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Agriculture Science: Research and Review

Volume XII

Editors

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PREFACE

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

PADDY STUBBLE BLAZING: ISSUES AND SUSTAINABLE MITIGATION

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Abstract:

Paddy (*Oryza sativa*) is perceived to be the most pivotal staple food for a majority of the population of humans, particularly in Asian countries. Management of paddy stubble – leftover paddy products after harvesting of fields mainly, rice straw is a major challenge. Burning of agricultural byproducts in the field is asserted to be an easy and cheap method for the disposal of excess paddy. Socio-economical, institutional and technological glitches compel the farmers to perform paddy residue burning. *In-situ* burning of paddy straw causes sudden temperature elevation, emits greenhouse and particulate matter causing harm to biodiversity, causes respiratory problems in humans and depletes the nutrient content essential for plant growth. However, Rice residues are wealth in disguise and can be utilized for economical benefits on industrial and domestic scale numerous with the help of preparation of framework and proper implementation of law policy. Guidance regarding *In-situ* and *Ex-situ*, cost-effective management methods, techniques and government policies such as incorporation and mulching of straw in the field, use of combine harvester with super SMS, baler and super seeder, government subsidies and wealthy uses of paddy residues to human kind should be given to motivate and active participation of farmer's to opt out of paddy residue burning to resolve this issue.

Keywords: Stubble burning, Consequences, Management

Introduction:

Setting up fire in the harvested crop fields to clear excess crop residues, to prepare the field for next crop is known as stubble burning. Paddy (*Oryza sativa*) is perceived to be the most pivotal staple food for a majority of the population of humans, particularly in Asian countries. However, management of paddy stubble – leftover paddy products after harvesting of fields mainly, rice straw is a major challenge. If paddy straw residues are left open in the field without any strategic or effective form of management, it may results into the spreading of various diseases, such as stem disease and encourages the pest population mainly of rats to surge in the fields. Due to its high silica content, animals relish to eat paddy straw, hence it is considered to be a poor feed for the animals. As a result of Socio-economical, institutional and technological glitches that compel the farmers to perform paddy residue burning and due to the farmer's perspective/perception and lack of knowledge in farmers, with no options left, paddy residue burning- a process of uncontrolled combustion, is asserted to be the only useful, easy and cheap way to get rid of excess paddy of paddy straw off of the paddy field, which helps to decrease diseases attack and pest population (Bindu *et al.*, 2018). Burning of agricultural byproducts in the field is asserted to be an easy and cheap method for the disposal of excess paddy.

Burning of surplus paddy straw is a serious issue worldwide, which has several ill effects resulting in a catastrophic impact on ecosystem and living beings. *In-situ* burning of paddy straw causes a sudden elevation in temperature in nearby areas leading to environmental changes and emission of harmful gases which act as one of the reasons for the environmental pollution, harm to the field and roadside trees, and danger to biodiversity as the bird's nests and eggs in fields and on the field and roadside trees, are burnt. It not only emits greenhouse gases and particulate matter but also depletes the nutrient content which essential for plant growth (Lohan *et al.*, 2018). The smoke produced by the burning of paddy spread widely, mixes with fog, and forms dark smog which reduces visibility leading to several injurious accidents along with diseases like cough, fever, cold, T.B., cancer, irritation in eyes, allergy, choking of lungs causing breathing and other respiratory problems.

Rice residues are wealth in disguise and can be used/utilize for economical benefits on industrial and domestic scale numerous with the help of preparation of framework and proper implementation of law policy. Guidance regarding *In-situ* and *Ex-situ*, cost-effective management methods, techniques and government policies such as incorporation and mulching of straw in the field, use of combine harvester with super SMS, baler and super seeder, government subsidies and wealthy uses of paddy residues to human kind should be given to motivate and active participation of farmer's to opt out of paddy residue burning to resolve this issue.

To solve the problem of burning, various alternative eco-friendly management techniques are discussed to manage paddy straw at proper time without delaying in sowing operation of wheat crop. This chapter reviews the potential effects of rice residues, its management options and future perspectives and benefits, on the basis of analysis of reported research results by different researchers that comprehensively cover the existing literature and current status of stubble burning in India, including

(1) the generation and burning of crop stubble
(2) the composition of emissions from stubble burning
(3) the transport and dispersion of emissions from stubble burning
(4) the effects of stubble burning
(5) the legislation and policies on stubble burning and
(6) the alternative techniques for managing crop stubbles.

The review also recommends some approaches that will profoundly assist in arresting the issues of burning agricultural stubble in the country and beyond.

Rationale of residue burning

Farmers in Punjab and Haryana are accountable for approximately 16.9% and 49.47% of total residue burning, respectively. Several laws have been passed by the government to prohibit the practice of stubble burning, but farmers continue to do so despite the negative consequences, so it is necessary to comprehend what motivates them to choose stubble burning over other disposal methods. Farm mechanization, short time window for the next crop, lack of acceptance as fodder, pest management and a variety of other issues have contributed to the blazing of paddy stubble.

Jain *et al*. (2014) observed state-wise crop residue generation and found a large variation in crop residues generation across different states of India depending on the crops grown in the states, their cropping intensity, and productivity. Generation of cereal crop residues was highest in the states of Uttar Pradesh (72 Mt) followed by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7 Mt).

Table 1: State-wise crop residue generation (mt/yr) per year by different crops (Jain *et al.*, 2014)

States	Crop residue generated per year (mt/yr)			
	Cereal	Fiber	Oilseed	Sugarcane
Haryana	24.73	7.58	2.15	1.93
Himachal Pradesh	1.95	0	0.01	0.02
Jammu and Kashmir	2.76	0	0.11	0
Punjab	45.58	9.32	0.08	1.76
Rajasthan	22.19	2.96	9.26	0.15
Uttar Pradesh	72.02	0.04	2,49	41.13
Uttarakhand	2.4	0	0.03	2.11
Andhra Pradesh	33.07	16.07	2.5	5.8
Gujarat	8.18	28.62	5.06	5.85
West Bengal	37.26	24.43	0.95	0.62
Maharashtra	8.75	19.51	0.57	22.8

Consequences of paddy stubble burning

Paddy stubble burning causes deleterious impact on both biotic as well as abiotic components of the ecosystem. The burning of crop residues has become an essential source of atmospheric pollution in India especially during paddy harvesting seasons embody the emission of green house gases causing sudden surge in the temperature leading to climate change at regional as well as global level having adverse impacts on health of human population, biodiversity and soil fertility with decreased crop output. Burning of paddy residues leads to the following impacts:

A) On environment: The illicit practice of burning crop residues generates various environmental issues. The most adverse effects of crop residue burning embody the emission of greenhouse gases (GHGs) that contribute to global climate changes. The enhanced level of particulate matter and other pollutants that cause health hazards, loss of diversity of agricultural land, and the degradation of soil fertility. The burning of the crop stubble in an open field influences soil fertility, eroding the sum of soil nutrients.

I) Air pollution: Crop stubble burning performed after the rice crop harvesting changes the chemistry of ambient air of the region like-

1) Depletion of air quality owing to aerosols and trace gas emission: The process of uncontrolled combustion emits carbon dioxide (CO_2)- the principal outcome of the incineration, in the atmosphere is a major GHG along with carbon monoxide (CO), unburnt carbon (as well as traces of methane i.e. CH_4), nitrogen oxides (NOx) and comparatively less amount of sulphur dioxide (SO_2). All of these are major GHG's acting as one of the main reasons of Global warming and acid rain bringing out severe weather anomalies.

2) Liberation of soot particles and causing smog in the environment: All emissions that generates due to residue burning like particulate matter mainly PM 2.5 being extremely light weight and fugitive, can stay in the air for a long time, causes smog and travel hundreds of miles along with wind. After stubble blazing huge quantities of particulate matter (PM), including PM of 10 microns or less (PM_{10}) and 2.5 microns or less ($PM_{2.5}$) are released into the atmosphere, causing negative impacts on human health because particulate matter release into environment causes people to die from cardiorespiratory diseases (Montes *et al.*, 2022; He *et al.*, 2020). The smoke from these emissions outflows through unplanned exit routes in the downwind direction.

II) Global warming: Burning of rice residue emits various trace gases, such as carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrogen oxides (NO_X), and sulfur oxides (SO_X). All these gases are the main drivers of exacerbating climate change and global warming. Arai *et al*. (2015) monitored GHGs emissions from a triple rice cropping system located in the central Mekong Delta of Vietnam where burning of rice straw is the common practice because of limited time period to prepare for next crop where they found that straw stack with higher moisture content emitted more carbon monoxide (CO), CH4 and NMVOC (non-methane volatile organic carbon). These gases have been proven to influence human health in a negative way in addition to their global warming potential (Oanh *et al.*, 2006; Arai *et al.*, 2015). Most studies consider the GHG emissions from burning to be much lower than the emissions from fresh straw incorporation without taking CO_2 emissions into account. However, if the CO_2 emissions are included, the immediate loss of a major percentage of carbon (C) makes the global warming potential of burning very close to that of the fresh straw incorporation (Lu *et al.*, 2010).

III) Weather anomalies: The many issues linked to the suddenly raised temperatures because of stubble blazing leads to global warming and sudden heat waves in the region changing the pattern of rainfalls.

IV) Soil health imbalance: Residue burning has unfavorable impact on soil fertility as well as productivity because crop stubble in an open field generates pollutants and enhanced levels of PM influencing soil fertility, eroding the sum of soil nutrients directly causes deterioration of soil fertility.

1) Deterioration in soil health: Burning of farm yield residue also increases ozone concentrations in the lower atmosphere farm residue burning elevated the soil temperature up to 33.8-42.2 ◦C, up to a depth of 1 centimeter (cm), which affects soil ecology. Thus, because of the elevated soil temperature, about 23-73% of the nitrogen in various forms is removed from the soil, and the beneficial microbial population also declines to the depth of 2.5 cm in the soil.

2) Reduction of soil fertility and crop productivity: The residue burning increases the temperature of the soil to a significant extent, which results in rapid changes in the carbon-nitrogen (C-N) equilibrium in the upper 3 inches of soil. The carbon is emitted to the atmosphere in the form of CO2, and nitrogen is converted to nitrate. From this process, approximately 824 thousand mt of nitrogen, potassium, and phosphorus (NPK) nutrients are lost from the soil (Kumar *et al.*, 2015) leading to loss of plant nutrients resulting in loss of vegetation (Mandal *et al*. 2004).

B) On biodiversity: Microbial size and activity are greatly influenced by residue incineration, but this is dependent on the intensity and duration of the burning. According to Gupta et al. (2004), soil temperatures can reach 43 C, with the top 2.5-3.5 cm soil layer being the most affected. The main reasons behind disrupted microbial activities are 1. direct effect of heat on microbial physiology 2. Change in substrate quality and quantity, as well as nutrient dynamics 3. formation of various toxic compounds such as polychlorinated dibenzo-p-dioxins, dibenzofurans, and polyaromatic hydrocarbons (PAH) (Kim *et al.*, 2003; Knicker, 2007). The impact of burning is more severe on fungi than bacteria; however, the impact on the microbial community is temporary, and the severity is greater on the mesothermic population.

C) On human population: Health risks resulting from environmental effects are a major source of concern all over the world. Air has always been a matter of basic concern due to its direct contact with the human physiological system. For centuries, human beings have been exposed to suspended particulate matter (SPM) from dirt and many other anthropogenic sources like biomass burning for cooking, warmth and for other personal benefits (Sint *et al.*, 2008). Nowadays, among other sources, agriculture crop-residue burning (ACRB) is one of the important anthropogenic sources of air pollution (Mittal *et al.*, 2009). Emission of air pollutants due to open burning of various materials is of concern to the public as well as various environmental and health regulatory agencies Air pollution contributes to the respiratory diseases like eye irritation, bronchitis, emphysema and asthma, which not only increase individuals' disease mitigation expenses but also affect their productivity at work. The ambient air which we breathe may have a significant effect on their working and functioning of lung and pulmonary function tests.

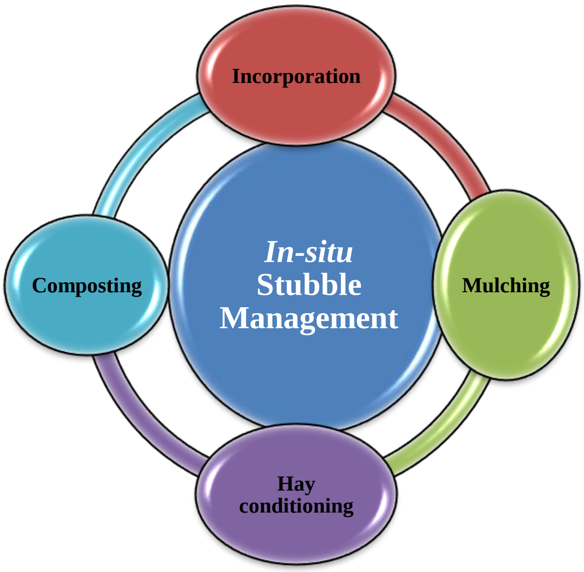
A number of side effects of the GR on human health have been identified Biomass burning is also a major emission source of polycyclic aromatic hydrocarbons (PAHs), a class of organic pollutants that receive great public concern due to their widespread occurrence and toxic effects on ecological safety and human health. India has been ranked the second largest emitter of PAHs in the globe, next to China.

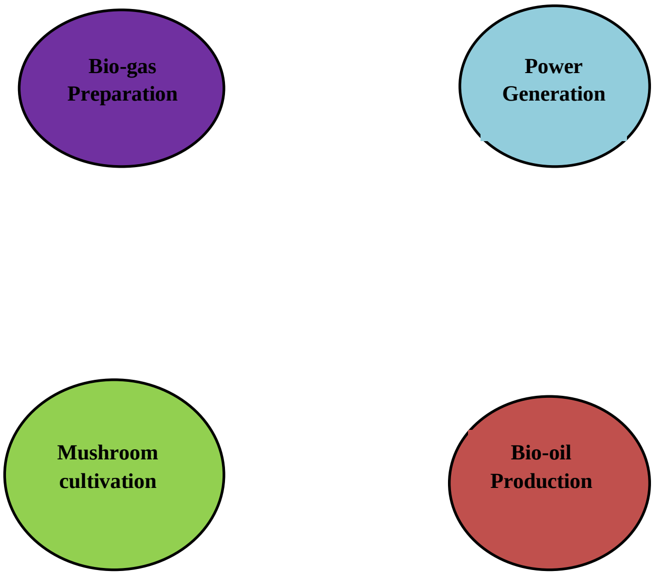
Management strategies:

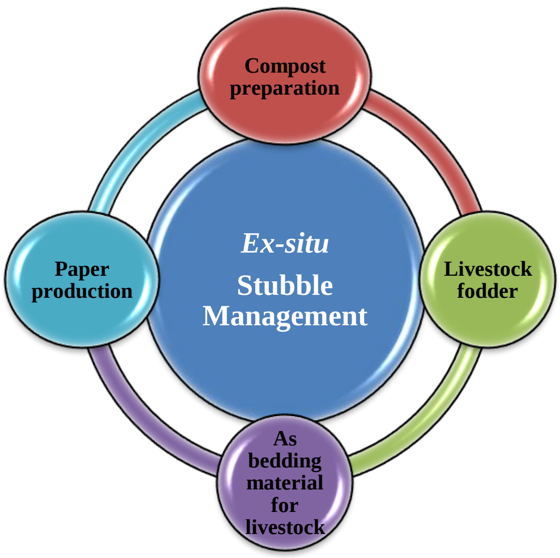
In order to implement sound selections of alternative crop residue management methods, it is necessary to scientifically perceive the short and temporary effects of various crop residue management practices and to develop new residue management technologies that are cost-efficient and environmentally acceptable.

Crop residue management choices should be measured on the premise of productivity, gain, and environmental impact. These criteria would overlap with those employed in the approach of ecological intensification for intensive crop production systems aiming to fulfill the increasing demand for food, feed, fiber, and fuel, while meeting acceptable standards of environmental quality. The best management approach is to tackle the problem at its base through the adoption of precautionary and preventive techniques. Some management practices are presented in the subsequent sections.

Eclectic burning of rice residue possesses a horrible threat for the ecology and society. due to a lack of user-friendly, cost-effective, and time-effective alternatives, farmers often choose to burn paddy straw in combine-harvested fields But, wasting this valuable resource is highly irrational because it has industrially and domestically multipurpose use from production of compost to power generation. Management strategies of rice residue is majorly sub-divided in two section namely *in- situ* and *Ex-situ*.







1. *In-situ* management: Paddy residues are an important natural resource and the recycling of these residues improves the physical, chemical and biological properties of the soil. *In-situ* management of paddy means on site management of paddy stubble by amalgamation of the stubble into the soil of the field in its natural environment either by retention of biological degradation. The benefits of retention of crop remain on the soil surface are:

i) Lesser weed growth thus, saves weedicide cost.
ii) Improves physical, chemical and biological attributes of soils.
iii) Prevents nutrients leaching; increase cation exchange capacity (CEC) and helps in recycling of plant nutrients hence, lower fertilizer use in the next successive crops.
iv) Enhances enzyme activities such as dehydrogenase and alkaline phosphatase.
v) Helps in soil moisture conservation by reducing evaporation losses up to 45 mm and increasing water holding capacity by 5-10% during the wheat growing season.

Straw incorporation, Straw mulching, Straw Composting and Hay conditioning are the suggested methods of *In-situ* management which are discussed under one by one:

a) Straw incorporation

The inclusion of the agricultural stubble into the soil is one of the best strategies for managing them. It increases soil fertility and helps in maintaining its organic matter content (Khaiwal *et al.,* 2018). Incorporating straw into the soil improves its nutrient levels (which would have been otherwise burnt) and enhances its productivity. Straw incorporation practice is mostly adopted when rice is followed by potato or other crops because of the misconception that under paddy-wheat rotation, its adoption is insignificant as it may decline the yield however several researches have proved otherwise. The stubble straws contain the vital nutrients essential for plant growth, i.e. nitrogen, potassium, and phosphorus. Stubble compost contains 1.7 to 2.1% of nitrogen, 1.5% phosphorous, and 1.4 to1.6% potassium and hence, improve crop yield by 4 to 9%. Incorporation or amalgamation of crop residues into soil increases the soil's OC by 14-29%. Incorporation of stubbles into the field is the easiest way to manage it. However, Farmers don't prefer *In-situ* incorporation as the stubble takes time to decompose in the soil that may adversely affect the wheat productivity in various ways such as late sowing of wheat and immobilization of inorganic nitrogen and its adverse effect due to nitrogen deficiency. Incorporation of crop stubble requires more tillage operations than of post burning. Machineries used for straw incorporation are:

1. **Paddy straw chopper**: It is used for chopping the paddy stubbles in smaller pieces of 7-10cm for easy incorporation of paddy straw into soil to get clear fields for wheat sowing.

2. **Super SMS**: It is additional equipment attached with combine machines. It cuts the standing stubbles into smaller pieces and spread evenly on the field. Direct drilling of wheat seeds can be done using happy seeder machine in paddy residues chopped and spread using Super SMS in combine machines.

3. **Rotary-till-drill**: The rotary-till-drill is a single pass soil pulverization and seeding machine. The sowing of wheat is completed in a single tractor operation leading to substantial savings on fuel and time required for conventional field preparation. This machine simultaneously incorporates anchored crop residue during seeding. It can also be used for pudding operation in rice cultivation

b) **Straw mulching** After rice crops have been harvested in the fall, this rice straw is used as mulch in the agricultural field. Rice straw is lightweight, biodegradable, and neutral in pH. Rice straw mulching has a significant effect on conserving initial soil moisture and reducing weed growth. Mulching is practiced where rice is followed by wheat. The ability to conserve the soil fertility and judicious application of water is perceived as the backbone to achieve the sustainability of the agricultural system. This is more significant for the areas where the atmospheric conditions are harsh. The agricultural waste is spread between the rows and plants to conserve the soil, preserve the soil moisture and control the weed growth. As the plants are biodegradable, they get dissolved in the soil at the later phase and contribute to the soil fertility status. The current trend is to use plastic mulching with different colours to check the impact on pest infestation and productivity of crops. These plastic mulches are laid with the help of manual, engine-operated, tractor-drawn and self-propelled mulchers with an ability to spread drip irrigation channels below the mulched layer. Machinery used for retention of paddy straw as mulch on soil is:

Mulcher: Mulcher with vertical axis of rotation is a rotation mower. It is used to chop the straw into smaller pieces which are then pressed by a roller attached at the rear side. It will compress the straw creating a mulch layer over the top soil. Afterwards Happy Seeder or reversible MB plough can be used to sow wheat or invert straw into the soil, respectively.

Happy seeder/super seeder: These are tractor-mounted machines that cuts rice straw into soil and deposit straw over the sown area that acts as mulch, it is an eco-friendly as it reduces air-pollution and green-house gas emission per hectare by 78% relative to burning.

Zero-till seed drill: With the significant increase in the adoption of zero-tillage and bed planting technologies in several areas of the Indo-Gangetic Plains, zero-till seed drill has become a very useful and important agricultural machine for the farmers. It helps them to seed a crop directly into the cultivated field just after the harvest of the previous crop with the least disturbance of the soil. It eliminates or reduces time and energy intensive conventional tillage operations reducing the cultivation costs.

c) **Straw composting:**

Compost preparation: The compost from agricultural stubble is rich in nutrients and therefore improves the productivity of the soil and crop yield by about 4-9 %. Composting produces nutrient-rich substance (compost) which contains nitrogen (2%), phosphorus (1.5%) and potassium (1.4-1.6%). The two methods to produce compost are:

1) Mechanized windrow composting

This technique uses mechanical aeration with a windrow turner to enhance aeration and speed up the composting process. The compost from this process is also rich in nutrients good for vegetable crops (Gummert *et al*. 2020).

2) Vermi-composting

Stubble Vermi-composting- generation of compost using earthworms and microorganisms to biologically oxidize and stabilize the organic material in the stubble producing stable and finely divided compost having high porosity, rich in nutrient content and good water holding capacity which significantly improves the productivity of the soil.

