphical Representation

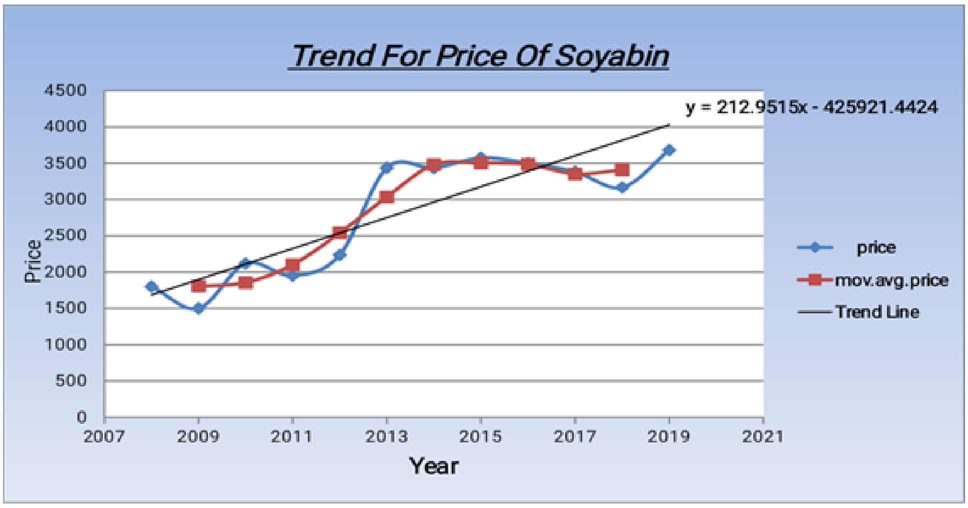
Trend for quantity (in quintal) of Soyabin



Conclusion (from graph):

1. The trend of Quantity decreases rapidly.
2. The lowest yield of this crop in year 2019 and highest yield of this crop in year 2016
3. The yield of this crop is nearly same in years 2013, 2014 & 2015

Trend for price of Soyabin



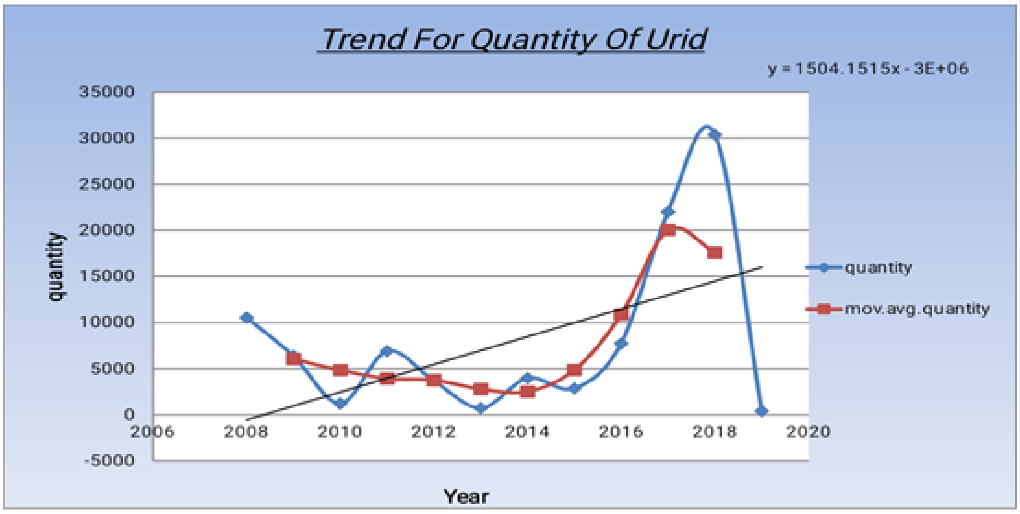
Conclusion (from graph) –

1. The trend of Price increases rapidly.
2. The lowest price of this Soyabin in year 2009 and highest Price of this soyabin in year 2019.
3. The price of this soyabin is nearly same in years 2013, 2014 & 2015

2. Analysis of Urid

Urid is one of the most important crop in Sangli district. Generally the season of this crop is. Here we study of the trend for price and trend for Quantity by moving average method. Then we have considered three months moving average.

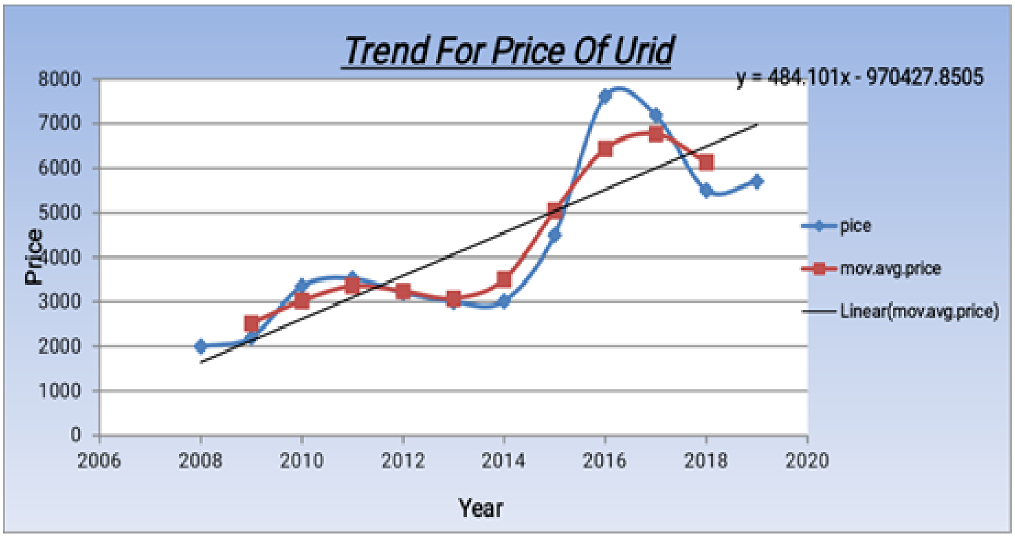
Trend for quantity (in quintal) of Urid



Conclusion (from graph)

1. The trend of Quantity increases rapidly.
2. The lowest Quantity of the Urid in year 2010 and highest Quantity of this Urid year 2018
3. The Quantity of this Urid is nearly same in years 2010 & 2013

Trend for price of Urid



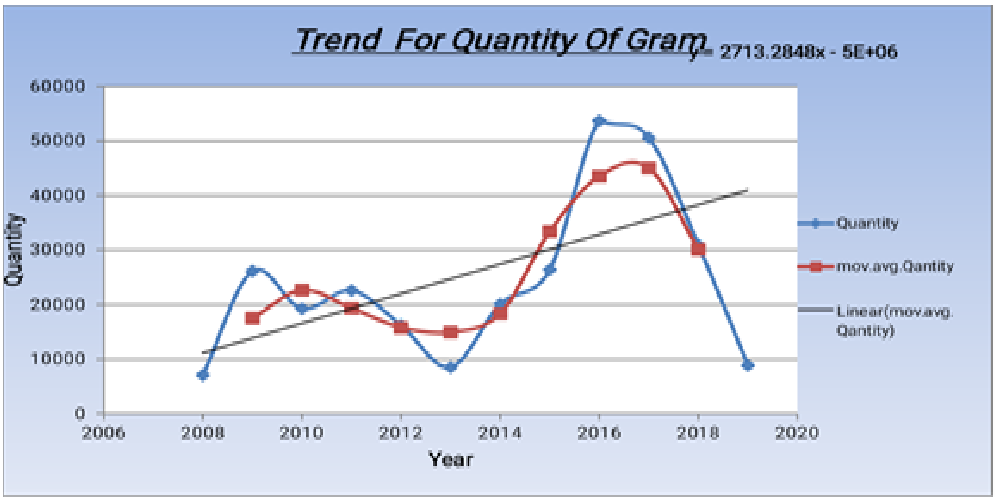
Conclusion (from graph)

1. The trend of Price increases rapidly.
2. The lowest price of this Urid in year 2008 and highest Price of the Urid in year 2016
3. The price of this Urid is nearly same in years 2010, 2011, 2012 2013 and 2014

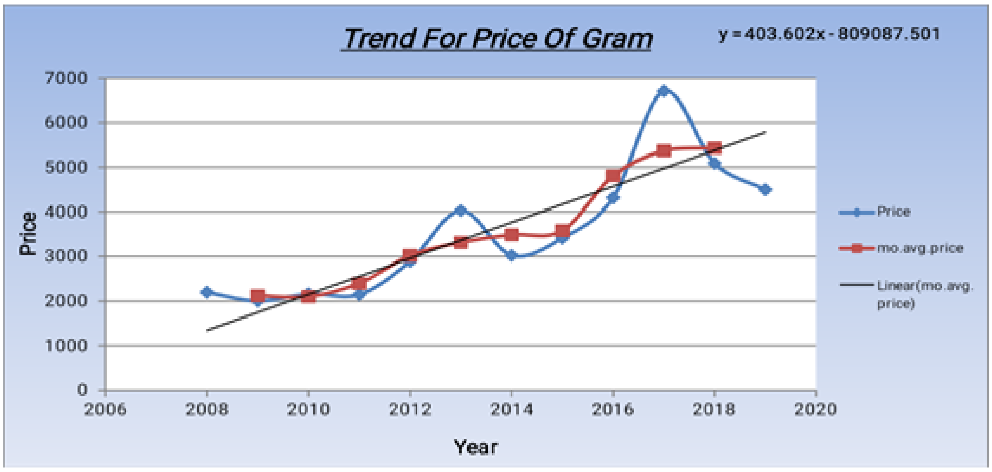
3. Analysis of Gram:

Gram is one of the most important crop in Sangli district. Generally the season of this crop is. Here we study of the trend for price and trend for Quantity by moving average method. Then we have consideredthree months moving average.

Trend for quantity (in quintal) of Gram



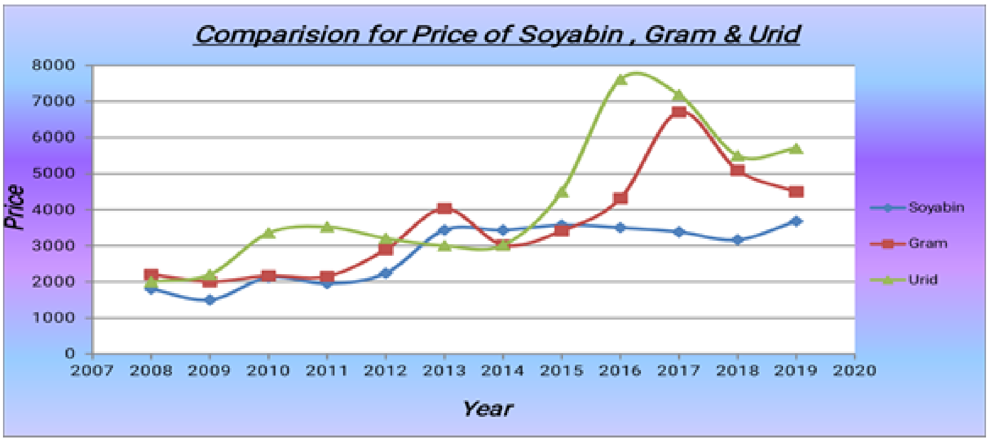
Trend for price of Gram



Conclusion (from graph)

1. The trend of price increases rapidly.
2. The lowest price of this Gram in year 2009 and highest price of this Gram In year 2017
3. The yield of this crop is nearly same in years 2008, 2009, 2010 and 2011

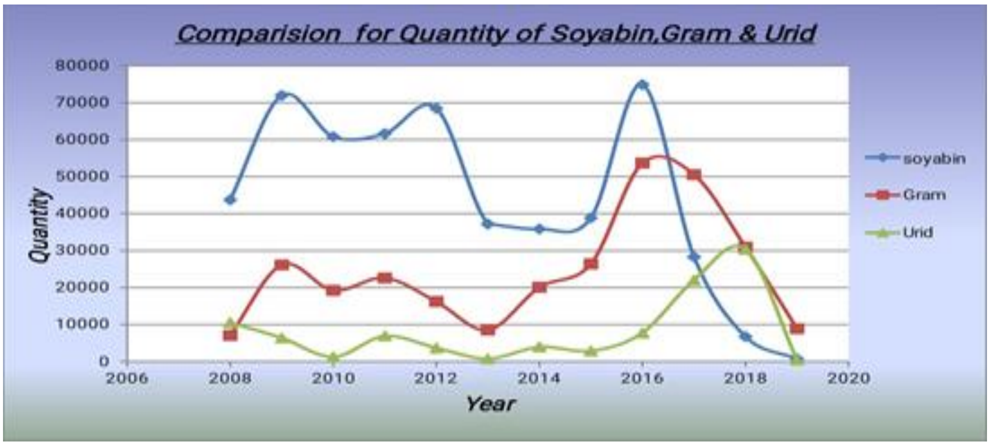
4. Comparison for prices of Soyabin, Gram and Urid:



Interpretation:

1. The price of Urid is increased as compared to Gram and Soyabin
2. The price of soyabin is steady in years 2013 to 2019.
3. The market value of Urid is comparatively higher than Gram & Soyabin

5. Comparison for quantity of Soyabin, Gram and Urid:



Interpretation:

1. The yield of Soyabin is increased as compared to Gram & Urid
2. The yield of Urid is steady for year 2008 to 2013.
3. All three crops (Soyabin, Gram and Urid) has very lowest yield in year 2018 & 2019.

Calculations:

Analysis by index number:

To compute percentage increase or decrease of price and quantity of commodity (Soyabin, Gram and Urid) in current year 2019.

Notations-

1] P_0 =Average price in baseYear 2018

2] P_1 = Average price in current Year 2019

3] q_0 = Average quantity in baseYear 2018

4] q_1 = Average quantity in current Year 2019

Calculation For price index no-

1. Lasperey's Price index no- 97.4

Interpretation-

Price of commodity has decreased by2.53% in current year 2019 compared to base year 2018.

2. Paasche's Price index no- 90.34

Interpretation-

Price of commodity has decreased by 9.66% in current year 2019 as compared to base year 2018.

3. Fisher's index no.- 93.7

Interpretation-

Price of commodity has decreased by 6.24% in current year 2019 as compared to base year 2018.

Calculation for Quantity index no-

1. Laspere's Quantity index no- 14.39

Interpretation-

Quantity of commodity has decreased by 85.61% in current year 2019 as compared to base year 2018.

2. Paasche's quantity index no- 13.3

Interpretation-

Quantity of commodity has decreased by 86.67% current year 2019 as compared to base year 2018.

3. Fisher's quantity index no- 13.83

Interpretation-

Quantity of commodity has decreased by 86.17% current year 2019 as compared to base year 2018.

Conclusion of index number:

1. The price of Soyabin is increased by 16.24% and Quantity is decreased by 89.42% in the year 2019 as compared to 2018.
2. The price of Gram is decreased by 11.61% and Quantity is decreased by 71.26% in the year 2019 as compared to 2018.
3. The price of Urid is increased by 3.65% and Quantity is decreased by 98.65% in the year 2019 as compared to 2018.

Correlation:

1] Correlation between quantity and price of Soyabin by using R-software -0.587463

Result- The correlation coefficient is Negative. It indicates that the price and quantity is Negative Correlation.

Note- 1. When price as well as quantity increases or decreases then we conclude that correlation Coefficient is positive.

2. When price increases and quantity decreases then we conclude that correlation coefficient is negative.

2] Correlation between quantity and price of Gram by using R-software- 0.545222

Result– The correlation coefficient is positive. It indicates that the price and quantity is positive correlation.

Note-1. When price as well as quantity increases or decreases then we conclude that correlation coefficient is positive.

2. When price increases and quantity decreases then we conclude that correlation coefficient is negative

3] Correlation between quantity and price of Urid by using R-software- 0.4192

Result– The correlation coefficient is positive. It indicates that the price and quantity is positive correlation.

Note-1. When price as well as quantity increases or decreases then we conclude that correlation coefficient is positive.

2. When price increases and quantity decreases then we conclude that correlation coefficient is negative

Over all conclusions:

1. The quantity as well as price of gram is increased in general there is an increasing trend.
2. The quantity of soyabin is decreased and price is Increased Hence production is inversely proportion to price.
3. The quantity and price of urid is increased. Hence quantity is directly proportion to price.
4. The Uridh as higher market value than the gram and soyabin Hence Urid is beneficial crop to farmer for better profit.
5. The total quantity of Soyabin is more than Urid. It may be due to increase in the area under crop.
6. This shows that the farmers hold first prefer for crop of Urid for more profit.

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CROPSAP: CROP PEST SURVEILLANCE AND ADVISORY PROJECT

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Abstract:

Agriculture Department of Maharashtra State is entrusted with the responsibility of sustainable Agriculture Development. For increasing crop production and productivity various activities like promoting use of improved / hybrid seeds, balance use of fertilizers, Integrated Pest Management, land development, micro-irrigation, mechanizations, technology transfer through extension services are carried out by the Agriculture Department. To avoid the crop losses due to pest and diseases recurrence and as a long-term strategy, Department of Agriculture has taken initiative and formulated and implemented "Awareness-cum surveillance programme for management of major pests in cotton-soybean based cropping system in Maharashtra" in 2009-10 under technical guidance of National Integrated Pest Management Centre (NCIPM), New Delhi and again continued as "Crop Pest Surveillance and Advisory Project" (CROPSAP) from 2010-11. Recently CROPSAP is one of the successful Crop Pest Surveillance and Advisory project and won several national awards.

Introduction:

The National e-Governance Plan of 2006, followed by the Digital India project of 2014, to transform India into a digitally empowered society, facilitated wider spread of knowledge and technological tools and procedures for our nation's advancement. The World Wide Web's launch in 1991 revolutionised the world's information service. Information and communication technology (ICT) integration strategies vary depending on the program's goals. The key to efficient pest control is to constantly monitor pests for their onset and severity during the growing season. Being comprehensive and knowledge-intensive, integrated pest management (IPM) necessitates real - time processing of temporal and geographical data obtained from crop-pest monitoring in order for extension functionaries to communicate need-based management measures for implementation by farmers. ICT enables the swift processing of data to make a decision on pest management utilising the existing knowledge base and crucial inputs that can be mobilised and adopted for plant protection on a broad scale. ICT also allows for the assimilation of pest data bases over location and time (Vennila, 2016). The adoption of preventative pest management measures that could lessen anticipated pest outbreaks and could prove the minimization of yield losses due to crop pests in relation to the effectiveness quickens the pace of IPM execution on a wider area. This method of pest surveillance is known as "e-pest surveillance." IPM is introduced regionally using ICT as a launchpad.

Genesis and conceptualization of CROPSAP:

Maharashtra's rural economy is mostly focused on rainfed agriculture. The mainstay of the State is the cultivation of kharif crops like cotton, soybean, rice, and pigeon pea in addition to the important Rabi crop of chickpea. *Spodoptera litura* (Fabricius), *Helicoverpa armigera* (Hubner), and other defoliators caused a significant pest epidemic in the cotton-soybean farming systems in 2008–09 that resulted in losses of Rs. 1392 crores and impacted 14.56 lakh hectares of soybean. The farmers received 450 crores of rupees in financial aid. Despite the expanded area planted with soybean in 2008, insect epidemics happened mostly because there was inadequate control over the pest's buildup during the early phases of an outbreak.

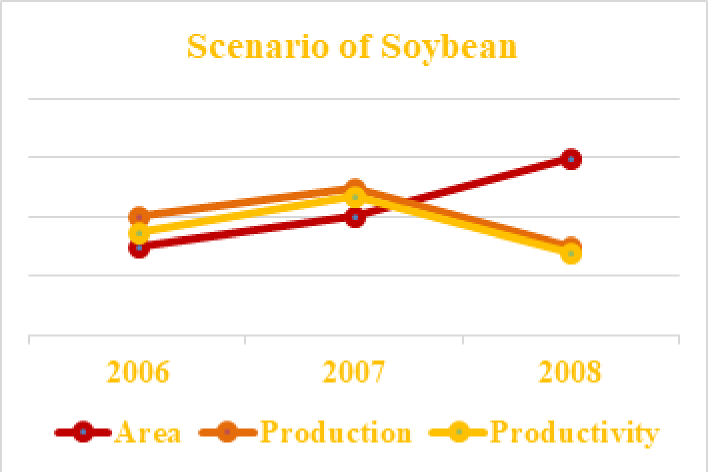

Figure 1: Scenario of pest outbreak in Soybean

Following are some findings from a post-epidemic scenario analysis conducted by a central team on the severity of the issue and challenges to its efficient management (Lokare *et al.*, 2014).

- Lack of knowledge and resources to control and identify pest appearance on soybeans.
- Different organisations with a stake in the region's agricultural industries do not take a constructive role.
- Agency's individualistic pest management strategies in reaction to an epidemic.
- The State Department of Agriculture's (SDA) staff members' multitasking hindered them from focusing on a particular crop and the challenges that arose with it.

- Lack of knowledge on the types of crop-defoliating pests and how to identify them.
- Lack of awareness of the value of IPM techniques in improving crop yields.
- Using pesticides improperly or in excess of the recommended amounts.
- The precise developmental niches of *S. litura*, a polyphagous pest with a wide range of dispersing potential, were unclear.
- The cropping system's use of *S. litura* pheromone traps has proved misleading, since several moths have been collected with no nearby incidents.
- In the tracts of Gadchiroli and Chandrapur, there was a drastic switch from rice to soybeans, which was always favourable for the growth of lepidopterous pests.
- The survival of a large population of *S. litura* was helped by areas secluded by jungle and the production of vegetables during the off-season.
- Due to conducive environment that later spread to other sites, patches of highly vegetative crop growth and intense *S. litura* infestations were also noted.

It is crucial to regularly monitor pests to prevent outbreaks due to the extensive range of factors that are linked to the onset and spread of the pest. A robust pest monitoring and advice structure has to be set up in order to implement such a preventative measure. Between March and May 2009, a number of meetings were held between the crop-based institutes of the Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs) of Maharashtra, and SDA of Maharashtra to develop the program's modalities, including its operational area, the roles and responsibilities of its various stakeholders, and the preparation of a work plan for funding under the Rashtriya Krishi Vikas Yojana (RKVY) by theCommissionerate of Agriculture, Government of Maharashtra. Although it was initially intended to develop a surveillance programme for four to five districts that might act as potential foci for the spread of the pest, factors like increased area under soybean on a par with cotton, the common pest status of S. litura on cotton and soybean, and the vulnerability of cotton to S. litura required the programme to be expanded to cover both crops, which was then followed by the integration of pigeonpea and the rabi crop of chickpea. Since 2011, the surveillance-based pest control guidance programme has also included rice farmed as a kharif crop. Using ICT technologies, Maharashtra farmers are constantly being educated about pest surveillance for all target crops and the issuance of real-time pest management recommendations. The RKVY of the Central Government provided financing to the SDA of Maharashtra, which was thereafter responsible for CROPSAP execution from 2013 until present.

Objectives:

- The use of a scientific pest surveillance strategy for pest control.

- Employing ICT to monitor and control target pests on selected crops in real-time.
- The widespread promotion of IPM among farmers and field staff.
- The identification of hotspots depending on pest status and the prompt issuance of alerts.
- Advice on how to manage pests of certain crops by sending farmers the proper advisories via print media, village boards, and short message services (SMS).
- Guaranteeing the timely availability of essential inputs and providing financial assistance for pest control to reduce pest numbers below economic threshold levels (ETL).

Stake holders and their roles:

<table>
<tr><th>Sr. No.</th><th colspan="2">Stake holder</th><th>Role</th></tr>
<tr><td>1.</td><td colspan="2">State Department of Agriculture, Commissionerate of Maharashtra</td><td>• Coordinating and maintaining a close eye on the entire programme.
• Facilitating stakeholder’s access to infrastructure.
• Educating farmers and field staff.
• Media-driven public awareness campaigns about monitoring and alerts.
• Timely dissemination of advisories to farmers.</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">ICAR Institutes:</td><td>NCIPM, New Delhi</td><td>• Technical nodal agency.
• Software for on-line pest monitoring/reporting/advisory system.
• Technical support for teams who monitor pests and provide surveillance.
• Maintenance of the server and database assistance in developing pest monitoring proforma and capsules for target crop’s pest control.</td></tr>
<tr><td>DSR, CICR, IIPR, IIRR, NRRI, CRIDA</td><td>• Electronic coordination and programme improvement.
• Development of pest-specific advice capsules and IPM techniques tailored to individual crops.
• Visiting pest hotspot locations to provide farmers and field staff with guidance.</td></tr>
</table>

		• Getting input to improve IPM tactics and conduct more study. • Coupling geographic and temporal meteorological information to pest population. • Development of modules for pest prediction and forecasting.
3.	NIPHM	• Training regarding pesticide application methods. • Assistance in evaluating pesticide residues.
4.	State Agricultural Universities of Maharashtra	• Training of the primary instructors and scouts. • Analysing data and issuing advisories. • Field visits especially the hot spot regions of pests and assisting farmers.
5.	Farmers	• Implementing the SAU's recommendations that SDA has received.