Vermin-stubble composting is conducted in two stages; anaerobic followed by aerobic process, each following 40 days period (Gummert *et al*. 2020). The earthworms are introduced during the aerobic stage to effectively condition the substrate and help alter its biological activity. Mixing of cow dung with stubble from wheat, millet, sugarcane, and pulse helps to generate highly valuable vermicompost.

d) Hay conditioning:

The agricultural grass is harvested by means of mowers at a height of 3–10 cm from the ground. The mowers can be engine-operated, tractor operated or self-propelled. The harvested grass is spread uniformly over the surface by means of tractor-operated tedders. These tedders are used to turn the grass in order to ensure faster curing (drying). The dried grass is collected in the form of windrows using tractor-operated rakes. The windrow of grass is then compressed into high-density bales to decrease its volume and increase its weight. The bales are then transported and stored for future use. The process of mowing, tedding, raking and baling are the sub-constituents of 'hay conditioning'.

2. *Ex-situ* management:

In *Ex-situ* management of paddy stubble, the residues are collected and transported to some other place where they are disposed or used for various off-farm purposes such as Power generation in bio-thermal power plants, cardboard making, mulch mats, ethanol production, as livestock feed, for mushroom cultivation, for animal bedding and compost, for bio-oil production. After collection of paddy stubble, these are transported to other places where they are kept and utilized for several purposes. The machinery used for *Ex-situ* management of stubble is:

(i) **Raker**: Raker is used for making windrows of harvested stubbles. To increase the capacity of straw baler, raker is operated to collect in rows after using shrub master. This reduces the number of pass of baler to collect straw for baling and thus field capacity is increase.

(ii) **Baler:** Straw baler collects the paddy straw and compress into bales for easy transportation to far flung area which then can be used for making packing material, card boards, biogas preparation and electricity generation.

***Ex-situ* utilization of paddy stubble:**

1. **As livestock fodder:** Wheat and maize straw residues is used as primary source of animal feed in Northern India nevertheless its high silica content, rice straw is used in first place in southern part of country. Rice husk is crushed into fine powder and fed to animals particularly, cattle in southern India. On the basis of crop residue requirement and availability statistics, green fodder demand is 221.63 MT whereas availability is 142.82 MT with nearly 36% shortfall, and for crop residue as feed, 415.83 million tons (MT) is required while only 253.26 MT of crop residue is available showing 40% shortage in livestock feed in the form of crop residue.
2. **As bedding material for livestock:** Paddy straw as bedding material for cattle sheds is commonly practiced in southern India however, now a day, on government recommendations; it is also practiced in northern parts during cold seasons because it provide (i) comfort by keeping the animal warm by regulation of body's heat loss (ii) leg and udder health (iii) improvement in quality and quantity of milk production as Healthy legs and hooves contribute to increased milk production and reproductive ability in

livestock (iv) creates a safe, hygienic, secure, dry, and gripping atmosphere, reducing the likelihood of lameness and injury.

3. **Paper production:** The technology of using paddy and wheat straws in conjunction with the 40:60 ratios to produce paper is common in paper mills now a day meeting 60 % of their energy requirement. The sludge left over after paper making can be subjected to bio-methanization for energy production. Paddy straw is also used as an excellent ideal raw material for paper and pulp board manufacturing.
4. **Mushroom cultivation:** The basic requirement for mushroom cultivation is the presence of a base material that helps fungus to grow and transform into an edible mushroom. The lignocellulosic agricultural wastes such as rice and wheat straw are commoly used as substrates and mediums for the fungus. It is a case of nutrient recycling, where the nutrients in the agricultural wastes are extracted and utilized for the production of mushrooms. The use of rice straw for mushroom cultivation is an eco-friendly ecologically sustainable, economically viable method of agricultural waste management and profitable agribusiness endeavor. The substrates are chopped, mixed with other ingredients and then placed in polythene bags of 5 kg or 10 kg before the addition of spawn (seeds). The spawn (seed) is added in two ways:

1) Spawn mixed with ingredients uniformly and filled in bags.
2) Spawns added in layers at the outer circumference of the polythene bags.

First case includes the addition of spawn seeds at the time of mixing and then filling in polythene bags with the help of a machine that fills only one bag at one time while in second case, the ingredients and spawn are added in layers where spawns are placed at outer circumference of layers. Small holes are made in polythene bags to allow spawn growth and germination.

On an average, 50–100 kg of mushrooms can be produced from 1 ton of dried rice straw as base material. Paddy straw can be used for the cultivation of Agaricus bisporus, *Volvariella Volvacea* and Pleurotus spp. Volvariella volvacea, also known as paddy straw mushroom because of their cultivation on paddy straw South Asia is high temperature mushroom of short incubation period of 14 days grown largely in tropical and subtropical regions of Asia, e.g. China, Taiwan, Thailand, Indonesia, India, and Madagascar; is one of the easiest mushrooms to cultivate. The basic requirement for mushroom production using paddy straw is paddy straw (60/cage bundles), spawn bottle (2/cage), wooden cage 1 no. (1m x 50cm x 25cm), 1 drum (100-ltr capacity), polythene sheet (4 meters), binding thread (3 meters), sprayer/rose can, Dithane Z-78/ Bavistin (200 gm), Malathion (250 ml), Dettol/Formalin (1/2 liter), Dao (hand chopper), and thermometer (Ahlawat and Tewari, 2007). Paddy straw mushroom accounts for 16 % of total production of cultivated mushroom in the world.

5. **Bio-gas preparation:** Rice straw can be used to generate fuel, heat, or electricity through technological interventions such as thermal, chemical, or bioprocesses. The conversion of biomass into energy in anaerobic conditions with the active involvement of microorganisms is gaining traction these days as the degradation of the agricultural biomass is accompanied by the liberation of methane and carbon dioxide, known as biogas. Biogas contains methane, carbon dioxide, hydrogen sulphide, ammonia, nitrogen and carbon monoxide with a calorific value of 4500 $kCalm^3$. Biogas can be used for the generation of heat, electricity and engine operation. Approximately 300 m^3 of biogas

(consisting of 55–60% methane) can be generated from the anaerobic digestion of one tonnes of paddy straw. The spent slurry produced in this process can be further used as manure in the crop field. In this way, paddy straw can be used to generate high-quality fuel gas in a non-destructive way along with manure which can be recycled in the soil. The biogas collected can be used for lighting, cooking and engine operation as fuel. The generation of the biogas from agricultural wastes can help to lower the greenhouse gases responsible for global warming. As per one estimate, the households utilizing biogas produce 50% lower greenhouse gas emissions than non-biogas households.

In batch anaerobic digester rice straw and cattle dung are arranged layer by layer with the top layer as cattle dung to cover up all substrates. Based on the weight, the ratio of rice straw to cattle dung is kept as 4:1 (1.6 tons of chopped straw with 15–18% MC and 0.4 tonnes of cow dung with 30–40% MC) and fed into a batch digester for 100–120 days. Biogas is generated on the 7th day of feeding, and gives an average yield of 4–5 m^3 /day in about 100 days. Fossil fuels can be replaced by biogas as an alternative, which is produced from agricultural wastes. Agricultural crop residues particularly, rice straw is a major source of lingo cellulose which is required in the production of biogas.

6. **Bio-ethanol production:** Bioethanol is produced by enzymatic hydrolysis of paddy straw that converts straw biomass into fermentable sugars such as glucose and xylose. Rice straw is pre-treated with alkali solution followed by enzymatic saccharification by the culture of fungus and yeast which ultimately produces bioethanol. This bioethanol can be used as motor fuel or as an additive in gasoline.
7. **Bio-oil production:** Bio-oil - a high density liquid with 55% more heating value than diesel can be obtained from biomass through rapid pyrolysis technology. It can be stored, pumped and transported like petroleum based product and can be combusted directly in boilers, gas turbines and slow and medium speed diesels for heat and power applications, including transportation. Further, bio-oil is free from SO_2 emissions and produces low NO_2. Certain Canadian companies (like Dyna Motive Canada Inc.) have patented technologies to produce bio-oil from biomass including agricultural waste.
8. **Power generation:** The use of rice straw alone or in conjunction with coal in a power plant is regarded as a viable source of energy. According to Datta *et al.*, 2020, burning residues in a boiler or gasifier under zero or low oxygen conditions at high temperatures converts the residues into producer gas (calorific value: 1000-1200 Kcal/Nm3 and composed of CO, H, and N) with a lower calorific value than liquefied petroleum gas while posing no environmental threat. A gasifier with a capacity of 1 Kilowatt-electric (kWe) requires nearly 8 tonnes of paddy straw. Reasons for suitability of rice straw for energy sector are:
   1. Very high calorific value (3950 Kcal per kilogram of straw versus 4200 Kcal of coal)
   2. Very less ash content (18% ash over 36% in case of coal)
   3. Renewable, Environment friendly and readily available.
   4. Can be burned easily in boiler with efficiency of almost 100%
   5. Additional income for farmer and for millers as they can directly sell the electricity to the power plants.

6. By-product generated from the power industry e.g. brick ash or fire ash could potentially be used in the cement industry
7. Less capital intensive over the conventional power industry.
   The major issue of using paddy straw is corrosion of inner wall of boiler due to alkalinity formed due to reaction of alkali and alkali earth metals with chlorine (Cl) and silicon (Si) (Singh *et al.,* 2015). This indicates cultivars with lower Si content in the leaf are most suitable for power generation.
8. **Miscellaneous use** – 1. Pelleting for utilising it in the industrial boiler or gasifier using hydraulic compressor (Verma, 2014).

2. Fine sized straw (1.5–2 mm) can be blended with polypropylene for reinforcing (Verma, 2014).

3. Mixing with wood and preparation of engineered wooden material or manufacturing of hardwood materials (Lohan *et al.,* 2018).

4. Making home décor materials.

5. Rice straws (bales) for controlling soil erosion (Bhattacharyya *et al.*, 2021)

6. As packaging material, raw material in briquetting and as straw mats

Paddy Stubble Blazing			
Reasons	**Effects**	**Management**	
Labour scarcity Short time limit for wheat sowing Lack of acceptance as fodder Weed and Pest management Slow rate of decomposition Storage problem To save energy Farm mechanisation	**Health and productivity** Carbon stock and nutrient dynamics Impact on soil biodiversity **Human Health** Poor vision Respiratory and Cardiovascular diseases Carcinogenic **Ecosystem** Global warming Acid rain Environment pollution Weather changes	***In-situ*** Paddy straw mulcher Happy seeder/super seeder Rotavator Straw chopper Super SMS Combine harvester with SMS Zero tillage Bailer Microbial and biological decomposition	***Ex-situ*** Power generation in bio-thermal plants Ethanol production Cardboard making For mushroom cultivation For animal bedding and compost As livestock feed Cardboard and mulch mat making

Conclusion:

The agricultural waste management is most debated topic in recent times because of its hazardous effects on environment and human life demanding appropriate management strategies to cope up with the negative effects. Technical solutions are majorly categorized into: On-farm (*In-situ*,) such as straw chopper, super SMS, happy seeder and Off-farm (*Ex-situ*), techniques like power generation, cardboard making for which only a few farmers have awareness. Farmers have numerous options in managing straw including use as cattle feed, mushroom production, bio-thermal plants, paper industries, mulching, soil incorporation etc. Happy seeder is one of the finest inventions which gave a major alternative to stubble burning. The main problem faced by farmers during management of paddy straw is cost, time, handling, supply chain discontinuities and lack of knowledge. The conversion of agricultural wastes is imperative to protect human health, environment and arrest global climate change. The 'waste to wealth' can ensure income augmentation of the farmers and sustainability of the agricultural system.

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SYMPTOMS OF POISONING, FIRST AID MEASURES AND ANTIDOTES-CROP PROTECTION PRODUCTS

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Abstract:

In agriculture, synthetic pesticides are widely employed to manage dangerous pests and avoid crop output losses. Pesticides may have unfavourable effects on the environment and human health because of their high biological activity and, in certain cases, long persistence in the environment. The amounts of pesticide exposure that farmers often endure are typically far higher than those that consumers experience. The preparation, use, and cleaning of pesticide spraying equipment expose farmers to the biggest risk. Farmers' exposure to pesticides can be decreased by using less pesticides and by using the right personal protection equipment at all times when handling pesticides.

Keywords: Synthetic pesticides, Harmful effects, Protection,

Introduction:

Poisoning of Crop Protection Products (CPP)

According to the UN food and agricultural organisation, farmers lose 30 to 40 percent of their crops due to pests and diseases worldwide. Farmers uses the chemicals to control weeds (herbicides), diseases (fungicides), pests (Pesticides). Frequent and unscientific use of very toxic pesticides in high quantities put farmers' health and livelihoods at serious hazard. Pesticides can enter in to the human body through different routes such as dermal (through skin), Oral (through mouth) or inhalation (through nose).

A pesticide's toxicity refers to its ability to harm a living system, which can include the ecosystem, a pond, a forest, and the organisms that inhabit there, as well as the human body or specific bodily components (such as the lungs or respiratory system). The fundamental principle of safety in the use of CPP is to prevent poisoning by exercising care. It is easier to prevent poisoning than to treat it. Different CPP act differently on the human body and the mechanism, and the mode of action varies for different insecticide, herbicide, and fungicide. Some general symptoms however apply.

Symptoms of Poisoning:

Improper use of pesticides may result in toxicity, which is refers to the ability of pesticide to produce adverse effects. Adverse effects may range from headaches to coma and convulsions which is identified by mild or moderate or severe symptoms of poisoning. Antidote is a substance which can counteract a form of poisoning.

Table 1: Various degrees of symptoms of poisoning

S.No	Mild poisoning	Moderate poisoning	Severe poisoning
1.	Headache	Vomiting s	Convulsion
2.	Nausea	Blurred vision	Respiratory failure
3.	Dizziness	Stomach cramps	Loss of consciousness
4.	Fatigue	Rapid pulse	Loss of pulse
5.	Irritation of skin, eyes, throat, nose	Breathing difficulty, Constricted pupils	
6.	Perspiration	Excessive precipitation	
7.	Loss of appetite	Trembling and twitching of muscles.	

Specific actions are required for specific poisoning cases, depending upon the route of exposure and the type of CPP. These are described in detail for the type of exposure

Oral exposure: is rare when compared to other routes of exposures. When it does occur, it poses the exposed person considerable danger. The first point is to identify the poison swallowed. If patient is conscious and has muscular control, induce vomiting immediately. This can be done by asking the patient to drink one to two litres of salted water and tickling the throat. A stomach wash performed by the doctor also assists in flushing the poison out of the system. Medical charcoal can be added to salt water. In case the swallowed CPP is an emulsion concentrate, the process of vomiting should be preceded by administration of a suitable demulcent such as beaten egg, milk of magnesia or even a starch solution. This helps in soothing the irritated surfaces.

Dermal exposure: Dermal exposure is by far the commonest source of exposure. This is mainly because the user is generally not careful enough about avoiding dermal contact with CPP. Also spills, if they occur, can sometimes go unnoticed. Prompt action, taken immediately on exposure, can normally prevent any development of poisoning. First aid measures include thorough washing of the exposed surface of the skin with soap and water. Plentiful clean running water is essential. If clothing is contaminated, it should be removed. Special care should be taken in washing of hair and skin tissues between toes in case the exposure is in the eyes the best procedure is to wash eyes immediately with a gentle stream of clean running water. The eyelids should be held open with the patient in supine position. The head should be tilted slightly towards the side of contaminated eyes. Clean water should be poured into the eye in a small continuous stream from a distance of about 6 to 8 inches. This process should be continued for at least 10 minutes. No chemical or drug should be added to the water. Normally eye irritation should stop with this treatment. If it continues, medical attention must be obtained immediately

Inhalation exposure: This exposure is one of the most common cases of CPP exposure. It happens most frequently while working in closed and poorly ventilated areas.

The toxicity of a pesticide varies person to person depending on:

A. Health conditions: Those who are sicker tend to be more sensitive.
B. Age: Most sensitive people tend to be the youngest and oldest.
C. Gender/sex: Females are more sensitive.
D. Body size: the effect of a dose is closely related to body weight.

Effects of Toxicity

a. Reproductive effects: effects on the reproductive system

b. Teratogenic effects: impacts on unborn children (birth defects)
c. Carcinogenic effects: makes live animal tissues cancerous.
d. Mutagenic effects: irreversible modifications to the genetic code that are inheritable.
e. Neurotoxicity: poisoning of the nervous system, including the brain.
f. Immunosuppression: blocking of natural responses of the immune system of the bodies

First aid for pesticide poisoning:

Pesticides can enter in to the human body through different routes such as dermal (through skin), Oral (through mouth) or inhalation (through nose) and accordingly first aid should be done. Speed is of essence in the treatment of any CPP relevant incident. With quick treatment it is possible to prevent a CPP exposure from a CPP poisoning People can take ill from other natural causes also. It is therefore important to first establish whether a CPP is involved in the illness or not. The layman can render first aid only. It is important to leave the treatment to a doctor and all efforts should be made to seek medical advice and care as soon as possible

A. Pesticide spilled on the skin or clothing

Remove all outerwear right away, then thoroughly wash the skin with soap and water.

Certain insecticides are quickly absorbed through the skin. To avoid contaminating other clothes, wash any contaminated apparel separately. Getting rid of badly contaminated garments might be ideal.

B. Pesticide inhaled:

First, get the victim to fresh air. Have the victim lie down and loosen all clothing. Keep the victim warm, and administer first aid if needed. Contact a physician as soon as possible.

C. Pesticide swallowed.

I. Don't induce vomiting.
II. Usually, it is best to void the swallowed poison fast, but never induce vomiting if the victim is unconscious or is having convulsions.
III. The words "emulsifiable concentrate" on the pesticide label are signals not to induce vomiting.
IV. Never induce vomiting if the victim has swallowed a corrosive poison, a strong acid or alkali (base). The victim may experience severe pain and have extensive mouth and throat burns.

First Aid: Speed is of essence in the treatment of any CPP relevant incident. With quick treatment it is possible to prevent a CPP exposure from a CPP poisoning People can take ill from other natural causes also. It is therefore important to first establish whether a CPP is involved in the illness or not. The layman can render first aid only. It is important to leave the treatment to a doctor and all efforts should be made to seek medical advice and care as soon as possible.

Almost all CPP have recommended antidotes. Antidotes are drugs and chemicals which counteract the effect of the CPP. They do not prevent poisoning, but once poisoning symptoms are developed, they counteract that action. Therefore, antidotes are not prophylactic and should not be used routinely, prior to handling the CPP. Administration of specified antidotes should be left to the doctor. Most antidotes are themselves poisons, and if used, without professional medical care, can cause greater damage than the CPP itself.

Table 2: Symptoms of poisoning, first aid measures and antidotes-crop protection products

Sr. No	Name of CPP	Symptoms of poisoning	Antidote/specific drugs
1.	Neonicotinoid (Acetamiprid, Clothianidin, Imidacloprid, Thiacloprid and Thiamethoxam)	Apathy, Myotonia, Tremor, Difficult Breathing and Myospasms, Nausea, vomiting, headache, dizziness, stomach-ache, decrease spontaneous movement, tonic convulsion and ptosis may occur.	No specific antidote is known. Treat Symptomatically
2.	Chloroacetanilides (Acetochlor Alachlor Butachlor)	Headache, nausea, vomiting, Giddiness, Diarrheal, vertigo, sweating, blurred vision, Salivation, Excessive lacrimation, Mild to moderate skin irritation	Treat symptomatically. Give the patient common salt in a glass of warm water followed by active charcoal 2 parts, Tannic acid 1 part and Magnesium Oxide 1 parts.
3.	Anthranilic diamide (Chlorantranilliprole, Cyanoantranillprole)	headache, dizziness, weakness, and nausea	There is no specific antidote. Treat symptomatically.
4.	Pyrethroid poisoning (Alpha cypermethrin, Cypermethrin, Lambda-cyhalothrin, Deltamethrin)	Nervousness, anxiety, tremor, ataxia, convulsion, Salivation, vomiting, Skin allergies, Sneezing, runny nose, irritation, stuffiness of the nose. Some individuals are more sensitive than others	No specific antidote is known, Treat symptomatically. Antihistamines may be given to control allergies
5.	Carbamates (Carbofuran, Carbaryl, Fenobucarb, Methomyl)	Headache, nausea, dizziness, Vomiting. Abdominal pain, Profuse sweating. Constricted pupils, Muscular incoordination, tightness in chest, Convulsions, Muscle tremor, blurred vision, abdominal cramps, diaries, Coma and death may occur.	Atropine sulphate should be used for treatment. Administer repeated doses, 1.2 to 2.0 mg Lv every 10 to 30 minutes until full atropinisation is achieved. Maintain atropinisation until the patient recovers Artificial respiration of oxygen may be necessary
6.	Organophosphorus insecticide (DOVP Malathion, Methyl Parathion)	Headache, giddiness, vertigo, nausea, vomiting, blurred vision, diarrhoea, convulsions, sweating. Excessive lacrimation, and salivation may occur	1. Atropinism the patient immediately and maintain full atropinisation by repeated doses of 2 to 4 mg. of atropine sulphate intravenously at 5 to 10 minutes interval.

			2. Dissolve 1-2 gm of 2 PAM in 10 ml distilled water and inject intravenously very slowly for 10-15 minutes.
7.	Bipyridiniums(paraquat)	Irritation, nose bleeding, abdominal discomfort, looseness of bowels and signs of liver and kidney Failure etc.	1. For ingestion, lavage stomach with at least 2 litters of normal saline or 5% sodium bicarbonate. Institute a slurry of 8-10 oz of absorbent (egg fuller's earth).
8.	Copper Compounds Copper hydrazide Copper oxychloride)	Vomiting, stomach-ache, diarrhoea, metallic taste in mouth, headache, and cold weak pulse sic.may occur.	1. Empty stomach by gastric lavage with milk or preferably sol of Potassium ferrocyanide Administer egg white and other demulcents Maintain electrolyte and fluid balance Morphine and Pethidine may be given to control pain. 2. Dimercaprol is given in the dose of 3mg g every four hours for first four days
9.	Organic acid and derivatives Ethephon Glyphosate, Kitazin MCPA and TCA	Vomiting, pain in chest and abdomen, diarrhoea Severn poisoning: Headache, mental confusion and blame behaviour, myotonia and muscle weakness	1. For ingestion lavage stomach with tap water. Instil 30 gm activated charcoal in 3-4 oz of water catharsis with 15 gm sodium sulphate in 6-8 oz of water.
10.	Triazoles (Epoxiconazole, Tebuconazole, Flusilazole, Paclobutrazol)	Weakness. Fatigue, Dyspnoea, Sedation and eye ration, abnormal posture may see	There is no specific antidote
11.	Urea triazene derivatives (Diuron)	Moderate skin, eye and mucous membrane irritant, may cause diarrhoea and vomiting.	If ingestion is of less than 10 mg/kg, the preferred treatment is administration of activated charcoal. If over 10 mg/kg, give syrup of ipecac.