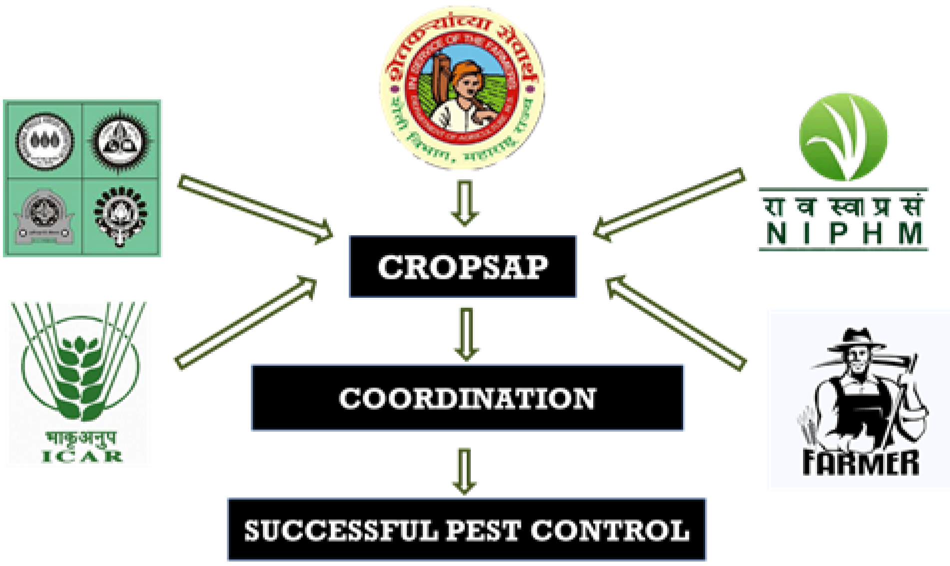

Figure 2: Stake holders of CROPSAP

Figure 3: ICAR institutes as a part of CROPSAP

Framework of field level pest surveillance:

Pest surveillance programs require a cohesive mechanism for coordination (Vennila, 2014). Pest surveillance/ monitoring units (PMU) have been established across the State based on the cropped area under each crop at the start of the season with allotment of required man power such as pest scouts, pest monitors and computer personnel (data entry operators and server supporters). The villages were clustered into 12000 ha area of target crops and those having maximum area under each target crop were selected for pest surveillance. For every 1500 ha area under the target crop two fixed (observations recorded from start to end of crop season from same field) and two random fields were selected for scouting. Fixed and random fields were selected from different directions of the village. During this process of field selection, it was ensured that the selected villages represent the cluster of villages. In each block, the villages not covered under for pest scouting were considered for roving surveys done twice a week by pest monitors wherein 10–15 fields spread across a minimum 10 villages were observed in a single day. The unit of field observations was one acre. In roving survey, qualitative pest status was recorded from randomly selected fields of villages other than those selected for quantitative surveillance.

Datasheets and guidelines of pest surveillance:

Two different types of data sheets were created for each of the target crops, including soybean, cotton, rice, pigeon pea, and chickpea: a proforma for scouts to use (to record the quantitative data for the pests of surveillance from fixed and random fields), and a pest monitor proforma (to record the qualitative data on the target and additional pests of importance). In the data books for pest scouts and monitors, instructions on how to collect each detail of information and data are supplied. For each of the target crops, there is a different pest scout and pest monitor template, as well as relevant recommendations for observations. Since the data is gathered by the pest scout using numerical values, it is referred to as quantitative data. In contrast, the pest monitor collects information on the pest population qualitatively rather than numerically. Each year, at steering committee meetings, the data sheets are updated as needed, taking into account the significance and evolving/emerging status of any specific pest(s). The State pest monitoring units and the pest scouts are deployed based on the cropped area under each of the crops nationwide. One pest monitor and a data entry operator would be assigned out for every ten pest scouts as shown in fig 4.

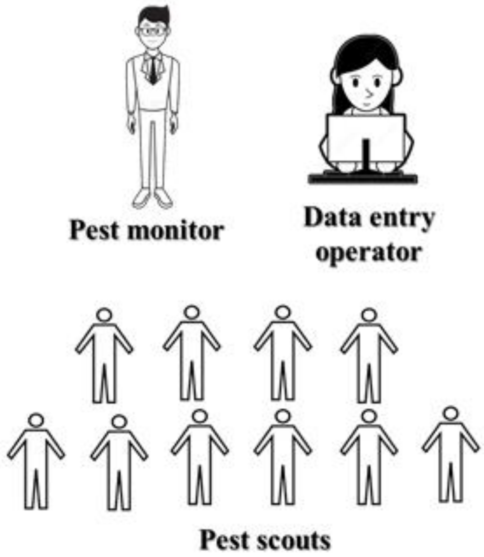

Figure 4: Composition of Pest monitoring unit (PMU)

Schedule of pest surveillance and pest management advisories:

Data collection	Data entry and uploads	Data analysis & issue of advisories (SAUs)	Dissemination of advisories by SDAO
Monday & Tuesday	Wednesday	Thursday	Thursday
Thursday & Friday	Saturday	Monday	Monday

Project evaluation:

Since its commencement, CROPSAP has undergone several evaluations. According to NCIPM, soybean output increased by 23.8% in 2009 compared to 2008, with gross financial benefits of Rs. 1047.5 crores gained in 2009, 2010 and 2011. In comparison to the 2008 season, the area under pest status (beyond the economic threshold level) decreased by three times in

2009. (4.8 and 14.64 lakh ha in 2009 and 2008, respectively). CROPSAP was hailed as innovative research that reinforced the information delivery platform for a productive agricultural knowledge management system, including the management of pest occurrence in addition to the requirement for its applicability for other crops. In 2013, the National Institute of Rural Development in Hyderabad advised that the project be scaled to include additional crops in the State because of its advantageous impacts on crop losses, reduced pest management costs, and improved returns for farmers due to the usage of IT technologies. After evaluating the project, Agricultural Finance Corporation, Mumbai (2013) also suggested CROPSAP's higher degree of utility (Lokare, 2014). With regard to cotton, soybean, pigeon pea, and chickpea, CROPSAP farmers were predicted to have an average yield gain of 580, 287,151, and 297 kg/ha above non-project farmers, with 69.14% of the pest control advice delivered via SMS being implemented by farmers across crops. One of the 13 good governance strategies identified by the Department of Administrative Reforms and Public Grievances (DARPG), Government of India, based on research and evaluation by the Indian Institute of Development Management (IIDM), Bhopal, with a goal to comprehend the impact, utility, user's satisfaction, sustainability, scalability, and replicability of the initiative, and to develop a model practise suggesting on the improvement. A workshop was already held in Bhopal in January 2016 to finalise the methodology and tools based on the created project-specific questionnaire. Since the launch of the CROPSAP, more advisories have been given to the recipients.

Year	No. of subscribers (lakhs)	No. of SMSs sent (lakhs)
2009-10	1.63	31.93
2010-11	2.40	112.00
2011-12	3.11	199.06
2012-13	3.40	360.83
2013-14	3.90	479.14
2014-15	15.0	550.27

Uniqueness of CROPSAP:

• Participation of stakeholders and transparency.

• The initiative's originality and its potential for replication.

• Enhanced output/process efficiency.

• Results that are more effective.

• Demonstrating leadership and teamwork.

• Alteration and the beneficial impact on output/productivity.

• The initiative's long-term viability.

CROPSAP as a success story:

- Online pest surveillance and real-time advisory distribution systems are essential for minimising crop losses in the face of a rapidly changing pest environment caused by a changing climate.
- The CROPSAP has helped to close the disparity between research and extension strategies.
- Raising public awareness among local through radio jingles, TV broadcasts, jingles in bus stations, and print media (newspapers, folders, pamphlets, and bulletins) in general and through meetings held at the village level with farmers in particular helped it become popular.
- The mechanics of pest surveillance and control have been brought into harmony through multi stakeholder cooperation.
- Advisory capsules, created in collaboration with SAU experts, improved the application of pest management recommendations. They are quite scientific as a result.
- Contractual employees hired just for pest surveillance, data feeding, and advise distribution insured that farmers would continue to use e-pest monitoring and need-based pest management.
- Regular staff trainings to pass on the know-how of pest surveillance and pest management empowered capacity building (departmental personnel of the Department of Agriculture, pest scouts, pest monitors, and data entry operators).
- Farmers and department officials received updated information and training on crop production and protection during exposure visits.
- The safe application of pesticides has been made possible by the real-time pest status based on ETL and management warnings.
- The agricultural community's access to mobile phones and participation in the free SMS advisory programme permitted the widespread distribution of pest control recommendations.
- Programme monitoring at several levels (from the state to the village levels) permitted timely information and action flow based on stakeholder roles.
- Need-based pesticide deliveries to the villages on a subsidised basis based on the actual pest situation made possible by the convergence of many State Department of Agriculture programmes (Maharashtra).
- All stakeholders' positive attitudes, ongoing passion, and dynamism in upholding their individual duties contribute to the program's success.

Awards:

The Government of India has recognised CROPSAP's distinctiveness, innovation, replicability, and resilience with higher levels of awards on a number of occasions:

Krishi Karman Award (2010):

The Government of India has notably acknowledged the impact of CROPSAP project, putting soybean, pigeon pea, and chickpea under pest monitoring. The State of Maharashtra earned the Krishi Karman award for 2010–2011 for the greatest pulse output.

e-Governance Gold Medal (2011-12):

At the 15th National Conference on e-governance held between February 9–10, 2012 in Bhubaneshwar, Odisha, the Crop Pest Surveillance and Advisory Project (CROPSAP) – Maharashtra won an award for excellent reuse of ICT-based solutions.

Prime Minister's Award for Excellence in Public Administration (2012-13):

In Maharashtra, the Crop Pest Surveillance and Advisory Project (CROPSAP) was recognised with the "Prime Minister's Award for Excellence in Public Administration" for the 2012–13 fiscal year. On April 21, 2015, the Department of Administrative Reforms and Public Grievances hosted the ninth Civil Services Day. Shri Prabhakar Deshmukh, then commissioner of agriculture for Maharashtra, was presented with the award

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ROLE OF DISPERSAL IN DIFFERENT PLANT PATHOGENS

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Introduction:

Transport of spores or infectious bodies, acting as inoculum, from one host to another host at various distances resulting in the spread of disease, is called dissemination, dispersal or transmission of plant pathogens (Agrios, 1972). It is very important for spread of plant diseases, for continuity of the life cycle and evolution of the pathogen. The spores of some fungi are expelled forcibly from the sporophore or sporocarp by a squirting or puffing action that results in successive or simultaneous discharge of spores up to a centimetre or so above the sporophore.

The seeds of some parasitic plants are also expelled forcibly and may arch over distances of several metres. These are dispersed mechanically by various means. In bacterial diseases, the bacterial cells come out on the host surface as ooze or the tissues may be disintegrated so that the bacterial mass is exposed and then dispersed by various physical and biological agencies. Insects, mites, phanerogamic parasites nematodes and human beings transmit viral diseases, which have no such organs (Mellado and Zamora, 2014).

The knowledge of these methods of dispersal is essential for effective control of plant diseases because possibilities of preventing dispersal and thereby breaking the infection chain exist.

The dispersal of infectious plant pathogens occurs through two ways-

I. Autonomous or direct or active dispersal
II. Indirect or passive dispersal

I. Autonomous dispersal

It is also known as active or direct dispersal. In this method the dispersal of plant pathogens (fungi, bacteria, and viruses) takes place through soil and seed or planting materials during normal agronomic operations.

1. Soil as means of autonomous dispersal

Soil-borne facultative saprophytes or facultative parasites may survive through soil. The dispersal may be by movement of the pathogen in the soil or by its growth in soil or by movement of the soil containing the pathogen. The former is known as dispersal in soil while the latter is called dispersal by soil (Schuster and Coyne 1974).

a. Dispersal in soil

The following are the three stages of dispersal in soil.

i. Growth and spread of the pathogen in soil

ii. Persistence of the pathogen

i. Contamination of soil

Contamination of the soil takes place by gradual spread of the pathogen from an infested area to a new area or by introduction of contaminated soil, plant debris to a new area or by introduction of infected seed or planting materials.

ii. Growth and spread of the, pathogen in soil

Once the pathogen has reached the soil it can grow and spread "depending on the multiplication and spread. Multiplication and spread depends on the characters of the pathogen, presence of susceptible host and cultural practices. The adaptability of the pathogen to the soil environment includes saprophytic survival ability. The survival ability of the pathogen is governed by high growth rate, rapid spore germination, better enzymatic activity, capability to produce antibiotics and tolerance to antibiotics produced by other soil microorganisms. The active saprophytic survival of facultative saprophytes and facultative parasites in soil is affected by soil structure, moisture, organic matter, pH; antagonism etc., specialized facultative parasites (or saprophytes) can pass their life in soil in the absence of the host plants, but they depend more on the residues of their host plant. e.g., *Armillariel/a mel/ea, Ophiobolus graminis, Phymatotrichum omnivorumand Fusarium.* The non-specialized facultative parasites can pass their entire life in the soil. e:g., *Pythium* sp., *Phytophthora* sp., The soil-borne obligate parasites such as *Plasmodiophora brassicae, Synchytrium endohioticum* requires the presence of active host.

Ill. Persistence of the pathogen

The pathogens persist in the soil as dormant structures like oospores *(Pythium; Phytophthora, Sclerospora,* etc.) chlamydospores *(Fusarium)* or smut spores *(Ustilago)* or sclerotia *(Rhizoctonia, Sclerotium,* etc.)

b. Dispersal by the soil

The pathogen enters the soil, grow and spread in the soil. During the cultural operations in. the field, soil is moved from one place to the nearby place through the agricultural implements and irrigation, worker's feet. Propagules of fungi or the dormant structures of fungi and the plant debris containing the fungal and bacterial pathogens thus spread throughout the field.

2. Seed and seed materials as the source of autonomous dispersal

The seeds serve as medium for autonomous dispersal of pathogens. Since most of the cultivated crops are raised from seed the transmission of diseases and transport of pathogens by seeds has much importance. The dormant structures of the pathogen (e.g., seeds of *Cuscuta*, sclerotia of ergot fungus, smut sori, etc.,) are found mixed with seed lots and they are dispersed as seed contaminant. The bacterial cells or spores of fungi present on the seed coat (such as in smuts of barley, sorghum, etc.,) are transported to long distances. Dormant mycelium of many fungi present in the seed is transmitted to long distances (Arneson, 2001).

This type of dispersal is highly erratic. The most important methods of dispersal of pathogen by the soil are transfer of soil from one place to another along with plant parts or propagating materials. e.g., transfer of papaya seedlings from a nursery infested with *Pythium aphanidermatum* (the cause of stem or foot rot of papaya) C311 introduce the pathogen in new pits for transplanting the seedlings. Similarly grafts of fruit trees transported with soil around their roots can transmit pathogens present in the nursery to the orchards. By this method, pathogens are not only spread from field to the field but also from district to district, State to State and often from country to country. There are three types of dispersal by seed-

a. Extemally seed – borne

b. Intemally seed - bome

a. Externally seed-borne

Close contact between structure of the pathogen and seeds is established in diseases like covered smut and loose smut VI Daney, snoll smut ot sorghum, stinking smut of wheat and bacterial blight of cotton where the pathogen gets lodged in the fomi of donnant spores or bacteria on the seed coat during growth of the crop or at the time of harvest and threshing. In many pathogens the externally seed-borne Structures such as smut spores can persist for many years due to their inherent capaCity for long survival. The spores of *Tilletia caries* (stinking smut of wheat) remain viable even after 18 years and those of *Ustilago avenae* (oat smut) for 13 years.

b. **Internally seed-borne**

The pathogen may penetrate into the ovary and cause infection of the embryo while it is developing. They become internally seed-borne. Internally seed borne pathogens like *Ustilago nuda tritici* are viable for more than 15 years. Other examples include *Helminthosporium oryzae, Sclerospora graminico/a*, etc. The bacterial pathogens include *Xanthomonas oryzae* pv. *Oryzae* on rice, *Pseudomonas syringae* pv. *syringae* in cucurbits, *Xanthomonas campestris* pv. *campestris* on crucifers, etc.

Mainly man distributes seeds of cultivated crops. Sometimes animals and birds also help in distribution of crop seeds. Man and animals are the main agencies of dispersal of pathogen through seed. The pathogens thus mixed with the seed or on the seed are transmitted.

Passive dispersal

Passive dispersal of plant pathogens happens through

I. Animate agents

a. Insects	e. Human beings
b. Mites	f. Farm and wild animals
c. Fungi	g. Birds
d. Nematode	h. Phanerogamic parasites

II. Inanimate agents

a. Wind b. Water

1. Animate agents

a. lnsects

Insects carry plant pathogens either externally or internally. Gaiiman (1950) used the terms epizoic and endozoic respectively for these two types of transmission. The external transmission of plant pathogens is of special interest in those fungi, which produce their conidia, oidia and spermatia in sweet or honey secretions having attractive' odours. Some of the well known diseases of this type are the ergot, the *Sc1erotinia* brown rot of pear and apple, the honey dew stage in the 'sugary disease' of sorghum and pearlmillet in parts of India and the pycnial nectar in the cluster cup stage of rusts. The spermatial oozing at the mouth of spermagonia in the Ascomycetes attract various types of insects, flies, pollinating bees and wasps which playa dual role *viz.,* pollination and transmission' of pathogens. The fire blight organism *(Erwinia amylovora)* pathogens and citrus canker bacterium, *(Xanthomonas axonopodis* pv. *cirri)* are also carried in this manner, the former by flies (bees) and ants and the latter by the leaf miner. The black leg of potato caused by *Erwinia carotovora* is disseminated by maggots, wilt of com caused by *X. stewartii*, gummosis of sugarcane caused by *X. vasculorum* are the other examples for bacterial diseases transmitted by insects.

Ingenious transmission of pathogens, of an internal nature (endozoic) is provided by the Dutch elm disease *(Ceratostomella ulmi)* and the olive canker *(Bacillus savastano i).* The former is transmitted by the elm bark beetles and the latter by the olive fly *(Olea . europaea).* These insects, unlike the epizoic group, appear to have a close biologic relationship with the pathogens, as they have not been reared without the contaminating pathogens.

Virus taxon	No. of members	Principal vector
No circulative, no persistent		
Caulimovirus	17	Aphids
Alfamovirus	1	Aphids
Carlavirus	55	Aphids
Cucumovirus	3	Aphids
Fabavirus	2	Aphids
Machlomovirus	1	Thrips and Beetles
Macluravirus	2	Aphids
Potyvirus	55	Aphids, Mites, and Mechanical
Potyvirus		
No circulative, semi persistent		
Badnavirus	16	Mealy bug and Leafhoppers
Closterovirus	25	Aphids, Whiteflies and Mealy bug
Nepovirus	39	Nematodes
Sequivirus	2	Aphids
Tobravirus	4	Nematodes
Sequivirus	2	Aphids
Tobravirus	4	Nematodes
Trichovirus	6	Aphids, Mealybug, and mites
Waikavirus	3	Aphids and Leafhoppers

Insects spread few important plant pathogenic bacteria. The cucumber wilt bacterium, *Erwinia tracheiphila* is spread by the striped cucumber beetles *(Acalymma vitata)* and the spotted cucumber beetle *(Diabrotica undecimpunctata).* When the beetles are feeding on the diseased plant, the bacterium contaminates the mouthparts and passes into the gut of the insect. During the winter season, the bacterium overwinters inside the beetle. Thus the beetle helps the bacteria in two ways, i.e. in their transmission and survival (Chapman and Onderdonk, 1998).

Different types of insects spread more than 80 per cent of the viral and phytoplasmal diseases. The insect, which act as specific carriers in disseminating the diseases, are called insect vector.

Both aphids (Aphidae) and leafhoppers (Cicadellidae or Jassidae) in the order Homoptera contain largest number and the most important insect vectors of plant viruses. Certain species of mealy bugs and scale insects (Coccoidae), whiteflies (Aleurodidae) and treehoppers (Membracidae) in the same order (Homoptera) also transmit virus diseases. Insect vectors of plant viruses are few in true bugs (Hemiptera), thrips (Thysanoptera),beetles (Coleoptera) and grasshoppers (Orthoptera). Aphids, leafhoppers and other groups of Homoptera and true bugs have piercing and sucking mouthparts. Thrips have rasping and sucking mouthparts. All other groups of insect vectors have chewing mouthparts and they transmit only very few viruses.

Transmission Strategy	Virus	Family (Genus)	Insect vector(s)
Non-persistent Non-circulative	*Potato virus Y* (PVY)	*Potyviridae (Potyvirus)*	Aphids e.g., *Myzus persicae*
	Cucumber mosaic virus (CMV)	*Bromoviridae (Cucumovirus)*	Aphids e.g., *Myzus persicae*
Semi-persistent Non-circulative	*Cauliflower mosaic virus* (CaMV)	*Caulimoviridae (Caulimovirus)*	Aphids e.g., *Acyrthosiphon pisum*
	Lettuce infectious yellows virus (LIYV)	*Closteroviridae (Crinivirus)*	Sweet potato whitefly *Bemisia tabaci*
Persistent Circulative Non-propagative	*Beet western yellows virus* (BWYV)	*Luteoviridae (Polerovirus)*	Green peach aphid *Myzus persicae*
	Tomato yellow leaf curl virus (TYLCV)	*Geminiviridae (Begomovirus)*	Sweet potato whitefly *Bemisia tabaci*
Persistent Circulative Propagative	*Tomato spotted wilt virus* (TSWV)	*Peribunyaviridae (Tospovirus)*	Thrips e.g., *Frankliniella occidentalis*
	Rice stripe virus (RSV)	*Phenuiviridae (Tenuivirus)*	Planthopper *Laodelphax striatellus*
	Fiji disease virus (FDV)	*Reoviridae (Fijivirus)*	Planthopper *Perkinsiella saccharicida*
	Rice ragged stunt virus (RRSV)	*Reoviridae (Oryzavirus)*	Brown planthopper *Nilaparvata lugens*
	Rice dwarf virus (RDV)	*Reoviridae (Phytoreovirus)*	Leafhopper *Nephotettix cincticeps*
	Lettuce necrotic yellows virus (LNYV)	*Rhabdoviridae (Cytorhabdovirus)*	Aphid *Hyperomyzus lactucae*
	Rice yellow stunt virus (RYSV)	*Rhabdoviridae (Nucleorhabdovirus)*	Leafhopper *Nephotettix cincticeps*

Aphids

Aphids are the most important insect vectors of plant viruses and transmit the great majority of all stylet - borne viruses. As a rule several aphid species can transmit the same stylet - borne virus and the same aphid species can transmit several viruses, but in many cases the vector-virus relationship is quite specific. Aphids generally acquire the stylet-borne virus after feeding on a diseased plant for only a few seconds (30 seconds or less) and can transmit the virus after transfer to and feeding on a healthy plant for a similarly short time of a few seconds. The length of time aphids remain viruliferous after acquisition of a stylet-borne virus varies from a few minutes to several hours, after which they can no longer transmit the virus. In few cases of aphid transmission of circulative viruses, aphids cannot transmit the virus immediately but must wait several hours after the acquisition feeding, but once they start to transmit the virus, they continue to do so for many days following the removal of the insects from the virus source (Robert, 2001). In aphid transmitting stylet-borne viruses, the virus seems to be borne on the tips of the stylets, it is easily lost through the scouring that occurs during probing of host cells, and it does not persist through the moult or egg.

Leaf hoppers

Leaf hoppers are phloem feeders and acquire the virus from the phloem region. All leaf hoppers, transmitted viruses are circulatory. Several of these viruses multiply in the vector (propagative) and some persists through the moult and are transmitted through the egg stage of the vector. Most leaf hopper vectors require a feeding period of one to several days before they become viruliferous, but once they have acquired the virus they may remain viruliferous for the rest of their lives. Usually there is an incubation period of 1 to 2 weeks between the time a leaf hopper requires a virus and the time it can transmit it for the first time.

b. Mites

Mites belonging to the families Eriophyidae (eriophid mite) and Tetranychidae (spidermite) transmit plant viruses. These mites have piercing and sucking type mouthparts. Family Eriophyidae have been shown to transmit at least 14 plant viruses including wheat streak mosaic, Wheat spot mosaic, Sterility mosaic of pigeon pea, Rye grass mosaic, fig mosaic etc (Nathan, 2001). Peach mosaic virus is transmitted by mites of the family Tetranychidae

c. Fungi

Some soil - borne fungal plant pathogens transmit plant viruses. *Olpidium brassicae, Ploymyxa graminis, P. betae* and *Spongospora subterranea* are the fungi involved in transmission of virus disease. The viruses are apparently borne in or on the resting spores and the zoospores, which upon infection of new host plants introduce the virus and cause symptoms characteristic of the virus they transmit. All these fungi are pathogens of the host, which carry of viruses (Rao, 2006). The zoospores of the fungi are released from the host and the zoospores carry the virus and transmit it to the susceptible hosts during their infection process. In some cases plant viruses are carried on the outside of the fungi. Examples are tobacco necrosis virus and cucumber mosaic virus.

The viruses like lettuce big vein virus are found inside the zoospores. They persist for years in viable resting sporangia. The types of transmission by fungi can be considered as non persistent and persistent transmission.

d. Nematodes

Nematodes are soil borne organisms. Some of the nematodes act as agents for dissemination of pathogenic fungi, bacteria and viruses. For example, the bacterium *Corynebacterium tritici* that causes yellow ear rot of wheat is disseminated by ear cockle nematode. Similarly, some pathogenic fungi such as, *Phytophthora, Fusarium, Rhizoctonia,* etc. are carried on the body of nematodes (Walling, 2008). Nematodes help these pathogenic fungi to enter into the host through punctures for their own entry and enter into hosts along with the nematodes. Plant nematodes play a vital role as vector in transmitting certain virus diseases. Nematode vectors transmit viruses by feeding on roots of infected plants and then moving on roots of healthy plants. Larvae as well as adult nematodes can acquire and transmit viruses, but the virus is not carried through the larval molts or through the eggs. After moulting, the larvae or the resulting adults must feed on a virus source before they can transmit again. Xiphinema, Longidorus and Trichodorus transmit both the polyhedral and tubular type of viruses.

e. Human being

Man is the most important factor responsible for.' short distance and 'long distance dispersal of plant pathogens. He helps in dissemination unknowingly by his usual agricultural practices. Human being's role in dissemination of plant pathogens is more direct of plant pathogens by human beings is known anthropochory. The ways and means by which human beings help in dispersal are as follows.

i. Transportation of seeds (Seed trade)

Seed trade is one of the different means of dispersal of plant pathogens in which man plays an important role. The import and export of contaminated seeds without proper precautions lead to movement of pathogens from one country to another or from one continent to another. Through this way pathogens of soybean and sugarbeet hither to not prevalent in India got introduced. Human agencies of individual, official and unofficial have transported new plants and plant products, the seed, the tubers, the propagating stock and fruits, which carried the plant pathogens, many times in a latent condition and which ultimately lead to the outbreaks of new diseases in places, hither to free from them. The diseases which are amenable to such transmission are mainly those that are carried in or on the propagative parts and seed such as late blight of potato, the downy mildew of grapevine, citrus canker, chestnut blight, Dutch elm disease, *Fusarium* wilt of banana, Katte disease of cardamom and bunchy top of banana.

Many of these diseases, not very destructive in their homelands, have brought in ruin and devastation. The sale of seeds for crops badly affected by a seed-borne pathogen is a common method of dispersal of destructive pathogens e.g. loose smut of wheat *(Ustilago nuda tritici),* grain smut of sorghum *(Sporisorium sorghi),* ergot of pearl millet *(Claviceps fusiformis)* and Kamal bunt of wheat *(Neovossia indica).*

ii. Planting diseased seed materials (vegetatively propagated materials)

Planting diseased bulbs, bulbils, corns, tubers, rhizomes, cutting etc. of vegetatively propagated plants such as potato, sweet potato, cassava, sugarcane, banana, many ornamentals and fruit trees etc. help in dispersal of pathogens from field to field, orchard to orchard, locality to locality or from one country to another.

iii. By adopting farming practices

Human beings (men and women) engaged in preparatory cultivation, planting, irrigation, weeding, pruning etc. help in dispersal of plant pathogens. The fungal spores (oospores, chlamydospores) dormant structures like sclerotia are carried by worker's clothing, shoes, hand etc. from field to field. Men or women engaged in inter cultivation in tobacco field spread the dreaded tobacco.

iv. Through clothing

Palm workers engaged in cleaning coconut trees spread bud rot disease.

v. By use of contaminated implements

Pathogens are transferred from one area to another through implements used in various cultural operations (weeding, hoeing thinning etc.) in the field. e.g: root rot of pulses and cotton *(Macrophomina phaseo/ina*, bacterial angular leaf spot of cucumber *(Pseudomonas lachrymans)* and bacterial canker of tomato *(Corynebacterium michiganensis).* Cutting knives and pruning knives help in dissemination from one plant to another e.g., Bunchy top of banana.

vi. By use of diseased grafting and budding materials

Grafting and budding between healthy and diseased plants is the most effective method of distribution of pathogens of horticultural crops (fruit trees, ornamentals etc.) e.g., Careless selection of stocks and scions in propagation of citrus trees.

Disease	From	To	Year
Powdery mildew of grape vine	USA	Europe	1845
Downy mildew of grapevine	USA	France	1878
Late blight of potato	South America	USA	1830
Panama disease of banana	Panama Islands	Bombay	1920
Bunchy top of banana	Sri Lanka	South India	1940
Citrus canker	Asia	USA	1907
Fire blight of apple	USA	New Zealand	1919

f. Farm and wild animals

Farm animals (cattles) while feeding on diseased fodder ingest the viable fungal propagules (spores or oospores or sclerotia) into their digestive system. Animals which feed on downy mildew affected pearlmillet or sorghum take the oospores along with the fodder. Oospores pass out as such in the dung. This dung when used as manure spread in the field and act as source of inoculums. Smut fungi like grain smut of sorghum, loose smut and head smut of sorghum are carried from field to field through the alimentary canals of farm animals. Soil inhabiting fungi especially sclerotia adhere to the hoofs and legs of animals and get transported to other places. Animals passing through the tobacco fields help in transmission of TMV.

g. Birds

In general, transmission by birds is of minor importance. But this method is important in dissemination of seeds of flowering parasites and certain. fungi. Many migratory birds, such as mistle thrush *(Turdus viscivorus)* in the temperate region and the crows *(Crovos brachyrhynchos)* in the tropics, take active part in the transmission of giant mistletoe *(Dendrophthoe* spp.) either through external contamination of their beaks and feathers or internally through the alimentary canals. These birds feeding on the fleshy, sticky and gelatinous berries of giant mistletoe deposit the seeds on the other trees with the excreta.

Stem segments of dodder *(Cuscuta* spp.) are carried by birds for building their nests. Thus the phanerogamic parasites are getting transported to new locations. Spores of chestnut blight fungus, *Endothea parasitica* are disseminated by not less than 18 species of birds. Internal transmission of this pathogen is carried out by the birds, which visit such diseased plants and get contaminated by the spores. Birds are also known to carry the spores of fungi on their, body.

h. Phanerogamic parasites

Plant viruses are transmitted from one plant to another through the bridge formed between the two plants by the twining stems of the parasitic plant dodder *(Cuscuta* spp). Dodder is yellow vine without green leaves. In this way viruses are transmitted between plants belonging to families widely separated taxonomically. The virus is transmitted in the food stream of the dodder plant, being acquired from the vascular bundles of the infected plant by the haustoria of dodder. After translocation through the dodder phloem the virus is introduced in the next plant by the new dodder haustoria produced in contact with the vascular bundles of the inoculated plant. *Cuscuta californica*, C. *campestris*, C. *subinclusa* are usually employed for dodder transmission of viruses and phytoplasmas. C. *europaea*, C. *epilinum* and C. *lupuliformis* are also employed in transmission of viruses.

2. Inanimate agents

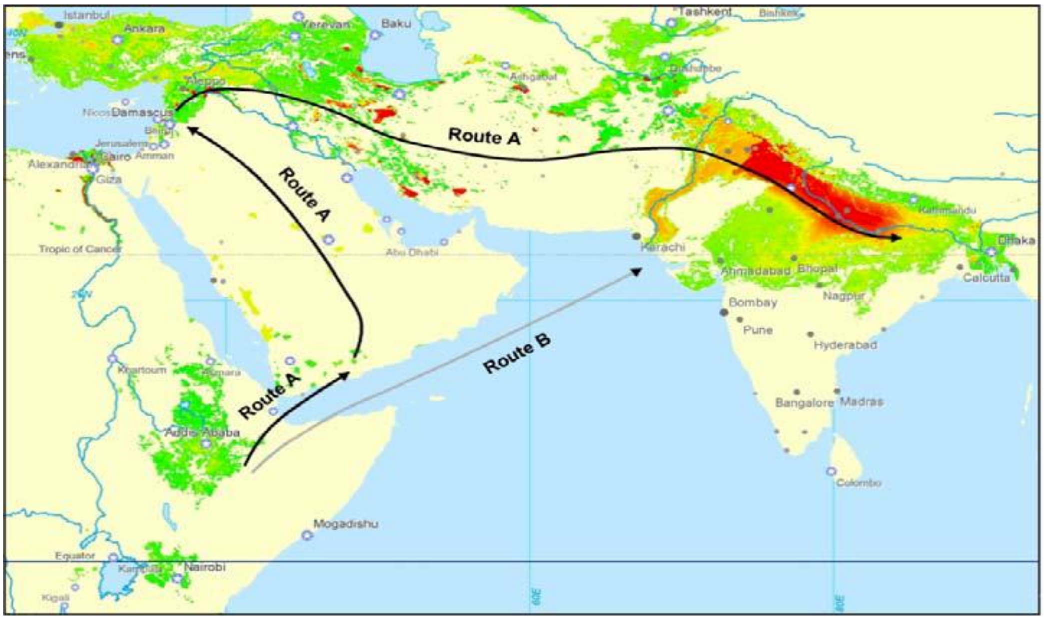
a. Wind

The wind dispersal of plant pathogens is known as anemochory. It is one of the most common methods of the dispersal of plant pathogens. It is the most dangerous and potent mode of travel for plant pathogenic fungi. It acts as potent carrier of propagules of fungi, bacteria and viruses. Usually the fungal pathogens are light in weight and are well adapted to wind dispersal. Some pathogenic bacteria are carried along with the infected material to short distances by wind. Damping-off pathogen *(Pythium* spp.), wart disease pathogen of potato *(Synchytrium endobioticum);* root rot pathogens *(Sclerotium* and *Rhizoctonia)* and seeds of phanerogamic parasites witchweed *(Striga)* are efficiently carried by wind. Viruses and phytoplasmas are not directly transmitted by wind, but the insect and mite vectors that carry the viruses move to different directions and distances depending upon the direction and speed of air.

The adaptations for wind dispersal in fungal pathogens include production of numerous spores and conidia, discharge of spores with sufficient force, production of very small and light spores so that they can move to long distances. The duration and periodicity of sporulation and discharge are also important factors for wind dispersal. Some fungal pathogens causing powdery mildews, downy mildews, rusts, smuts, sooty moulds, leaf spots, blast, apple scab etc., produce large number of very light spores and conidia on the surface of the host. Uredial stages of the rust fungi travel long distances through air currents and are thus responsible for destructive epidemics over wide areas.

Wind transmission involves the upward air currents, velocity and the downward movements of wind. All are equally responsible for the spread of infection and ultimate outbreak of diseases and have been of special significance in the rust, smut fungi. Uredospores of rust fungi have been carried to long distances, both cross-wise and upwards. Christensen (1942) and Stakman (1946) determined by exposure of Vaseline slides in the upper air through aeroplane flights, that uredospores and aeciospores of *Puccinia gramminis tritici* could be gathered in a viable condition up to a distance of 4,200 m, above infected fields, *Alternaria* sp. at2,400 m. and those of *Puccinia tritici* at 3,750 m. The transmission of aecial spores of *Puceinia graminis tritici* from several groups of barberry bushes to the wheat crop showed that these spores travelled successfully over a radius of 3 km round about these bushes. The blister rust fungus, *Cronartium ribicola,* is known to travel to a distance of 500 metres or 3,750 m. inside a plantation that the range is probably more in the open. Similar observations have been made in respect of dissemination of chlamydospores of the smut fungi.

In long distance dissemination with intervening stages of infection, the retention of viability of spores is an important factor that determines the extent and severity of epidemics, over wide areas. The outbreaks of cereal rusts and blast of rice are examples of such dissemination. Spores differ widely in their ability to survive long distance travel through air. Uredospores of rusts, chlamydospores or smut fungi and conidia of *Alternaria*, *Helminthosporium*, *Pyricularia* and others are well adapted for long distance travel in a viable condition and are known to play a vital role in epidemiology. The conidia of downy mildews, powdery mildews and the aeciospores and basidiospores of the rust fungi are unable to withstand such long distance dissemination when they are exposed to desiccation and direct sunshine and thus are only capable of producing local epiphytotics of limited magnitude.



- Route (A) via Arabian peninsular, Middle-East and South Asia
- Route (B) connecting East Africa directly with southern Pakistan/ western India

The bacteria causing fire blight of apple and pear *(Erwinia amylovora)* produce fine strands of dried bacterial exudates containing bacteria and these strands may be broken off and they are transmitted by wind. Bacteria and nematodes present in the soil-may be shown away along with soil particles. Wind also helps in the dissemination of bacteria, fungal spores and nematodes by blowing away rain splash droplets containing these pathogens. Wind carries insects and mites that may contain or are smeared with viruses, bacteria or fungal spores to short or long distances. Wind also causes adjacent plants or plant parts to rub against each other. The wound created in this manner help the spread by contact of bacteria (citrus canker), fungi, some viruses (Tobacco mosaic virus) and viroids and possibly of some nematodes.

b. Water

Transmission of plant pathogens by water (hydrochory as called by Gaiimann, 1950) is not as significant as wind transmission. Although water is less important than air in long-distance transport of pathogens, water dissemination of pathogens is more efficient, in that the pathogens land on an already wet surface and can move or germinate immediately. In case of some diseases the surface flow of water after heavy showers of rains or irrigation water from canals and wells carries the pathogens to short distances. Soil inhabiting fungi like, *Fusarium*, *Ganoderma*, *Macrophomina Phytophthora*, *Plasmodiophora*, *Pythium*, *Rhizoctonia*, *Sclerotium*, *Sclerotinia*, *Sporisorium*, *Ustilago*, *Verticillium* etc., in the form of mycelial fragments, spores or sclerotia, soil-bone bacteria and nematodes carrying viruses are transmitted through the above process. They are transmitted through rain or irrigation water that moves on the surface or through the soil.

All bacteria and the spores of many fungi are exuded in a sticky liquid and depend for their dissemination on rain or (overhead) irrigation water, which either washes them downward or splashes them in all directions.

Raindrops or drops from overhead irrigation pickup the fungal spores (uredospores of *Hemileia*, *Puccinia* and *Uromyces* and bacteria (bacterial blight pathogen of rice, *Xanthomonas Olyzae* pv. *oryzae;* bacterial leaf streak pathogen, *X oryzae* pv. *translucens;* citrus canker pathogen, *X. axonopodis* pv. *citri;* tomato bacterial blight pathogen, *Clavibacter michiganensis* and cotton bacterial blight pathogen, *X.axonopodis* pv. *malvacearum* present in the air and wash them downward where some of them may land on susceptible plants.

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GENE PYRAMIDING: FOR RUST RESISTANCE GENE(S) IN WHEAT

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Abstract:

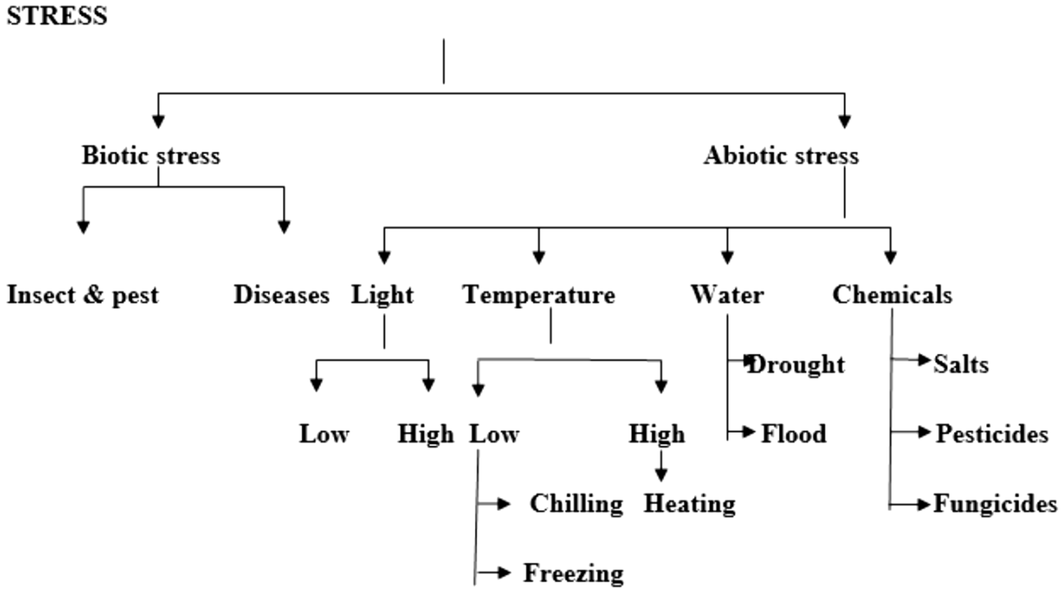
Bread wheat (*Triticum aestivum* L.) is a prehistoric Indian crop that has been cultivated for thousands of years. Wheat makes a significant contribution to global food and nutritional security. Thus, developing high-yielding varieties with improved nutritional quality and resistance to all major diseases is an important goal of wheat breeding. Wheat yield has risen tremendously, but also the chance of several biotic and abiotic stresses was also increased. Rust is a major biotic stress in wheat that had a devastating impact on crop yield in past years. The Yr9/Lr26/Sr31/Pm8 gene linkage provided long resistance in wheat cultivars such as PBW343, HD2687, and HD2932, but it became obsolete due to susceptibility to rust. Every year, biotic stress diseases such as rust cause approximately $ 50 billion in global losses. So, it becomes noticeable. Leaf rust causes 20-40% yield losses, stem rust causes 50-100% yield losses, and stripe rust causes 25-100% yield losses. Gene pyramiding is an effective method for improving elite cultivars' disease resistance.

Keywords: wheat, rust, gene pyramiding

Introduction:

Wheat (*Tritium aestivum* L.) is the world's basic staple food crop, accounting for nearly 20% of total human calorie intake (Wang *et al.*, 2021). India, one of the green revolution's biggest success stories, is the world's second-largest wheat grower, trailing only China in terms of production of 108.75 million tonnes from 31.76 million acres (DES, MoA&FW, 2020-2021). Wheat demand is expected to increase by half by 2050 compared to today. Meanwhile, the crop is under attack from new and more aggressive pests and diseases, dwindling water resources, limited accessible land, and erratic weather patterns, particularly heat (IIWBR Vision, 2050).

Stress: Any environmental factor capable of inducing a potential injurious strain in living organisms (Levitt, 1972). The effect of stress on plant conditions is called strain. In plants, biotic and abiotic stresses occur. Biotic stress includes pests and diseases while abiotic stress includes light, drought, flood, chilling, freezing and salinity stresses.



Living things, in particular viruses, bacteria, fungi, nematodes, insects, arachnids, and weeds, cause biotic stress in plants. Plant death can result from the agents causing biotic stress directly depriving their host of its nutrients. Pre- and post-harvest losses can cause significant biotic stress. Biotic stress can become major because of pre-and post-harvest losses.

It differs from abiotic stress, which is the adverse effect that non-living factors like temperature, sunlight, wind, salinity, flooding, and drought have on organisms. The kinds of biotic stresses that an organism is subjected to depend on both the climate in which it lives and the capacity of the species to withstand particular stresses. The term "biotic stress" still has a broad definition, and those who study it face numerous difficulties, such as how much harder it is to control biotic stress in an experimental setting than abiotic stress. Due to the significant economic losses to cash crops caused by biotic stressors, agriculture research has a strong focus on these issues. The relationship between biotic stress and plant yield has an impact on both practical development and economic decisions.

The Irish famine of 1845 was caused by the late blight of potato (*Phytophthora infestans*), an oomycete and had devastating consequences for humanity. This biotic stress wiped out Ireland's entire potato crop. Another example is grape phylloxera, which arrived from North America in the nineteenth century and caused the Great French Wine Blight. The Great Bengal Famine of 1943 was caused by the disease brown spot of rice (*Helminthosporium oryzae*). An estimated 2.1-3 million people died of starvation, malaria, and other diseases exacerbated by malnutrition, population displacement, unsanitary conditions, and a lack of health care in a population of 60.3 million. The Bhopal gas tragedy occurred on the night of December 2-3, 1984, at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh.

Methylene isocyanate (MIC) gas was inhaled by over 500,000 people. The gas release killed 3,787 people and injured 574,366 others. Carbaryl (Sevin) insecticides were made using MIC.

Plants are expected to be more susceptible to pathogens as a result of the effects of climate change. Furthermore, increased abiotic stress threats (such as drought and heat) are likely to contribute to plant-pathogen susceptibility.

Table 1: Major biotic stresses in wheat

S.N.	Diseases	Causal Organism
1	Leaf rust, also known as brown rust	*Puccinia recondita*
2	Stem rust, also known as black rust,	*Puccinia graminis f. sp. tritici*
3	Stripe rust, also known as yellow rust	*Puccinia striiformis f. sp. tritici*
4	Powdery mildew	*Erysiphe graminis f. sp. tritici*
5	Loose smut	*Ustilago tritici*
6	Flag smut	*Urocystis agropyri*
7	Karnal bunt	*Tilletia indica*

The concept of multiline development was hypothesized after the green revolution. For example, Sonalika and Kalyan Sona. These high-yielding varieties increased production during the green revolution. For a decade, the wheat variety Kalyan Sona dominated Indian agriculture, but it became susceptible to leaf rust. HD2733 was developed for irrigated timely sown conditions in India's northeastern plains zone, but it became susceptible to leaf rust, a major disease in the region, later on.

Three rusta in wheat are major threat

Table 2: Salient features of important wheat rust diseases

Rust	Favorable temperature	Pustules color	Target Area
Yellow Rust	15-18 °C	Yellow	North Western region
Brown Rust	22-25 °C	Orange	Central and North Western region
Stem Rust	30°C	Black	Southern and Central region

Table 3: Important Source of Rust Resistant Genes

S.N.	Leaf Rust Resistance Gene(s)	Source	Yellow Rust Resistance Gene(s)	Source	Stem rust Resistance Gene(s)	Source
1	*Lr9*	*Aegilops umbellulata*	*yr5*	*Triticum spelta*	*Sr2+Lr27+Yr30+ Pseudo black Chaff*	*Triticum aestivum*
2	*Lr28*	*Aegilops speltoides*	*Yr9+Sr31+Lr26 +pm8*	*Secale cerale*	*Sr22*	*Triticum boeoticum*
3	*Lr32*	*Aegilops squarossa*	*Yr10*	*Triticum spelta*	*Sr24+Lr24*	*Thinopyrum ponticum*
4	*Lr34*	*Triticum aestivum*	*Yr15*	*Triticum dicocoides*	*Sr25+lr19*	*Thinopyrum ponticum*
5	*Lr37*	*Aegilops ventricosa*	*Yr16*	*Triticum aestivum*	*Sr26*	*Thinopyrum ponticum*
6	*Lr39*	*Triticum tauschii*	*Yr17+Lr37Sr38*	*Triticum venticosum*	*Sr27*	*Secale cerale*
7	*Lr41*	*Triticum tauschii*	*Yr18+Lr34*	*Triticum aestivum*	*Sr29*	*Triticum aestivum*
8	*Lr42*	*Triticum tauschii*	*Yr24*	*Triticum aestivum*	*Sr30*	*Triticum aestivum*
9	*Lr44*	*Triticum spelta*	*Yr27+Lr13*	*Triticum aestivum*	*Sr32*	*Aegilops speltoides*
10	*Lr45*	*Secale cerale*	*Yr28*	*Triticum tauschii*	*Sr33*	*Triticum tauschii*
11	*Lr46+Yr29*	*Triticum aestivum*	*Yr29+Lr46*	*Triticum aestivum*	*Sr35*	*Triticum monococcum*
12	*Lr47*	*Aegilops speltoides*	*Yr30+Sr2+Lr27*	*Triticum aestivum*	*Sr36+pm6*	*Triticum timophi*
13	*Lr48*	*Triticum aestivum*	*Yr35+lr53*	*Triticum dicocoides*	*Sr38+Lr37+Yr17*	*Aegilops ventricosa*
14	*Lr49*	*Triticum aestivum*	*Lr67+Yr46*	*Triticum aestivum*	*Sr42*	*Aegilops speltoides*
15	*Lr53+Yr35*	*Triticum dicocoides*			*Sr43*	*Triticum aestivum*
16	*Lr57*	*Aegilops geniculata*				

Gene pyramiding

Gene pyramiding or stalking is a method of introducing multiple QTLs or genes for a single trait or multiple traits into a cultivar that is lacking in those traits.Gene pyramiding was first proposed by Watson and Singh in 1953.

Importance

The transfer of multiple disease-resistance genes for imparting long-term disease resistance is one of the most important applications of gene pyramiding. In India, conventional backcrossing was used to successfully pyramid genes for rust resistance against all three rusts [leaf (LR), stem (SR), and yellow (YR) rusts].

Table 4*:* Gene pyramiding in common wheat for disease resistance

Scientist Name	**Year**	**Significant work**
Cox *et al.*,	1993	Successfully pyramided three-leaf rust resistance genes *Lr41, Lr42* and *Lr43* into the common wheat (*Triticum aestivum* L.).
Santra *et al.*,	2006	Successfully pyramided two single, dominant genes *Yr5* and *Yr15*, which independently confer complete resistance to all stripe rust races found in North America.
Barloy *et al.*,	2006	Pyramided the two CCN resistance genes (*CreX* and *CreY)* in a wheat background through marker-assisted selection.
Singh *et al.*,	2017	Marker-assisted pyramiding of Thinopyrum-derived leaf rust resistance genes *Lr19* Land *Lr24* in bread wheat variety HD2733
Charpe *et al.*,	2012	Marker-assisted gene pyramiding of leaf rust resistance genes *Lr24, Lr28* and *Lr9* in a bread wheat cultivar HD2329
Pietrusimska *et al.*,	2011	Pyramiding two Genes for Leaf Rust and Powdery Mildew Resistance in Common Wheat
Savita B.S. *et al.*,	2016	Identification of SSR Marker Linked to Leaf Rust Resistant Gene *Lr24* and Marker Assisted Transfer of Leaf Rust Resistance Genes into Bread Wheat
Chhuneja *et al.*,	2011	Marker-assisted pyramiding of leaf rust resistance genes *Lr24* and *Lr28* in wheat (*Triticum aestivum*)
Datta *et al.*,	2006	Pyramiding of leaf rust resistance genes *Lr9* and *Lr24* through molecular marker-assisted selection in wheat (*Triticum aestivum L.)*
Yadawad *et al.*,	2017	Pyramiding of leaf rust resistance genes in bread wheat variety DWR 162 through marker-assisted backcrossing

Types of gene pyramiding

1. **Conventional technique:** Serial gene pyramiding: Genes are deployed in the same plant one after other

   1. Pedigree breeding

   2. Backcross breeding

   3. Recurrent selection

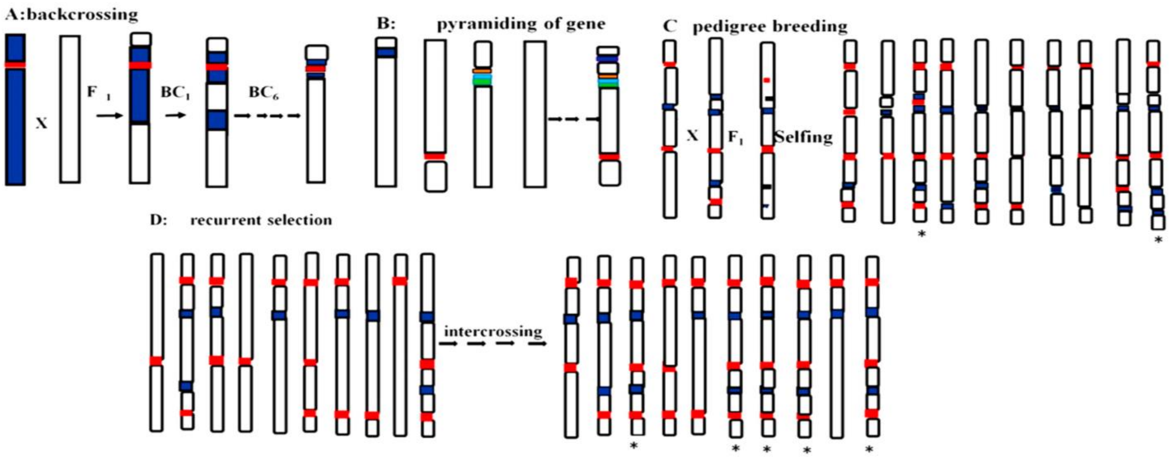


Figure 1: Conventional techniques for gene pyramiding

Disadvantages of conventional methods

The primary application of gene pyramiding is to improve qualitative traits such as disease and insect resistance. Other factors influencing the success of gene pyramiding include the inheritance model of the genes for the target traitsand linkage and/or pleiotropism between the target trait and other traits. Allelic genes, for example, cannot be combined in the same genotype. A recessive gene's effect cannot be evaluated on heterozygous individuals, and progeny testing is required.