12.	Aluminium Phosphide fumigants	Headache, nausea, giddiness, blurred vision, dry cough, dyspnoea, chocking or vomiting sensation and loss of muscle co-ordination. Invariably fatal if inhaled	Gastric lavage with 1: 5000 potassium permanganate solutions. In case of pulmonary edema give hypertonic glucose solution intravenously. No specific antidote, treat symptomatically.
13.	Avermectin	Early symptoms of poisoning may be a combination of dilation of pupils, muscular in coordination, ataxia and muscle tremors	There is no specific antidote
14.	Di thiocarbamate (Mancoast, Zineb)	Headache, Itching, tightness in chest, palpitation, hypotension. Nausea, abdominal pain, vomiting, diarrhoea. Hypothermia and ataxia may occur. When inhaled as fine dust irritation to bronchi tubes and lungs tissues.	There is no specific antidote
15.	Thiocarbamate	Headache, nausea, vomiting, abdominal pain, diarrhoea, irritation bronchial, lungs, nose, throat,eyes skin may occur.	Not alcohol complicated 1. Lavage stomach with tap water. Instill 30gm of activated charcoal in 3-4 oz of water. 2. Sodium sulphate cathartic Alcohol complicated 1. 100% oxygen for symptomatic relief 2. Lavage stomach with tap water. Instill 30 gm activated charcoal in 3-4 oz of water. 3. sodium sulphate cathartic 4.1 gm of vit. C intravenously not exceeding 0.2 gm/min. 5. infuse with 5% glucose solution. 6. watch for complications

General First Aid Measures for CPP Exposure Cases Are as Under:

- Remove patient from the source of contamination
- Remove contaminated clothing and bathe the patient
- Wash the patient thoroughly with plenty of soap and water
- Keep the patient calm, comfortable and warm
- Take steps to obtain immediate medical attention
- Identify, as accurately as possible, the product associated with exposure. If possible, ask the patient. Save the container, label and leaflet to show to the doctor
- If breathing has stopped, provide artificial resuscitation

E. First aid to unconscious person:

- Turn the patient on his side with the head extended and lower than the stomach level
- Remove any vomit or food from his mouth. Use your finger, if necessary
- Ensure that the patient can breathe properly. Pull the tongue forward to prevent blocking the throat. If necessary, immediately seek medical help.

a) Universal antidote: 7g of activated charcoal + 3.5g of Magnesium Oxide + 3.5g of tannic acid in half glass warm water followed by gastric lavage.

b) Specific Antidotes: Atropine 2-4 mg or 2-PAM (1-2g) IV for OP and Carbamate Poisoning.

c) Administer oxime or pralidoxime @ 30mg/kg by intravenous therapy.

d) Convulsions may be treated with Diazepam.

e) Zinc phosphide poisoning -Morphine for the relief of abdominal pain, Soluble Vitamin K

f) Fumigant poisoning – administer aminophylline for normal liver functioning, Dimercaprol injection

Remember that prevention is the key to safe handling of pesticides. Reading and following the pesticide label is the best way to prepare for handling pesticides. If there is any doubt about the seriousness of any poisoning or you are unsure about which procedures to take, contact the Poison Control Centre.

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HYBRIDIZATION IN SELF POLLINATED CROP: AN OVERVIEW

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Introduction:

In crop plants which are cultivated by seeds the process of pollination plays important role because the formation of seeds depend on pollination and fertilization. From pollination point of view these crop plants are classified into two categories i) self pollinated crops and ii) cross pollinated crops. In self pollination anthers are deposited on stigma of same flower. Means male and female gametes from the same individual are involved. This process is known as self pollination results in self fertilization.

Some of the important example of self pollinated crops lime pea, chick pea, groundnut and oil seed crop mustard. In early days when plant breeding was in its initial stage the improvement in these crop plants was mainly achieved by mass selection method in the form of preservation of seeds having desirable qualities like good shape, size and colour etc. From the present season crops, but after the developments in plant breeding techniques the improvements in self pollinated crop plants is achieved mainly by hybridization.

The self pollination increase homozygosity with corresponding decrease in the heterozygosity. During self pollination due to involvement of male and female gametes from the same individual. In such crop varieties for the further improvement new genetic variability can be achieved by crossing two different varieties using hybridization techniques followed by suitable selection method. From a such crosses the hybrid seeds are obtained and they are used to raise the F_1 generation are then used to raise F_2 generation plants till desirable variety is obtain from F_2 generation. There are one method of self pollinated crops are as fallows Multiple cross method.

Multiple cross method (Composite cross method)

The varieties develop by this method are called maultiple varieties because they are developed by crosses involving many pureline varieties. Generally the pureline varieties exhibit limited adaptation and their performance is not stable due to change in the environment condition i.e. a pureline varieties having single gene for resistance shows resistance to only some strains of the pathogen. For examplewheat variety kalyansona originally resistant to brown rust soon become susceptible to new races of the pathogen. To overcome these limitation multiline varieties are developed by involving different varieties in a multiple cross.

The multiline varieties are mixture of several pureline varieties having many desirable characters similar but different genes for some important character like disease resistance. The pureline involved in multiple cross must be compatible and should not show decrease in their yield when grown in the form of mixture. The idea of multiple cross was described by Jenson in

1952 and later on in 1954 N. Borlaug suggest that using one recurrent parent and many non recurrent parents' multiline variety can be developed through back crossing.

Procedure of multiple cross

Multiple cross involve many pureline varieties. The involvement of many varieties in the procedure of multiple cross can be explain some varieties. Let the varieties be A, B, C, D, E, F, G and H. The character in pureline varieties is combined and a variety having mixture of characters is developed. The varieties selected for multiple cross are divided into four groups each consisting of two varieties. The initial crosses are made to combine the characters in two varieties in each group. If the four group are made 1. A with B 2. C with D 3. E with F 4. G with H with their F_1 as AB, CD, EF and GH respectively. These F_1plants produced single cross are divided into two groups and two second crosses are made to combine the characters of four varieties together. If the two groups are 1. AB and CD 2. EF and GH the two second crosses will be AB X CD and EF X GH with their F_1 as ABCD X EFGH respectively.

These F_1 plant is produced from double cross and each of them shows combination of four varieties. Finally, the third cross is made involving both double cross F_1 individual which produces the F_1 of triple cross. The final third cross ABCD X EFGH and its F_1 is ABCDEFGH. The multiplication of F_1 plants (triple cross) individual is carried out by selfing and selection. For selection either bulk or pedigree method is followed. Generally, at the end the seeds obtained from many individuals of bulked to form a new variety since the variety develop after three crosses involving eight purelineindividuals it is called multiple or composite variety and the process multiple cross.

The multiple cross variety in Barley has been developed involving 15 varieties are selected as per their combining ability and are crossed systematically to get fertile F_1 plants in each cross.

Parents-------------------- Pureline varieties A, B, C, D, E, F, G, H

First Cross------------------- A X B C X D E X F G X H

Combining two varieties ↓ ↓ ↓ ↓

F_1 Single cross AB CD EF GH

Second cross------------ AB x CD EF x GH

Combining four varieties ↓ ↓

F_1 Double cross ABCD EFGH

Third cross-------------- ABCD x EFGH

Combining eight varieties ↓

F_1 Triple cross ABCDEFGH

Selfing Multiplication by pedigree or bulk method

New varieties (Multiple or Composite) seeds are collected and mixed

Merits and demerits of multiple cross method

Merits

1. The disadvantages of pureline mixture does not remain in suitable multiple varieties.
2. Out of many lines in the variety only one or two lines become susceptible to any new race of pathogen during anyone season so the loss to the cultivators is reduced to some extent.

3. Due to reduction in the number of susceptible lines the damage to the entire population is also reduced and disease is not allowed to spread.
4. Combination of many character from many varieties can be achieved in relatively short duration.
5. Every cross produced new seeds.

Demerits

1. If the new races in the pathogen are produced rapidly the multiple varieties are to be changed.
2. An entirely new races of the pathogen can attack all the lines in the multiple varieties.
3. Sometimes the multiple varieties shows undesirable combination of characters and in such cases the desirable characters cannot be recovered.

Examples of multiple cross

The following varieties of crops have been developed by multiple cross.

1. Wheat: Kalyan Sona-KSML3 (8 lines of rust resistant), NP—809.
2. Barley: New varieties are involving 16 varieties.

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ROLE OF WOMEN IN INDIAN AGRICULTURAL ECONOMY

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Abstract:

In India, 80 per cent of all economically active women work in the agricultural sector. They represent 33 per cent of the agricultural work force and 48 per cent of farmers who are independent. However, only men are given priority in this field. In this business, men make the majority of the decisions and tend to pursue advantages. In India percentage of female cultivators to female workers has regional variation. There is quite difference between the wage rate given to men and women workforce engaged in Agriculture sector in India. Government takes various initiative through launching schemes in regard and by providing material and financial allocation. agricultural industry and the growth of the rural sector both benefit from the contribution of women farmers.

Keywords: Agriculture, cultivators growth, rural, women

Introduction:

According to renowned agricultural scientist Swaminathan, it was women who cultivated the first crop plants and began the art and science of farming. Women started collecting seeds from the local flora and started cultivating those that were valuable for food, feed, fodder, fuel, and fibre while males went out hunting for food.

In the development of agriculture and related industries like horticulture, post-harvest work, agro/social forestry, fisheries, *etc*., women play a significant role. The type and degree of women's agricultural involvement vary widely from region to region. Despite these variations, women are rarely involved directly in any agricultural production activities other than ploughing. They are so dominant in storage and processing that the number of male employees is negligible. India's economy is heavily reliant on agriculture. According to the 2011 Census, it provides 54.60 per cent of Indians with their principal source of support and accounts for 17 per cent of the country's Gross Value Added (GVA). Agriculture, India's major output endeavour and a significant contributor to GDP, is increasingly being carried out by women.

In India, Women represent 33 per cent of the agricultural work force and 48 per cent of farmers who are independent (Oxfam Report 2018). However, only men are given priority in this field. In this business, men make the majority of the decisions and tend to pursue advantages. According to IAASTD report, World Bank, 78 per cent of India’s employed work in agriculture, 70 per cent of farm work is led by women, 50 per cent of rural women are agricultural labourers and 60 per cent of world food volume is grown by women.

Table 1: Study of women farmers through different census

Years	Total female Population (million)	Cultivators (%)	Agricultural labourers (%)
1951	173.54	45.30	31.30
1961	212.46	55.70	23.90
1971	263.90	29.60	50.60
1981	321.35	33.20	46.20
1991	402.35	34.50	43.60
2001	494.00	36.50	43.50
2011	586.46	24.01	42.00

Source: Registar General of India

According to census 1951, total female population was 173.54 million, 45.30 per cent were cultivators, 31.30 per cent were female agricultural labourers. Whereas, in census 2001, 494 million was total female population, 24.01 per cent were cultivators, 43.50 per cent were female agricultural labourers. However, according census 2011, 42 per cent were female agricultural labourers.

Statistical profile of women workers in agricultre

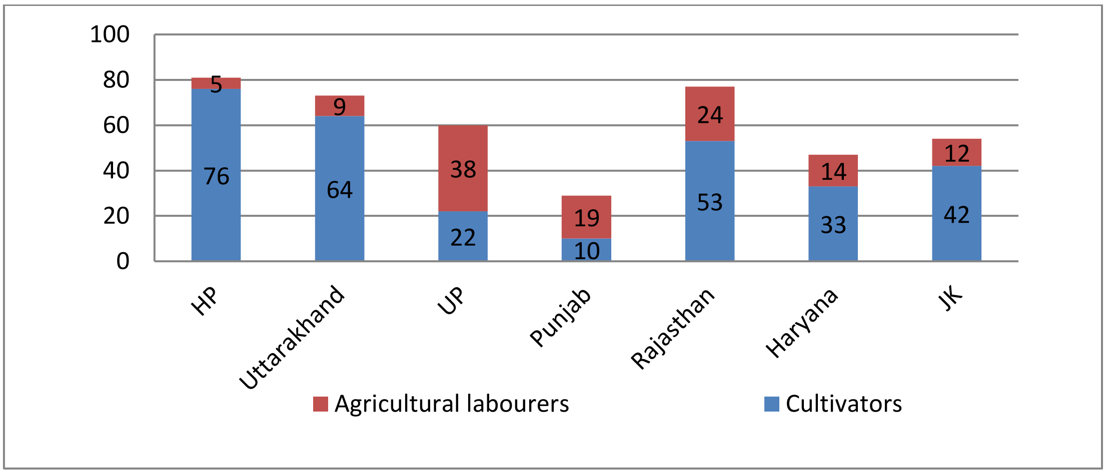

Figure 1: Percentage of agricultural female to total female workers (Northern)
Source: Labour Bureau, Ministry of Labour and Employment

Among Northern states (Fig. 1), highest percentage of agricultural female cultivators to total female workers are 76 per cent in Himachal Pradesh followed by 64 per cent in Uttarakhand, Rajasthan (53%), Jammu & Kashmir (42%), Haryana (33%), U.P. (22%) and Punjab (10%).

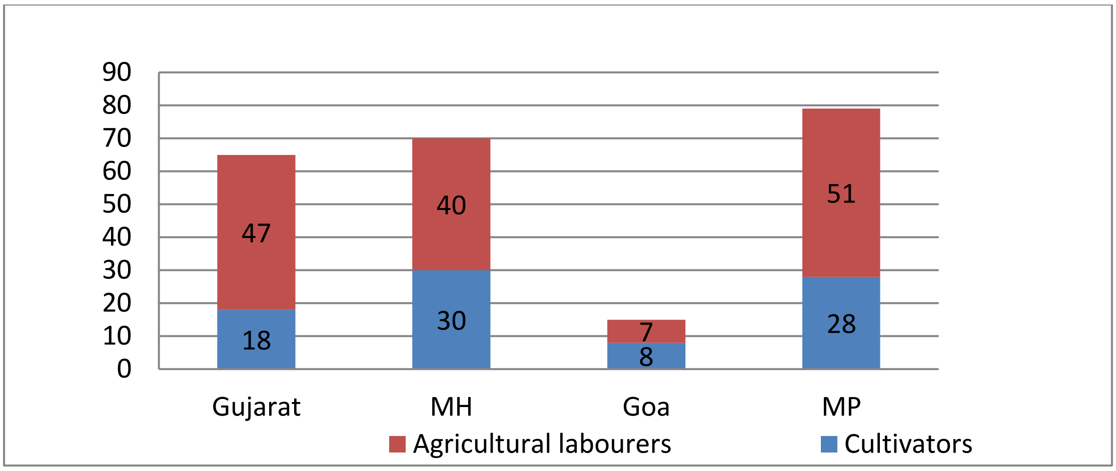

Figure 2: Percentage of agricultural female to total female workers (Western)
Source: Labour Bureau, Ministry of Labour and Employment

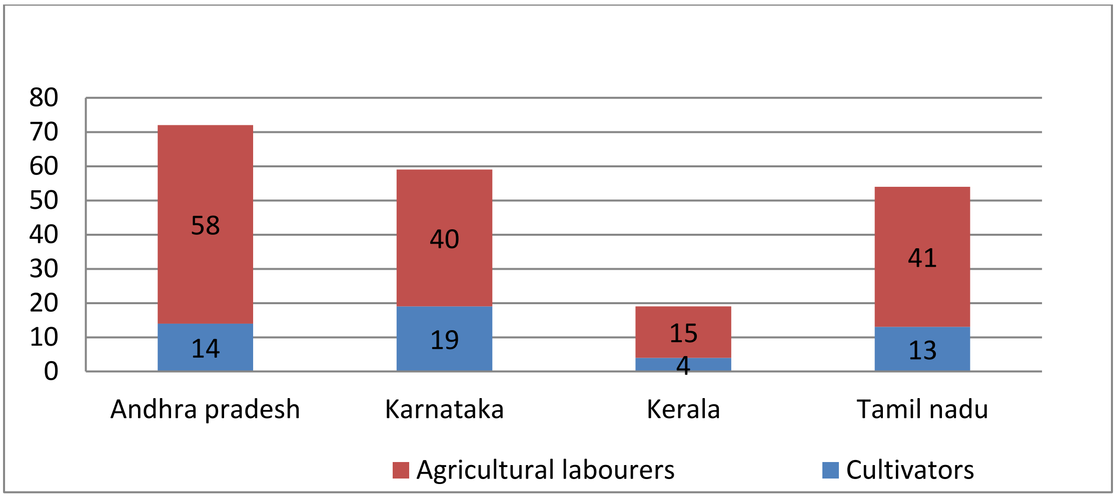

Figure 3: Percentage of agricultural female to total female workers (Southern)
Source: Labour Bureau, Ministry of Labour and Employment

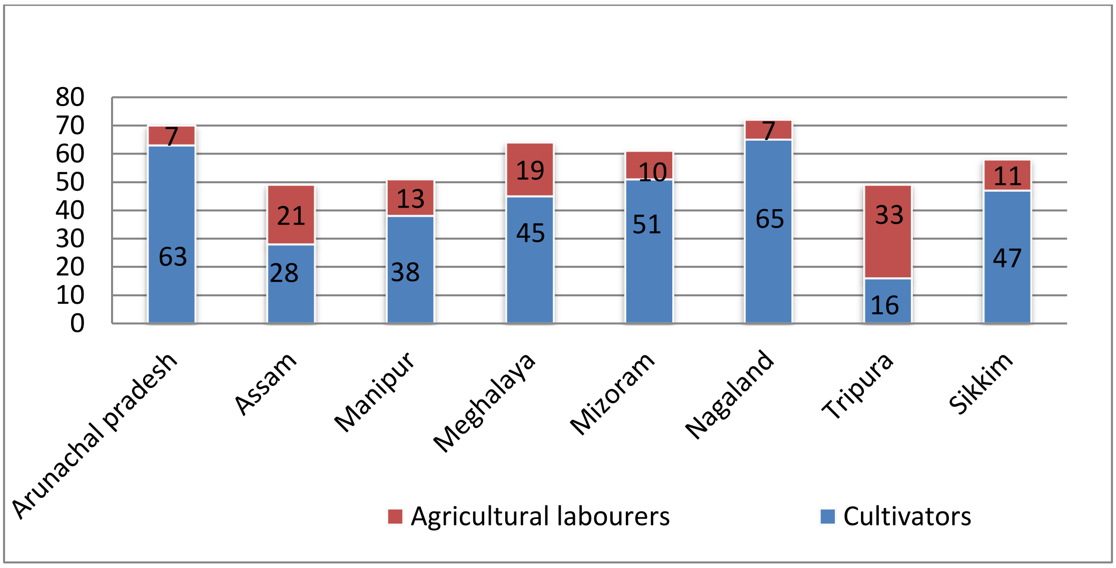

Figure 4: Percentage of agricultural female to total female workers (Northeastern)
Source: Labour Bureau, Ministry of Labour and Employment

Among Western states (Fig. 2), 51 percent female agricultural labourers to total female workers are in Madhya Pradesh, 47 per cent in Gujarat, 40 per cent in Maharashtra and 7 per cent of agricultural female to total female workers in Goa.

Among Southern states (Fig. 3), highest percentage of female agricultural labourers to total female workers are 58 per cent in Andhra Pradesh followed by Tamil Nadu, Karnataka and Kerala 41, 40, 15 per cent, respectively.

Among Northeastern states (Fig. 4), percentage of female cultivators to total female workers are 65 per cent in Nagaland followed by Arunachal Pradesh (63%), Mizoram (51%), Sikkim (47%), Meghalaya (45%), Manipur (38%), Assam (28%) and Tripura (16%).

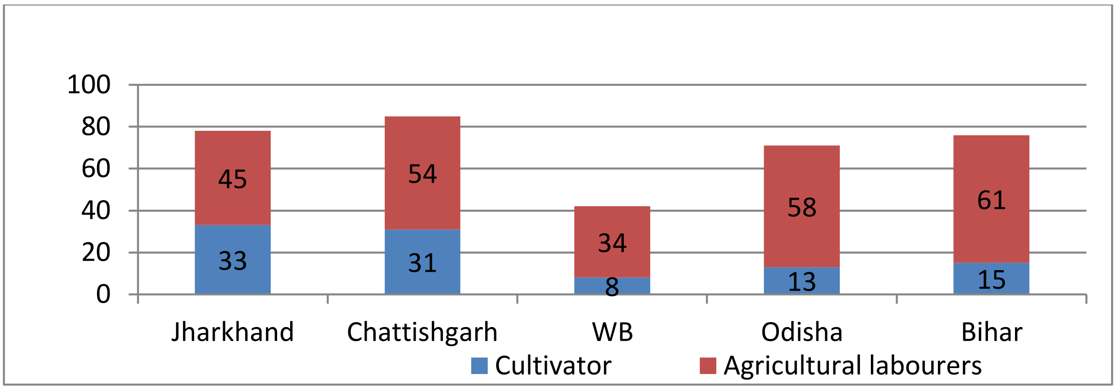

Figure 5: Percentage of agricultural female to total female workers (Eastern)

Source: Labour Bureau, Ministry of Labour and Employment

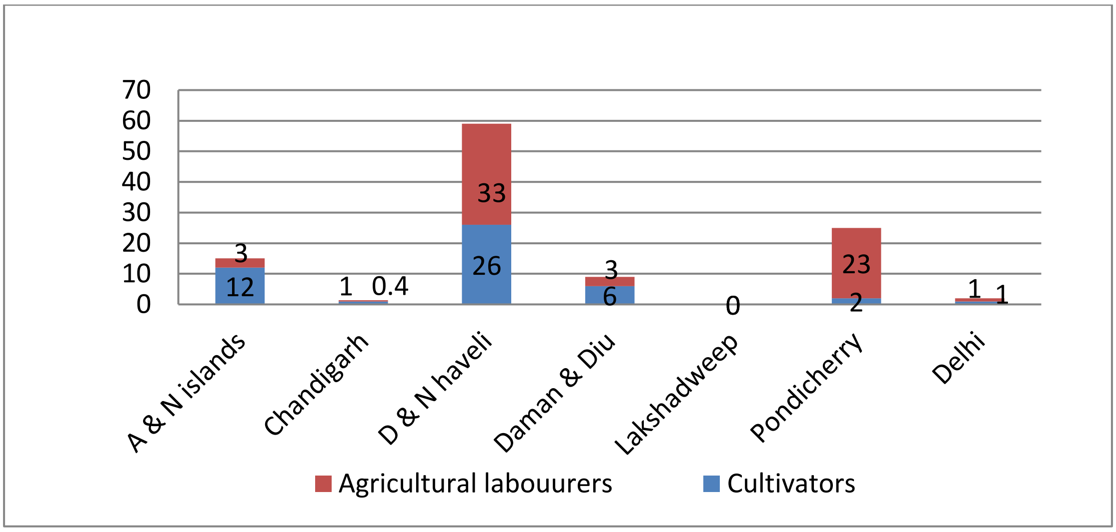

Figure 6: Percentage of agricultural female to total female workers (UT)

Source: Labour Bureau, Ministry of Labour and Employment

Among eastern states (Fig. 5), percentage of female agricultural labourers to total female workers are 45 per cent in Jharkhand, 54 per cent in Chattisgarh, 15 per cent in Bihar, 13 per cent in Odisha and 8 per cent in West Bengal. Among Union Territories (Fig. 6), in Dadar and Nagar Haveli 33 per cent of female agricultural labourers to total female workers, and 23 per cent female agricultural labourers in Pondicherry.