Molecular technique

1. **Marker-assisted selection**

Gene pyramiding in wheat for better nutritional quality and rust resistance (Tyagi *et al.*, 2014)

In the current study, four improved lines (in the background of wheat cv. PBW343) were used. CCS University, Meerut, developed one of these four lines, PBW343, which has resistance genes for LR, SR, and YR as well as high GPC *(Lr24/Sr24* + *Gpc-B1/Yr36*; transferred from Yecora Rojo). The following three lines were developed at PAU, Ludhiana: (1) PBW343 with PHS tolerance QTL (*QPhs.ccsu-3A.1*; transferred from SPR8198), (2) PBW343 with genes for leaf and stem rust resistance and a QTL for high GW (*Lr24/ Sr24* + *QGw.ccsu-1A.3*; transferred from Rye Selection 111), and(3) PBW343 has two tightly linked *GluA1* genes that encode two HMW glutenin subunits, *Glu-A1* "x-type" and *Glu-A1* "y-type" (*Glu-A1-1/Glu-A1-2*).

Initially transferred from *T. dicoccoides* to *T. durumcv*. PBW34, the tightly linked genes *Glu-A1-1/Glu-A1-2* were later transferred to the wheat cv. PBW343 (unpublished results). For the pyramiding of eight QTLs/genes, these four lines were crossed in pairs to create two single-cross F_1 hybrids, which were then intercrossed to create a double-cross hybrid (DCH).

Selfing was used to raise the subsequent five generations (DCHF1 to DCHF6), and MAS was applied to each generation. Eventually, four improved lines, known as PYL1 to PYL4, were chosen. To evaluate phenotypic traits and grain yield, 58 progenies of each of the four PYLs were multiplied as single plants. Data analysis and evaluation of the recipient parent and the PSLs. At the Research Farm of CCS University, Meerut, 58 offspring from four pyramided lines (PYL1-PYL4) and the recipient parent (PBW343) were assessed using a randomized block design with three replications. The recipient cultivar and the offspring of PYLs were grown in 1.125 m2 plots, each with three rows that were 1.5 m long and spaced 25 cm apart between them.

The pyramided lines created during the current study contained QTLs/genes for grain quality, grain weight, and disease resistance, and they should serve as helpful genetic resources for future breeding programs for wheat to improve the quality and tenacity of host plant resistance. These pyramided lines (PYLs), which may be used as genetic resources in wheat breeding and may also be released as a next-generation improved version of wheat cv. PBW343 with superior grain quality and enhanced disease resistance has already been scheduled for multi-year/multi-location trials.

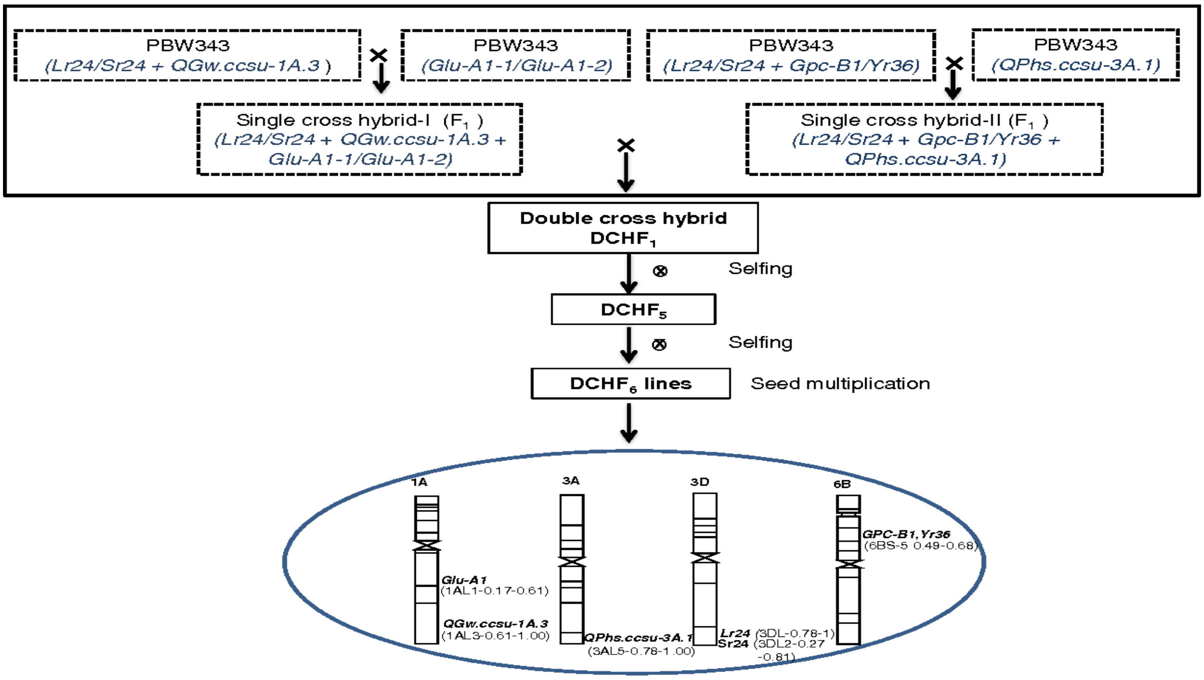


Figure 2: Marker-assisted selection for gene pyramiding in wheat for better nutritional quality and rust resistance (Tyagi *et al.*, 2014)

1. Distinct gene pyramiding scheme

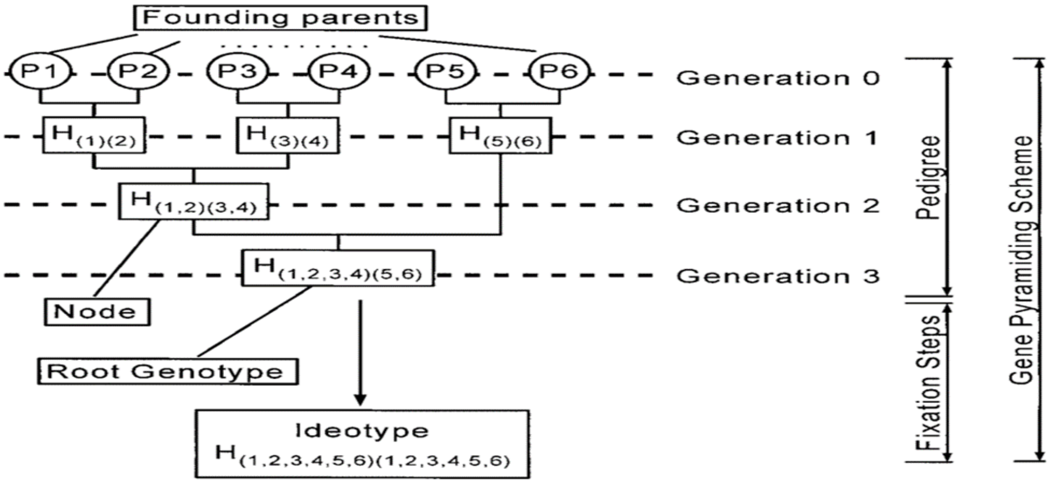


Figure 3: A distinct gene pyramiding scheme cumulating six target genes (Hospital *et al.*, 2004)

Marker-assisted backcrossing

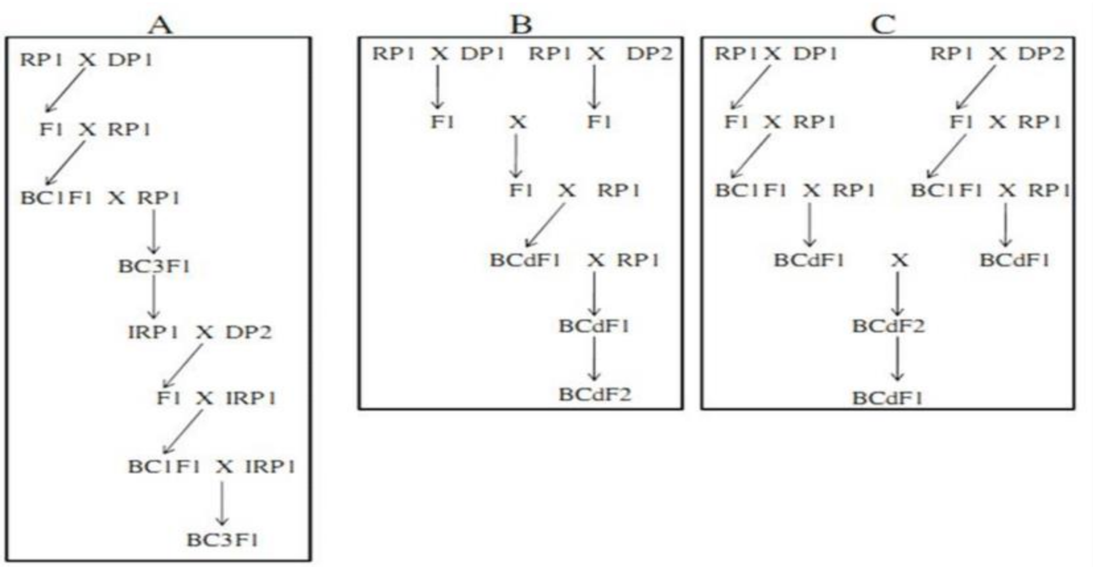


Figure 4: Different schemes of backcrossing for gene pyramiding. RP- Recurrent parent; DP- Donor parent; BC- Backcross; IRP- Improved recurrent parent. A. Stepwise transfer; B. Simultaneous transfer; C. Simultaneous and stepwise transfer

In general, marker-assisted backcross-based gene pyramiding can be accomplished in three ways (Fig. 2). The recurrent parent (RP1) is crossed with the donor parent (DP1) to produce the F1 hybrid, which is then backcrossed up to the third backcross generation (BC3) to produce the improved recurrent parent (IRP1). This improved recurrent parent is then crossed with a different donor parent (DP2) to pyramid multiple genes. This strategy is less acceptable because it takes time, but pyramiding is very precise because it only involves one gene at a time. In the second strategy, the recurrent parent (RP1) is crossed with donor parents (DP1, DP2, etc.)

to get the F1 hybrids which are then intercrossed to produce improved F_1 (IF1).Backcrossing this improved F_1 with the recurrent parent results in the improved recurrent parent (IRP). As a result, the pyramiding occurs during the pedigree step. When the donor parents are different, however, this method is less likely to be used because the pyramided gene may be lost in the process. The third strategy combines the first two by crossing a recurrent parent (RP1) with multiple donor parents and then backcrossing them up to the BC3 generation. The pyramided lines are created by undercrossing backcross populations with the individual gene. This is the most acceptable method because it not only saves time but also ensures complete gene fixation.

Marker-assisted pyramiding of Thinopyrum-derived leaf rust resistance genes *Lr19* and *Lr24* in bread wheat variety HD2733 (Singh *et al.*, 2017)

In 2009-2010, HD2733 was crossed with donor lines HD2687+*Lr19* and HD2687+*Lr24* to produce two separate F_1 generations. To create the BC1F1 generation, F_1 plants were crossed with the recurrent parent HD2733. Marker-assisted selection for *Lr19* and *Lr24* was performed in BC1F1 generations. Background analysis was performed on BC1F1 gene-positive plants. Plants with the highest RPG in the targeted leaf rust resistance gene were backcrossed with the recurrent parent HD2733 to produce two distinct BC2F1 populations. As in BC1F1, foreground and background selections were practiced in BC2F1.As in BC1F1, foreground and background selections were practiced in BC2F1. BC2F1 plants with rust resistance genes and the greatest RPG were selfed and intercrossed to produce BC2F2 and NILF1 generations, respectively. In respective BC2F2 populations, marker-assisted foreground selection identified plants homozygous for *Lr19* and those carrying *Lr24* in a homozygous/heterozygous state. BC2F3 families were created by selfing selected BC2F2 plants with *Lr24*. *Lr24*-linked marker identified Nonsegregating BC2F3 families carrying Lr24 in the homozygous state. Background analysis was performed on plants carrying a single leaf rust resistance gene in a homozygous state in the BC2F2 generation, and plants with the highest RPG (NILs) were identified. The NILF2 generation was produced by selfing intercrossed NILF1 plants carrying both *Lr19* and *Lr24*. Plants carrying *Lr19* in the homozygous state, as well as *Lr24,* were identified with respective markers in the NILF2 population. Based on progeny testing in NILF3, NILF2 plants homozygous for *Lr24* were identified. As a result, NILF3 families with both *Lr19* and *Lr24* in a homozygous state were created.

Background selection using polymorphic markers began with BC1F1 generation in the current experiment. RPG recovery was aided by the phenotypic selection of plants similar to recurrent parent HD2733, followed by marker-assisted background selection. Parental polymorphisms between HD2733 and the two donor lines, HD2687+*Lr19* and HD2687+*Lr24*, revealed markers that aided in the recovery of HD2733-specific alleles in each backcross generation. The number of markers required for background selection in BC2F1 and BC2F2 was significantly reduced, so that after each backcrossing, some alleles of HD2733 became fixed, requiring no further selection. Using MABB, desirable plants with high RPG and resistance genes were selected in each generation, which accelerated the development of HD2733 NILs.

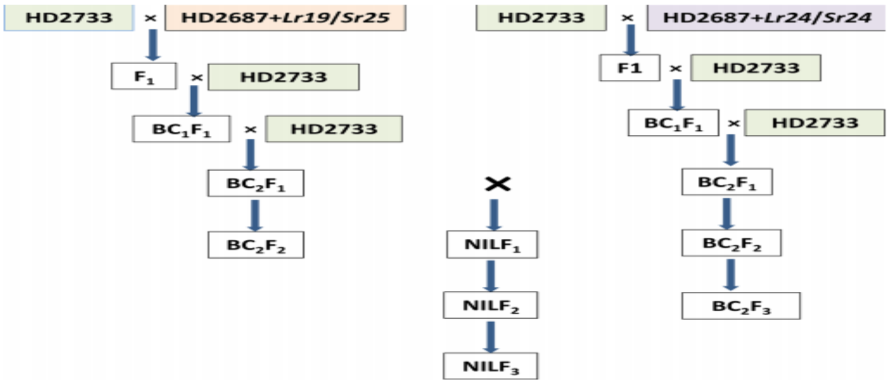


Table 5: Successfully pyramided genes and their traits of different crops

Crop	Traits	Pyramided Genes	Reference
Wheat	Leaf rust resistance	*Lr41, Lr42, Lr43*	Cox *et al.*, (1994)
	Powdery mildew resistance	*Pm2 +Pm4a; Pm2 +Pm21; Pm4a+Pm21*	Liu *et al.*, (2000)
	Aphid resistance	*Gn2* and*Gn4*	
	Cereal cyst nematode	*CreX and CreY*	Dominiques*et al.*, (2007)
Rice	Blight resistance	*Xa4, xa5, xa13, Xa21Xa5, Xa13*and*Xa21*	Singh *et al.*, (2001), Narayanan *et al.*, (2002)
	Blast resistance	*Pi (2)t, Piz5, Pi(t)a*	Hittalmani*et al.*, (2000)
	Gall-midge resistance	*Gm2, Gm6Gm1, Gm4*	Katiyar*et al.*, (2001) Kumara vadivel*et al.*, (2006)
	BPH resistance	*Bph1*and*Bph2*	Sharma *et al*. (2004)
	Multiple resistance	Bacterial blight *(Xa21)* Sheath blight *(RC7)* Yellow stem borer *Bt* fusion gene*(cry1AB/cry1Ac)*	Datta *et al.*, (2002)

Cotton	Insect pest resistance	*Cry1Ac*, *Cry2Ac*	Gahan *et al.*, (2005)
	BacterialblightandSheath blight	*chi11, tlpandXa21*	Maruthasalam*et al.*, (2007)
Pea	Nodulationability	*Sym9, Sym10*	Schneider*etal*, (2002)
Barley	Yellowmosaicvirusresistance	*rym4, rym5, rym9, rym11*	Werner*et al.*, (2005)
	Striperustresistance	3QTL	Castro*et al.*, (2003)
Broccoli	Diamondbackmoths'resistance	*cry1A c +cry1c*	Cao*et al.*, (2002)
Soybean	Soybean mosaicvirusresistance	*Rsv1, Rsv3, Rsv4*	Zhu*et al.*, (2006)
	Lepidopteranresistance	*cry1Ac+cornearworm QTL*	Walker*etal*., (2002)
Chickpea	Lepidopteranresistance	*cry1Ac + cry1Ab*	Meenakshi *et al.*, (2011)

Conclusion:

Gene pyramiding is an important crop improvement strategy. For long-term resistance, several genes can be transferred at the same time. The use of gene pyramiding allows for the correction of defects in elite high-yielding cultivars. The most widely grown Wheat variety, PBW343, which was released in India in 1995, was improved against leaf rust and stripe rust resistance by pyramiding leaf rust resistance genes *Lr24* and *Lr28* and stripe rust resistance genes *Yr5*, *Yr10*, *Yr15*, *Yr17* and *Yr70* in different introgression programs.

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OMICS TECHNOLOGIES IN CROP DEVELOPMENT

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Abstract:

Human population is projected to reach 8.5 billion by 2030, feeding this population is going to be a very difficult task when it's taken into account that the nutritive content is going down and climate oscillates radically causing crop loss. Ergo we need to design plants more resistant to abiotic stressors, with the advent of next generation sequencing technologies and the high throughput omics technologies such as genomics, ionomics, metabolomics, phenomics, proteomics and transcriptomics crop development has become easier. These tools have enabled us to get a better comprehension of plant growth, yield, senescence, and epigenetics. Whereupon this knowledge has been applied to improve the desired characteristics of numerous crops. This chapter highlights the omics technologies that are currently used in crop development and the roadblocks to correct implementation of these tools.

Keywords: Crop plants, Omics, genomics, ionomics, metabolomics, phenomics, proteomics, transcriptomics

Introduction:

The genome of plants has modified since the advent of agriculture, these experiments were based on selective breeding to ensure manifestation of desired characteristics. Mutation breeding of plants are carried out by exposing them to mutagenizing sources to obtain desired traits. Varieties of commercial plants such as rice, cotton and bananas have been created by this method (Busanello and Costa de Oliveira, 2019). However, plants created by mutagenesis procedures or cross breeding, on the other hand, have random, numerous, and unspecific genetic modifications, typically resulting in thousands of unsatisfactory plants before obtaining the required features (Jung and Till, 2021). These generic genetic alterations have a considerable risk of causing unanticipated and maybe harmful compositional changes. However, the success of these genetic alterations has prompted researchers to look for more efficient and controlled methods of transferring genetic features across plants while reducing the danger of harmful mutations via precision genetic changes such as the numerous omics methodologies that have been developed. Furthermore, with the advent of next generation sequencing this provides plethora of data elucidating the genes' function, protein networks, epigenomic effects due to physiological and environmental stressors, as well as the transcriptome and proteomes of the plant under investigation. These platforms enable discovery of genes that would be responsible for specific characteristics, depending on whether it is desired or not it could either be amplified, transferred to other plants, or silenced; these result in a transgenic plant. Thereby traits that would otherwise have to be selected after decades of breeding could be found and expressed/silenced withing a year.

Omics platforms approaches have been used to uncover and decode critical components of senescence, yields and stress responses in a number of commercially important crops for example toxins from *Bacillus thuringiensis* has been expressed in brinjal (*Solanum melongena*), corn (*Zea mays*) and cotton (*Gossypium herbaceum*) to protect it from pest species, the expression of beta carotene has been enhanced in rice (*Oryza sativa*) to provide Vitamin A to human populations deficient in it (Wu *et al.*, 2021). The current omics platforms have been summarised in figure 1.

Genomics

The omics nomenclature came to being with this field “gene-omics”, it is a broad discipline which focuses on the mapping the sequence of the genome, its physical architecture, evolution, modulation by external factors and genome editing. The genome of a plant contains information about its domestication and breeding history, the first plant which had its genome sequenced was Thale cress ("Analysis of the genome sequence of the flowering plant Arabidopsis thaliana", 2000). Since then, there has been an explosion in the sequences available online thereby numerous databases of genomic sequences have been developed which are continuously updated. The availability of these sequences enables precision molecular breeding in agriculture, this is brought to fruition by either enhancing the gene in the plant of origin, transformation of a desired plant with the isolated genome sequence or silencing the gene with RNA interference (Kim and Rossi, 2008). This has enabled creation of edible vaccines and fortification of food products to name a few (Saxena and Rawat, 2013). As the field of genomics has a huge scope, they have multiple disciplines in it such as structural genomics, functional genomics, epigenomics, mutagenomics and pangenomics. The various tools used for the field of genomics, transcriptomics, proteomics, epigenetics and metabolomics is illustrated in figure 2.

Structural genomics deals with the conglomeration of sequences to create genetic maps and isolate features of interest. Functional genomics uses this information to determine gene regulation of the desired features. Epigenomics builds on this by investigating the epigenomic alterations to histones, DNA or sRNA (Wang and Chang, 2018). Modifications to histone can cause formation of euchromatin and heterochromatin, depending on the modification this can either repress or activate the translation of certain sequences/factors (Wang and Chang, 2018). Mutagenomics aids in screening of naturally occurring mutant which might have specific sequence alteration that gives a mutant superior characteristic. Pangenomics, collects all the genes from all strain of an organism from a clade, genes which might be shared or unique. (Tettelin *et al.,* 2005). Genomics has been used to identify SNPs, genes associated with domestication, modify genes to reduce allergens, create transgenic plants, effect of abiotic stressors on oil content, and many more applications as detailed in table 1.

Structural genomics

Structural genomics utilizes Non-PCR/PCR based molecular markers, to map genes. The most common Non-PCR based marker is randomly amplified polymorphic DNA(RAPD), restriction fragment length polymorphism(RFLP), sequence characterised amplified region (SCAR), and amplified fragments length polymorphism(AFLP) are some of the other markers that are PCR based (Lin, 1996; Williams *et al.,* 1990; Rabouam *et al.,* 1999, Vos *et al.,* 1995). RFLP identifies DNA polymorphs by hybridising a tagged DNA probe to a DNA which has been digested and southern blotted (Agarwal *et al.,* 2008). RAPD utilizes a single primer to amplify random DNA sequences by PCR. AFRPs are similar to RAPD but they amplify sequences obtained from a complete genomic DNA digest. SCAR utilizes longer primers for a higher specificity during PCR. However recent advances have led to the use of diversity arrays technology (i.e., DArT) which enables genotyping of the multiple polymorphism sites (Jaccoud, 2001). Furthermore, NGS enables identifying quantitative trait loci, faster identification of SNPs and genome wide association studies (GWAS). QTL aids in correlation of phenotypes and genotypes by utilization of SNPs and AFLPs this can later be confirmed with functional genomics techniques. GWAS has been utilized for correlating how abiotic stressors i.e., droughts, floods, temperature, humidity, sunlight effect the production of desired products or the overall phenotype of the crop. Marker assisted selection, nested association mapping and multiparent advanced generation intercross are commonly used to statistically improve hybrid breeding, and these are often used in tandem with genotyping-by-sequencing.

Functional genomics

Functional genomics will eventually make use of the huge resources and knowledge supplied by structural genomes. The development of worldwide experimental methodologies to determine gene function is referred to as functional genomics. This is brought about by the numerous tools that been honed through the years to clone, express, knockout, overexpress genes i.e., mega nucleases, CRISPR, Zinc finger nucleases, TALENs, RNAi, Virus-induced gene silencing (VIGS), CRE-LOX. These techniques have been empowered with the evolution of genome sequencing methods; before this due to the time-consuming nature of sequencing by techniques such as suppression subtractive hybridization, expressed sequence tag, and cDNA-AFLP-sequencing gene manipulation was a tedious and lengthy process (Vuylsteke *et al.,* 2007).

Mutagenomics

Mutagenomics has extensively been used to investigate gene functions by silencing and interrupting candidate genes using reverse genetic methods such as RNAi and VIGS. These techniques are essential when the gene of interest is a housekeeping/essential gene and thereby cannot be knocked down entirely. Tools such as targeted induced local lesions in genomes are used as an alternative to transgenics by enabling high throughput mutations. This method has also been utilised functional genomics and to identify mutations. Several reverse genetic techniques have been used to identify mutations in commercial plants such as *Triticum aestivum*, *Pisum sativum L.*, *Hordeum vulgare*, *Cicer arietinum L.*, and *Solanum lycopersicum* (Tomlekova, 2010; Dwivedi *et al.,* 2008; Suzuki *et al.,* 2007; Caldwell *et al.,* 2004; Gupta *et al.,* 2008; Cooper *et al.,* 2008; Minoia *et al.,* 2010).