Feminization of agriculture:

Operational land holdings operated by women are presented in table 2. In India, 12.80 per cent of land was operated by women in year 2010-11 and 13.90 per cent of land was operated by women in year 2015-16 with an increase of 8.59 per cent during 2010-16. Highest percentage change in case of large farmers i.e., 13.23 per cent during 2010-16 followed by medium size operational holdings (12.94%), semi medium size operational holdings (9.52%), small size operational holdings (9.01%) and marginal size operational holdings (7.35%).

Table 2: Operational Land holdings Operated by Women

Different size groups	2010-11(%)	2015-16(%)	% change
Marginal (below 1.00 ha)	13.60	14.60	7.35
Small (1.00-2.00 ha)	12.20	13.30	9.01
Semi medium (2.00-4.00 ha)	10.50	11.50	9.52
Medium (4.00-10.00 ha)	8.50	9.60	12.94
Large (10.00 ha and above)	6.80	7.70	13.23
All size groups	12.80	13.90	8.59

Source: Agriculture Census 2010-11 and 2015-16

Table 3: Top 10 states having highest per cent of female operational holdings

Sr. No.	States	% of female operational holding
1.	Andhra Pradesh	12.60
2.	Maharashtra	11.60
3.	Bihar	11.20
4.	Uttar Pradesh	8.90
5.	Karnataka & Kerela	8.50
6.	Tamil Nadu	7.60
7.	Telangana	6.70
8.	Madhya Pradesh	5.80
9.	Gujarat	4.30
10.	Rajasthan	3.80
14.	Haryana	1.18

Source: Agricultural Census 2015-16

Andhra Pradesh having highest percentage of female operational holdings which is 12.60 per cent followed by Maharashtra (11.60%), Bihar (11.60%), Uttar Pradesh (8.90%), Karnataka (8.50%) and Kerala (8.50%). Percentage of female operational holding in Tamil Nadu is 7.60 per cent, followed by Telangana (6.70%), Madhya Pradesh (5.80%), Gujarat (4.30%), Rajasthan (3.80%) and Haryana (1.18%).

Invisibility of women farmers

There is quite difference between average daily wage rate of male and female field labour. The average daily wage rate of male field labour is Rs. 350 per 8 hours whereas, for female field labour average daily wage rate is Rs. 280 per 8 hours.

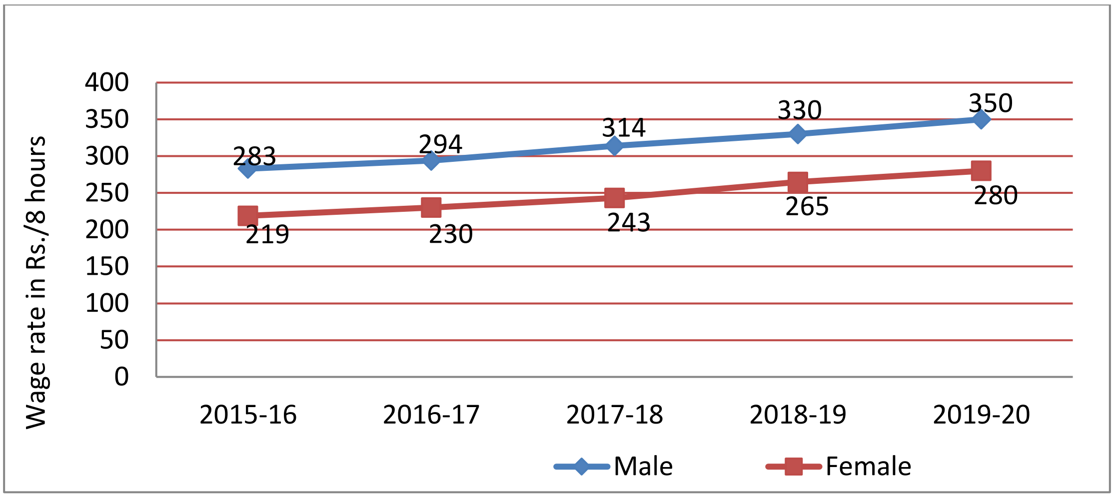

Figure 7: Average daily wage rate of male and female field labour
Source: DES, Ministry of Agriculture & FArmer's Welfare

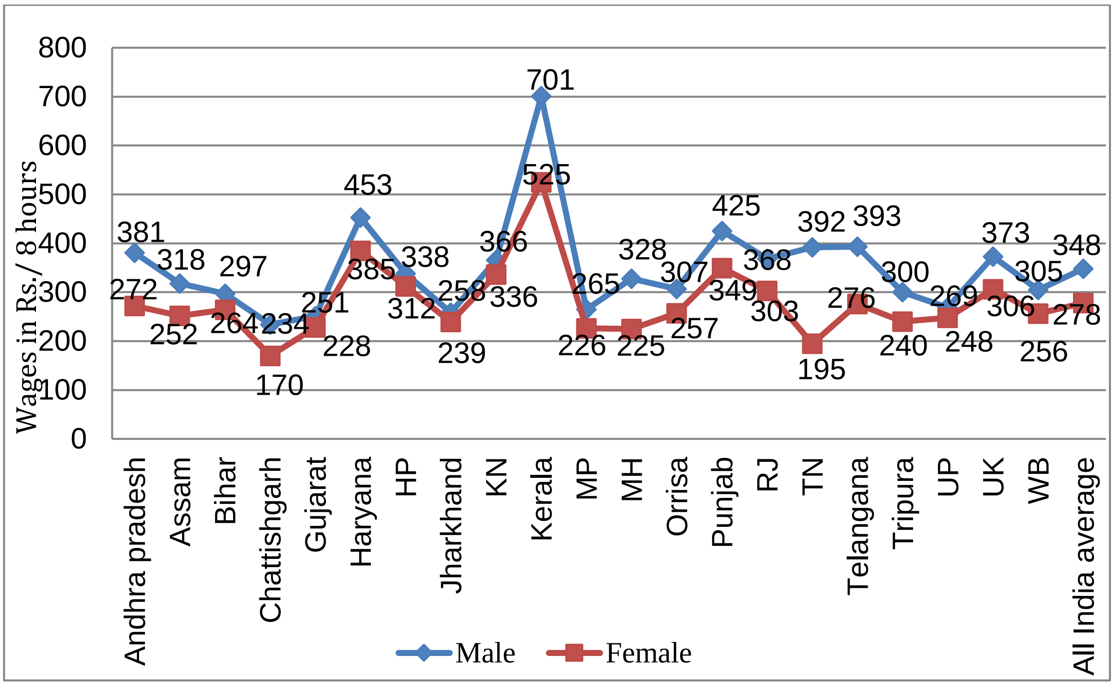

Figure 8: State wise annual average daily wages of male and female field labour: 2019-20
Source: DES, Ministry of Agriculture and Farmer's Welfare

Table 4: State-wise comparison of NREGA wage rates for 2021-22 and 2020-21

States	Wage rate in Rs . (2021-22)	Wage rate in Rs. (2020-21)	Increase in wage rate (%)
Andhra Pradesh	245	237	3.4
Arunachal Pradesh	212	205	3.4
Assam	224	213	5.2
Bihar	198	194	2.1
Chhattisgarh	193	190	1.6
Goa	294	280	5.0
Gujarat	229	224	2.2
Haryana	315	309	1.9
Himachal Pradesh	254	248	2.4
Jammu and Kashmir	214	204	4.9
Ladhakh	214	204	4.9
Jharkhand	198	194	2.1
Karnataka	289	275	5.1
Kerala	291	291	0
Madhya Pradesh	193	190	1.6
Maharashtra	248	238	4.2
Manipur	251	238	5.5
Meghalaya	226	203	11.3
Mizoram	233	225	3.6
Nagaland	212	205	3.4
Orissa	215	207	3.9
Punjab	269	263	2.3
Rajasthan	221	220	0.5
Sikkim	273	205	3.4
Tamil Nadu	273	256	6.6

Telangana	245	237	3.4
Tripura	212	205	3.4
U.P.	204	201	1.5
Uttarakhand	204	201	1.5
West Bengal	213	204	4.4

Source: https://nrega.nic.in Ministry of Rural Development

Reasons for women's low land rights

- The persistent patriarchy that manifests itself in preconceptions, attitudes, perceptions, and norms and puts barriers in the way of women's advancement in the legal, political, and economic spheres is the primary cause of discrimination against them when it comes to access to land.
- Women in rural areas lack the authority to assert and secure their rights to land. Typically, they are unaware of their rights.
- Because they have been socially pressured to do so as well as a result of education, rural women are frequently constrained to the conventional gender norms of food production and child rearing.
- Promoting women's land rights, making land institutions gender-responsive, and creating functional, affordable, and culturally acceptable instruments are not possible since there is no enabling environment or political will.

Challenges faced by women in agriculture sector

- **Low land and asset ownership:** Fewer than 15 percent of agricultural landholders around the world are women and 85 percent are men.
- **Wage Gap:** Despite being predominant, women get 20 per cent lower wages than men. More than 90 percent of the rural females are treated as a cheap source of laborers. The concentration of gender wage disparity (threshold is above 75 percent) is high in the southern states such as Kerala, A.P, Karnataka and Tamil Nadu, whereas, the states with low gender wage disparity (below 75 percent) are Haryana, Punjab, and Rajasthan.
- **Lack of supportive infrastructure:** New machinery and infrastructural facilities in agriculture, in general, are not designed with women farmers in mind.
- **Lack of institutional credit:** As per a study more women (49.5%) indicated that the untimely nature of the loans was a problem to them as compared to 46% of the men.
- **Non-recognition:** According to Oxfam India, women are responsible for about 60-80 per cent of food and 90 per cent of dairy production, respectively. But the work by women farmers, in livestock management, crop cultivation or at home, often goes unnoticed.
- **Access to useful resource and inputs:** Men (74%) has more access to the inputs than women (67%). Another study indicates male farmers (14.5%) has more access to agricultural information than the female farmers (10.5%).

- **Absence of decision-making power:** Women have agreed that their opinion are not considered while making decisions related to the money spending on the purchase of machines, seeds, implements and paying wages to labourers respectively.
- **Limited to drudgery work:** They undergo hard physical drudgery especially while transplanting rice in mud with bending position for a long time, harvesting by bending with traditional sickle etc.
- **Illiteracy:** According to census 2011, an estimated 52-75 per cent of Indian women engaged in agriculture are illiterate.

Suggestions for the recognition of women contribution

1. Working women in rural areas can be compensated in monetary terms for their labour.
2. More resources for land, agricultural, and livestock extension services should be made available to rural women.
3. Women must be given preference when it comes to obtaining loans from banks and other financial organisations on favourable conditions for purchasing real estate, starting a business, building a home, etc.
4. Efforts should be made to increase the literacy rates of women. This might be accomplished by having a separate education policy for women.
5. Women must be represented in decision-making groups that can bring about structural reforms. The gender relations in society will shift as a result of this activity.
6. The state government should set a minimum and equal wage for women working in agriculture, and the rates should be evaluated on a regular basis.
7. Women need to be informed about their legal options, their access to judicial relief and remedy, their ability to challenge discrimination in court, and the availability of legal aid, assistance, and counselling.

Government initiatives towards empowering women in agriculture

1) Mahila Kisan Sashaktikaran Pariyojana (MKSP) (2011)

- ✓ It is a sub component of the Deendayal Antodaya Yojana – NRLM.
- ✓ This scheme is being applied with the objective to enhance the productive participation of women in agriculture, to improve the skills and capabilities of women in agriculture to support farm and non farm based activities etc.

2) ICAR- Central Institute for Women in Agriculture (ICAR-CIWA)

- ✓ It focuses on participatory action research in different technology based theme areas involving rural women to test suitability of technologies for women and suggest their refinement.
- ✓ It is first institution in India that is exclusively devoted to gender related research in agriculture.

Earmarking at least 30 per cent of the budget allocation for women beneficiaries in all ongoing schemes/programmes and developmental activities.

Special provisions for women farmers in national schemes

- **Support to States for Extension Reforms (2005-06):**
  - Since inception of the Scheme, total 1.36 crore Farm Women (24.56 per cent of the total benefited farmers) have participated in farmer oriented activities like Exposure Visits, Training, Demonstrations & Kisan Melas.
  - Farm Women's Food Security Groups (FSGs) @ at least 2 per block to be formed annually for ensuring household food and nutritional security providing assistance of Rs. 10,000/ per group.
  - Women farmers are to be involved in different decision making bodies at district and block level such as (ATMA) Governing Board and ATMA Management Committee at district level
- **Establishment of Agri-Clinics & Agri-Business Centres (AC & ABC) (2002)**
  - 5929 women agri-preneurs have been trained of which 1804 have established agri-ventures and of these 129 got subsidy benefit.
  - Provision of 44 per cent Back-ended composite subsidy towards cost of project to women as compared to 36 per cent to men.
- **Mass Media Support to Agricultural Extension (2004)**
  - One day specially allocated to cover areas of core competence women farmers in programmes of All India Radio & Doordarshan.
- **Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) (2019)**
  - The number of Female Farmers Registered under PM-KISAN since inception is 2.88 crore.
- **Pradhan Mantri Kisan Maan-Dhan Yojna (PM-KMY) (2019)**
  - The number of Female Farmers Registered under PM-KMY since inception is 6.62 lakh.
- **Sub-Mission for Seed and Planting Material (SMSP)**
  - Till Dec. 2020, 11.75 lakh women farmers were benefitted under Seeds Village Programme.
- **Sub Mission on Agricultural Mechanization (SMAM) (2014-15)**
  - Total 3648 and 3986 women were trained during the FY 2019-20 & 2020-21 resp.
  - 10 per cent more assistance for women beneficiary to procure Agricultural Machinery, implements and equipment.
- **Integrated Scheme for Agricultural Marketing (ISAM) (2014)**
  - Women under Agricultural Marketing Infrastructure (AMI) are eligible for subsidy @ 33.33 per cent as against 25 per cent for others.

Conclusion:

The agricultural industry and the growth of the rural sector both benefit from the contribution of women farmers. The chapter makes clear that there is a developing trend in the country toward the management and operation of agricultural holdings by women, a phenomenon known as the "feminization" of agriculture. Despite being more prevalent, they are paid less than male agricultural labourers for the same type of work, even though they perform it. Due to employers' preconceived notions about women's primary responsibilities as homemakers, their labour force is viewed as inferior. The government has made a number of actions to

improve the position of women in the agricultural sector. But this is insufficient on its own. There should be a workable solution for the issue in addition to the implementation of legislation and various programmes. Since agriculture is essential to any nation's economic development. It is crucial to end the gender inequality in this industry if we
are to increase production and guarantee food security.

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SPEED BREEDING: NOVEL TOOL TO REDUCE THE GENERATION TIME OF A VARIETY

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Abstract:

The continuously growing human population and changing environmental conditions have raised significant concern for global food security. The current improvement rate of several important crops is inadequate to meet the future demand. The time of breeding cycle, largely determines the efficiency of crop genetic improvement. This slow improvement rate is attributed partly to the long generation times of crop plants. Here is, an innovative and dynamic approach named as 'speed breeding', which greatly shortens generation time and accelerates breeding cycle and research programmes. The concept of speed breeding was first ever recognised by taking an inspiration from NASA, later adopted by the University of Queensland scientists. This technique was first described and implemented for wheat (*Triticum aestivum*) and peanut (*Arachis hypogaea*). This brilliant and novel discovery revolutionized whole of the world in terms of agriculture production and productivity. This concept mainly based on increasing the duration of daily exposure of plants to light combined with early seed harvest to quickly generate seed-to-seed by reducing generation time. It uses an artificial source of light which is continuously kept on to activate the photosynthetic process which leads to growth and reproduction much earlier than normal. The researches show that by speed breeding techniques we can grow approximately 6 generations of wheat, chickpea & barley and around 4 generations of canola plants in a single year. Therefore, to increase the efficiency of crop breeding, plant breeders and researchers around the world are using this novel strategy to alleviate food scarcity problems and increases food security. Various technologies such as genotyping, MAS, highthroughput phenotyping, gene editing, genomic selection and re-domestication can be merged with speed breeding to enable plant breeders to keep up with rapidly changing climatic conditions and alarmingly-increasing human population.

Keywords: Accelerated breeding, Controlled environment, Crop improvement, Rapid generation advancement, Speed breeding

Introduction:

The world population is growing over the last several years and is projected to increase by at least 25% in geometrical way but the food resources are still limited (Ray *et al.*, 2012; Ray *et al.*, 2013).To provide adequate food subsistence to the people living with diverse diet will require at least 0.5 hectare of arable land per person (Lal and Steward, 1990), and at this time, we have only 0.27 hectares per capita land available to us, which will drastically be reduced to 0.14 hectare per person within the next 40 years due to loss of land caused by population pressure

(Pimentel, 1993; Pimentel *et al.*, 1994; Pimentel *et al.*, 1995; Pimentel, 1997).Conventional plant breeding strategies are unable to maintain the growing food demands worldwide. Various approaches have been used to reduce the duration of plant reproductive cycles. Newly introduced techniquessuch as genomic selection, high-throughput phenotyping (HTP), and speed breeding, have been shown to speed upthe procedure used in the development of new crop varieties.

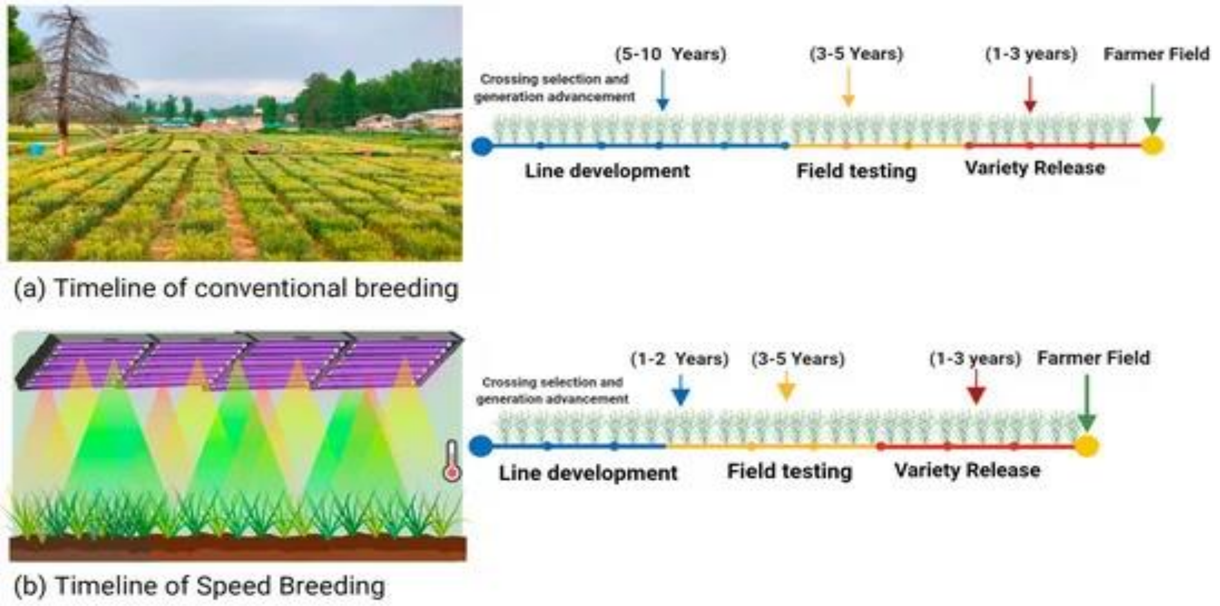

Figure 1: Rapid generation advancement through speed breeding

Source: Shanmugavel *et al.* (2022) https://www.intechopen.com/online-first/82538

Speed breeding has the immense capability to significantly accelerate the pace of breeding programs for different crops by decreasing the generation time (Watson *et al.*, 2018; Voss Fels *et al.*, 2018). Speed breeding protocols are applied by modifying the temperature and light requirement of different crop species. Light plays a very important role in various plant metabolic processes such as photosynthesis, photoperiodism, and most importantly photomorphogenesis. Photomorphogenesis is the process of plant development, in which incident light determines the growth potential of plants. Speed breeding can be performed in smaller regions, and scientists who do not have access to bigger areas are able to set up smaller speed breeding units.

Objectives of speed breeding:

- **Time-saving tool:** Most of the plant species have cumbersome and lengthy breeding programmes, creating a bottleneck effect in their research and development. Speed breeding provides a suitable alternative for conventional approaches by reducing the generation time of a variety. Speed breeding is based on the principle of using optimum light intensity, temperature, and photoperiodism (22 h light, 22 °Cday/17 °C night, and high light intensity) to stimulate the rate of photosynthesis, which results in early flowering, along with annual seed harvesting to reduce the generation time.
- **Aids to Global food security:** Speed breeding fastens the photosynthesis rate which results in early growth of crop. This protocol aids in reducing the generation time of variety as compared to conventional breeding methods and ultimately provide support to

growing human population worldwide by timely availability of food. Speed breeding helps to reduce the risk of hunger and malnutrition by supplementing the nutritional requirement for present as well as future generations.