Epigenomics

Heritable alterations other than those in the DNA sequence are referred to as epigenetics. Epigenetic alterations can be caused by modification of histones, DNA or sRNAs by methylation, acetylation or a host of other post translational modifications. Epigenomics tries to comprehend how gene expression and epigenomic structure is influenced by biotic and abiotic factors. Genome methylation is often determined by bisulfite sequencing, ChIP sequencing or by methylation-sensitive amplified polymorphism (Cokus *et al.,* 2014). Epigenomics are significant as they can detect ncRNA in drought stressed plants and hypo/hypermethylation states that can affect fruit yield (Gelaw & Sanan-Mishra, 2021) other such examples are listed in table 1.

Pangenomics

It refers to a species' whole genetic makeup, it is further separated into core and accessory/dispensable genes (Lei *et al.,* 2021). Core gene sets are common in all individuals, whereas accessory/dispensable gene sets are specific to an individual or a small subset of the population. Advent of NGS has led to the discovery that accessory genes greatly contribute to crop diversity and quality as they often confer disease resistance (Wang *et al.,* 2021).

Iterative assembly, “map-to-pan” and de novo are utilized to build pangenomes and has been used in rice and soybean to compare their genome to their wild relatives (Li *et al.,* 2014). Pangenomics enables screening of mutants and wild relatives to breed new crops with higher stress tolerance and crop yield. Thereby pangenomic research might thus be utilised to select for superior genes in CWRs for crop enhancement (Della Coletta *et al.,* 2021) and other factors listed in table 1.

Transcriptomics

Transcriptomics is concerned with all the RNA transcripts in a cell. It helps determine the effects of different stimuli on the transcriptome over time. Initially transcriptomic studies utilised methods such as differential display-PCR, SSH and cDNAs-AFLP. However, NGS, microarrays, SAGE, RNA sequencing and expression profiling has largely replaced these methods as they are higher resolution.

Studies of soybean under drought stress has revealed the change that occurs in the transcriptome from the embryonic till the reproductive phases (Xu *et al.,* 2018). Similar studies in sorghum which also analysed the effect of drought, temperature, hormone therapy and osmotic stress on the transcriptome identified a group of differentially expressed genes as detailed in table 1. This method for analysing differential transcriptomes and expression patterns in response to abiotic and biotic factors is known as comparative transcriptomics (Chang *et al.,* 2019).

Proteomics

Proteomics is utilised to analyse and collect data about the total expressed protein in an organism (Liu *et al.,* 2019). Like genomics proteomics is a broad field and thereby it is separated into four predominant disciplines which study protein sequence, structure, function, and expression. It has been used to study the modulation of chlorophyll content and plasma membrane protein alterations due to unavailability of water as listed in table 1.

Amino acid sequences for sequence proteomics are typically identified by HPLC (Twyman, 2014). Structural proteomics studies utilize nuclear magnetic resonance, x-ray diffraction and electron microscopy to study protein activities (Shin *et al.,* 2008). Protein microarray profiling and yeast-one or two hybrid assays are further employed to understand in vivo interactions (Popescu *et al.,* 2007).

Although traditional proteome analysis utilizes ion/size exchange chromatography but for analysis of specific proteins ELISA, SDS-PAGE, 2D electrophoresis and 2D-DIEG are employed; if the protein concentration is particularly low, microarray analysis is used. Advanced approaches such as isobaric tag for relative and absolute quantification, isotope-coded affinity tag labelling and stable isotope labelling with amino acids in cell culture have also been developed to detect proteome changes in-vivo (Hsu & Chen, 2016; Becker, 2008; Vélez-Bermúdez *et al.,* 2016).

Metabolomics

Metabolomics is the study of the entirety of metabolites involved in various cellular activities in a biological system. Here too NGS has resulted in a paradigm shift, when combined with metabolic quantification by MS aids in predicting the metabolic network from the genome of the organism (Scossa *et al.,* 2018). As the metabolites are the cells biochemical phenotype it goes one step further than proteomics as unveils biochemical processes that can be critical for gene function and modulation. However, owing to their diverse nature they are difficult to detect and there is no one for all method. Thereby it includes enlists techniques such as gas/liquid chromatography, Fourier-transfer infrared, capillary-electrophoresis, thin layer chromatography, NMR and liquid chromatography electrochemistry mass spectrometry. As plants produce much more metabolites as compared to animal or bacterial systems the analysis of the metabolome is critical to understanding stress responses in plants.

Ionomics

The entirety of the mineral nutrient and trace elements that compose plant systems compromise the ionome. Ionomics is the quantification of an organisms ionome and its changes which are caused by biotic and abiotic factors. Ionomics are accomplished using high throughput elemental profiling utilising various analytical technologies, which are done in tandem with plasma-mass/optical emission spectroscopy (ICP-MS/OES), X-ray crystallography and neutron activation analysis (NAA). X-ray crystallography is cheaper than ICP-MS/OES however its processing rates are like ICP-MS/OES, ICP-OES can process hundreds of samples as compared to ICRP-MS. NAA on the other hand can only detect 30 elements at once (Salt *et al.,* 2008). Ionomics combined with other omics platforms will help in discovery of gene networks that improve crop resilience in response to abiotic and biotic stress (Guo *et al.,* 2017).

Phenomics

Phenomics is described as the study of phenotypes on an organism-wide scale by collecting high-dimensional phenotypic data. The phenotype is determined by the entirety of the genome, environment, and interactions the plant has with its surrounding. By QTL mapping and imaging technology the most optimal germplasm lines could be found, the imaging can analyse parameters such as far IR imaging of the canopy, pulse amplitude modulated imaging, RGB imaging, laser-induced fluorescence transient imaging, LIDAR and magnetic resonance imaging to evaluate growth or infection; such non-invasive technologies are key for high throughput phenomics.

When studying crops in the field, phenotyping procedures are more crucial than when analysing plants in the laboratory or greenhouse. Various agronomic variables may be determined using multispectral and hyperspectral technology (Rascher and Pieruschka, 2008).

Bioinformatics

Bioinformatics is an interdisciplinary science which aids in comprehension of biological systems through an integrated approach utilizing molecular biology, mathematics, and computer science (Raza *et al.,* 2021). These omics platforms enable us to better comprehend molecular mechanisms however this often results in a lot of data, the mining and structuring of which becomes virtually impossible without bioinformatics platforms. Nonetheless, bioinformatics complements these omics techniques and serves as a foundation for gathering data on plant abiotic stressors. As a result, bioinformatics is critical for data mining and organising in support of various omics technologies. Furthermore, bioinformatics analyses information offered by such powerful technologies concerning the functioning system of genes. Bioinformatics also makes computational modelling and simulation analysis more accessible by merging several omics technologies. Bioinformatics tools based on several software packages were utilised to analyse multi-omics techniques in agricultural research. Recently, the availability and developments of omics platforms have increased dramatically, allowing information to be used in multi-dimensional plant science research. Not only have computing resources made it feasible to store, classify, and analyse accessible data, but they have also made it simple to access user-friendly databases. Several multi-omics databases for crop sciences have been created such as GabiPD, PMND, KNApSAcK, KOMICS, PlantTFDB, BioLeaf, EasyPCC, KaPPA-View4 KEGG, STRING, GSDS, VISTA, Gramene, Plant Reactome, GAP4, SIMCA-P 14.0, LemnaLauncher and Gromacs. These platforms aid in integration of multi-omics by providing data regarding genomics, gene structure analysis, transcriptomics, proteomics, protein-protein interactions, metabolomics and protein, lipid simulation

Panomics

Panomics is a framework for integrating many all the omics platforms to prognosticate complicated features to better understand terroir-phenotype interdependence at the molecular level. Such omics data integration aids in identifying genes, QTLs, and markers. As only 40% of the genes explain the phenotypic appearance of the plant the use of panomics can help in identification of the 60% of the phenotypic variation which would aid in breeding efforts and understand phenotypic variation. Tools such as KaPPA-view, PAINTOMICS, COWAIN are utilised to integrate and visualise omics datasets on KEGG pathway maps.

Conclusion:

Crop development has come a long way from mutagenization of crops and finding optimal variants. With the current capabilities to sequence entire genomes within days at a low cost and the ability to modify a single nucleotide crop development has undergone a paradigm shift. Omics platforms have been key in identifying and modifying aspects of plant physiology and biochemistry and how they are affected by varying abiotic and biotic stressors. These platforms have aided in creating superior crop variants which are resistant to pests and with higher nutritive content to feed the exploding population.

Table 1: Crop varieties for which omics technologies were utilised to discover or optimise specific characteristics

Crop	Omics platform	Modification/ discovery	Technique	Reference
Wheat *(Triticum aestivum* L.)	Genomics	Improving grain quality	Tilling	Dong *et al.*, 2009
	Epigenetics	Salinity induced epigenetic changes	methylation-sensitive amplified polymorphism	Lan *et al.*, 2009
	Proteomics	Crosstalk between the plant and *S. tritici*	MS, HILIC fractionoatino, Phosphopeptide Enrichment	Yang *et al.*, 2013
Oil palm (*Elaeis guineensis*)	Epigenetics	Identification of MANTLED locus	epigenome-wide association studies	Ong-Abdullah *et al.*, 2015
Sugarcane (*Saccharum officinarum L.)*	proteomics	Modulation of chlorophyll levels with varying water availability	SPAD Chlorophyll Meter Reading	Jangpromma *et al.*, 2010
Barbera grapevines (*Vitis vinifera*)	Proteomics	Role of protein modifications in pathogen resistance	RT-qPCR	Margaria *et al.*, 2013
Barley (*Hordeum vulgare*)	Genomics	HvPM19	CRISPR-Cas9	Lawrenson *et al.*, 2015
	Pangenomics	Role of HvCBF4-HvCBF2 in frost resistance	RT-qPCR	Francia *et al.*, 2016
Soybean (*Glycine max*)	Genomics	Genes responsible for domestication	GWAS	Zhou *et al.*, 2016
		DD20, DD43 mutagenization	CRISPR-Cas9	Li *et al.*, 2015
	Transcriptomics	Gene expression under drought stress	Affymetrix GeneChip array	Khan *et al.*, 2017
	Proteomics	Osmotic stress induced plasma membrane protein alterations	LC MS/MS	Nouri *et al.*, 2010
Peanuts (*Arachis hypogaea L.)*	Genomics	Allergen reduction	TILLING	Knoll *et al.*, 2011
Tobacco (*Nicotiana tabacum*)	Genomics	Cas9 production to express GFP	CRISPR-Cas9	Jiang *et al.*, 2013

Tomato (*Solanum lycopersicum)*	Epigenetics	Epigenetic marks during droughts	Cytosine methylation	González *et al.*, 2013
	Metabolomics	Comparison of metabolites of various tomatoes varities	GC-MS	Semel *et al.*, 2007
Thale cress *(Arabidopsis thaliana)*	Genomics	Improving QTL mapping for use in multiparent advanced generation inter-cross (MAGIC)	MAGIC	Kover *et al.*, 2009
		Cas9 production to express GFP	CRISPR-Cas9	Jiang *et al.*, 2013
	Epigenomics	Dehydration induced methylation patterns	ChIP-Seq	van Dijk *et al.*, 2010
	Transcriptomics	Change of transcriptome due to abiotic stressors	tiling array	Matsui et al, 2008
Foxtail Millet (*Setaria italica* L.)	Epigenomics	Change of methylation patterns due to salinity	methylation-sensitive amplified polymorphism	Pandey *et al.*, 2016
Rapeseed (*Brassica SPP napus)*	Genomics	SNPs in disease resistance	GWAS	Gabur *et al.*, 2018
Rapeseed *(Brassica oleracea)*	Genomics	BolC.GA4.a	CRISPR-Cas9	Lawrenson *et al.*, 2015
Sunflower (*Helianthus annuus*)	Genomics	Effect of abiotic stressors on oil content	GWAS	Mangin *et al.*, 2017
		mutation of fatty acid biosynthesis traits	GWAS	Suzuki *et al.*, 2007
Coconout *(Cocos nucifera L.)*	Genomics	Cold stress tolerance	iTRAQ	Yang *et al.*, 2020
Bambra groundnut (Vigna subterranea)	Transcriptomics	Dehydration induced transcriptomic alteration	Soybean Affymetrix GeneChip array	Khan *et al.*, 2017
Groundnut *(Vigna*	Transcriptomics	SSR gene markers	RNAseq	Chen *et al.*, 2017

unguiculata L. Walp.)				
Levant cotton *(Gossypium herbaceum L.)*	Proteomics	Alteration of proteome due to drought stress	MALDI-TOF-TOF	Deeba *et al.*, 2012
Rice (*Oryza sativa*)	Genomics	Screening for drought resistance traits	GWAS	Guo *et al.*, 2018
		Cas9 production to express GFP	CRISPR-Cas9	Jiang *et al.*, 2013
	Epigenomics	Gene expression and methylation under drought stress	ChIP-Seq and RNA-Seq	Zong et al. ,2013
	Pangenomics	Genome sequencing of Asian cultivated rice	QUAST	Wang *et al.*, 2019
		Genomic variation of wild and cultivated rice	MUMmer	Zhao *et al.*, 2018
	Metabolomics	Metabolic reprogramming during infection	GC-MS	Parker *et al.*, 2009
		Metabolic reprogramming during infection	GC-TOF	Sana *et al.*, 2010
	Ionomics	Evaluation of mineral content of rice variants	ICP–MS	Pinson *et al.*, 2015
Maize (*Zea mays* L.)	Genomics	QTLs that confer drought resistance	GWAS	Millet *et al.*, 2016
		SNPs that confer drought resistance		Shikha *et al.*, 2017
		Transforming ALS1, ALS2, LIG1, Ms26 and Ms45	CRISPR-Cas9	Svitashev *et al.*, 2015
		Nested association mapping(NAM) to analyse quantitative traits	NAM	Yu *et al.*, 2008
		Mutants with mutated DMT102 chromomethylase	TILLING	Till *et al.*, 2004

		gene		
	Ionomics	Analysis of line B73	ICP-MS	Mascher *et al.*, 2014
Great Millet *(Sorghum bicolor)*	Genomics	SNPs that are associated with environmental adaptation	GWAS	Lasky *et al.*, 2015
		Genes that encode heat shock proteins, antifreeze proteins and other components that modulate plant stress responses	GWAS	Spindel *et al.*, 2018
		Cas9 production to express GFP	CRISPR-Cas9	Jiang *et al.*, 2013

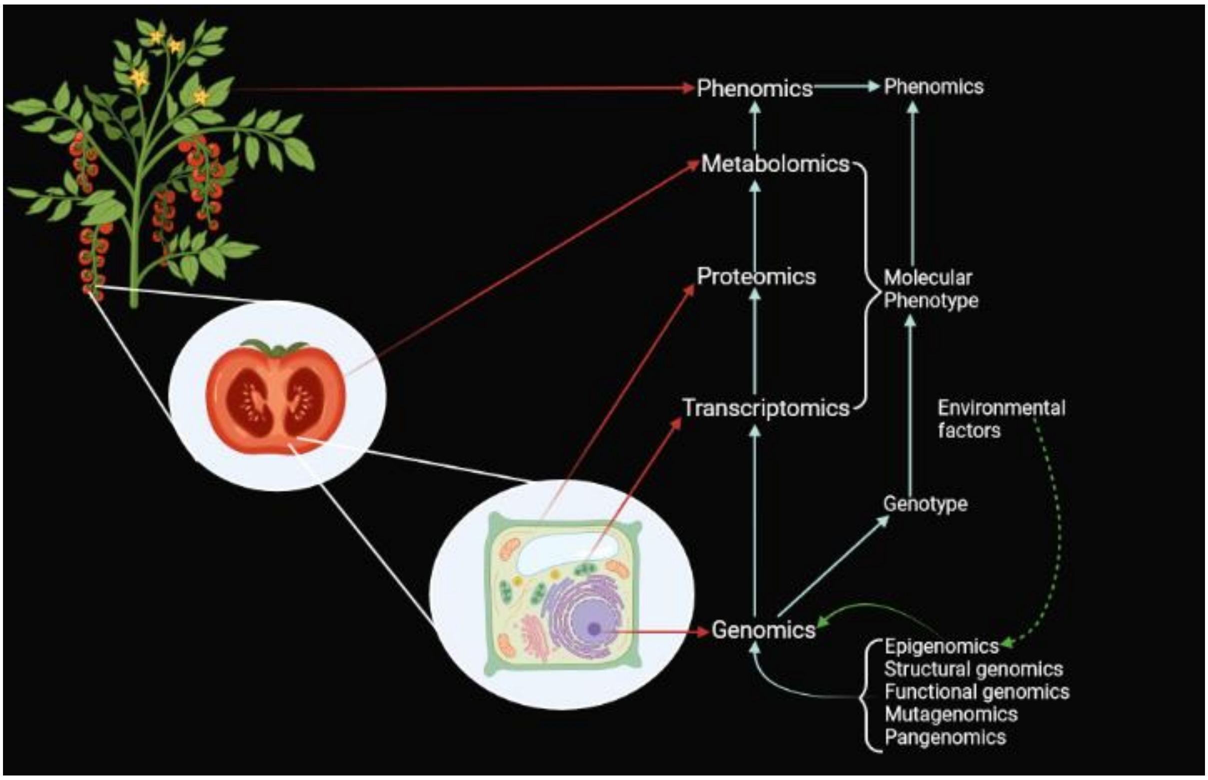

Figure 1: Overview of different omics platforms and its interactions with the environment Created with BioRender.com

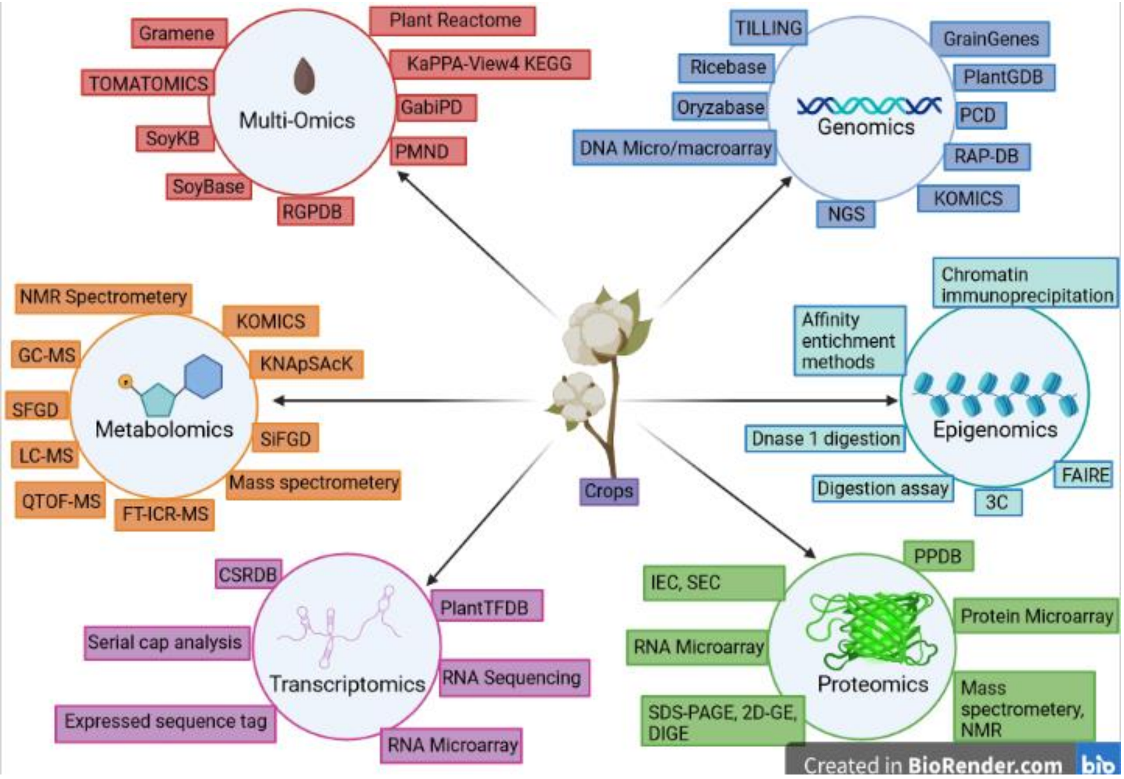

Figure 2: Overview of different techniques and software's used in crop development

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SOIL SOLARIZATION: AN EFFECTIVE AND ECOFRIENDLY DISEASE MANAGEMENT STRATEGY

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Introduction:

For the management of illnesses caused by different plant pathogens, a number of techniques have been developed, including fungicidal treatment, breeding for disease resistance, sanitation, crop rotation, biological control, and soil disinfestations. The necessity for several techniques of managing plant diseases derives from the fact that, in general, none of them are ideal or applicable in all situations. Furthermore, different agricultural systems may have diverse pathogen life cycles, necessitating the use of various control techniques. Therefore, since it expands on our very small toolbox of illness management strategies, each novel approach has merit. This is especially true for cutting-edge non-chemical methods that are required to replace dangerous chemicals.

The idea of controlling soil-borne infections has evolved recently. In the past, eradication was the main focus of pathogen control. Later, it was understood that, rather than total control, effective disease control may be achieved by halting the disease cycle, plant resistance, or the microbial balance, resulting in a disease decrease below the level of economic harm. The notion of integrated pest control includes a variety of components. Soil solarization may be important in this situation. Growing experts and extension personnel in Israel proposed using the intense warmth that happens in mulched soil to prevent illness. An Israeli team of employees created a solar heating method for soil disinfestation by covering the soil with clear polyethylene sheets during the hot season before planting (Katan, 1995). Using a translucent polyethylene sheet applied to a damp soil surface, soil solarization raises the temperature of the soil in order to prevent soil-borne infections and pests. With solarization, there are a lot of options for illness prevention. It has been observed that using this technique helps to decrease the number of weeds, fungus, bacteria, and other soil-borne diseases. (Pullman *et al.*, 1981; Katan *et al.*, 1983; Barbercheck *et al.*, 1986; Verma *et al.*, 2005).

Mechanism of disease control

The effects of solarization on the host, pathogen, and soil microbiota, as well as on the physical and chemical environment, which in turn influences the activity and interactions of the organisms, result in a decrease in the incidence of illness in solarized soils. Even while these activities largely take place during solarization, they may continue to varying degrees and in a variety of ways after the polyethylene sheets are removed and the planting is done. The physical effect of polyethylene soil mulching, or a rise in soil temperatures, is the most noticeable consequence for a number of the day's hours. However, when examining disease control mechanisms, additional processes like changes in microbial populations, alterations in the chemical and physical makeup and structure of the soil, high moisture levels maintained by the mulch, and alterations in the gas composition of the soil should also be taken into account. For the sake of this analysis, the following equation suggested by Baker (1968) for linking the numerous elements involved in biological control should be used:

Disease severity is determined by the product of two variables: inoculum potential and disease potential. Inoculum potential is the energy available for the surface colonisation of an infection court and disease potential is the host's susceptibility to the disease. In further detail, the equation is as follows: Disease severity is determined by the following equation: (inoculum density x capacity) x (proneness x susceptibility), where capacity is the environment's impact on the energy required for colonisation and proneness is the environment's influence on the host. Inoculum density (ID), one of these four factors, is the one most impacted by solarization, either directly by the heat's physical effects or indirectly by the microbial activities it triggers in the soil. However, the other factors (apart from vulnerability, which is genetically determined) might also be impacted. Since any harmful agent in the soil affects more than just the target organisms, microbial activities caused by solarization in the soil may help manage illness. An increase in the pathogen's susceptibility to soil microorganisms or an increase in the activity of soil microorganisms toward the pathogen or plant, if induced by solarization, may have an impact on biological control, which will ultimately result in a decrease in disease incidence, pathogen survivability, or both. As a result, both immediate and long-term impacts may be anticipated. Through antibiosis, lysis, parasitism, or competition, biological control may be effective at any stage of pathogen survival or disease progression during or after solarization. Following is a summary of the biological regulatory systems that solarization may induce or create:

I. The impact on the soil's existing inoculum

A. Reduction in ID (during host penetration or in the dormant state) by

1. Pathogen destruction by microbes after being previously weakened by sub lethal heat;

2. Partial or total annulment of fungistasis and lysis of the propagule that is now sprouting;

3. Parasitism or lysis caused by antagonists that are activated by solarization.

B. reduced inoculum potential (IP) brought on by solarization-induced antibiosis or competition.

C. Decreased saprophytic competitiveness of the pathogen due to antibiosis or competition when the host is not present.

II. by the actions of microorganisms with mechanisms, preventing reinfestation A2, A3, B, and C

III. Combining solarization with additional techniques, such as insecticides or biocontrol agents, increases disease control due to the effect on the host caused by cross protection. When a pathogen is weakened by heat, even lower doses may be necessary when combined with biocontrol agents, organic amendments, etc. for greater control.

Advantages

There may be benefits to using soil solarization as a technique of pest removal. It is a non-chemical procedure that poses no risk to the user and doesn't employ any toxicants for either the consumer, the host plant, or other living things. When seen properly, it is less expensive than alternative techniques. This method is simply transferable to common farmers, and it may be used both manually and mechanically across a vast region. As a result, it is appropriate for both wealthy and developing nations. Since effective disease management lasts for more than one season, it could have long-term effects. Since physical, chemical, and biological mechanisms are involved and a variety of pests are controlled, this technique fits the definition of an integrated control.

Limitations

1. Solarization has restrictions, challenges, and even harmful side effects. It can only be utilised in areas with a hot environment and soil that has been free of crops for at least a month at a time prior to trapping with PE sheets.
2. It is unsuccessful at controlling certain diseases and too costly for particular crops.
3. Although selection for resistance to deadly agents is unlikely to emerge with disinfestation procedures that are not target specific, heat tolerant pathogens may evolve after repeated treatment.
4. An rise in the number of pathogens as a result of a negative impact on their adversaries is still another possibility.

Disease Management

Numerous fungal infections, including *Rhizoctonia solani*, *Fusarium spp*., *Pythium spp*., *Phytophthora spp*., *Verticillium spp*., and *Sclerotium rolfsii*, among others, have been shown to cause diseases in various crops, and soil solarization has been shown to prevent these diseases.

(Katan *et al.,* 1983; Abdul *et al.,* 1995; Raoof and Rao, 1997). Additionally, it has been demonstrated that soil solarization greatly reduces the number of pathogen-causing Agrobacterium and *Pseudomonas*. (Raio *et al.,* 1997; Chellemi *et al.,* 1994). Soil solarization has been effective in controlling a number of nematode diseases brought on by *Meloidogyne* spp., *Heterodera* spp., etc. (Rao and Krishnappa, 1995; Grinstein *et al.,* 1995).

Beneficial side effects

Control of weeds

In certain circumstances, solarization's weed control is so powerful that it lasts for more than two or three seasons. (Abdel Rahim *et al.,* 1988; Verma *et al.,* 2005). In general, it has been discovered that most annual weeds and many perennial weeds can be efficiently managed.

Increased growth response

It is a well-known occurrence that solarized soil causes plants to develop more quickly, and this phenomena has been demonstrated in both greenhouse trials and outdoor settings. (Katan, 1987; Chen *et al.,* 1991; Singh, 2008).

Conclusion:

In a number of nations, soil solarization for soil disinfestations has been thoroughly established and proven in experimental or commercial settings. Both fundamental and applied research are necessary to develop this method for use in field settings. Although SS is a straightforward method, the research necessary to establish it in new fields is challenging and calls for interdisciplinary work. SS should not be viewed as a panacea, but rather as a supplementary technique that, when applied appropriately, can decrease pest damage in a safe, efficient, and cost-effective manner. Our hungry world continues to scream for innovative strategies for decreasing crop losses brought on by soil borne pathogens more than 100 years after the advent of soil disinfestations and more than 50 years after Sanford's classic paper on biological management. When employing traditional management measures, we are always up against challenges like the emergence of new physiological races and the emergence of pesticide resistance. We are disappointed by the stark contrast between successful outcomes in the fields and promising outcomes in the greenhouses. As a result, we have learned humility. Instead of achieving total control, our goal now is to reduce the prevalence of the illness economically. It makes sense that plant pathologists all over the world have embraced the integrated control strategy, which asks for properly integrating all available control approaches. Solarization is a brand-new extra choice that may be used and appropriately included in such IPM plans. Our ability to weigh its advantages and disadvantages and use it effectively will determine the extent and rate of its spread in the future.

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SALINITY: IT'S INFLUENCE ON THE ENVIRONMENT AND SUSTAINABLE AGRICULTURE AND THE STRATEGIES INVOLVING PHYTOPROTECTANTS AGAINST IT

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Abstract:

One of the main factors limiting agricultural productivity for many crops is salt stress, which has a negative impact on the physiology and biochemistry of plants as well as their ability to grow. In contrast, the developing world is moving much more slowly toward salinity decrease. To ensure a future food supply for a growing population, crop plant tolerance to salt stress needs to be increased in this context. In this article, we get it over the use of phytoprotectants of microbial origin (arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria), osmoprotectants, and melanin-related compounds as salt stress relievers in a variety of plant species. The nature, applicability, and role of phytoprotectants in the plant in terms of physiological and phenotypic effects are all discussed in detail. As a result, it is possible to increase crop yield and crop quality, which has a positive effect on food security.

Keywords: Salinity, arbuscular mycorrhizal fungi (AMF), plant growth promoting bacteria (PGPR), melatonin, osmoprotectants.

Introduction:

Global water resource scarcity, environmental pollution, and an increase in soil and water salinization are characteristics of the 21st century early decades. Two threats to agricultural sustainability are an increase in human population and a decrease in the amount of accessible agricultural land (Shrivastava *et al.*, 2015). The FAO recently emphasized the importance of producing strategies to address the effects of climate change on agriculture and food security globally (Acosta-Motos *et al.*, 2020). Globally, high salinity is thought to affect 20% of all cultivated lands and 33% of irrigated agricultural lands. Due to conditions such as low precipitation, high surface evaporation, native rock weathering, irrigation with salinized water, and poor cultural practices, salinized areas are also expanding at a 10% annual rate. (Shrivastava *et al.*, 2015). By 2050, it is predicted that more than half of the world arable land will be salinized. The production and cultivation of agricultural crops have been negatively affected by several environmental stresses, including windy conditions, high temperatures, salinization, drought, and flood. Soil salinity, one of the worst environmental stresses, drastically lowers the amount of cultivated land, crop productivity, and crop quality (Yamaguchi and Blumwald 2015). Saline, sodic, and alkaline soils belong to the category of salinity and are distinguished by their excess salt, high pH and sodium cation (Na^{+}) respectively. On a worldwide scale, 800 million hectares of cropland are affected by soil salinity. The majority of crops yield less when grown in saline soil, which typically has an electrical conductivity of 4 dS m^{-1}, an osmolality of about 0.2 MPa, and lower crop yields. 2020 (Acosta-Motos et al).

There are two main causes of salinity in soil: man-made (secondary salinization) and natural (primary salinization. Primary salinization is the process by which salts gradually increase in the soil naturally over time, either as a result of salts released during rock erosion or sea salt deposition by winds and water. However, human activities are too held responsible for secondary soil salinization such as improper agricultural technologies in agriculture (Lewis, 1984). Although numerous approaches have been introduced, but depending on the environments in a specific location, the significant proportion of these showed to be unsustainable or to have only reasonable success. One such problem is soil salinity between developing and developed regions.

The toxicity of salt to plants as a consequence of salinity development is generally understood to be salt stress. When the concentration of salt is high enough to reduce the water potential, it is said to be under salt stress (0.5 to 10 bars). International Journal of Chemical Studies reports that saline soils affect plants morphological, physiological, and biochemical responses (Amirjani, 2010; Siringam *et al.*, 2011)

One of the abiotic environmental stressors that hinders global plant development, growth, and productivity is salt stress. Plants react to salinity stress in various ways depending on their physiology, morphology, and biochemistry (Siringam *et al.*, 2011). Mineral distribution, membrane permeability and instability are some of the physiological processes that are adversely affected by salt stress because sodium displaces calcium in the body (Gupta *et al.,* 2002) as well as a reduce in photosynthetic efficiency (Hasegawa *et al.*, 2000). Because there is a limited amount of agricultural land which can be used for sustainable crop production, it is necessary to use the areas that are under stress for crop production and other purposes.

Effect of soil salinization in India

Increasing soil salinity in India and its detrimental effects on agricultural soils have a negative impact on agricultural yield, which has become both an environmental and a financial concern. The subcontinents agricultural land is becoming more salinized every year as a result of salt accumulation in the soil. 3.88 million hectares of India's 9.38 million hectares of salinized soils are alkali soils, and 5.5 million hectares are salinized as a result of climatic and environmental factors (Jaleel *et al.*, 2008). Because of the lack of rain and erratic farming practices, soil salinization proportionally increases. Approximately 1100mm of rain fall occurs on average on the Indian subcontinent, of which 46% enters various bodies of water. Only 22% of the rain's moisture restores the soil and groundwater aquifers—the remaining 32% evaporates. Although India has a vast supply of water, due to the desires of the monsoon, it is distributed seasonally and spatially, causing floods or droughts (Hemapriya et al, 2010). It affects both growth and yield (Ramana *et al.,* 2012). The salinity of the soils increased as a result of agriculture in arid and semi-arid regions. Even though Indian farmers depend on groundwater for their agricultural needs, permanent water table levels are falling, which causes salt to accumulate at the root zone. Increased sodicity and salinity of the soils will negatively affect the physical structure of the soil, reducing aeration and water transfer. Farmers are trying to solve this issue, though, by using alternate irrigation methods or a mix of groundwater and canal water to irrigate their farmlands (Datta *et al.*, 2002).

Origin of salinity and how it affects plants

Salt stress is an accumulative process that can be caused by anthropogenic or environmental reasons (Hussain *et al.,* 2019; Pitman *et al.,* 2002). Soil salinity is caused by various types of mineral salts (Na^+, K^+, Cl, Mg, Ca, etc.) and can mitigate effects from a variety of sources, including climatic conditions (erosion and evaporation), manufacturing, and environmental factors. The presence of hemophilic PGP (Plant Growth Promoting) bacteria in soil can alleviate the effects of salt stress and enhance a number of vital plant mechanisms, thereby enhancing vegetal nutrition and growth. Salinity effects from the solubilization of inorganic salts, the due to the accumulation of dust, an imbalance in the rates of precipitation and evapotranspiration, or a rise in the capillary infiltration of saline underground water (Essington and M.E., 2004). When salt concentrations increase in the root zone, salinization affects plant development (Pitman *et al.,* 2002). Crops require more water and fertilizer inputs to remain productive in saline environments, which likely increases soil salinity and ultimately expands the area affected by secondary salinization (Ramadoss *et al.,* 2013). For plants, salinity is a two-phase stress that first affects them rapidly through osmotic change and then more slowly through ion accumulation (Negrao *et al.,* 2017). Salinity causes a disorder in water and ionic homeostasis in the first phase, which increases the metabolic costs of cellular metabolism (Maggio *et al.,* 2007; Gupta *et al.,* 2014) and affects, among other things, nutrient uptake (Wu *et al.,* 2015; Farkhondeh *et al.,* 2012), photosynthesis and respiration (Cassaniti *et al.,* 2013), lipid metabolism and protein synthesis (Parihar *et al.,* 2015; Bensidhoum *et al.,* 2019), oxidative stress, phytohormone production, gene expression, and lengthy transportation which in turn impact on plant seed germination, seedling survival and plant phenotype. Similar physiological changes to those brought on by water stress are induced in plants as a consequence of the plants osmotic response to salinity (Parvaiz *et al.,* 2008). Salinity may inhibit the process of dividing biomass between shoots and roots, in addition to its effect on plant biomass accumulation (Maggio *et al.*, 2007).

1. Plant growth and production

The physiological activities of the seed are affected by salinity stress, which inhibits seed germination. Many plant germination seeds, such as broccoli and cauliflower, lose water potential, protein content, and nutrition as a result (wu *et al.,* 2019). Salt stress inhibited seed germination by reducing phosphatase activity in Arabidopsis thaliana seeds (Nasri *et al.,* 2016). By raising levels of soluble sugar, starch, and ABA while lowering levels of gibberellic acid (GA3), salt inhibited plant germination. Furthermore, the yield of the plant and its component were also significantly impacted by salt stress. Salinity decreased yield, stem and root length, number of leaves, and biomass (Zorb *et al.,* 2019).

2. Photosynthesis, transpiration and stomatal conductance

A vital physicochemical process is photosynthesis. To salinity, though, it is extremely sensitive. Salt stress reduces photosynthesis in salt marsh plant species by making stomata more sensitive (Betzen *et al.,* 2019). High salinity also inhibits the activity of the oxygen-evolving complex (OEC), limits the activity of quinine acceptors, and disintegrates PSII reaction centers. Soil salinity reduces stomatal conductance and transpiration, resulting in decreased gas exchange and photosynthetic rate. Because of salinity, halophyte grasses lack photosynthetic pigment. Salinity of the soil reduced the photosynthetic apparatus, capability, and attributes. In rocket plants, salinity significantly effect on net photosynthesis, Fv/Fm ratio, stomatal conductance, and transpiration rate (Hniliˇckov´ a *et al.,* 2017). Reduced levels of carotenoid and chlorophyll, photosynthetic activity, and rate content are caused by high salinity conditions in maize (Hessini *et al.,* 2019). Through stomatal closure and a reduction in photochemical and carbon metabolism, salinity inhibits photosynthesis. By reducing the synthesis of ultrastructure, chlorophyll, and carotenoid conductance, salt in plants causes a decrease in photosynthesis, chlorophyll fluorescence, transpiration, and stomatal closure.

3. Plant water uptake, ion homeostasis and ROS

Turgor pressure (p), osmotic potential (w), and leaf water potential (w) are all decreased by salinity. While K+ and Ca2+ levels declined in plant cells, the concentration of harmful ions increased, causing ion toxicity and the formation of ROS. The plants require a certain amount of ROS to function normally; any variation in ROS concentration could have a negative impact on the physiology of the plant and result in oxidative stress. Salinity enhances the level of ROS, leading in abnormalities in the ultrastructure of organelles and leakage of therapeutic electrolytes. Salinity has a significant impact on soil water potential. As a result, plants have trouble absorbing water, which further reduces their above-ground water potential and turgor

(Betzen *et al.,* 2019). Because of decreased soil matric potential and plant osmotic potential, salinity reduces the amount of water that is available to the plants (Sheldon *et al.,* 2017). Toxic ions (Na+) accumulate due to salinity. High salinity lowered the relative leaf water content in pomegranates (Soori *et al.,* 2019). The level of ROS increased and ionic homeostasis and leaf water potential decreased due to soil salinity (Wani *et al.,* 2019). Normal ion compartmentalization and leaf water balance are hampered by salinity (Ashrafi and Rezaei Nejad, 2017). The water and ion levels in maize are significantly impacted by high salinity (Hessini *et al.,* 2019). Salinity causes the osmoticum to decrease, which results in osmotic stress and ion toxicities. These further lead to issues with water absorption. Salinity increased the production of ROS, which are extremely toxic to cells and disrupt redox balance. Overproduction of ROS in cells accelerates the breakdown of proteins and enzymes as well as lipid peroxidation. It also impairs the electron transport system, the PSII system, and the structure of different membranes (Li *et al.,* 2017).

Strategies to alleviate the adverse effects of salinity

1. Phytoprotectants produced from Nitrogen

1.1. Osmoprotectants: Proline, Glycine Betaine and Polyamines

Osmolytes, which are low-molecular-weight water-soluble compounds that increase stress tolerance without affecting cellular machinery, are accumulated by many plants (Chen *et al.,* 2002). The three most commonly used osmolytes are glycine betaine (GB), proline (Pro), and polyamines (PA) (Nounjana *et al.,* 2012; Singh *et al.,* 2014; Wutipraditkul *et al.,* 2015) Plants' internal osmotic potential is lowered as a result of molecules accumulating in their cytosol and organelles in response to the decrease in the external soil osmotic potential carried on by an excessive accumulates of phytotoxic ions in the substrate. The integrity of the cell membrane and macromolecules is sustained as a result. An enzyme reaction involving glutamate dehydrogenase and 1-pyrroline-5-carboxylate synthetase is required for pro biosynthesis to occur from glutamate.

By enhancing the antioxidant enzyme system, photosynthetic activity, water status, and consequently plant nutrition, pro supplements have been shown to improve olive tree plant performance. These advancements increase plant growth and salt tolerance. Furthermore, Pro-treated plants used to have reduced soluble sugar contents, proving the osmoprotectant function of Pro (Ahmed *et al.,* 2010). Foliar spray of Pro has been shown to have positive effects, but there have also been reports of toxic side effects.

A strong osmoprotectant is GB, a quaternary ammonium compound that many plant species produce in response to salt stress (Chen *et al.,* 2002; Nounjana *et al.,* 2012; Singh *et al.,* 2014; Wutipraditkul *et al.,* 2015). Two enzymes known as betaine aldehyde dehydrogenase

(BADH) and choline monooxygenase (CMO) are present in the chloroplast as part of the metabolic pathway for GB biosynthesis in plants. The negative effects of environmental stress may be lessened by overexpressing GB in plants with little to no GB accumulation (Ashraf *et al.,* 2007) Using GB under salt stress conditions was found to facilitate the accumulation of other osmotic compounds in plant organs, such as free Pro and soluble sugars (Korkmaz *et al.,* 2011; Liang *et al.,* 2009).

Plants contain large amounts of the polybasic aliphatic amines, or PA, which are important to many cellular functions (Tiburcio *et al.,* 2014). Cadaverine (Cad), putrescine (Put), spermidine (Spd), and spermine (Spm) are the four PAs that are most frequently revealed in halophytes (Shevyakova *et al.,* 2006). These substances are found in every plant organ and play a role in a number of metabolic processes, including the senescence of leaves, morphogenesis, growth, and embryogenesis. Additionally, they act as genetic indicators of stress-tolerant genotypes (Zhao *et al.,* 2004).

1.2. Melatonin

Almost all living things, including plants, contain the amino acid tryptophan, which is also the source of the widely used molecule melatonin (N-acetyl-5-methoxytryptamine) (Hardeland, 2016). Fish, reptiles, and amphibians are among the animals whose skins can be pigmented by melatonin, hence its name. Its importance in organogenesis, plant growth, seed germination, and the senescence of leaves and fruits has been shown in numerous studies. Melatonin has the potential to control a wide range of cellular processes, including primary metabolism, redox processes, lipid and carbohydrate metabolism, the cell cycle, DNA replication, photosynthesis, and genes linked to senescence, among others, by upregulating the expression of specific genes (Wei *et al.,* 2015). Furthermore, it enhances secondary metabolism and protections the photosynthetic activity. Melatonin has amphiphilic properties to its chemical components, which makes it more likely to cross plasma membranes and enter various cellular compartments, including the cytoplasm, endoplasmic reticulum, and chloroplasts.

2. Microbial approaches

Various useful microbes can be used to enhance plant growth and resilience to stress, including increased tolerance to salt stress, according to novel techniques in agriculture and basic science. It has been proved that both bacteria and fungi increase a plants ability to tolerate salinity.

AMFs are beneficial microorganisms that enhance the soil fertility of both agricultural fields and natural ecosystems. It create an immediate interaction between and soil and plant roots physically are a vital component of natural habitats. Numerous host plants, including cucumber, lettuce, tomato, maize, acacia, and citrus, have been found to benefit from AMF symbiosis in terms of increased salinity tolerance. AMF changes the levels of phytohormones, enhances antioxidant defenses (both enzymatic and non-enzymatic), improves soil-root interaction, increases soil water absorption through the mycelium and mobilization in the plant, decreases the negative effects of phytotoxic ions on the integrity of the plasmatic membrane and cell organelles, changes the balance of phytohormones, and stimulates the expression of genes related to salt stress (Kumar *et al.,* 2015). Moreover, it has been revealed that AMF inoculation results in less disruption of chlorophyll production in plant responses to salt stress. In order to improve growth potential and use less water and fertilizer, AMF can be used as phytoprotectants. . In this circumstance, it is essential to choose the AMF cautiously in order to ensure that the fungi species function effectively under salinity.

Rhizobacteria that promote plant growth are known as "plant growth-promoting rhizobacteria" (PGPR). Such bacteria live freely in the soil and interact in a positive way with plants. Bacteria that are PGPR compensate 1% to 2% of the total. In the multiple genera, Pseudomonas and Bacillus species are common. Numerous studies have revealed that PGPR improves the vegetative growth and elevates the yield of different plant species. The use of chemical fertilizers and pesticides has been decreased because of PGPR, which improves nutrient uptake and protects plants. Due to this, soil fertility, environmental sustainability, and economic viability all improve. For agricultural production, a number of PGPR formulations are currently provided as commercial goods (Bhattacharyya *et al.*, 2012).

Under salinity-growing conditions, PGPR-inoculated plants typically exhibit an improved nutrient and water balance as well as improved rooting and plant growth (Paul and lade,2014). Wheat inoculation with PGPR has resulted in Na+ reduction in the leaves. Under salt stress, PGRP-inoculated plants showed an overall improvement in water use efficiency. In conclusion, it is remarkable that PGPRs are suggested as an adaptable and eco-friendly method to enhance crops to ameliorate adverse conditions. In order to achieve more sustainable agrarian systems, more commercial formulations may be developed as our knowledge expands.

3. Nanoparticles as phytoprotectants

Nanoparticles (NPs; sizes between 1 and 100 nm) have great potential to accelerate a range of scientific disciplines, including biological, medical, industrial, and agricultural sciences. Nanoparticles are used in agriculture as nano fertilizers and nano pesticides to increase crop yield and productivity in both challenging and routine circumstances (Hakeem *et al.*, 2020). Reports claim that nanoparticles can enter plant cells and correctly balance osmotic pressures to increase water uptake (Martinez-Andjar *et al.,* 2020). The nanomaterials enter the seed tissues during seed germination through intercellular spaces or develop new pores by upregulating the production of genes involved in cell divisions and other processes with elevated expression. By assisting the enzymes in releasing the seed dormancy, ZnO and TiO2 nanoparticle application successfully restored embryonic differentiation. Genes involved in water transport, cell wall formation, and cell divison, including CycB, NtLRX1, extensin, and NtPIP1, have been up-regulated as a result of the treatment of tomato seeds with multi walled carbon nanotubes. They enhanced tomatoes final germination (Khodakovskaya *et al.,* 2012).

Other studies revealed various positive effect of NPs. For instance, silver nanoparticles (Ag-NPs) increased germination rates and decrease harmful effects of salt when implemented to rice under salinity stress conditions. The improvement in seed germination under salt stress caused by the application of nanoparticles may be due to their enhanced infiltration into seed pores, which increased water uptake and maintained the enzymatic activities of seeds (Wahid *et al.,* 2020).

Conclusion:

Salinity is a major threat to agriculture because it affects soil, microorganisms, and plants from germination to maturity.

Furthermore, salinity may have an influence on a variety of vital plant functions, including photosynthesis, respiration, senescence, and flowering. A sustainable agricultural system retains the environment, enhances and maintains health of people, provides producers and consumers financial and spiritual benefits, and produces sufficiently food to supply a growing global population. One of the biggest obstacles to global agricultural production is the existence of abiotic stress conditions in the atmosphere. The advancement of abiotic stress resistance can be significantly influenced by microbes which are found in plants. These organisms, which may include rhizosphere, endophytic bacteria, rhizoplane, symbiotic fungi, and others, perform a variety of activities, such as inducing new plant genes and osmotic responses, as well as providing nutrients and other necessary elements. In comparison to the emergence of crop varieties that are stress-tolerant through genetic engineering and plant breeding, microbial inoculation to alleviate plant stresses may be a more affordable, environmentally friendly preference that could be made available in a shorter period of time. Future research in this area needs to be planned with a focus on the field assessment and use of potential organisms as biofertilizers in stressed soil.

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INDUCED PLANT'S DEFENCE TO INSECT HERBIVORY: AN OVERVIEW

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Introduction:

The largest and most diverse category of creatures on the planet is the class Insecta, which has more than one million known species. The majority of bug species are herbivores, which means they eat live plants. The willingness of plants to sustain in such a harsh environment depends on the development of resistance mechanisms that enable them to flee from herbivores in space or time, to directly combat herbivores by influencing host plant preferences or reproductive success, or to indirectly combat herbivores by forming associations with other species. It has long been understood that plant defences against insect herbivores can alter throughout the course of evolution and even over the course of a single plant's life. However, until recently, it was widely believed that plant defences were constitutively produced, i.e., unaffected by herbivore invasion. When Green and Ryan discovered that Colorado potato beetle wounds generate a fast build-up of proteinase inhibitors in potato and tomato leaves, this perception was altered in 1972. Proteinase inhibitors were proposed as a plant defence mechanism against herbivores because they obstruct the digestion process of insects that consume leaves. Many other features that are caused by injury or herbivory have been discovered in the 35 years after Green and Ryan's original finding. With the development of new methods for transcriptome analysis, it was possible to fully understand the range of induced responses, which revealed extensive alterations in gene expression in response to herbivory. In fact, many of the chapters in this book are devoted to discussing how herbivore-induced responses including the findings of transcriptome analyses—relate to plant defence. At this point, a word of warning is necessary: A gene's (or any trait's) ability to be induced is not adequate proof that it plays a role in resistance or plant defence. Adopting the definitions advocated by Karban *et al.* the term ‘induced resistance’ refers to induced changes in preference, performance, or reproductive success of the attacker.

Thus, induced resistance is defined from the perspective of the herbivore, and it may not always be advantageous to the plant. The cost of inducing resistance, for instance, can be greater than the gain from less herbivore damage, or inducing resistance might make the plant more vulnerable to other pressures. On the other hand, defence is defined from the viewpoint of the plant and indicates a benefit for the plant. Induced characteristics are only regarded as supporting plant defence when they increase plant fitness. Therefore, field studies that indicate variations in fitness for plants that differ in the attribute of interest are necessary to prove a function in plant defence. Only a small minority of herbivore-induced responses have been proven to improve the plant's fitness. However, researchers in the area and the writers of this book usually refer to induced changes in plant architecture, metabolism, or physiology as "defence" since they are thought to lessen the detrimental effects of herbivory. It is typical to distinguish between two forms of defence: direct and indirect. Direct defence is when induced reactions directly influence how herbivores interacts with their host plant. It depends on resistance elements that work alone or in combination to influence the host plant preferences of insect herbivores (antixenosis), or the behaviour of the insect on its host plant (antibiosis). The chemical makeup of the plant, which serves as the main criterion for host plant selection, as well as the morphological characteristics of the plant that serve as physical barriers to fend off invading pests, are resistance elements.

Plants may develop tolerance as an extra direct defence mechanism, enabling them to tolerate herbivore population comparable to that on a sensitive host without suffering a corresponding decline in plant fitness. Similar to resistance traits, the features underlying tolerance may be constitutive of inducible by herbivory. These traits are connected to plant morphology and the production or distribution of resources. Plants rely on the herbivores' natural enemies for indirect defence. The existence, number, and efficacy of predators or parasites of herbivorous insects are supported by morphological and chemical characteristics, which may thus operate as resistance factors. Examples include hollow thorns (domatia), which offer shelter, and extrafloral nectar, which is generated as a food source for ants, which defend myrmecophilic plants through a symbiotic relationship. Furthermore, in response to herbivory, plants may produce odours that attract predators or parasitoids of herbivores and guide them to their prey. This chapter will provide an overview of physical and chemical defence traits, and review the role of various chemicals that account for their inducible expression after insect attack.