- **Boosting genetic gain:** Speed breeding coupled with genetic selection are used to increase the genetic gain of different crop species by shortening the breeding cycles during varietal development programmes. Speed breeding protocol helps to boost the genetic gain by supporting the gene editing technologies resulting in generation of diversity as well.The rate of genetic gain in a breeding procedure can be represented by the breeder's equation, an equation of the expected change in a component trait in response to selection. The equation can be written as $R= \delta g \times i \times r/L$, where R is the change in the trait mean per year, δg is the amount of genetic variation within the population, i is the selection intensity, r is the selection accuracy, and L is the length of the breeding cycle. Based on this equation, speed breeding protocols can increase genetic gain of crop by increasing the number of plant generation per year, which can simultaneously reduce the length of the breeding cycle.
- **Aids to Research and development breeding:** this protocol helps in acceleration of crop variety development by combining potential techniques, such as gene editing, high-throughput phenotyping and genotyping, genomic selection (GS), and MAS, with speed breeding protocols for the improvement of complex traits. Being a cost effective and time saving approachwith low input requirement speed breeding avoids the challenges of various cumbersome approaches such as doubled haploid technology, shuttle breeding and so on. Single seed descent method can serve as a promising approach to include with speed breeding for the early development of a variety in both field and greenhouse environment. To overcome the drawback associated with MAS, researchers can employ genomic selection with various speed breeding protocols to identify several minor QTL's associated with biotic and abiotic stress resistance. Speed breeding serves as a promising approach for the acceleration of haplotype breeding as well as for the rapid generation of varieties through transgenic crop breeding. The SNP marker-assisted selection is integrated with speed breeding methods for rapid development of various mapping populations associated with different biotic and abiotic stress resistance.
- **For early domestication**: Domestication is a process in which wild species bring under human management with the help of artificial selection for further selection. speed breeding is a novel method used to accelerate the domestication of polyploid crops such as peanuts and banana mainly by reducing their breeding cycles. Some researchers performed an experiment to determine the ease of using the speed breeding approaches in peanut breeding. In comparison to the conventional breeding methods, this experiment decreases the time it takes to produce several generations in shorter duration.

Scope of speed breeding in Indian agriculture context:

Conventional breeding being a time consuming and cumbersome process takes minimum 8 to 10 years for the development of a variety. By keeping plant breeding into consideration, rapid advancement of segregating generation to reach homozygosity will add up genetic gain to the crop for its component traits results in development of improved cultivar. The process of speed breeding uses artificial environment for photoperiodism control to speed up the breeding cycle of various photo-insensitive crops. This novel technique being successful in model crops such as wheat, barley, chickpea, and pea greatly reduce their generation time and even helpful in achieving up to six generations per year. Rapidly growing Indian population is in urgent need of such novel breeding techniques to fulfil their present and future nutritional requirement to develop a healthy and prosper society, and to ensure better living standards for the people of our country.

Concept of speed breeding:

Speed breeding concept can be applicable in three best possible ways- Speed breeding I (within controlled chambers), Speed breeding II (within glasshouse conditions), and Speed breeding III (home-made growth room designed manually on low-cost basis).

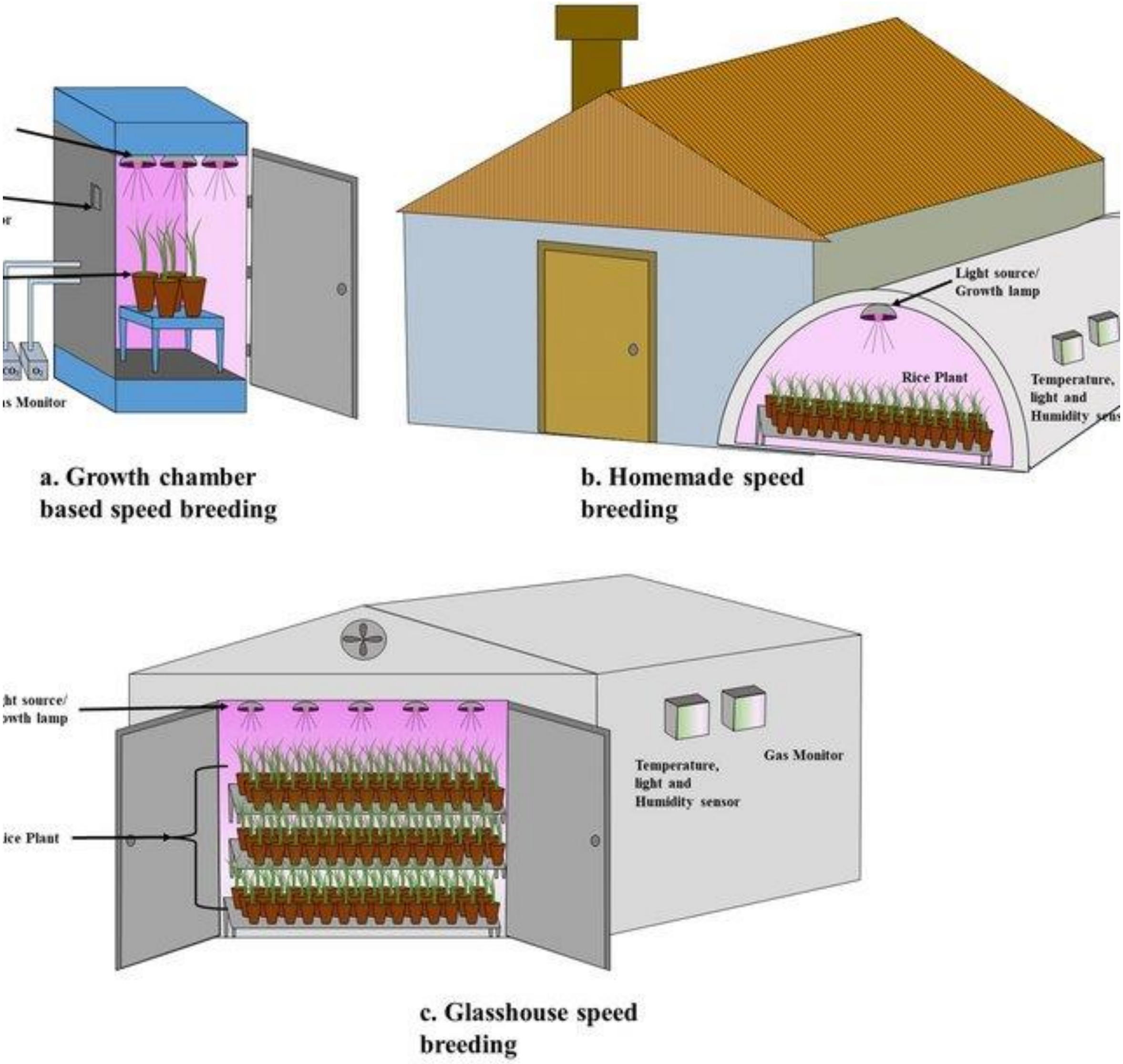

Figure 2: Different methods of speed breeding
Source: Ch. Sai Nayan Raju and C. Kalyan Sagar (2020)
https://doi.org/10.20546/ijcmas.2020.912.128

- **Speed breeding I (within controlled chambers):** BDW chamber, Temperature (22^{o}C) during photoperiod of 22hrs & 17^{o}C during 2 hours of dark period, Humidity (70 %), Lighting of white LED bars, far-red LED lamps & ceramic metal hydrargyrum quartz iodine lamps, Light intensity (60-380 umol m^{-2} s^{-1}) are required in this method. With the application of this method number of spikes per plant and viability of harvested seed remain unaffected while seed count per spike slightly reduced along with anthesis time reduced by a factor of half.
- **Speed breeding II (within glasshouse conditions):** Glasshouse fitted with high pressure sodium vapour lamps (22 hours photoperiod) and controlled temperature, Temperature (17 to 22^{o}C) regime and Light intensity (440-650 umol m^{-2} s^{-1}) are required along with period of 2 hours without lamps with 17^{o}C during night.This method results in rapid development of some cereal crops such as wheat and barley with unaffected grain numbers. Seed production and viability showed positive response in chickpea and canola crops.
- **Speed breeding III (home-made growth room designed manually on low-cost basis):** A room with dimension of 3m × 3m × 3m with insulated sandwich panelling fitted with seven LB-8 LED light boxes, Lightning (12- hours photoperiod) for 4 weeks and then increased to 18 hours, 1.5 hp inverter split system domestic air conditioner (18^{o}C of darkness and 21^{o}C when LED lights on), automatic watering system with irrigation controller are required.

Basic procedure of speed breeding:

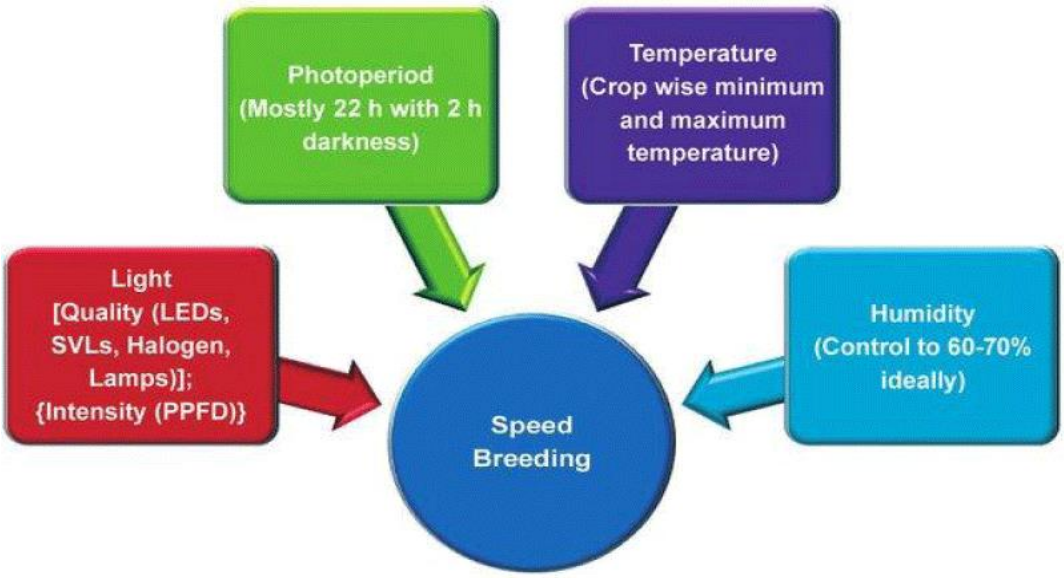

Figure 3: Different inputs of speed breeding

Source: Begna T. (2022) https://doi.org/10.17352/2455-815X.000161

There are some key factors which are used in speed breeding protocol to reduce the generation time of a variety. A suitable spectral range (400-700 nm) can be maintained by using LED's and other sources of light such as halogen lamps. Intensity of light can be managed by using photosynthetic photon flux density of approx. 450 to 500 µmol/m 2 /s. Photoperiod of 22 hours daylight with 2 hours of darkness needed to be maintained in a 24 hours diurnal cycle. Optimum temperature requirements may vary crop wise and ideal humidity conditions should be in range of 60-70 (%).

Speed breeding procedure followed in wheat:

Generalized speed breeding procedure followed in wheat are as follows:

- A photosynthetic photon flux density of 450-500 µmol m^{-2} s^{-1}at canopy height of plant is recommended. As mentioned above, a photoperiod of 22 hours with 2 hours of darkness was used. The temperature cycling regime to apply is: 22 °C / 17 °C for 22 hours light and 2 hours dark, respectively. Humidity rangeof 60-70 per cent is ideally recommended.
- Standard procedure of wheat sowing should be followed. However, early seed sowing or pre germination of seeds are recommended as speed breeding treatment can induce stress, which possibly become a cause of necrosis resulting in death of plants.
- After reaching dough stage, immature harvesting of spikes are recommended, then seed can be dried at 30°C. by using a desiccator. It is possible that harvested seeds may look shrunken in appearance, but no grain dormancy is found.
- Sufficient amount of fertiliser and soil-mixture should be given to the plants to conquer the nutrient deficiency caused by accelerated growth due to speed breeding. Deficiency of calcium at early growth stages can produce symptoms such as bumps and bubbles on leaves. Foliar application of calcium-containing fertilisers is recommended to eradicate the symptoms of calcium deficiency.

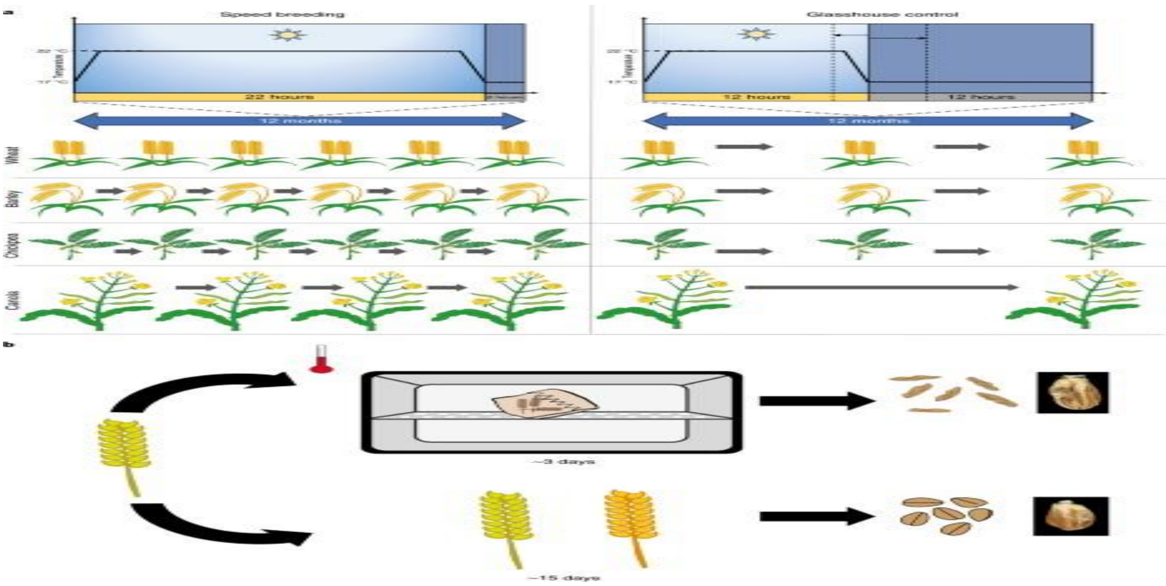

Figure 4: Speed breeding procedure in wheat

Source: Watson *et al.* (2018) https://doi.org/10.1038/s41477-017-0083-8

Table 1: Techniques for rapid generation advancement with corresponding days to flowering, number of generations achieved per yearand selection methods used in different crops

S. No	Crop	Techniques	Days to flowering	Number of generations/year	Selection method
1.	Amaranth	Photoperiod, temperature and HDP	**28**	**6**	**SSD**
2.	Arabidopsis thaliana	Photoperiod, temperature and immature seed germination	**20-26**	**10**	**-**
3.	Barley	Photoperiod, temperature and immature seed germination	**24-36**	**9**	**SSD**
4.	Canola	Photoperiod, temperature, soil moisture and immature seed germination	**73**	**4**	**SSD**
5.	Chickpea	Photoperiod, and immature seed germination	**33**	**7**	**SPD**
6.	Faba bean	Planthormones,photoperiod,light intensity and immature seed	**29-32**	**7**	**SPD**
7.	Groundnut	Photoperiod and temperature	**25-27**	**3**	**SPD**
8.	Lentil	Planthormones,photoperiod,light intensity and immature seed	**31-33**	**8**	**SPD**
9.	Pea	Planthormones,photoperiod,light intensity and immature seed	**33**	**5**	**-**
10.	Pigeonpea	photoperiod,light intensity and immature seed	**50-56**	**4**	**SPD**
11.	Rice	Photoperiod, temperature and HDP	**75-85**	**4**	**SSD**
12.	Sorghum	Photoperiod, temperature and immature seed germination	**40-50**	**6**	**SSD**
13.	Soybean	Photoperiod, temperature and immature seed germination	**23**	**5**	**SSD**
14.	Wheat	Photoperiod, temperature, soil fertility, immature seed germination and embryo rescue	**28-41**	**7.6**	**SSD**

Source: Wanga *et al.* (2021) https://doi.org/10.1111/pbr.12909

Selection procedure followed in speed breeding:

Earlier approaches to speed up the breeding cycle was shuttle breeding and doubled haploid technology. Shuttle breeding refers to a method in which breeding generations from same crosses are alternatively selected in contrasting environment to develop improved variety with higher adaptability along with reducing the generation time.In double haploid technology, generation time of a variety is reduced by direct chromosomal doubling of pollen or egg cells to restore the fertility in limited time. Both these methods are suitable to hasten the breeding cycle but tedious and complicated in nature. Single seed descent method serves as one of the most suitable approaches for selection in field and greenhouse environment. After inbreeding, single seed of each individual plant is forwarded to next generation for the rapid attainment of homozygosity. This method is quite useful to be performed in small nursery and growth chambers with limited use of resources. No selection is imposed in any successive generation which may carry more inferior progenies in a population compared to other selection methods.A small deviation from the single-seed descent method was followed for successful selection in legume species. The selection of one pod per plant was followed from F_2 to F_4 generation instead of a single seed. Integration of speed breeding and SSD methods can effectively accelerate the generation of inbred lines for different varietal development programmes.

Potential advantages of speed breeding:

Green revolution facilitated the creation of high-yielding variety using semi-dwarf genes in potential cereal crops such as rice and wheat, but these crops attained yield plateaus after some period of time. Speed breeding technology being able to produce more generations in a year, provide enough chances for useful genetic combinations to come across and break the barrier of further improvement. This technology is helpful in developing climate-smart cultivars in short duration of time to cope with continuously changing global climatic conditions. Modern breeding and advance management practices have contributed 0-2.-0.8 per cent annually in crop productivity but this is not sufficient to meet the nutritional requirements of rapidly growing population. This necessitate regular efforts and innovative programmes such as speed breeding for crop improvement and their chief focusshould be on stability and sustainability of cropyieldsThe quality parameters and yield of plants associated with speed breeding are much better because crop is propagated under controlled environment of glass house. This technology can be extended to various horticultural crops and other advanced approaches such as vertical farming in near future to meet the increasing demands of growing population.

Challenges of speed breeding:

Speed breeding is one of the best methods available to overcome the drawbacks associated with conventional breeding methods through early development of a variety. But this technology required expertise, costly infrastructure, continuous financial support, high initial investment and sufficient knowledge of plant phenomics. Lack of trained and skilled plant breeding workers hindered the growth associated with speed breeding. Developing countries still dependent on public sector for food security, negatively impact the adoption of scientific innovations such as speed breeding. Speed breeding required advanced infrastructure facilities for the regulation of various environmental aspects such as temperature, photoperiod and humidity limits the adoption of this technology to a large extent. Speed breeding in collaboration with advanced breeding approaches such as genomic selection, MAS and gene editing needs specialized biotechnological labs and tools which results in restriction of its wide spread usage. Limited and unpredictable supplies of electricity is a major issue concerned with management of temperature and photoperiod for speed breeding in public sector plant breeding programmes. At last, early harvesting of immature seeds and spikes can interfere with the phenotyping of some seed related traits.

Conclusion:

Speed breeding protocols in crop improvement programs will speed up and strengthen the breeding cycle to a great extent with improved selection efficiency through various approaches. It advances the rapid delivery of improved varieties by collaborating with modern breeding techniques with generation advancement protocols. Superior genotypes with multiple traits such as yield, quality, biotic and abiotic stress resistance can be developed in a limited period of time with the integration of high-throughput genotyping and phenotyping platforms in speed breeding technology. So many advanced varieties have been rapidly developed in commercially important crop species such as wheat, rice and so on through the emergence of speed breeding methods. The integration of MAS, gene editing and genomic selection approaches in speed breeding cleared the pathway for the improvement of various complex traits. Few modified conventional approaches *viz*., single plant selection, single-pod descent and single-seed descent method are merged with speed breeding protocols which greatly reduced the generation time, cost, and labour requirements. The emergence of advanced genomic techniques in relation with rapid gene fixation approaches provides early realization of genetic advances in varietal development breeding programs. Along with accelerated advancement toward the attainment of homozygosity, the speed breeding procedure is quite efficient in the rapid evaluation of genetically modified/transformed lines of a crop species.Speed breeding protocols suitable for controlled environmental conditions are convenient to meet the growing demand of people worldwide but it still remain as a unidentified breeding procedure because of the various drawbacks associated with it such as cost-ineffective infrastructure, limited financial assistance, lack of trained personnel and essential resources. With the collaboration of multidisciplinary organization, speed breeding can emerge as a novel tool to meet the ever-challenging hunger and nutritional demand of global population under continuously changing climatic conditions.

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STATUS AND COUNTERMEASURES OF HEAVY METAL POLLUTED SOILS IN INDIA

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Abstract:

Heavy metal contamination of the soil environment is becoming increasingly common around the world. Heavy metal pollution is becoming more likely as a result of rapid industrialization and poor industrial effluent management. Heavy metals, even at low levels of exposure, can cause cancer in humans and animals, as well as harm to soil microorganisms and crop plants. Excessive concentrations of heavy metals, such as Cr, Cd, As, Ni, Se, and Pb, have been discovered in agricultural soils near cities, mines, and industrial areas all over the world. Although geogenic sources of pollution for some trace elements have been observed in various parts of the world, including India, secondary sources of anthropogenic pollution are more dominant, localised, and cause higher magnitude soil pollution. The use of contaminated water for agricultural purposes has harmed soil health and reduced crop productivity over time. Heavy metal contaminated soil remediation is required in order to have a safe and healthy environment that will sustain our life on the beautiful Earth planet. This paper confers heavy meal sources, types, and status in India, as well as remediation techniques and safety precautions for the safe use of industrially contaminated water.

Keywords: Heavy metals, Remediation, Soil microorganisms, Wastewater

Introduction:

The term “heavy metals” refers to a group of metals and metalloids with an atomic density greater than 5 g cm-3, or 5 times or more that of water. In other words, "heavy metals" refers to any metallic element with a relatively high density that is toxic or poisonous at low concentrations. Arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), mercury (Hg), selenium (Se), and other important metals and metalloids are of environmental concern. While heavy metals are ubiquitous in the environment and some are important micronutrients, they are all toxic to biota above a certain concentration. Heavy metal pollution of soil is a major environmental issue all over the world. Heavy metal pollution of surface soils, in particular, has become a major concern in many developing countries as a result of rapid industrialization and urbanisation (Mireles *et al.*, 2012). Many anthropogenic activities, such as mining, improper disposal of industrial and urban waste, transportation, and unscientific agricultural practises, can cause heavy metal pollution in the soil. The chemical composition of soil, particularly its metal content, is important for the environment because the presence of these metals in the soil affects the environment in several ways, including food contamination from plants grown in polluted soil, as well as a decrease in crop productivity and soil microbial activity (Akerblom *et al.*, 2007). Many studies to determine the risk caused by metal levels in soil on human health and forest ecosystems have attracted attention in recent years due to their environmental significance. The extent of soil pollution with heavy metals from various anthropogenic sources and subsequent crop uptake are affected by a number of factors, including source, soil type, frequency of application, organic matter content, seasonal variations, major and minor nutrients, and chemical pollutant load. However, heavy metal pollution of soil is an irreversible process, and it is difficult to manage and reclaim these types of metal polluted soils.

In India, information on the extent of soil pollution and its effects on other functional areas, plants, and human health is insufficient. The data provided by various agencies on 321 soil degradation primarily focus on physical aspects of soil deterioration such as erosion, waterlogging, and so on, with little attention paid to chemical degradation except for soil salinity issues. Information on the impact of various developmental activities, such as mining, industries, urbanisation, transportation, and others, on soil environment, such as heavy metal build up and persistent organic pollutants, toxic substances, and so on, is limited and needs to be addressed. Heavy metal contamination of large areas of land has become a major concern in recent years. Many urban and dense cities in India with significant industrial waste generation have contaminated soil in and around their areas. We must not forget that, while the estimated land area affected by pollution is smaller than that of other types of degraded land, these are generally located in more fertile areas near cities, and reclamation of such land is generally very expensive (many times with a lower degree of success) than that of other types of degraded land. We need first-hand information on the state of soil pollution in the country in order to develop an action plan for remediation of such areas. Unlike in India, the extent of contaminated land is well known in many developed countries such as North America and Western Europe, with many of these countries having a legal framework in place to identify and address this environmental problem. Despite the fact that some developing countries have undergone significant industrialization, they tend to be less tightly regulated. As a result, soil pollution regulations, guidelines, and policies are critical. The extent, diversity, and impact of soil pollution in the country are not well documented. As a result, this article focuses primarily on heavy metal contaminated soils in the context of heavy metal sources and their impact on soil environment, as well as the current situation and extent of heavy metal polluted soils in the country, as well as remediation and sustainable management of heavy metal contaminated soils.

Sources of heavy metal contamination in soil

Excess heavy metals in soil come from a variety of sources, including atmospheric deposition, sewage irrigation, improper industrial solid waste stacking, mining activities, and pesticide and fertiliser use (Zhang *et al*., 2011). Heavy metals released from smelters, waste incinerators, industrial wastewater, and the application of sludge or municipal compost, pesticides, and fertilisers can contaminate large areas of land. Heavy metal accumulation, regardless of its source in the soil, can degrade soil quality, reduce crop yield and agricultural product quality, and thus have a negative impact on human, animal, and ecosystem health. Aside from quantifying heavy metal concentrations and spatial variability in soils, it is critical to identify the sources of heavy metals.

Geogenic sources of heavy metals

The parent material has a large influence on the heavy metal content of many soil types, with concentrations occasionally exceeding critical values (Palumbo et al. 2000). Several heavy metals, including Ni, Cr, and Mn, are found as trace elements in volcanic and metamorphic rocks. The primary crystalline structures of some rock minerals are completely broken during weathering processes, and relevant chemical elements are thus either adsorbed in the topsoil or transported to surface water or groundwater targets. Natural sources include rock seepage into water, volcanic activity, forest fires, and so on. As, F, Fe, and Se are reported to be of geogenic origin in India, but their release into the environment is exacerbated by anthropogenic activities such as untreated waste disposal, indiscriminate use of agrochemicals and agricultural inputs, unscientific mining, dumping industrial wastes, outdated technology, inadequate treatment and safe storage/management/disposal of chemicals and waste, and a lack of designed engineered landfills.

Table 1: India's hazardous metal sources (CPCB 2009)

Metal	Industry
Chromium (Cr)	Mining, industrial coolants, chromium salts manufacturing, leather tanning
Lead (Pb)	lead acid batteries, paints, e-waste, smelting operations, coal- based thermal power plants, ceramics, bangle industry
Mercury (Hg)	Chlor-alkali plants, thermal power plants, fluorescent lamps, hospital waste (damaged thermometers, barometers, sphygmomanometers), electrical appliances etc.
Arsenic (As)	Geogenic/natural processes, smelting operations, thermal power plants, fuel burning
Copper (Cu)	Mining, electroplating, smelting operations, vanadium Spent catalyst, sulphuric acid plant
Nickel (Ni)	Smelting operations, thermal power plants, battery industry
Cadmium (Cd)	Zinc smelting, waste batteries, e-waste, paint sludge, incinerations & fuel Combustion
Zinc (Zn)	Smelting, electroplating

Irrigation with contaminated ground and sewage water

It is estimated that sewage water can irrigate approximately 1.0 Mha to 1.5 Mha of land area in India each year. Farmers in peri-urban areas typically use year-round, intensive vegetable production systems (300-400% cropping intensity) or other perishable commodities like fodder to earn up to four times more per unit land area than freshwater farmers. However, studies have shown that heavy metals accumulate in soils to varying degrees after repeated use of WW for crop irrigation. Over GW irrigated soils, sewage irrigation resulted in a significant buildup of DTPA-extractable Zn (208%), Cu (170%), Fe (170%), Ni (63%) and Pb (29%), while Mn content was depleted by 31%. Soils irrigated with sewage water for 20 years accumulated significantly more DTPA extractable Zn (2.1 times), Cu (1.7 times), Fe (1.7 times), Ni (63.1%), and Pb (29%) than adjacent tube well water irrigated soils. Similarly, Yadav (2003) stated that the sewage water discharged through all of Haryana's districts contained micronutrients such as Zn, Fe, and Co in amounts of 30.1, 178.8, and 4.3 mg L-1, respectively. Excessive heavy metal accumulation in agricultural soils due to WW irrigation may result not only in soil contamination, but also in increased heavy metal uptake by crops, affecting food quality and safety. This heavy metal loading frequently degrades soil health and contaminates the food chain, primarily through vegetables grown in such soils.

The indiscriminate application of agrochemicals and agricultural inputs

Agriculture is a common source of heavy metal contamination, usually due to impurities in the fertilisers used. Other sources include sewage sludge used as an organic amendment, manure and compost, and airborne particulate transport. Despite the fact that these materials are widely used in India, no cases of heavy metal contamination from fertiliser and agrochemicals have been reported. However, periodic monitoring of soils treated with these materials is required to determine the amount of HM accumulation in soil and its impact on the food chain and human health.

Heavy metal pollution in soil

Heavy metal accumulation in soil and plants as a result of anthropogenic activity has been reported in various parts of India (Deka and Bhattacharyya 2009).

Arsenic: Arsenic enters the human body frequently through crops grown on arsenic-contaminated soils or contaminated groundwater used for irrigation. The presence of as in groundwater has been reported from various countries, and the extent of as contamination in groundwater is steadily increasing as more countries/areas are added to the existing list. According to the Central Ground Water Board (CGWB), the higher incidence of arsenic in groundwater is restricted primarily to the upper Delta plain along the Bhagirathi and other rivers. Nineteen (19) districts in West Bengal have recently been arsenic-affected, with high cropping intensities. A large amount of arsenic-contaminated groundwater is used to irrigate agricultural crops, particularly Boro (summer) rice during the lean season (March to May). The majority of fertile alluvial soils in Malda, Dinajpur (North and South), Murshidabad, Nadia, Burdwan, 24 Parganas (North and part of the South), and Hoogly are contaminated with arsenic as a result of the use of arsenic-laden groundwater as a source of irrigation, affecting soil quality and crop production. Arsenic accumulation in soils may be caused by leftover roots after harvest, which contribute significantly to arsenic accumulation (Garari *et al.*, 2000). The toxicity of As is determined by the forms or species of As in soil rather than the total As content, with Arsenite (III) being more toxic to animals and humans later in life.

Selenium: The distribution of selenium in soils is heavily influenced by the composition of geological materials. Selenium moves efficiently through the soil-plant-animal-human system. Seleniferous soils have been discovered primarily in the northwestern parts of Punjab, India. The selenium content of surface (2.12 1.13 mg kg-1) and subsurface (1.160.51mg kg-1) soil layers was 4-5 times higher in seleniferous areas than in non-seleniferous areas. The development of seleniferous pockets has been attributed to the deposition of seleniferous materials transported by seasonal rivulets from the higher reaches of the Siwalik Hills and the use of underground water for frequently irrigating crops such as lowland rice (Dhillon and Dhillon, 2003). Dry land areas in Rajasthan and southern parts of Haryana state had above-average soil selenium levels (due to low rainfall or lack of irrigation water). These soils were also discovered to have an alkaline reaction.

Chromium: Koelmel and Prasad (2013) calculated the anthropogenic terrestrial and atmospheric Cr emissions. In 2008, the major atmospheric chromium emission sources in India were stainless steel (43%), ferric chrome industries (42%), coal (9%), cement (2%), crude steel (2%), and chromite mine (2%) operations, according to one emission control scenario. Chromite tailings (62%), ferric chrome slag and dust (28%), fly ash (5%), and tanning effluent (2%), were the most significant sources of pollution to soil and water bodies. Tanning industries in Tamil Nadu and Uttar Pradesh are major sources of Cr contamination of agricultural lands via tannery effluent. There are several contaminated sites in the Tamil Nadu districts of Vellore, Erode, and Dindigul, where more than 60% of Indian tanneries are located. The assessment of Cr in contaminated soils in the Vellore district revealed that the soils around tannery industries are severely contaminated with Cr, exceeding the maximum threshold limit prescribed in various countries in most places. Similarly, Cr contaminated sites have been reported in Kanpur (UP), Orichem (Orissa), Ranipet (TN), and Nibra (WB).

Mercury: The caustic chlorine industry, steel industry, coal-based thermal power plants, cement industry, thermometer factory, paper industry, pharmaceuticals, pesticides, hospital and municipal solid wastes are the main contributors to Hg emissions in India. Hg levels have been reported to be extremely high in Singrauli, Madhya Pradesh, Sonbhadra district, Uttar Pradesh (a major site of Thermal Power Generation in India), and Kodaikanal, Tamil Nadu (Thermometer factory). Mercury in dust fallout from a steel plant near Raipur revealed that the fallout of elemental mercury over the soil horizon ranged from 60.36 to 836.18 g /km/month depending on the distance, wind direction, and location of the area with respect to the domestic environment. A comparison of the presence of mercury in the air dust particulates from two Indian metropolitan cities revealed that mercury in the ambient air dust from the paper mill was 20.5 + 0.8 g g-1 compared to 0.08 to 0.91 g g-1 in cities. Mercury emission and ambient mercury levels were found to be in the 1.13-4.00g m3 and 0.055-6.17g m3 ranges, respectively. Due to the discharge of industrial effluents containing mercury ranging from (0.058-0.268 mg/l) against 0.001mg/l as per WHO and Indian standards, mercury contamination in water in India has reached alarming proportions. Mercury levels in water near a caustic chlorine plant have been reported as high as 0.176 0.0003 mg/l in water and 596.67 25.17 mg/kg dry wt. soil, compared to the prescribed limit of 0.001 mg/l in water and 0.05 mg kg-1 in soil (Srivastava, 2002).

The Effects of heavy metal contamination on soils

Impact on soil microorganisms and enzymatic activity Microbial activity and enzymatic activity in the soil can sensitively reflect the quality of the soil. Microbial biomass of the soil was an important indicator of determining the extent of soil contamination. Microbial activity is inhibited significantly in the heavy metal contaminated soil. Kandeler (1997) indicated that the microbial biomass in the soil contaminated by Cu, Zn, Pb and other heavy metals were inhibited severely. The soil's microbial biomass near the mine was significantly lower than that 325 far away from the mine. The effects of different concentrations of heavy metals and different heavy metals on soil microbial biomass were different. Chander (1995) studied the effect of different concentrations of heavy metals on soil microbial biomass, and found that only if the concentration of heavy metals in the soil was three times above the environmental standard, established by the European Union, it could inhibit microbial biomass. Fliepbach (1994) found that low concentrations of heavy metals could stimulate microbial growth and increase microbial biomass; while high concentrations could decrease soil microbial biomass significantly. Enzymes in the soil play an important role in the process of organic matter decomposition and nutrient cycling. Studies have shown that the activities of enzymes in the soil are related to the heavy metal contamination. Saha (2013) found that the activities of almost all enzymes in the soil were significantly reduced with the increase of the concentration of heavy metals.

India's heavy metal polluted areas

Although India's economic growth is aided by higher levels of industrialization, there is also a huge concern for the environmental degradation that has followed. Researchers identified critically polluted industrial areas and clusters or potential impact zone based on its Comprehensive Environmental Pollution Index (CEPI) rating. There are43 critically polluted zones that were reported in the 16states, which has CEPI rating more than 70. Among the43 sites, 21 sites prevailing in only 4 states, namely Gujarat, Uttar Pradesh, Maharashtra and Tamil Nadu. Some of the severely polluted industrial clusters of India are discussed.

Madhya Pradesh's Ratlam and Nagda industrial areas:

In Ratlam the groundwater at about 60-80 m depth in several villages has been polluted with salts due to contamination with percolating industrial effluent and is being used for irrigation to winter crops. While mean EC values of ground water of unaffected villages were in the range of 0.85-0.92 dS m-1, the same in affected villages ranged from 1.49 to 4.50 dS m-1 with an overall mean of 2.84 dS m-1. Contents of sodium, sulphate and chloride in groundwater of affected villages were, respectively, 348%, 288% and 364% more than the similar values obtained in groundwater samples of unaffected villages. About 40% of the water samples in the polluted area can be categorized as having very high salinity (>2.25 dS m-1) and sodium hazard (SAR > 9) and about 71% of the samples have potential for severe Cl-1 hazard (>10 meq Cl-) permitting their use as irrigation only in tolerant crops. Use of such bad quality irrigation water has caused the disappearance of vegetable cultivation from the polluted groundwater area. Groundwater samples of the polluted area contained, on an average, 9.1 g/l Pb, 4.1 g/l Cd and 18.5 g/l Cu, which were more by about 162, 26 and 83% respectively over those in groundwater samples of unpolluted area. Considering WHO limits for groundwater, samples from Bhajankheda, Jadwasa khurd and Dosigaon villages of polluted area contained unsafe levels of Pb and Cd (Saha and Sharma 2006).

In Nagda, water of Chambal river has become severely polluted with effluents from textile industry and is being used for irrigation to winter crops in nearby areas of several villages. Irrigation water near affected villages had EC ranging from 2.38 to 4.11 and contained Na, K, Ca, Mg, SO4 -2 and Cl-, on an average, 4.7, 9.9, 7.7, 5.8, 1.8, 9.0, and 6.9 times more than the corresponding mean values obtained in irrigation water (ground water) in unaffected villages.

Long-term application of these polluted water to soil resulted significant accumulation of salts in the root zone layer of both these areas. There were significant increases in salinity as well as ESP levels in soils due to irrigation with polluted water in both the area, magnitude being much more in the soils irrigated with polluted river water at Nagda. Significant increases in concentrations of Na+, Cl-, SO4 -2 and HCO3 - and decreases in the concentrations of K+ and NO3 - in the soil solution were observed in the polluted soils of Ratlam. Similarly, polluted soils of Nagda recorded much higher concentration of major cations and anions (except NO3 -) in the soil solution. Available Cu contents in soils of polluted area were higher as compared to the soils of unpolluted area. Concentrations of Zn and Cu were also considerably more in the in the wheat plant tissue of the polluted area as compared to those of unpolluted area. This indicates possible contaminations of Zn and Cu in the food chain through the soil-plant-animal in the villages using polluted Chambal river water for irrigation in growing crops.

Madhya Pradesh's Pithampur (Dhar) industrial area:

Pithampur is the second largest industrial area in Asiahas both large- and small-scale industries. The majority of the vehicle-producing companies of India have their factories in Pithampur. Also, this area is housing, food processing, chemical processing, distilleries, manufacturing, and textile industries. Water of wells and tube wells in Cheerkhani and Silotia villages near to the industrial area is having high salinity EC (1.91 - 4.07 mScm-1) and sodium hazard (SAR > 10) and about 82% of the samples have potential for severe C l- (>10 me l-1) hazard permitting their use as irrigation only in tolerant crops. The EC of some of the tubewell water of polluted villages has gone up more than 2.5dSm-1 cm-1 indicating that effluents of industrial area have contaminated the ground water. The ground water samples of polluted area contained, on an average, 84.2µg/l Cr, 3.7 µg/l Pb and 1.2 µg/l Cd. Several groundwater samples of polluted area had Cr concentrations more than the WHO permitted level for drinking water. Surface soil samples of ground water polluted area of Cheerkhani and Silotia villages had, on an average, higher EC (3.4 times), SAR (3.1 times) due to considerable accumulation of salt ions. The soils receiving polluted ground water were higher in Co (7.5 times) and Cr (1.5times) as compared to soils of unpolluted area (Panwar *et al.* 2006).

Patancheru industrial area, Medak District, Andhra Pradesh:

It has about 300 pharmaceutical, heavy engineering, paints, chemical and paper factories established over thelast two decades. They generate more than 10 million liters of effluent water per day, most of which directly discharges to the natural hydrological system. Arsenic levels were high in effluent water from industrial areas with concentrations ranging from 1.8 to 97.3 µg/l with an average of 26.3 µg/l (Panwar *et al*. 2006). The high as values up to 15,000 - 30,000 µg/l were also reported near the exit of central effluent treatment plant (CETP). Nickel concentration varies from 4.7 to 57.4 (average of 23.4 µg/l), Pb varies from 0.3 to 14.2 µg/l (average of 2.0 µg/l) and Zn varies from 32.9 to 293.9 mg kg-1 (average of 81 µg/l). Some sample shows high values of Fe, Ni, Pb and Zn, which are near the vicinity of industrial areas (Panwar *et al.* 2006). The ground water in some places near the study area is also contaminated with salts (high pH and EC) and some metals like As, Ni, Cr and Zn.

Udaipur, Rajasthan, zinc smelting area:

The zinc smelter plants near Udaipur have smelting capacity of about 49,000 TPA. With the expansion of smelter plant a number of other production units have been commissioned, including sulfuric acid (87,000 TPA), cadmium metal (190 TPA), phosphoric acid (26,000 TPA), single superphosphate (72,000 TPA) and zinc dust (36,000 TPA). Since its inception the effluent from the plant has been discharged into a stream which flows about 3 kms to the east and merges into Berach river. The effluent of zinc smelter is being discharged into a stream, employed for irrigating the crops in the vicinity of the smelter plant. Concentrations of zinc and fluoride in the river water were higher than the permissible limit of 5 and 2 mg/l, respectively (Panwar *et al.* 2006). The concentration of these (Zn and Cd) heavy metals decreased with the distance from the discharge point in effluent irrigated soils nearer to the discharge point (Gorla and Bichhari village). A large variation in the content of total zinc (65 to 1590 mg/kg), total cadmium (0.07 to 8.37 mg/kg) and DTPA extractable zinc (19 to 173 mg/kg) have been recorded in the soils of the area under study. In comparison to a safe concentration determined for soils (Saha, 2013), most of the soil nearby Zn smelting area has accumulated toxic levels of Zn and Cd. With few exceptions, total zinc, cadmium and available zinc content of the soil decreases with an increase in the lateral distance from the stream and river (Panwar *et al*. 2006).

Textile industries pollute the soil and water in Pali, Rajasthan:

The textile printing and dyeing industries (more than 800 textile units) located in the Pali town (one of the critically polluted areas identified by CPCB) are discharging industrial effluents into the river Bandi, a non-perennial river with no flow in the lean season, thus severely contaminating both the river as well as the groundwater. The industries here discharge a variety of chemicals, dyes, acids and alkalis besides heavy metals and other toxic compounds. The effluents are multi coloured and highly acidic and/or alkaline. Ground water from downstream villages was highly saline as compared to upstream villages. These well waters were high in soluble Na. Copper concentration in well water samples were above the drinking water standards in all the wells in downstream villages; while Pb is high in Kerla, Sukarlai and Nehada; Cr level is high in Kerla, Sukarlai, Gadhwara and Phikaria; As is high in Jewadiya, Kerla and Phikaria (Panwar *et al.* 2006). The above well water was not suitable for irrigation due to high salinity (>4 dS m-1). The Nahada dam built for storing water, become an industrial storage tank and thus leads to groundwater contamination. The soils cultivated using contaminated well waters have also developed high salinity (irrigation with high saline water) (Panwar *et al.* 2006).

Korba industrial area (Chhattisgarh):

Korba city is the Power Capital of Central India with the NTPC's Super Thermal Power Plant working at 90% Plant Load Factor. Korba is also having aluminium industry (BALCO), textiles, engineering workshops, hardware (Al & Fe), detergents, plastic toys, PVC cable pipes, cement products, electricity transformer, bakelite, distemper, clay insulator manufacturing units and other small industries, generating large quantity of acidic effluent, which directly drained in agricultural fields and contaminate the soil. Groundwater samples collected from villages nearby industrial area contained higher levels of heavy metals Cd, Co, Cr, Ni, and Zn as compared to those collected from far away villages (Panwar *et al.* 2006). The majority of the groundwater samples from the polluted area had heavy metals more than the levels permitted for drinking purpose. Soil irrigated with effluent turned highly acidic. Other soil properties viz. EC, soil organic carbon, DTPA extractable heavy metals and total heavy metals were increased with the application of industrial waste/effluent or contaminated water as compared to the non-polluted soils. The total as well as DTPA extractable heavy metals particularly, Cr and Cu were high in most of the polluted soil (Panwar *et al*. 2006).