1. Basic concept of plant defence against insect herbivores

1.1 Induction of direct defence in plants by wounding and insect herbivores

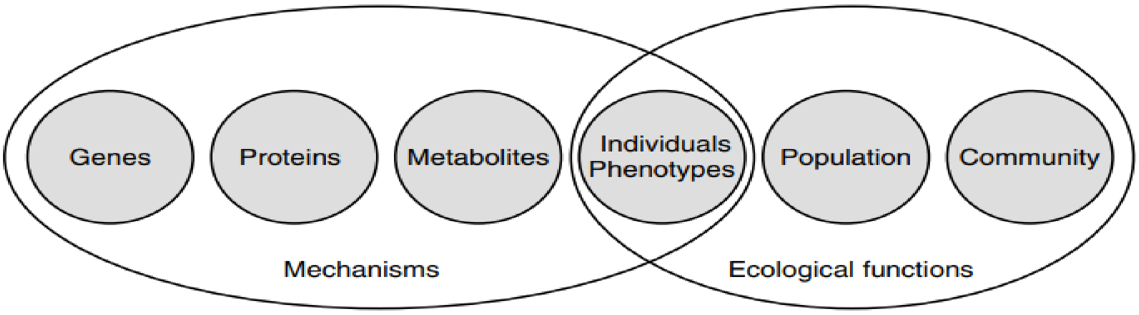
The size and shape of plants, especially blooming plants, vary greatly; they can be as little as a few millimeters in the case of duckweeds or as large as approximately 100 meters in the case of eucalyptus trees. Others survive for thousands of years, while some may complete their life cycle in a few weeks. As evidenced by the early history of terrestrial plants, the astounding variety is the consequence of adaptation to various, sometimes harsh conditions. With the exception of the areas near the poles, the highest mountaintops, and the deepest seas, flowering plants currently dominate every ecosystem on World. According to fossil evidence, plants initially colonized the earth 480 million years ago, marking the start of an evolutionary success story (Kenrick and Crane, 1997). A significant event in the history of plant life was the colonization of the land, which also set the way for the rapid evolution of terrestrial ecosystems. Despite being vulnerable to harmful biotic and abiotic circumstances as sessile creatures, plants actually rule over much of the land's surface. Because blooming plants have developed efficient resistance mechanisms based on a mix of physical, chemical, and developmental properties, their seeming success depends on their capacity to endure in harsh and unpredictable settings. (Schoonhoven *et al.,* 2005).

Stahl noted in 1888 that "plants evolved a large variety of mechanical and chemical measures of defence in their battle for survival within the animal world," which led to the conclusion that 'the animal world deeply influenced not only their morphology but also their chemistry' (Stahl 1888; Fraenkel, 1959). Consequently, the dizzying array of plant secondary compounds witness to the selection pressure applied by phytophagous animals, in addition to thorns and spines as morphological resistance features. (Fraenkel, 1959; Ehrlich and Raven, 1964). After Ryan and colleagues made their first finding, 35 years of study revealed that plant resistance to insect herbivores is a very dynamic process. Numerous more inducible factors have been found that, in addition to the proteinase inhibitors, aid in direct defence and may even improve host plant fitness following herbivore attack. It is obvious that when an insect feeds, a signal must be produced locally. This signal must then spread throughout the plant and be able to cause the synthesis of defence proteins at remote places. (Green and Ryan, 1972; Ryan and Moura, 2002).

1.2 Herbivore-induced indirect defence

Herbivore-induced indirect plant defences have primarily been researched in a tritrophic setting in simple feeding chains, without considering the potential implications they can have on other community members. One of the main difficulties that ecologists encounter in their study of herbivore-induced plant defences is determining the consequences of phenotypic changes on community dynamics. (DickeandVet, 1999; Kessler and Baldwin, 2001). Understanding the selection pressures and the dynamics of ecological interactions is important for understanding the ecology and evolution of communities. All of them contribute to the existence and quantity of herbivorous arthropods' carnivorous adversaries and, as a result, to the decline in herbivore numbers. Herbivory can induce the production of extrafloral nectar (Wackers *et al.,* 2001) or plant volatiles (Van Poecke and Dicke, 2004) and as a result the plant's phenotype changes. Numerous animals in the neighbourhood may eat the extrafloral nectar, and they may also utilize the volatiles to locate the plant. Many plant species have been shown to create herbivore-induced info-chemicals that entice carnivorous adversaries of herbivorous arthropods throughout the plant world. (Dicke, 1999). The effect of these phenotypic changes on carnivorous enemies of herbivores has received most attention (Van Poecke and Dicke, 2004; Turlings and Ton, 2006). For instance, spider mite infestation causes lima bean plants to release a variety of volatiles, such as methyl salicylate and terpenoids, some of which draw predatory mites that feed on the herbivorous spider mites (Dicke *et al.,* 1990, 1999). Additionally, herbivory cause's Lima bean plants to produce extrafloral nectar, which lengthens and increases the frequency of visits by insects like ants and wasps (Kost and Heil, 2005). Carnivorous arthropods are more likely to visit the plant, which reduces the amount of leaf damage (Heil, 2004).

A full comprehension of the underlying processes is necessary to explore the effects of induced indirect plant defences on communities because mechanistic knowledge enables the creation of manipulative instruments. To investigate the impact of induced defence on a variety of individual contacts or on the entire set of interactions, manipulative studies are crucial (Kessler and Baldwin 2001; Dicke and Hilker 2003).



Induced indirect defense can be investigated at different levels of biological organization: by investigating mechanisms of induction at the levels of genes up to individuals, or by investigating ecological functions at the levels of individuals up to the community. An integration of these two approaches proved to be most rewarding. Phenotypic plasticity plays a central role in understanding both, the underlying mechanisms of induced defense, and the consequences of induced defense for community dynamics

2. Induced direct defence

Plant traits that adversely affect insect preference (host plant selection, oviposition, feeding behaviour), performance (growth rate, development, reproductive success), or both result in increased plant fitness in a hostile environment are considered resistance factors for direct plant defence against herbivorous insects. These characteristics include morphological defensive mechanisms including trichomes, spines, and thorns, wax coatings and crystals on the epicuticle, tissue hardness, as well as secretory organs and channels for latices or resins. Along with secondary metabolites, digestibility-reducing proteins, and antinutritive enzymes, they also comprise substances for chemical defence. All of these features may be produced constitutively as resistance factors that are already present, or they may be induced and only activated in response to an insect herbivore assault.

The induction of defensive traits spreads to healthy, non-infested areas of the plants in addition to the assault site. Because plant responses to herbivore assault are systemic, a long-distance signalling system that can generate, transmit, and comprehend alarm signals from the plant-herbivore interface is required. On tomato and other solanaceous plants, most of the study on the signalling processes brought on by herbivory has been conducted. In this model system, the peptide systemin increases the synthesis of jasmonic acid by acting at or close to the wound site. Jasmonic acid or its by-products act as phloem-mobile long-distance signals and activate defence genes in the plant's distant regions. A summary of physical and chemical defensive features will be given in this chapter, together with a study of the signalling systems responsible for their inducible expression in response to insect attack.

2.1 Anatomical defences.

2.1.1 Leaf Trichome.

Trichomes are hair-like appendages that develop from cells of the aerial epidermis and are produced by most plant species (Werker, 2000). Leaf trichomes can serve several functions including protection against damage from herbivores (Levin, 1973). Trichomes on the leaves of plants help plants withstand herbivory. Despite herbivore damage, the trichome density of fresh leaves rises in a number of plant species. Between plant species, communities, and even within individual plants, leaf trichome form and density can vary greatly. Trichomes can be unicellular or multicellular in construction and can have any number of different shapes, including straight, spiral, hooked, branching, and unbranched (Southwood, 1986; Werker, 2000). Some trichomes have glands that release secondary metabolites (e.g., terpenes and alkaloids) which can be poisonous, repellent, or trap insects and other organisms. These trichomes are commonly referred to as glandular trichomes (Duffey, 1986).

Trichomes may be produced by both annual and perennial plants and by both artificial wounding and damage caused by herbivores. The observed rise in trichome density ranges in size from 25% to 100%, but can occasionally reach 500%–1000%. Frequently, the reactions entail trichome density alterations that manifest within days or weeks. (Agrawal, 1999, 2000; Baur *et al.,* 1991; Rautio *et al.,* 2002; Dalin and Bjorkman, 2003). Numerous insects and other herbivores are affected by trichoms' effects on insect oviposition and/or eating (Levin, 1973). Non-glandular trichomes primarily protect the plant's structure against tiny herbivores. They make it more challenging for insects to access the leaf epidermis beneath for feeding by obstructing the migration of insects and other tiny arthropods across the plant surface. (Southwood 1986). Trichomes may develop in response to abiotic stress like as drought and UV exposure. (Nagata *et al.,* 1999; Hoglund and Larsson, 2005), and abiotic conditions may modify damage induced responses in trichome density. for instance, in the willow Salix, Bjorkman *et al.* (2005) demonstrated that the increase in trichome production caused by leaf beetle herbivory is stronger in the shade than under direct sunlight, indicating that the plants expended more resources on trichome defence when growing in the shade.

2.1.2 Cuticle

All of the plant's above-ground tissue is shielded from the environment by the cuticle, which also serves as a vital barrier of defence against biotic threats from the outside as well as water loss through transpiration. This outer plant surface so creates the first contact zone for any approaching creature. The cuticle can very effectively prevent attachment, motility, eating, or oviposition before herbivorous insects harm the plant tissue. By doing this, it is typically possible to avoid (unadopted) insects from coming into contact with a variety of main and secondary plant compounds, whereupon damage might trigger enzyme activities, inducing induced plant defensive responses.

Nearly all of the above-ground sections of terrestrial plants are protected from water by a plant cuticle. The range of its thickness is 0.01 to 200µm (Nawrath, 2006). The cuticle is a membrane with two layers. On the exterior of the main cell wall, the cuticle proper, which consists of soluble and polymeric lipids, is initially created. The cuticle layer underneath the cuticle proper, which can vary in thickness, is formed during organ development when a zone of the main cell wall and then the secondary cell wall get saturated with cutin (Jeffree, 1996, 2006; Bargel *et al.*, 2006).

It is made up of three primary components, all of which are deposited at the epidermis' outermost extracellular matrix: the cuticle layer, which serves as the foundation for the cuticle proper, which is then coated by epicuticular waxes. The bio polyester cutin provides a densely networked structural support and is made up of -hydroxy and hydroxyepoxy fatty acids. The cuticular waxes are a complex combination of cyclic chemicals, such as pentacyclic triterpenoids, as well as extremely long-chain fatty acids and their derivatives (Riederer and Markstadter, 1996; Muller and Riederer, 2005). The cuticle's ultrastructure is determined by its individual chemical makeup and can vary greatly between species. Barthlott *et al.* (1998) classified a total of 23 wax types, which differ in thickness and in presence and shape of local wax projections, among other features.

2.1.3 Wound-Periderm Formation.

One of the plant's defence strategies is the formation of wound periderm at the boundaries of the invaded or damaged region to isolate it from non-wounded healthy tissue. The development of wound periderm following insect feeding has never been specifically examined; although studies of herbivory and wound signalling have indicated extensive overlap in the respective sets of induced genes. Its protective characteristics are mainly due to the suberized walls of its outer cell layers. Suberin is composed of aromatic and aliphatic polyester domains, and associated waxy material, providing biochemical and structural barriers against pathogen infection, and contributes to water-proofing of the periderm. Most of the current knowledge on wound periderm derives from healing processes of mechanically wounded potato tubers. The review summaries these studies, in light of plant response to herbivory.

A very early reaction to injury in potato tubers is the creation and integration of hydroxycinnamic acid amides of tyramine and octopamine into the cell walls (Negrel *et al.*, 1993). These amides have antimicrobial effects and are thought to help construct a primary phenolic barrier to prevent pathogen invasion. They are also thought to be the building blocks, along with other phenolics, of the suberin polyaromatic domain, which acts as a long-lasting barrier (Bernards *et al.*, 1995), replacing the cuticle. The suberin aromatic domain further strengthens the cell walls against fungal enzymatic hydrolysis (Negrel *et al.*, 1995). The suberin aromatic domain further protects the cell walls from fungal enzymatic hydrolysis, and a strong correlation exists between pathogen resistance and the thickness of the suberized cell layers. (Morris *et al.*, 1989).

The deposition of suberin aliphatic components in potato-tuber wound-healing tissue has also been linked to the formation of resistance to water vapour diffusion at the tissue's surface (Kolattukudy and Dean, 1974). However, waxes linked with the suberin polymer were proposed to have a critical function in periderm water-proofing.

2.2 Production of secondary metabolites.

2.2.1 Insect-Induced Terpenoid Defences in Spruce.

The synthesis of a broad variety of monoterpenoid, sesquiterpenoid, and diterpene resin acid defence compounds helps explain, at least in part, the effective defence and resilience of conifers against most herbivores and diseases. These chemicals build up in enormous quantities as preformed or induced oleoresin combinations. Some terpenoids, particularly monoterpenes and sesquiterpenes, can be actively released from conifer needles as volatile organic molecules having semiochemical activities. Conifer oleoresin is stored in anatomical structures such as resin canals, resin blisters, or resin cells in stems, roots, or needles. Except for the well-established fact that the formation of so-called traumatic resin ducts is induced in the cambium zone of conifer stems in response to insect or fungal attack, mechanical wounding, or chemical elicitation with methyl jasmomate (MeJA) or ethylene treatment, the developmental programmes for the constitutive formation of these specialised, resin accumulating structures are unknown. Several reviews of terpenoid oleoresin defences in conifers have been published in recent years. (Bohlmann and Croteau, 1999; Phillips and Croteau, 1999; Trapp and Croteau, 2001; Keeling and Bohlmann, 2006).

2.2.2 Phenylpropanoid Metabolism Induced by Wounding and Insect Herbivory.

Plants have a high concentration of phenols, which build throughout normal growth and development. As a result, phenolics are present in plants prior to insect or animal herbivory-induced harm (i.e., wounding). Indeed, phenolics have well-documented roles as pre-formed (constitutive) herbivory defences, including physical barriers such as cell wall bound phenolics, lignins, suberin, and cuticle-associated phenolics, as well as stored compounds that have a deterring (anti-feedant) or directly toxic (insecticidal) effect on herbivores. (Ding *et al.,* 2000; Mutikainen *et al.,* 2000; Treutter 2005; Santiago *et al.,* 2005, 2006, Walling, 2000). Induced defences are activated only after tissue harm has occurred. While this may offer defence at a lower energy cost, it also results in some biomass loss. To ensure long-term survival, plants must balance the distribution of carbon and nitrogen resources between these two types of defences and vegetative and reproductive development (Walling, 2000). However, distinguishing between constitutive and induced defence mechanisms is not always straightforward since some defence-related chemicals are constitutively generated and stored, as well as created de novo in response to herbivore damage (Ding *et al.,* 2000; Gatehouse, 2002).

3. Induced Indirect Defence

Herbivory may trigger plant defences that encourage the activities of herbivores' natural enemies. The process of producing plant volatiles that draw carnivorous arthropods or extrafloral nectar that these arthropods use as an alternate source of food is known as induced indirect defence. Different signal-transduction pathways, including the ethylene, salicylic, and jasmonic acid pathways, are involved in induced indirect plant defence and may require extensive transcriptome reorganisations. It is possible for enemies to be discouraged, natural enemies to be recruited, pollinators to vary their flower visits, and nearby plants to use the knowledge from the attacked plants to start their own defence reactions when induced indirect plant defence responses result in a changed phenotype.

Throughout their lives, plants must overcome several obstacles. Drought, flooding, extremes of temperature, and attacks by a variety of organisms, such as pathogens, insects or animals that eat entire plants, are just a few of the problems that might arise. Despite all these limitations plants have built defensive systems to secure themselves in order to reproduce. Plant defences against herbivorous arthropods can be classified as "direct defences" that affect the physiology of the invader (Howe and Schaller) or "indirect defences" that boost the efficacy of natural barriers. Indirect defence consists of (a) providing refuge, such as hollow thorns utilised by ants for nests. (b) the generation of alternative food, such as extrafloral nectar utilised by carnivorous arthropods like ants and parasitic wasps, or (c) the emission of herbivore-induced plant volatiles that direct carnivorous arthropods like predators or parasitoids to their herbivorous prey. All of factors contribute to the prevalence and abundance of carnivorous enemies of herbivorous arthropods, resulting in a decline in herbivore presence.

Herbivory can cause the generation of extrafloral nectar (Wackers *et al.*, 2001) or plant volatiles (Van Poecke and Dicke 2004), causing the plant's phenotype to alter. The extrafloral nectar can provide food for a variety of organisms in the neighbourhood, and the volatiles can help the organisms to locate the plant. Many plant species have been shown to create herbivore-induced infochemicals that entice carnivorous enemies of herbivorous arthropods throughout the plant world (Dicke, 1999). Most research has focused on how these phenotypic alterations affect carnivorous enemies of herbivores (Van Poecke and Dicke, 2004; Turlings and Ton, 2006). For instance, spider mite infestation causes lima bean plants to release a variety of volatiles, such as methyl salicylate and terpenoids, some of which draw predatory mites that feed on the herbivorous spider mites (Dicke *et al.*, 1990b, 1999). Additionally, herbivory causes Lima bean plants to produce extrafloral nectar, which lengthens and increases the frequency of visits by insects like ants and wasps (Kost and Heil, 2005). There is less leaf damage as a result of the plant receiving more visits from carnivorous arthropods (Heil, 2004).

3.1 Induction of indirect plant defence

Depending on the feeding guild to which they belong, herbivores have a wide range of ways in which they might harm plants. Caterpillars, for instance, consume tiny pieces of leaves, whereas other insects, such as aphids and leaf-mining insects, consume parenchymal tissue and phloem respectively. The plant may mount a variety of defensive mechanisms in response to various kinds of injury.

3.1.1 Response of the Plant

The JA (jasmonic acid), SA (salicylic acid), and ET (ethylene) pathways are three important signal transduction pathways that the plant may activate in response to arthropod herbivory (Dicke and Van Poecke, 2002). Different feeding groups or induced injury differentially trigger these signalling pathways (Ozawa *et al.,* 2000; Walling, 2000; Dicke and Van Poecke 2002; De Vos *et al.,* 2005; Zheng *et al.,* 2007). Also interacting between the three signal-transduction pathways: SA can interfere with JA-mediated induction, while JA can counteract SA's effects. (Pena-Cortes *et al.,* 1993; Sano and Ohashi, 1995). Similar to this, JA and ET influence tomato defence gene expression in a synergistic manner (O'Donnell *et al.,* 1996), although ET counteracts JA's ability to induce nicotine in tobacco (Kahl *et al.,* 2000). The generation of substitute food that the third trophic level's inhabitants may consume, such as extrafloral nectar (EFN), is another indirect defensive strategy utilising JA signalling (Van Rijn and Tanigoshi, 1999; Kost and Heil, 2005; Wackers and Van Rijn, 2005). Outside of the blooms, nectaries, which may be found on the petioles, secrete EFN (Koptur, 2005). One plant's floral and extrafloral nectaries have quite different nectar compositions (Koptur, 2005). Upon herbivory, EFN production rises (Heil *et al.,* 2001; Wackers *et al.,* 2001). It can increase in systemic leaves but is more prevalent in leaves where herbivores are feeding (Wackers *et al.,* 2001). Wounding and JA application increase EFN production. EFN, acting as a substitute food supply, could prolong predator visits to plants. Predators disperse from plants with higher levels of EFN more slowly than plants with lower levels of EFN, and plants may benefit from the presence of predators (Choh *et al.,* 2006).

3.1.2 Induction by Herbivores

When an herbivore consumes a plant by chewing on its leaves, consuming its phloem, or consuming its cell contents, they activate phytohormone signalling pathways, which then cause the plant to respond. The characteristics of induced phytohormones are attacker-specific: in terms of quality, quantity, and time (De Vos *et al.,* 2005). Plant volatiles caused by herbivores may be particular to the herbivore species or even the herbivore instar that is consuming the plant (De Moraes *et al.,* 1998; Takabayashi *et al.,* 2006). The main groups of plant volatiles induced by herbivory are green leaf volatiles, terpenes, and phenolics. The JA, SA, and ET pathways, which may be variably stimulated by insects from various feeding guilds, are the three-primary signal-transduction routes that mediate the induction of volatile emission (Walling, 2000). Both JA and SA accumulated in response to damage, but the accumulation differ based on attack by chewing insects or piercing-sucking insects (Leitner *et al.,* 2005). Similar distinctions in feeding guilds may be seen in Arabidopsis thaliana's driven alterations in gene expression. Five distinct attackers, ranging from chewing insects to pathogens that cause necrotic lesions, exhibited varying degrees of relative induction of the three crucial signal-transduction pathways (De Vos *et al.*, 2005). In general, it appears that plants' reactions to phloem-feeding herbivores are more comparable to those to pathogen attacks, whereas responses to herbivores that chew on leaves trigger pathways that are also engaged by wounding (Walling, 2000).

3.1.3 Mechanical wounding versus herbivory

A portion of the plant's reactions to herbivory are triggered when herbivores attack it and cause physical harm to it. Plant responses to wounding and dehydration have a great deal of similarities because water loss at the wound site may cause osmotic stress. The plant also reacts to substances from the oral secretions of herbivores. Both physical injury and elicitors from herbivores play a role in the plant's reaction to herbivores. However, the reaction to mechanical injury varies from the one carried on by herbivory in many plant species (Schoonhoven *et al.*, 2005). This may be partially because accurate mimicry of herbivory is technically challenging. The amount of tissue removed, the age of the tissue, the location of the damage, and the timing of the damage distinguish mechanical injury from damage caused by herbivores (Baldwin, 1990). The plant's reaction when herbivore regurgitant is given to mechanically damaged leaves might resemble the plant's response to herbivory (Turlings *et al.*, 1990; Halitschke *et al.*, 2001).

3.1.4 Priming

In addition to directly increasing defensive signalling cascades or gene expression, priming is a technique that can improve a plant's capacity to quickly activate cellular defence responses (Conrath *et al.*, 2002). Instead of producing defensive molecules right away in response to a priming stimulus, a plant establishes a state of sensitization that enables it to react quicker or more powerfully to future threats (Turlings and Ton, 2006). Priming has been shown to be effective in interactions between plants and pathogens (Conrath *et al.*, 2002, 2006) and between plants and microorganisms in the rhizosphere (Verhagen *et al.*, 2004), and it may reduce the metabolic costs involved with defence. Priming can happen in response to a variety of stimuli, including herbivory, pathogen infection, or plant volatiles. Induced volatile emission and EFN secretion both exhibits priming of indirect defences. Comparatively to plants that are not exposed, plants that are exposed to the green leaf volatiles of nearby injured plants emit more volatiles upon mechanical or herbivorous injury and have greater endogenous JA levels.

3.2 Responses of Community Members to Induced Indirect Plant Defense

Once released from the plant, induced infochemicals (Dicke and Sabelis, 1988) can be used by any of its neighbours, including nearby plants, herbivores, predators, parasitoids, pollinators, and other community members, both above- and belowground. By discouraging herbivores, the infochemicals can serve as a direct line of protection. For example, butterflies stay away from plants where oviposition has been prompted by the presence of eggs or damage from eating (Rothschild and Schoonhoven, 1977; Landolt, 1993; De Moraes *et al.*, 2001). Increased rates of direct defence may prevent herbivores from eating or ovipositing on a plant and may also limit larval development, making them more susceptible to natural enemies. Direct and indirect defensive systems, nevertheless, can compete with one another. Ingested plant poisons by herbivores may be stored to alter carnivore growth or negatively impact carnivore fitness due to weakened host size or quality (Ode, 2006).

3.2.1 Responses of pollinators

The pollination of many plant species by honey bees, bumble bees, solitary bees, syrphid flies, or moths is necessary for sexual reproduction (Klein *et al.*, 2006). Early herbivory decreases the photosynthetic area of the plant, which might lead to smaller plants and a shorter blooming time. This may be because resources are being directed on defences rather than development and reproduction (Poveda *et al.*, 2003). Herbivory has been shown to indirectly affect pollination in a number of studies. Herbivory may have an impact on floral characteristics, such as fewer blooms, smaller flowers, or shorter plants. Pollinator visits to flowers may be impacted as a result (Lehtila and Strauss, 1997; Adler *et al.*, 2001; Hamback, 2001). Bee preference for undamaged radish plants over damaged plants (Lehtila and Strauss, 1997) however this difference might be attributed to smaller and fewer flowers. Even when the plants were regulated for bloom size and quantity, syrphid flies still preferred intact plants to damaged ones, indicating a chemical foundation for their attraction. While it did so in this instance, herbivory can also increase pollinator attractiveness.

3.2.2 Responses of neighbouring plants

Plants may benefit in terms of fitness if they react to volatiles produced by nearby plants that are under attack by herbivores. Such a signal indicates an impending threat, and the receiving plant might take use of this knowledge by preparing its defence (Dicke and Bruin, 2001). Neighboring plants of the same species and those of different species can take advantage of herbivore-induced plant signals (Engelberth *et al.*, 2004; Baldwin *et al.*, 2006). Strong signals may rapidly activate a plant's defences, but weaker signals (more prevalent in nature) may prepare the plant for an attack (Turlings and Ton, 2006).