Tiruppur industrial area:

Tiruppur has been identified as one of the critically polluted area by CPCB. Industrial area discharges more than 90MLD into Noyyal river (tributary of Cauvery river). It passes through Tiruppur and stored up in the Orathapalayam Dam to be used in agriculture and drinking purposes for the downstream villages in the Tiruppur and Erode District. The Industrial area is having 729 bleaching and dyeing units Due to pollution, drinking water quality, fisheries and the agriculture in Tiruppur area and downstream villages of Noyyal river has been affected. The river water is quite harmful (EC >3 dS m-1) to agriculture in an area of 146 km2 and critical (EC 1.1 to 3 dS m-1) in 218 km2 (Panwar *et al*. 2006). The groundwater in some villages is having high values of Pb and Cr which may be attributed to the industrial activities. The majority of the samples are not suitable for domestic purposes and far from drinking water standards. Irrigation of cropping land with polluted water transformed the productive soils into saline soil (> 4 dS m-1); the dominant cations and anions being Na+ and Cl- and SO4 -2. Irrigation with polluted Noyyal river water resulted build-up of salinity (EC > 4 dS m-1) in 328 soils of agricultural land (Panwar *et al*. 2006).

Coimbatore industrial area, Coimbatore:

Coimbatore industrial area is the 2nd largest industrial area in Tamil Nadu. The industrial area is having about 500 textile industry, 200 electroplating industry, 100 foundries and 300 dyeing industries. All the industrial effluent/sewage is going to Ukkadam river, which is the source of irrigation in the nearby area (16000 acre). Heavy metal contents in the city sewage water were quite high and varied widely with the season. IISS investigated changes in soil properties in agricultural land nearby different industrial clusters; namely electroplating industry, textile industry, dye industry and city sewage irrigated areas (Panwar *et al*. 2006). Groundwater near industrial area has developed salinity due to contamination, mainly with salts of Na+ and Cl-; the magnitude of contamination was more near Textile and dye industries. Sulphate contamination was maximum in the groundwater near electroplating industries. Soils of agricultural land near textile and dye industries have developed severe salinity (EC > 6 dS m-1) and slight alkalinity (pH >8.0). Soils of agricultural land near industrial areas contained 47 to 178 mg/kg Ni, 47 to 214 mg/kg Pb, 0.5 to 4.2 mg/kg Cd and 43 to 241 mg/kg Cr. Most of the soil had all the heavy metals more than the safe concentration limits determined by Saha (2013), which indicate that these soils may pose threat to the environment. Nickel and Pb concentrations were higher in soils near the electroplating and sewage industrial area; Cd concentration was higher in soils irrigated with mixed effluents, and sewage; Cr concentration was higher in soils irrigated with textile, dye and sewage effluent (Panwar *et al*., 2006). DTPA extractable heavy metal contents have been also very high as compared to those normally observed in unpolluted soils, which indicates soils of agricultural land near the industrial area of Coimbatore are likely to impart considerable threat to living organisms.

Katedan industrial development area in South of Hyderabad, Andhra Pradesh:

Very high concentrations of lead, chromium, nickel, zinc, arsenic and cadmium throughout the industrial area, housing 300 industries dealing with dyeing, edible oil production, battery manufacturing, metal plating, chemicals, etc. (Govil *et al*. 2008). The random dumping of hazardous waste in the industrial area could be the main cause of the soil contamination spreading by rainwater and wind. The residential area is also contaminated by as and some small areas by Cr, Cu, Pb and Zn. Effluent generated from different industries in and around Katedan area were let into the ponds without proper treatment. As a result, groundwater nearby areas were contaminated with salts and several heavy metals (Cd, Cr, Ni and Cu). All the heavy metals (except Pb) in the groundwater were more than the permissible limits. Due to use of such contaminated groundwater for irrigation, contents of Pb, Ni and Cr in the soil increased.

Maharashtra's Thane district:

The random dumping of hazardous waste in the industrial area caused groundwater and soil contamination (Bhagure and Mirgane 2011). Very high concentration of total dissolved solids, total hardness, total alkalinity, chemical oxygen demand, chloride etc. Groundwater samples are heavily contaminated by arsenic, cadmium, mercury, and nickel. Soil samples collected from residential, commercial and industrial areas are heavily contaminated by arsenic, cadmium, mercury, and nickel. In the residential areas the local dumping is expected to be the main source of heavy metals.

Keonjhar District, Orissa's Baula-Nuasahi (Chromite) mining belts:

The overburden soils have low nutrient (N, P, and K) content and the microbial population was low. The metal ions were found to have leached to nearby agriculture lands, making them less fertile for crop production. Overburden dumps and seepage water were found to be the main sources of chromium pollution (Dhal and Pinaki, 2014)

Chennai's Manali industrial area:

In a study, considerable accumulation of Cu, Cr, Co, Ni, and Zn has been observed in soils of the Manali industrial area in Chennai, which is saturated by industries like petrochemicals, refineries, and fertilizers generating hazardous wastes (Krishna and Govil 2008). Soil samples were collected from the industrial area of Manali had elevated concentrations of Cr (149.8-418.0 mg/kg), Cu (22.4-372.0 mg/kg), Ni (11.8-78.8 mg/kg), Zn (63.5- 213.6 mg/kg) and Mo (2.3-15.3 mg/ kg).

Tamil Nadu's Coimbatore-Pollachi highway is polluted with lead:

Lead contamination arises mainly from the combustion of petrol transmitted a particulate of lead halide and also 329 as Pb from the evaporation losses of petrol to the atmosphere. An investigation was undertaken to know whether there is a problem of Pb pollution along the road side of Coimbatore-Pollachi highway of Tamil Nadu. Forty soil and plant samples were collected from a soil depth of 0-15 cm at a distance of 3 and 6 m from the road (Stalin *et al*., 2010). Lead enrichment factor was worked out considering the 10µg/g as the average Pb content from non-contaminated soils and the results showed that the sample nearer to the road (3m) contains more Pb than at 6 m distance. There is an average enrichment factor of 6.60 for the soil samples with the maximum of 54.9 mg/kg. Among the plant samples soybean contains a higher concentration of Pb and the enrichment factor was high at 3 m distance (1966 mg/kg) than other plants.

Management of heavy metal polluted soil

Soils have varying capacity to immobilize metals (through sorption, complexation, precipitation etc.) due to variable contents of clay types, organic matter, oxides, carbonates, phosphates, sulphides etc. as well as due to prevailing chemical conditions (pH and Eh) and therefore, tolerable level for metals depends considerably on soil properties. Expression of toxicity to organisms, therefore, depends on the degree of contamination and properties of soil. Remediation technologies to counter the toxicity can be grouped into engineering, chemical, and biological approaches.

1. **Engineering approaches:** Such technologies can be excavation and landfilling, insitu vitrification, *Ex-situ* solidification/ stabilization, *Ex-situ* soil washing & soil flushing, creating a subsurface barrier to protect groundwater from contamination, thermal treatment, electrokinetic method etc. All these technologies, though quicker and provide a relatively long-term solution, are cost and energy intensive and applicable to a limited volume and area of soil body.
2. **Chemical approaches:** Most of the chemical approaches aim at reducing both total and free ion activity of the metals in soil solution so that their uptake by plant and toxicity to organisms are reduced. Among the chemical methods, application of amendments like phosphates, liming material, Fe/Mnoxyhydroxides, organic materials, zeolites, modified aluminosilicates (beringite) etc. has been advocated.
3. **Biological approaches:** Certain hyperaccumulator plants like *Thlaspi caerulenscens, Haumaniastrum robertii, Ipomoea alpina, Macadamia neurophylla, Psychotria douarret, Thlaspi rotundifolium, Cystus ladanifer*, Salix sp. etc are employed to remove heavy metals from soils. Such plants can tolerate high metal levels in soil and accumulate10~500 times higher levels than other plants & crops. Application of chelates like EDTA has been found to enhance metal extraction by the hyper accumulators. Rock phosphate has been found to accelerate arsenic removal by hyper accumulator *Pteris vittata*. Most of the phyto remediating plants capable of accumulating high concentration metals, also produce less biomass, which limits their overall phyto-extraction efficiency. Using modern techniques of biotechnology, several high biomass producing phyto accumulators have been developed by introducing relevant genes (from hyper accumulator, bacteria, animals) into non-accumulator plants. Some of high biomass hyper accumulators for which regeneration protocols are developed include Indian mustard (*Brassica juncea*), sunflower (*Helianthus annuus*), tomato (*Lycopersicon esculentum*) and yellow poplar (*Liriodendron tulipifera*) (Mello-Farias *et al.*, 2011). Plants have also been used to remove certain metals from soil by converting them to volatile forms (termed as phyto volatilization). Several plants have also been used for the phyto stabilization purpose (inactivation of soluble forms of metals in the rhizosphere) in order to prevent metal contamination of deeper soil layers and groundwater. Some researchers

have demonstrated the potential of microbes for removal of metals from soil using 'Bio metal slurry reactor' technique and indirectly by microbially generated bio-surfactant. However, the feasibility of such technologies is yet to be proved at field level.

Integrated management of polluted soil:

Generally, engineering methods of decontamination and immobilization are adopted for soils having very high levels of toxic metals so as to prevent their spread in unpolluted 330 area and in living organisms, and the threat is required to be brought down to an acceptable level within a short span of time. Also, successful execution of these technologies requires intervention by the State due to involvement of high cost which may not be bearable by farmers. On the other hand, agricultural land affected with low to moderate level of pollutants may require modifications/interventions in the existing soil, crop and input managements in order improve and sustain soil quality, crop productivity and produce quality. For sustainable agriculture on unpolluted land, integrated soil management involves a combined strategy of effective nutrient, crop, water, soil and land management, fulfilling the objectives of improving soil fertility, water use efficiency, conservation of soil and water and increasing cropping intensity. In the context of polluted agricultural land, however, soil management should additionally address the issues like protection from pollutant build-up and its remediation and improving soil biological environment (Saha *et al*., 2014). Most often, such management strategies are dependent on:

- Type of pollutants and their mode of toxicity expression
- Contamination level
- Purpose of land use during and after remediation process
- Soil type, depth of profile and topography
- Climate of the area
- Cropping pattern
- Availability of resources
- Economics

There exist complex inter-relationships among the above determining factors as well as agricultural management technologies. As a result, arriving at an appropriate strategy for combating threats in polluted soil is often not so simple. The task becomes more complex because of two reasons: firstly, ownership of land (and consequently the decision making process) lies with farmers' and secondly, threat from pollutants is occasionally more to consumers rather than to the growers of food due to contamination.

Soils vary widely in respect of physical (depth, texture, structure, compactness etc.), chemical (mineralogical composition, clay type, oxides, organic matter, base-saturation, CEC, soil solution composition, nutrient availability etc.) and biological properties (microbial population, diversity and activity). These soil properties determine effectiveness and adaptability of some of the management options over others. While *In-situ* soil washing and removal of metal ions may be convenient in light textured soils, these may not be easily achieved in Vertisols due to high clay content. On the contrary, manipulation of redox potential for reducing metal toxicity may be easier in latter soil type due to its slower infiltration capacity. Climatic factors, particularly the magnitude and distribution pattern of rainfall and temperature also influence mobility, transformation, transfer and degradation of pollutants in the rhizosphere.

Agricultural operations influencing polluted land remediation

Fertilization: Fertilizers are considered essential in both types of usage of polluted agricultural land: (1) for higher production of food and other economic crops, and (2) for higher removal of metals by phytoremediating crops through higher biomass production. While fertilizer management should enhance mobilization of metals in case of phytoremediation, the reverse is desired during growing of food and fodder crops. Application of chloride containing fertilizers like NH4Cl and muriate of potash (KCl) should preferably be avoided in Cd contaminated soil for growing food & fodder crops as this enhances mobility of the metal through the formation of soluble CdCln2-n complex and promote crop contamination (Lopez-Chuken *et al*. 2012). Fertilizers like ammonium sulphate and mono-ammonium phosphate lowers the soil pH during their continuous application and consequently, may increase the availability of metal pollutants and hence, may be avoided in metal polluted neutral & calcareous soils. In a laboratory experiment, monoammonium phosphate decreased soil pH and the amount of Cd adsorbed by two soils (thereby increasing the availability), while diammonium phosphate precipitated Cd particularly in low organic matter containing soil. Contamination of several food crops with as is widely observed in lower Gangetic plains of India and Bangladesh due to irrigation with contaminated groundwater. Phosphorus application has been found to reduce its contamination of wheat grain. In rice plants (grown on flooded soil), however, added P suppressed uptake of arsenate, not arsenite indicates a different uptake mechanism for different forms of as species. High available calcium in soils inhibits accumulation of several heavy metals by crop and hence, frequent application of Ca containing fertilizers (like SSP, CAN, gypsum) and lime may be advisable in non-calcareous soils in high rainfall areas.

Soil organic matter management: Due to its role in maintaining soil fertility and crop productivity, improvement and maintenance of organic matter status in agricultural soil are essentially advocating, particularly in tropical regions where rate of C mineralization is quite high. Application of organic matter has been found to reduce the availability of heavy metals in contaminated soil. However, strength of metal complexes with humic acid increases with increasing pH and decreasing ionic strength and therefore, combined application of lime and organic matter may be most effective strategy in reducing/eliminating the adverse impacts (i.e. phytotoxicity and food contamination) in heavy metal polluted acidic soils.

Tillage operations: Tillage methods influence root proliferation (hence rhizosphere depth and volume), aeration, partitioning of rainwater and soil erosion and therefore, can be important for the management of polluted soils. Limited studies have indicated a role of tillage for amelioration and management of polluted soil. Conservation tillage has been recommended in case of polluted land as it reduces runoff & soil erosion during high intensity rainfall and, thereby, protects the nearby unpolluted area and aquatic life from toxicants. Reduced tillage or no-tillage promotes higher metal uptake from surface horizon due to restricted root proliferation in the deeper layer and therefore may be advisable during phytoextraction of surface contaminated land. On the contrary, enhanced aeration and exposure of below surface soils to sunlight due to repeated tillage operations can accelerate biodegradation of organic pollutants.

Soil and water conservation and management: Highly polluted agricultural land is also a source of contamination for nearby land and surface water bodies and therefore, management strategies warrant appropriate measures to check soil erosion. In high rainfall area, soil tillage across the slope, contour farming, cover cropping, mulching, etc. may be adopted to reduce impact of raindrops and soil loss through runoff water. Growing grasses and cover crops having high phytoremediation potential can be a good alternative in such situation as these can reduce runoff soil loss as well. However, trees (like Populus spp. and Salix spp.) may be grown along with grasses so as to phytostabilize metals in deeper soil layer and prevent downward metal flux. In arid regions, contaminated soil particles carried away by wind may have severe health implications on human and animal populations when enters the body through the respiratory route. Capping of polluted land with fertile soils and growing grasses can prevent air pollution with contaminated dust. Often groundwater of the area surrounding industrial cluster records elevated salinity and use of such water for irrigation is likely to increase the osmotic potential in the rhizosphere causing physiological water stress to the crop. Moreover, elevated Cl- (normally associated with salinity of the groundwater) in soil solution may enhance the mobility and uptake of heavy metals (particularly Cd) in contaminated land (Lopez-Chuken *et al*., 2012). Therefore, water management strategy for cultivated land around the industrial area should focus on increasing water use efficiency through efficient irrigation methods and also on reducing dependency on groundwater through conservation of rainwater and soil moisture.

Selection of crops and cropping systems: Crops differ widely in respect of their ability in uptake of metals and in combating heavy metal stress by adopting various mechanisms like exclusion, sequestration, metal homeostasis. Selection of crops for the polluted land can be decided based on the perceived threat(s) to the farming. A comparatively lower level of pollution poses threat only to the quality of food and fodder due to contamination with toxic metals (Saha *et al*., 2013) and therefore, appropriate strategy in such situation would be to minimize their transfer to aboveground biomass. Results indicate that bio-concentration is generally the highest in leafy vegetables followed by root vegetables and minimum in grain crops. Therefore, the cultivation of leafy and root vegetables (like spinach, lettuce, cabbage, potato, radish, beet, coriander etc.) in soils having elevated levels of metals should be avoided and growing of other crops can only be taken up after ensuring that national requirements for food & fodder quality in respect of heavy metal contents is met. In an experiment under controlled condition, different cereals, oilseeds, sugarcane, and fiber crop exhibited tolerance to high soil Cd levels. Though grain of cereal crops got contaminated, edible parts of other crops remained free from contamination. Even varieties differ in the metal contamination in grain due to difference in uptake pattern, upward and basipetal translocation in plant parts indicating the importance of genotype selection in the contaminated soil. Crop rotation can also influence heavy metal mobilization and uptake by plants due to residual effects of several organic acids in the root exudates from previous crops. Concentration Cd in grain was more in wheat grown after lupins and lowest in wheat grown after cereal, particularly under zero-tillage.

Conclusions:

Heavy metal pollution is emerging with speedy rate, due to industrialization and modern lifestyle. It is moving through the soil - plant continuum to human or animal, and interfere with the biological process in the human body. Most of the remediation techniques, converting the toxic form of heavy metal to non-toxic form; or available form to unavailable form in soil and reduced the crop uptake. The primary strategy should be segregation of heavy metal containing waste, and its safe disposal. Use of heavy metal contaminated for the non-edible food crops like flowers, caster & jatropha etc. The regular monitoring of effluent, soil, crop produce, where the contaminated water is used for crop production activities. A strong policy should be initiated to the contaminated water discharging units as well as its consumers. A wide awareness campaign with the help of the government agencies or non-government organizations (NGOs) regarding heavy metal toxicity and its consequences.

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ROLE OF DRONES IN INSECT PEST MANAGEMENT

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Abstract:

The impact of technology in agriculture is a positive trend, as it is the solution to feed the burgeoning population. Food security is a question that needs to be addressed, in the background of environmental degradation, pollution, and water scarcity, and an effective solution is a high priority. This is where usage of drone can guarantee a sustainable solution. Agriculture with drones could undergo a significant transformation in terms of productivity. Drones are a tool for more precise pest control. Sensing drones and actuation drones are the terms used to describe the drones that are used to precisely distribute solutions and locate insect hotspots. For the purpose of creating a closed-loop IPM solution, both varieties of drones might converse. The detection and identification of plant stress brought on by pest insects and allied arthropods has received a lot of attention in drone research. Use of various spectral images from unmanned aerial vehicles to identify stress brought on by pest insects (UAV). The discharge of the biocontrol agents is a component of the use of actuation drones in pest management systems. Precision agriculture and IPM are incorporating drones more and more. To keep an eye on crop health and spot insect outbreaks, drones with sensors are used. Different drones (actuators) could be used to deliver prompt treatments to pinpointed insect hotspots when outbreaks do happen. automating the release of biological control agents and the application of pesticides through communication between sensor and actuation drones.

Keywords: Unmanned Aerial Vehicles, Remote sensing Drones**,** Actuation Drones.

Introduction:

The impact of technology in agriculture is a positive trend, as it is the solution to feed the burgeoning population. Food security is a question that needs to be addressed, in the background of environmental degradation, pollution, and water scarcity, and an effective solution is a high priority. This is where usage of drone can guarantee a sustainable solution. DRONE (Dynamic Remotely Operated Navigation Equipment), also known as UAV, is a type of drone that can be flown physically using radio signals via a remote control or smartphone app or automatically using GPS coordinates and autopilot to follow a predetermined course. With so many sensors at their disposal, drones can find objects that are invisible to the human eye. As a result, drones can provide real-time, more precise, trustworthy, and objective information with less mistake and higher detail.

History of drones

Earliest military drones appeared in the mid-1850s	In 1849 Austria attacked Venice using unmanned balloons stuffed with explosives.
Earliest military drones appeared in the mid-1850s	In 1849 Austria attacked Venice using unmanned balloons stuffed with explosives.
1915-1920 saw a big leap forward in the technology	The U.S. Army built the Kettering *Bug*
1930-1945 saw other major leaps forward in military drone technology:	Radio-controlled aircraft Curtiss N2C-2 Drone in 1937 and in 1935 the British developed "Queen Bee
Assault military drones were seriously beefed up during 1980-1989.	U.S. and Israel in 1986 RQ2 Pioneer – a medium-size reconnaissance aircraft
1990-2010 was a pivotal period	Military and civilian drone development
2010-today ("Golden Age") of drones	Present commercial drones

As far as we are aware, drones have a wide range of uses, including military surveillance, cinematography, wedding videography, railroad track monitoring, animal monitoring, small package delivery, security operations, law enforcement activities, search and rescue operations, and disaster management. Hence, it is impossible to discount the likelihood that drones will contribute significantly to the development of sustainable agriculture in the near future as a component of green technologies. Farmers currently deal with a variety of issues, such as the lack of or high cost of labour, health issues caused by contact with chemicals (such as fertilisers, insecticides, etc.) while using them in the field, bites from insects or other animals, etc. In this situation, drones can benefit farmers by assisting them in avoiding these issues in addition to the advantages of being an environmentally friendly technology. Drones are now becoming a part of precision agriculture and helping to promote sustainable farming. According to their intended application, drones employ a variety of sensors.

UAV classification:

Based on their structural design, UAVs can be divided into two categories: fixed wing and multirotor. Multirotor UAVs work best for monitoring and the detection of crop pests, diseases, and weeds, whereas fixed-wing UAVs are excellent for aerial surveys, high-resolution aerial photography, mapping, and land surveying. Data gathered by drones are superior to satellite data in many ways because they may avoid cloud obstructions, which prevent missing data from being captured during image capture, a major issue with satellite data collection, particularly during the monsoon season. A drone also has the advantage of being operable at any time, whereas a satellite can only be used at a set, predetermined time. So, when compared to satellite data, real-time data from drones is more accurate and detailed. Drone data can be combined with satellite data to improve the accuracy of the satellite data and prevent drones from flying over the same areas repeatedly. Drone-collected data can so supplement satellite data.