3.2.3 Indirect defense in a complex and variable world

Parasitoids and predators can discriminate between distinct induced mixes from different plant species, herbivore species (or even herbivore instars), feeding and egg-induced reactions, and local and systemic damage.The ability of the organisms detecting plant-emitted signals to discriminate between signals signalling the presence of their host from non-host signals and other background odours is crucial for community dynamics. Several species of arthropods, including *Phytoseiulus persimilis*, *Cotesia marginiventris*, and *C. glomerata*, are capable of learning to relate particular odours to rewards (Geervliet *et al.*, 1997; Turlings and Fritzsche 1999; De Boer *et al.*, 2005). One method to cope with the diversity in volatile mixtures may be to learn to correlate odours with the presence of host or prey. It could take some time and several experiences to learn new associations. While the parasitoid or predator loses time seeking for plants without its host or prey, the host or prey species may benefit from its "invisibility" to its natural opponent (Shiojiri *et al.,* 2002).

3.3 Manipulation of indirect plant defense

A manipulative strategy yields the most fruitful results when examining the impact of indirect defences and their constituent parts. A plant's defensive systems and the ecological effects of phenotypic alterations can both be learned via manipulating defence responses.

3.3.1 Perfuming with individual compounds

A single compound added to an unharmed plant can easily alter the phenotype of the plant. Using this approach, it is possible to assess the significance of certain chemicals for the plant's ability to attract predators and parasitoids to it against the background of other natural odours (Dicke *et al.,* 2006). Even while complex odour mixes are often what attract carnivorous arthropods, this technique has shown that adding individual chemicals can improve the attractiveness of carnivores (De Boer and Dicke, 2004).

3.3.2 Fractionation and filtering

Additionally, phenotype manipulation of the volatile blends can be achieved by fractionating the headspace and subsequently testing various fractions of the blend for biological activity (Turlings and Fritzsche, 1999; Van den Boom, 2003), or by using filters to selectively collect compounds with particular chemical properties (D'Alessandro and Turlings, 2006). These approaches have the benefit of preserving the ratios of various volatiles as they are present in natural herbivore-induced volatile blends, as opposed to examining single compounds. These approaches have the benefit of preserving the ratios of various volatiles as they are present in naturally occurring herbivore-induced volatile blends, as opposed to examining single compounds.

3.3.3 Genetic modification

By genetically altering signal-transduction or biosynthetic pathways, one may also control the induced defences of plants. To learn more about the processes of induced defence and the associated ecological implications, carefully manipulated plants that are different from wild-type plants in a particular gene can be compared with those that are not.

3.3.3 Chemical elicitors and inhibitors

The use of particular inducers or inhibitors can be used to change the way that signal-transduction and metabolic pathways function. It is feasible to examine ecological interactions at different trophic levels or in the entire community by experimentally activating or suppressing certain phases of the pathways. The signal-transduction processes may be disrupted to control the volatile mixtures released by plants, and specific enzymes in the pathways can be activated or blocked to study the significance of certain stages. The insect population will be provided these modified mixes, which will shed light on the ecological significance of these routes.

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STORAGE GRAIN PESTS AND THEIR INTEGRATED PEST MANAGEMENT

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Abstract:

In India, nearly half of the population is dependent on agriculture. With the invention of high-yielding varieties, Indian food grain production has been touched 291 million tonnes in 2019-2020. The seed is the critical raw material and important input for agricultural production. Although India is one of the self-sufficient countries in food grain production, still millions of people have been living with an empty stomach. Several factors such as post-harvest losses, which contribute to 25-30% loss of food grains could be minimized to make the availability of food to empty stomachs. Almost 10% of these losses have been attributed to insect pests causing quantitative (direct feeding) and qualitative losses (indirect effects such as food contamination), so it is of utmost importance to control these pests in a coordinated manner by adapting all available management practices which are economically and ecologically feasible. Preventive measures such as cleaning and proper drying of grains, grain stores, containers, etc. offer the best control of pests at a negligible cost. Spraying of insecticides such as Malathion, synthetic pyrethroids on storehouses, and gunny bags could delay the commencement of infestation. Biorational measures such as the use of pheromones, insect growth regulators, botanicals, etc. should be deployed upon the commencement of the pest infestation as curative measures. Various other methods like legal (for invasive species), physical (such as desiccants, hematic control, heating, cooling, etc.), and chemical methods including fumigation (phosphine gas, etc.), spraying of pesticides (fenitrothion, bifenthrin, etc.) and bioactive nanoparticles (silver nitrate, etc.) can be deployed for the effective control of storage pests.

Keywords: Biorational measures, Curative measures, Nanoparticles, Preventive measures, Storage pest

Introduction:

Integrated pest management is a program utilizing available pest management practices such as cultural, physical, mechanical, biological, genetic, and chemical methods inappropriate manner to bring the pest population below those causing the economic damage. The IPM in storage grains is of utmost importance due to the difficulty in controlling the storage pests with available pesticides. The main aim of the IPM in storage grains is to minimize the pest population to a level that doesn't cause any economic damage and to prevent or delay the pest resistance to pesticides by adopting the best management practices.

Most of the storage losses are caused by inadequate and poor storage facilities and major losses annually by pests and diseases. Of the many pests that have adapted themselves to the diet of dried vegetable products, only a few are the primary pests of grains, which can be adapted to sound kernels. Their initial attack opens the way through the harsh seed coat. With the advent of the Green Revolution in the early 1960s, India emerged as one of the leading food-producing countries, increasing food grain production by 291.95 million tonnes per annum**.** Despite surplus food production, hunger and poverty are still exist because millions of tons of grain worth more than 2000–3000 billion rupees are damaged or lost each year due to a lack of knowledge on scientific methods of storage. Biotic and abiotic factors contribute 25-30% of food grain loss worldwide, with the highest in the tropics and subtropics, where conditions are relatively favourable for the rapid growth and reproduction of organisms that cause damage. Stored-product pests can cause severe harvest losses, estimated to be 9% in developed countries and 20% or more in developing countries (Pimentel, 1991), but they also contribute to food contamination due to living pests and insects. Chemical discharges, insect residues, and the accumulation of pesticide residues in food as a result of pest control efforts. Most developing countries need reliable pesticides and storage techniques to reduce damage to stored food grains. If we can save these losses, our food grain reserves will grow to feed millions of hungry people around the world.

Most insect pests belong to the order Coleoptera and Lepidoptera, which make up about 60 and 10% of the total storage insect pest population (Atwal and Dhaliwal, 2008). They feed on grains, destroy part of the germ, and cause heat and decay in stored materials. This leads to massive losses as a result of malnutrition and deterioration of market value, as well as contamination caused by their effluents, and endangering the health of humans who process and eat infected grains. Thus, the storage losses include not only quantitative but also qualitative losses of food grains. Qualitative loss is caused by chemical changes in proteins, carbohydrates, amino acids, fatty acids, and vitamins, which ultimately deteriorate the nutritional value of grains.

Source of infestation

Through the three main sources, the infestation of stored grain pests takes place viz.,

i. In field infestation, some insects like pulse beetle, grain moth, and rice weevil lay eggs on grains in the field itself, and those are carried to grain stores and act as a source of the infestation.
ii. Pre-existing pests in grain stores especially in cracks and crevices of godowns infest new arrivals.
iii. Storage bags and containers may also act as a source of infestation if they are not properly disinfected.

Factors influencing the infestation

Apart from the food, the infestation of storage pests will be influenced by three factors, viz., Water, oxygen, and temperature. The main source of water for the storage pest is either from the atmosphere or through the metabolism (an end product of respiration). These pests obtain atmospheric moisture through the containers in which the products are stored. The source of oxygen is also the atmosphere and oxygen diminish in the containers with time, resulting in the scarcity of oxygen that negatively impacts the pest population in the containers, so it is necessary to maintain the airtight containers to avoid the population growth storage pests. Temperature is created within the deeper layers of grain heaps and will get spread throughout the heap due to the temperature gradient.

Types of storage loss caused by pests

a) Quantitative loss: Feeding directly by insects reduces the weight of stored grains. For example, a rice moth eats 14 of 20 mg of rice kernel during its growth period.
b) Qualitative loss: Qualitative changes such as chemical changes in the grain content. Contamination of grains with moulted skin and body parts of insects is also more likely to spread pathogenic microorganisms.
c) Damage to storage structures: Some pests such as low grain borers have the potential to destroy bamboo and wood storage structures, containers, polythene, and lined bags. The direct effect of this is the loss of food by leakage, while indirect losses occur as a result of reducing the quality of food. According to Lal (1988), post-harvest losses in India in 1988 were estimated at 9.33%.

Categories of Storage pests

(i) Primary pests capable of infiltrating the intact kernels of the grain and the immature stages that can develop immediately within the kernel of the grain. Eg. Rice weevil, pulse beetle, cigarette beetle, etc.
(ii) Secondary invaders do not affect the sound grain but feed on broken kernels, debris, and grains damaged by the primary pest. In general, immature stages of these insects are found outside the grain. Eg. Rice moth, Indian meal moth, flour beetles, etc.

Non-insect pests such as rats, moths, gerbils, squirrels, and hedgehogs can cause significant damage in various countries. Some feed on grains, some on land near shrubs and buildings.

Elements of an IPM approach

1. Planning and managing storage ecosystems to prevent insect infestation
2. Identifying pests and understanding their biology and ecology
3. Monitoring populations of pests and the storage environment
4. Making control decisions based on the information collected
5. Reducing pest populations to acceptable levels
6. Evaluating the effect and efficacy of IPM decisions

Components of IPM

IPM relies on physical and biological control techniques and, if necessary, the management of pests with chemical pesticides. The IPM approach incorporates various components to effectively manage insect pests in stored grains.

Sampling: Pest tracking is an important component of the IPM post-harvesting practice for stored grains. Pest management decisions should be made frequently, especially after the first storage (Subramaniam and Hoxstrm, 1995). Population density estimation methods include the following techniques:

(i) Absolute estimates (number of insects per kg of grain or number of moths per square meter)

(ii) Indirect estimates (mark-release-retrieval methods)

(iii) Relative estimates (number of insects trapped in the adhesive web, perforated inspection trap, food trap, *etc*.).

Samples should be taken at regular intervals (sequential sampling) to gather information on population changes over time. Generally, for grains stored above 20 ^{o}C, sampling should be done monthly. Grains below 20 ^{o}C allow sample intervals to be longer than one month. The selection of the sampling frequency is based on the time it takes for the insects to complete a life cycle. IPM relies heavily on the model because the use of physical and biological controls is very effective in small populations. However, if the pests exceed an economic limit, fumigation is recommended. Monitoring the number of pests and deteriorating quality over a while can be a valuable tool for determining the economic threshold in storage.

Preventive measures

Prevention is an important factor in any effective pest management plan because preventing the introduction of pests indicates preventing the loss of both product and time. Properly inspected grains, cereals, and other packaged materials can prevent pests from entering storage facilities any contaminated material should be disinfected or disposed of immediately. Using screens over windows and doors can prevent the entry of insects. Prevention requires good hygiene and sanitation. Routine preventive measures include

- Keep the grain yard clean, free from pests, and away from villages/warehouses.
- Harvesting and irradiating machines should be cleaned before use.
- Trucks, giants, or bullock carts used to transport should be cleaned.
- Food grains must be free from pest infestation.
- Storage structures should be cleaned before storing freshly harvested crops.
- All dirt, rubbish, broom, web pages, etc. Should be removed and destroyed.
- All cracks in the walls and roof should be closed with mud or cement.
- Food stores should be whitewashed before storing food grains.
- Food grains should be stored in rat and moisture-free stores.
- Proper stacking of bags helps in grain protection.

- Before using stores should be disinfected with approved residual pesticides, preferably Malathion 50% is diluted to 1: 100 and applied at a ratio of 3 L / 100 m^2.

Proper storage

The objectives behind the proper storage are

i. Protection from storage pests
ii. To protect the seed from environmental vagaries (temperature, humidity, etc.)
iii. To retain the viability of seeds for longer periods and nutritive qualities
iv. To create airproof conditions to make the fumigation more effective
v. To get protection against theft

Storage structures should be built using locally available materials to minimize costs. The storage structures could be broadly categorized into two groups: aboveground and underground structures.

I. Aboveground structures

i. Bamboo structures in a cylindrical form with a narrow mouth for storage of paddy, wheat, etc., having 500 kg capacity and 4-5 years of life.
ii. Mud and earthen structures are made and sun-dried & then burnt in the fire, used to store food grains, and have a capacity of 500 to 1,000 kg and 8-10 years lifespan. Cracks and crevices may be developed upon the moisture absorption followed by pest infestation
iii. Wooden structures with inlet and outlets facility are painted black. These are used to store paddy @ 1,000 kg and have a 15-20 years lifespan.
iv. Brick structures are rectangular made up of cement, having a wall thickness of 40-50 cm with an inlet at the top and outlet at the bottom. Cereals @ 10,000 to 20,000 kg can be stored however these structures are not insect and moisture-proof.
v. Metal corrugated galvanized iron sheets are held vertical and their edges are overlapped and bolted to each other to form a cylindrical container of 2-4 meters in diameter and 3 meters in height. In which various types of grains can be stored for temporary periods.

II. Underground structures

Underground structures of various forms (square, rectangular, and flask-shaped) are having 10,000 to 20,000 kg capacity and are mainly used to store cereals. The structures offer various advantages such as

i. Stored grains are least exposed to temperature and humidity fluctuations
ii. Insects and non-insect pests find hardly their way into these structures
iii. Greater accumulation of carbon dioxide due to minimal diffusion will kill the insects by inhibiting the respiration
iv. Easy to fumigate these structures
v. It can save space on the ground

Physical control

The use of physical control measures includes temperature, mechanical methods, humidity and humidity control, structural methods (grain pits, packaging), radiation, and hygiene (Fields, 1995). The red light is not preferred by *T. castanium* adults, so beetles can be managed without the use of chemical pesticides. Using sodium rather than mercury lamps can also make the area less attractive to insects. Heat and cold treatments can be used to manage ecologically modifying cations storage pests because the heat kills some pests while the cold prevents their growth. Storage at 15 ^{o}C has been reported to prevent insects from feeding and at 4^{0}C to kill them over some time. The cold treatment causes death at temperatures below 4^{0}C, especially in the immature stages of almost all insect pests. Death occurs rapidly in frost. *D. Castanium* and *Oryzaphilus mercator* are more susceptible to cold, whereas *Trocoderma* spp., *Ephestia* spp. and *Plodia interpunctella* are cold-tolerant species.

a) **Heat treatment:** Dies grain insects stored at 50-60^{0}C temperature for 10-20 minutes. Exposure to a temperature of 5^{0}C higher than optimal for the organism will stop growth. Exposure to 50^{0}C for 2 hours removes most pests.
b) **Grain heating:** A hot-air stored grains 399 fluidized bed, using infrared radiation or high-frequency dielectric and microwave heating to achieve uniform grain temperatures throughout the storage system.
c) **Controlled atmosphere / hermetic storage:** The use of a controlled atmosphere for storing grains involves the use of high CO_2 (9.0– 9.5%) and low O2 (2–4%) levels, which are dangerous to all pests. This technology for controlling stored insects is widely used.
d) **Desiccants** such as earth, silica gel, and non-silica and diatomous earth can protect from pest damage. Desiccants are removed from grains or stored foods before processing by the cleaning process, which also removes debris. The ratio for whole grains is 100–300 g /q depending on the insect species and grain moisture. Alternative dust products include ash, laterite dust, clay dust, or very fine sand. However, depending on the type of dust, an acceptable safety effect can be achieved with significantly smaller amounts.

Legal systems: The entry of pests not found in a particular area can be prevented by enacting laws.

Harvest separation

It is always best to divide the product into two parts for storage, one for short-term daily needs and the other for long-term storage. Generally, the pest does not cause any damage for 3-4 months. Therefore, it is not necessary to treat food grains intended for consumption during this period, while those aimed at long-term storage require proper treatment. Lime dust is one of the most important cheap dusters used for food grains stored in their husks and has a dehydrating effect on insects and inhibits their respiratory orifice.

Biorational management

I. Pheromones

Pheromones are commercially available to approximately 20 types of stored-product insects that are slow-release formulations of traps to be used in surveillance traps (Phillips et al., 2000). For beetles that land and crawl to an odour source, the traps are designed so that they sit and fly in a meadow on the surface and eventually catch the insects that enter the trap when they get stuck on the trap surface or trapped inside the trap receiver. Barack and Burgolder (1985) developed a trap with horizontal layers of corrugated cardboard in which the responding beetles walked through the corrugated tunnels and reached a cup of oil where they fell and suffocated.

II. Natural enemies

Many natural enemies are associated with stored-product insects such as parasitic wasps from Steromalidae are ectoparasitoids (solitary) of beetles that feed on grain, as well as several common species associated with the stored product. Populations of parasites and predators in storage systems show density dependence.

III. Antimicrobials

Spinosad is a commercial insecticide derived from the Actinomycete bacterium *Saccharomyces cerevisiae*. It is very effective in controlling pests associated with stored wheat (Flinn *et al*., 2004). In field-grown crops, Spinosad loses its activity after a week due to deterioration caused by ultraviolet radiation from sunlight but retains its activity to a minimum of more than 12 months in grain stores. Spinosad is used for wheat at 0.1 and 1.0 mg/kg to kill all types of insects.

Bacillus thuringiensis (Bt) is a registered pesticide for use in grain stores in the United States. The larvae of *P. interpunctella* and the dried currant moth (*Ephestia caudella*) are more susceptible to Bt. Nuclear polyhedrosis virus, granulosis virus, and cytoplasmic polyhedrosis virus are mainly isolated from Lepidopteran insects and can control these pests.

IV. Biological control

Many insect predators and parasitic wasps attack stored grain pests and could yield the best results if they are used in large numbers. Biocontrol agents have limited commercial availability and are cost-effective except when used in organic production (Weaver and Petroff, 2004). The biocontrol of storage pests can be very difficult because different species can infect the grain. *Trichogramma* spp. has been evaluated against various types of stored product moths and is promising as biological control agents because they attack the egg stage of insects, thereby preventing the stored products from being invaded by first instars.

V. Insect growth regulators

Insect Growth Regulators (IGR) are the chemicals that affect the ability of an insect to properly develop or cross various growth stages. They are less toxic to humans compared to organophosphate, carbamate, and synthetic pyrethroid pesticides. Several IGRs have been evaluated for performance towards stored-product beetle species as they are generally safer to spray directly on raw materials due to less toxicity. An IGR is only effective if it comes in direct contact with the target pest, so can be used as a spray for grains when the insects are at the right stage of growth. Occasionally, the use of an IGR extends the larval period, so the larvae may continue to feed for some time before being destroyed (Lorini *et al*., 2007).

VI. Fumigation

Fumigant emission is required to control stored product pests in bulk containers, warehouses, and other large storage structures/areas. Fumigants help kill insects in hidden places, which can otherwise become a problem. The area to be cleaned should be properly sealed so that the fumigants can reach a lethal concentration and once it has reached the required level it should be maintained for a certain period for best results. Care should be taken not to explode the containers as a result of creating a vacuum. Thus, the lid is tightened only when the container is heated to room temperature. Of the various fumigants available, the methyl bromide acts rapidly in less than 48 hours against almost all storage pests and it reduces ozone in the atmosphere. Carbon dioxide can be used as a fumigant, but it is less toxic and less harmful to insects than some other fumigants, so it is unlikely to be widely accepted except in controlled atmospheric storage.

Spraying of storage premises: Different methods are to be followed to treat the storehouses such as

a) For irregular areas (raw wood, breeze-block, bricks, etc.), spraying an insecticide by mixing it with water is preferable
b) For Smooth, solid substrates (metal, polyester), Spraying in the form of viscous spray is preferred.
c) Ambient treatment in hermetically sealed premises to destroy active fliers by using aerosols.

Managing non-insect pests in storage

Managing non-insect pests in stored materials can be achieved using a variety of chemicals, including Aluminium phosphide, a fumigant used to kill rats and mice, Bromadiolone, coumachlor, coumetarol, and warfarin are anticoagulants, Sodium cyanide, a respiratory poison, Zinc phosphide @ 2%, a highly toxic mineral compound with aroma and taste similar to garlic, which is commonly used in bait and effective for 5-7 days.

The following points should be considered in IPM

1. Monitoring

Information on pest distribution can be used to create a highly representative stratified random sample plan. Accurate estimates of pest densities often require taking more samples than is possible and are a viable way to determine if the population of pests will soon reach the density at which economic losses occur. When the population is close to the economic threshold (ET), several samples must be determined to determine whether the density is above or below ET, and then it is recommended to sample again, but the same is true for ET when density is close. Automation is considered a tool for creating more cost-effective pest control programs. An infestation of storage pests can be detected by the following methods

i. Visual observations (sampling, sifting, and counting)
ii. Light traps and other such traps too early detection of the presence of a pest
iii. Use of semiochemicals such as synthetic pheromones and food attractants to locate the pest population
iv. Use of food baits especially for moths and beetles
v. Use of x-rays, chemical and sound amplification to detect the latent infestation
vi. It is best to use a combination of given methods

2. Selection of pest management system

Understanding the primary benefits of each pest management method will make it easier to choose the best pest management method. The rest of the pesticide and pesticide packaging provides long-term protection. Natural enemies, smoke, and heat enter areas where insects hide. Ventilation of grains stored in cans and warehouses, ionizing radiation of stored products including grains, spices, and nuts; In addition to the long-term planning need, pest management methods and operating costs can be more expensive than purchasing more expensive equipment, heat treatment, and impact and disinfection used in food processing facilities.

3. Selecting a combination of pest management methods

Research on synergistic combinations of pest management methods has recently been expanded. System combination models can be used to compare different combinations. The effectiveness of other methods is generally reduced by poor hygiene, and it has been decided that hygiene should be of paramount importance to food facility managers. Essential oils increase the effectiveness of diatomous earth against the *Sitophilus granarius* (L). The essential oil mixture usually contains more repellent action than single oil, with lemon and vanilla acting as the strongest repellent at a 1: 1 mixture.

4. Timing of pest management

Computer simulation models can be used to improve insect handling time. Delayed harvest or smoking reduces the time available to the pests to colonize. The population is 5 to 25 times larger per month if cooling by ventilation is delayed. On the 20th day release of the parasitoid, *Cephalonomia waterstoni* showed that the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), is reduced by 75% more than the same number of parasitoids released on the 40^{th} day. The release of parasites when the host reaches the first sensitive stage prevents most insects from reproducing.

5. Improve pest management

The stored product initiates their resistance to any pesticides by monitoring the presence of pests in the pest management facility. The presence of pests should be monitored before and after management to demonstrate the efficacy of the management practices.

Pesticide resistance management (Lorini *et al*., 2007)

i. Changing behaviour through training of the storage facilities personnel
ii. Improving knowledge of stored grain unit
iii. Cleanliness of the equipment and premises and, after that, spray a residual insecticide
iv. Identification of grain-stored pests
v. Resistance tests
vi. Insecticide treatment and fumigation
vii. Sampling and monitoring the grain

Use of Bioactive Nanoparticles

Diatomaceous earth, synthetic silica (SiO2), sands, silica aerogel, aluminium oxide (Al2O3) zinc oxide (ZnO), copper oxide (Cu2O), titanium dioxide, silver nanoparticles like AgNO3 can be used to control the storage pests. Green Ag NPs are synthesized from *Azadirachta indica* (Tripathi *et al*., 2009); *Glycine max* (Vivekanandhan *et al*., 2009), and *Camellia sinensis* (Begum *et al*., 2009). Goswami *et al*., 2010 have observed a 90 % mortality of *S. oryzae* by using silver nanoparticles. Diatomaceous earth and synthetic silica are used in the form of inert dust and kill the insects by physical rather than chemical means. 100% mortality of *Corcyra cephalonica* (Vani and Brindhaa, 2013) and 80-95% mortality of *S. oryzae* (Debnath *et al*. 2011) were obtained by using amorphous silica nanoparticles.

Conclusion:

In the modern era of technology, it is not impossible to control the storage pests by adopting new technologies such as pest detection techniques and models, nanoparticles, biotechnology, and novel pesticides. However, still, 25-30 % of post-harvest losses have been taken place. It is time to limit those losses by framing the economic, social, and ecologically feasible management system which coordinates various management practices in such a way to avoid any adverse consequences such as pesticide resistance development in pests.

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Agriculture Science: Research and Review Volume X

ISBN: 978-93-91768-88-1

About Editors

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Ms. Neeta Mahawar is presently working as research fellow at RVSKVV, Gwalior in MOU with IISS, Bhopal, M.P. She received Best M.Sc. Thesis award in 2020 and Best Research Scholar in 2020 and Best article in 2022. She received ICAR-NTS fellowship during M.Sc. Ms. Neeta qualified ICAR-ASRB NET in 2020, appeared in RPSC-ARO (Soil Science) interview. She has published research papers, review papers, Book Chapters, abstracts, popular articles and co-editorship in agricultural book. She also participated in many National and International conferences, trainings and workshop etc. Her area of research interest includes Soil Chemistry and fertility, nutrient management, FAO Standard operating procedures.

Mr. Aravinthraju K, M.Sc. (Ag.) Entomology, Ph.D. Scholar, Tamil Nadu Agricultural University, Coimbatore has completed his post graduate studies and awarded M.Sc. degree during the year 2021. Area of research during his post-graduation was on IPM for tea mosquito bug. Also he has qualified ICAR and UGC National Eligibility Test during the year 2021 and 2022 respectively. In addition qualified UG Diploma (Horticulture Nursery management) and CABI online certificate course (Pest Diagnosis). He served as Senior Research Fellow at Tamil Nadu Agricultural University for nearly 1.5 years. He has published seven research articles, six book chapters, sixteen popular articles and one cover story. He attended seven international conferences, twelve national conferences, seven workshops and two trainings during which published nine extended abstracts and six abstracts with five oral and eleven poster presentations. He was awarded with two best oral presentation awards, three best popular article awards and two innovative popular article awards. In addition he was serving as reviewer for Agriculture & Food: e-newsletter magazine for the year 2022 – 2023.

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ISBN 978-93-91768-88-1

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