UAV Classification	**Altitude**	**High altitude platform (HAP)**	Long endurance Wide coverage Quasi-stationary altitude above 17 km
		Low altitude platform (LAP)	Fast and flexible deployment quick mobility cost-effective Typically flies up to several hours
	Type	**Fixed-wing**	Such as small aircrafts cannot hover high speed can carry high payload can fly for several hours
		Rotary wing	Such as quadrotor drone Can hover, low speed More energy limited than fixed-wing less than 1 hour flight. duration for typical drones

When used as flying, aerial base stations, UAVs can assist the connectivity of modern terrestrial wireless networks like cellular and broadband networks. UAVs have several advantages over traditional ground base stations, including the ability to change their height, avoid obstacles, and increase the likelihood of establishing line-of-sight (Loss) communication links to ground users.

Table 1: UAV base station versus terrestrial base station

UAV Base Stations	**Terrestrial Base Stations**
The nature of deployment is three-dimensional.	Most deployments are two dimensional.
quick deployments that regularly change.	mostly permanent, long-term deployments
Locations with few restrictions.	Few, selected locations.
Mobility function	a few, chosen places.

Table 2: UAV Networks versus Terrestrial Networks

UAV Networks	**Terrestrial Networks**
The spectrum is limited.	Lack of spectrum
elaborate and strict energy models and limitations.	energy limitations and models with clear parameters.
different cell associations	static association mostly.
restrictions on hover and flying times	No time restrictions, BS constantly present

Applications of drones in agriculture

1. **Soil analysis for field planning:** To evaluate the soil and fields in order to plan irrigation, crops, and soil nitrogen levels. Drones can also be used to provide exact 3-D maps that can be utilized to conduct soil studies on soil properties, moisture content, and soil erosion.

2. **Seed Pod Planting:** Although they have not yet gained widespread adoption, several companies have created additional attachments below drone systems that can shoot pods containing seed and plant nutrients into the already prepared soil.
3. **Crop Monitoring:** By gathering multi-spectral spatial and temporal datasets at pre-defined scales related to crop development and health, drones can be utilized to design monitoring routes. Data analytics allows for the early identification of crop health issues that might otherwise go unreported by human field scouting.
4. **Crop Spraying:** For quicker agricultural spraying, drones may transport adequately sized reservoirs that can be filled with fertilizers, herbicides, or pesticides. Due to its self-contained operation and pre-programmed operation on precise times and routes, crop spraying is much safer and more economical. Drones may also self-adjust their altitude and speed to provide uniform and optimal spraying results over a variety of topography using ultrasonic echoes, TOF lasers, and GNSS signals.
5. **Irrigation:** Drones with thermal, multispectral, or hyperspectral sensors can find areas of the field that lack moisture using multispectral indices. This facilitates careful irrigation planning for the designated zones.
6. **Crop surveillance:** Drones scan the field with infrared cameras and compute light absorption rates to gauge the health of the crops. Based on precise and real-time data, farmers can take steps to enhance the condition of plants in any area of the field. By cross-verifying farmers' claims, this aspect of crop surveillance and crop health assessment also forms the basis for the use of drones in agricultural insurance products.
7. **Controlling insect, pest and diseases**: Drones can detect and alert farmers about weeds, disease, and insect pest infestations in addition to soil conditions. Farmers can optimise the usage of chemicals needed to combat pests based on this knowledge, lowering costs and contributing to greater field health.

Problems and bottlenecks

a. **Flight Time and Range** Drones used in agriculture have limited flight durations, ranging from 20 to 60 minutes, due to their relatively higher payloads. As a result, each charge only covers a small area of ground.
b. **Initial Cost:** Agricultural drones used for surveys typically have fixed wings and can cost up to $25000 (Precision Hawk's Lancaster), depending on the features and sensors needed for the intended function. Because image sensors, software, hardware, and tools are all included in the price, some drones are more expensive.
c. **Connectivity:** In most arable farms, internet access is not available. In this case, any farmer who wants to employ drones must either invest in connectivity or purchase a drone that can store data locally in a format that can be transferred and processed later.
d. **Weather Dependent**: Drones, unlike regular aircraft, are difficult to fly in windy or rainy circumstances. Drones are affected by the weather.
e. **Knowledge and Skill:** Drone photographs necessitate specialised skills and knowledge to convert into useful data, which the common farmer lacks. In these situations, the farmer must either learn and comprehend image processing software or hire expert individuals who are familiar with the software.

f. **Misuse:** There is a risk of misuse to infringe on people's privacy and to transfer information illegally.

Precision pest management is twofold:

i. First, reflectance-based crop monitoring (using ground-based, airborne, or orbital remote sensing technologies) can be used to identify pest hotspots.

ii. Second, precision control systems, such as distributors of natural enemies and pesticide spray rigs, can provide localized solutions. Both technologies can be mounted on equipment moving through fields (such as irrigation equipment), on manned or unmanned vehicles driving around in fields, or on aerial drones.

iii. Drones used for detection of pest hotspots are here referred to as sensing drones, while drones used for precision distribution of solutions are referred to as actuation drones. Both types of drones could communicate to establish a closed-loop IPM solution.

iv. Importantly, use of drones in precision pest management could be cost-effective and reduce harm to the environment. Sensing drones could reduce the time required to scout for pests, while actuation drones could reduce the area where pesticide applications are necessary, and reduce the costs of dispensing natural enemies

Table 3: Sensing drones versus actuation drones

Sensing drones	Actuation drones
Drones used for **detection of pest hotspots** are here referred to as sensing drones	drones used for **precision distribution** of solutions are referred to as actuation drones.
Sensing drones could reduce the time required to scout for pests,	actuation drones could reduce the area where pesticide applications are necessary, and reduce the costs of dispensing natural enemies
Both types of drones could communicate to establish a closed-loop IPM solution (Teske *et al.*, 2019).	

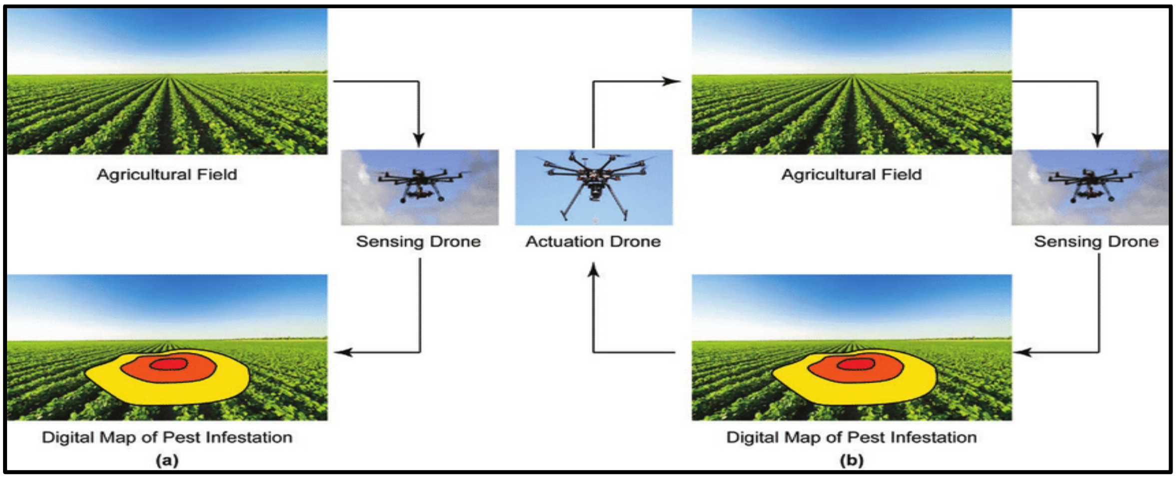

Figure 1: State-of-the-art open-loop remote sensing paradigm and (b) closed-loop IPM paradigm envisioned in this article. Sensing drones could be used for detection of pest hotspots, while actuation drones could be used for precision distribution of solutions. Adapted from (Teske *et al.*, 2019).

Traditional field scouting Methods

a. For pest infestations is often expensive and time-consuming.
b. It may be practically challenging, such as when a large acreage is involved, when the arthropod pests are too small to see with the naked eye, or when they reside in the soil or in tall trees.
c. In some cropping systems, effective scouting is hampered by lack of reliable pest sampling techniques. Hence, one of the main drivers for the implementation of drone-based remote sensing technologies into agriculture is the potential time saved by automatizing crop monitoring, making the technology cost-effective for growers (Dara,2019).

Remote sensing in precision agriculture

Remote sensing is the detection of energy emitted or reflected by various objects, either in the form of acoustical energy or in the form of electromagnetic energy (including ultraviolet [UV] light, visible light, and infrared light) (Usha and Singh, 2013). It is a non-invasive, relatively labour-extensive method that could be used to detect plant stress before changes are visible by eye. For crops, remote sensing equipment generally assesses the spectral range of visible light or photosynthetically active radiation (PAR 400–700 nm) and near infrared light (NIR, 700 1,400 nm), with most studies referring to the 400–1,000 nm range (Nansen, 2016).

An RGB sensor is low-cost, but results in limited spectral information. A multispectral sensor results in more spectral information, but a hyperspectral sensor is generally much better at differentiating subtle differences in canopy reflectance than a multispectral sensor (Yang *et al.*, 2009).

Mostly the sensors sensitive to the following bands of electromagnetic waves are used in agriculture:

1. Red, Green, and Blue (RGB) bands: These bands are used for counting the number of plants, for modelling elevation, and visual inspection of the crop field.
2. Near Infra-Red (NIR) band: This band is used for water management, erosion analysis, plant counting, soil moisture analysis, and assessment of crop health
3. Red Edge band (RE): It is used for plant counting, water management, and crop health assessment.
4. Thermal Infra-Red band: This band has applicability in irrigation scheduling, analysing plant physiology, and yield forecasting.

Spectral signatures of vegetation

The health of a crop by relating electromagnetic, or spectral, reflectance to plant biological components and physiology, such as foliar pigment content, cellular structure, water content, as well as canopy coverage and architecture (Pinter *et al.*, 2003).

Healthy vegetation

i. Low reflectance (high absorption) in blue and red regions
ii. High reflectance in NIR due to internal cell structure
iii. Low reflectance (water absorption bands) in mid IR region

Any deviation from these patterns will be indicative of some stress on crop.

Most commonly used spectral indices for remote sensing in agriculture is the normalized difference vegetation index (NDVI).

NDVI is particularly helpful because it combines red reflectance with near-infrared reflectance (NIR).

NDVI = (NIR-Red \NIR + Red)

$$\mathbf{NDVI} = \frac{(\text{NIR-Red})}{(\text{NIR} + \text{Red})}$$

NDVI value ranges from -1.0 to +1.0

a. **Red reflectance** is an indicator of **chlorophyll content** of the plant canopy and active photosynthesis
b. **NIR** provides information about the **cellular structure and intracellular air spaces** within leaves, overall canopy coverage, and above ground biomass (Hatfield *et al.*, 2008).
c. **NDVI:** it provides a measure of overall plant health and has frequently been correlated with crop yield (Ma *et al.*, 2001).

Remote sensing and arthropod pests

Remote sensing technologies have been used in precision agriculture for the last few decades, with various applications, such as yield predictions and evaluation of crop phenology (Mulla, 2013). Also, these techniques are being used:

a. To monitor different abiotic plant stressors, such as drought (Jorge *et al.*,2019),
b. To monitor nutritional deficiencies (Quemada *et al.*, 2014), and
c. To monitor biotic plant stressors, such as pathogens, nematodes and weeds (Pena *et al.*, 2015).
d. To monitor detection of relatively large sessile insect life stages

Likewise, remote sensing technologies have been successfully used to detect stress caused by various arthropod pests on a wide variety of field and orchard crops (Nansen and Elliott, 2016). A limited number of studies concerning arthropod-induced stress detection used drone-based aerial remote sensing

Table 4. Current scouting practices versus Remote sensing

Current scouting practices	Remote sensing
a. Current scouting practices do not provide complete coverage of a field creating the potential to miss areas heavily infested with soybean aphid. difficulty associated with counting aphids within a large field of densely planted soybean and the lack of coverage provided b. Current scouting methods has led some farmers to use prophylactic applications of insecticides rather than base chemical treatment on estimates of aphid populations in the field (Olson *et al.*, 2008).	a. Remote sensing offers the potential to improve management of soybean aphid by decreasing the effort and cost of scouting while increasing field coverage. b. It may increase adoption of management practices based on estimates of in-field pest abundance and thereby decrease unnecessary pesticide applications.

Table 5: Studies on drone-based hyperspectral, multispectral, and RGB remote sensing to detect arthropod-induced stress in crops and orchards

S.No	Crop	Scientific Name	Pest	Scientific Name	Family and Order	Field observations	S R	References
1	Grape	*Vitis vinifera*	leafhopper	*Jacobiasca lybica*	Hemiptera: Cicadellidae	Visual inspection of images	RGB	del-Campo-Sanchez *et al.*,2019
2	Wheat	*Triticum aestivum*	FAW	*Spodoptera frugiperda*	Lepidoptera: Noctuidae	Outbreak reported by grower	RGB + M	Zhang *et al.*, 2014
3	Grape	*Vitis vinifera*	phylloxera	*Daktulosphaira vitifoliae Fitch*	Hemiptera: Phylloxeridae	Ground traps and root digging, visual vigor assessments	RGB + M + H	Vanegas *et al.*, 2018
4	Grape	*Vitis vinifera*	phylloxera	*Daktulosphaira vitifoliae*	Hemiptera: Phylloxeridae	Ground traps and root digging, visual vigor assessments	RGB + M + H / RGB	Vanegas *et al.*, 2018
5	Onion	*Allium cepa*	Thrips NA		Thysanoptera: Thripidae		M	Nebiker *et al.*, 2016
6	Canola	*Brassica spp.*	Green peach aphid	*Myzus persicae*	Hemiptera: Aphididae	Arthropod counts, soil and plant tissue nutrient analyses	M	Severtson *et al.*, 2016a
7	Cotton	*Gossypium hirsutum*	Two-spotted spider mite	*Tetranychus urticae*	Acari: Tetranychidae	Damage assessments	M	Huang *et al.*,2018
8	Potato	*Solanum tuberosum*	Colorado potato beetle	*Leptinotarsa decemlineata*	Coleoptera: Chrysomelidae	Damage assessments	M	Hunt and Rondon,2017; Hunt *et al.*, 2017

9	Sorghum	*Sorghum bicolor*	Sugarcane aphid	*Melanaphis sacchari*	Hemiptera: Aphididae	Arthropod counts	M	Stanton *et al.*, 2017
10	soybean	*Glycine max*	Soybean aphid,	*Aphis glycines Matsumura*	(Hemiptera: Aphididae),	Detection of Stress Induced by Soybean Aphid	M	Marston *et al.*,2020
11	urban trees		oriental moth	*Monema flavescens*	Lepidoptera: Limacodidae)	can locate cocoons of the oriental moth, for precise and accurate detection of the cocoons in winter to prevent defoliation in the subsequent summer		Park *et al.*,2021

#SR: Spectral Resolution H: Hyperspectral, M: Multispectral

Table 6: Actuation drones for precision releases of natural enemies

Sl no	Natural Enemies	Scientific Name	Family and Order	Insect Pest	Scientific Name	Family and Order	Actuation Device	References
1	Egg parasitoid	*Trichogramma ostriniae*	(Hymenoptera: Trichogrammatidae)	European corn Borer	*Ostrinia nubilalis (Hübner*	Lepidoptera: Crambidae),	Entobot: the beneficial insect spreader	Martel *et al.*,2018
2		*Trichogramma minutum*	Hymenoptera: Trichogrammatidae	Eastern spruce budworm	*Choristoneura fumiferana (Clemens*	Lepidoptera: Tortricidae).	Entobot: the beneficial insect spreader	Martel *et al.*,2018
3	Mile-a-minute weevil	*Rhinoncomimus latipes Korotyaev*	Coleoptera: Curculionidae	Mile-a-minute weed	*Persicaria perfoliata (L.) H. Gross*	(Caryophyllales: Polygonaceae).	Bug Pod for the detection of P. Perfoliata and aerial release of R. Latipes	Kim *et al.*,2021
4	Lacewings	*Chrysoperla rufilabris (Burmeister),*	Neuroptera: Chrysopidae]	Lettuce aphid	*Nasonovia ribisnigri (Mosley)*	(Hemiptera: Aphididae),	The effects of drone-released lacewing eggs on lettuce aphid densities in organic romaine lettuce fields.	Del Pozo *et al.*, 2021
Reducing pest populations: Sterile insect technique and mating disruption								
			Scientific Name	**Family and Order**	**Mechanism**			
1.	Sterile Mexican fruit fly	Mexican fruit fly a major pest of citrus	*Anastrepha ludens(Loew)*	(Diptera: Tephritidae)	Designed a conveyor belt mechanism underneath a straight walled insect compartment to meter and expel insects Release device			Moses-Gonzales *et al.*,2021
2.	Sterile Codling Moth	Codling moth	*Cydia Pomonella (Linnaeus)*	(Lepidoptera: Tortricidae)	Comparing Deliveries of Sterile Codling Moth by Two Types of Unmanned Aerial Systems and from the Ground			Lo *et al.*,2021s
3.		Cranberry fruitworm	Acrobasis Vaccinii (Riley)	Lepidoptera: Pyralidae)	Mating disruption extruder system that effectively delivered one-gram droplets of mating disruption over cranberry beds			Luck *et al.*,2021

Actuation drones for precision releases of natural enemies

i. Biological control is a potential sustainable alternative to pesticide use. It is the use of a population of one organism to decrease the population of another, unwanted, organism (Van Lenteren *et al.,* 2018).
ii. Drones may be a particularly useful tool for augmentative biological control, which relies on the large-scale release of natural enemies for immediate control of pests (Van Lenteren *et al.,* 2018). They could distribute the natural enemies in the exact locations where they are needed, which may increase biocontrol agent efficacy and reduce distribution costs.
iii. Coverage of larger areas compared to manual distribution, reducing application costs per acre, potentially increases the use of natural enemies in favor of pesticide sprays.

Novel uses for drones in precision pest management

i. Sensing and actuation drones could potentially contribute to the prevention of pest outbreaks.
ii. Pest management focus could shift from being based mainly on responsive insecticide applications to a more preventative approach in which maintaining crop health is the main focus (West and Nansen, 2014).

Use of sensing and actuation drones could contribute to this shift, by assessing plant stress status, and preventative applications of water and fertilizers.

Reducing pest populations: sterile insect technique and mating disruption

Drone release of the sterile insects may be cheaper and faster than ground release, which occurs for instance by means of all-terrain vehicles (ATVs), or release by manned aircraft
Drones could also be deployed to place mating disruptors such as SPLAT (specialized pheromone & lure application technology) in commercial fields (FlyH2 Aerospace 2018).

Pest population monitoring

a. Drones could also be used to track populations of mobile insects that can be equipped with transponders, such as locusts (Tahir and Brooker, 2009).
b. Drone data were obtained at night, and specific software was developed to visualize individual insects. This system provides a relatively fast alternative for manual, time-consuming, mark-release recapture studies.
c. The method eliminates the need to physically recapture the insects.
d. Also, it removes the need for destructive sampling, so that insects could potentially be sampled over a longer time period.
e. Thus, use of this novel, drone-based system could improve efficiency and cost-effectiveness of mark-release-recapture studies of insect migration (Stumph *et al.,* 2019).
f. Furthermore, drones could be used to collect pest specimens for monitoring (Kim *et al.,* 2018), or to survey for pests, such as Asian longhorned beetles [*Anoplophora glabripennis* Motschulsky (Coleoptera: Cerambycidae)], in tall trees, assisting tree climbers (Rosenthal, 2017).

g. The use of drones for collection of plant volatiles and plant volatiles induced in response to herbivory could indicate the presence of specific pests (De Lange *et al.,* 2019) and
h. Drone-based volatile collections have been deployed for air quality measurements (Villa *et al.,* 2016). Development of novel sensors and technology will undoubtedly open the door to various other uses of drones in agricultural pest management

Incorporating remote sensing offers the potential

a. To improve management of insect pest by decreasing the effort and
b. Cost of scouting while increasing field coverage,
c. Which may increase adoption of management practices based on estimates of in-field pest abundance and
d. Thereby decrease unnecessary pesticide applications.

Previously, remote sensing in agriculture used either ground-based systems, which are often restricted by

i. Small mapping swaths and
ii. Limited transportability, or satellites and
iii. Piloted aircraft which have been expensive, low-resolution, and
iv. Limited by atmospheric conditions and
v. Orbital periods. (Zhang and kovacs,2012).

More recently, however, unmanned aerial vehicles (UAVs) equipped with ultra-high spatial resolution multispectral sensors have become increasingly available to consumers and promise low cost near real-time image acquisition for use in agricultural applications (Nebiker *et al.,* 2008).

a. **There are several challenges in the application of drones in Indian agriculture, which is responsible for its limited adoption.**

There are certain regulations by the government regarding the flying of the drones, which makes farmers skeptical about it. Most of the farmers in India are small and marginal with poor economic status. Therefore, they are not willing to spend money on any device other than the basic requirements. After the acquisition of images by the drones, there is a need to process those images in order to derive meaningful information. Therefore, skilled personnel are required for both operations of drones as well as for processing their images. As most of the Indian farmers are not well-educated, so, they are reluctant to adopt this new technology.

b. **Drones have great potential to transform Indian agriculture**.

Currently, drones can provide financial benefits to the farmers only when operated in large farms like in contract farming and co-operative farming. This technology can be useful for small and marginal farmers if **government support** is established. The modern youth are not attracted towards farming due to hard work and drudgery involved in it. The next agricultural revolution would be data-oriented, and drones can play a major role in it. Therefore, drones may become part and parcel of agriculture in the future by helping farmers in managing their fields and resources in a better and sustainable way

c. **Using drones allowed for combating desert locust menace to aerially spray pesticides**

The Union Ministry of Agriculture said that India had become the first country to have controlled locusts by using drones. The ministry said 15 drones are deployed at Barmer, Jaisalmer, Bikaner, Nagaur and Phalodi in Rajasthan for effective control of locusts on tall trees and in inaccessible areas through spraying of pesticides. **India is the first country that is using drones for locust control.**

Future prospects:

i. Automating pesticide applications and/or release of biological control organisms, through communication between sensing and actuation drones, is the future.

ii. This approach requires multi-disciplinary research in which engineers, ecologists, and agronomists are converging, with enormous commercial potential.

Conclusion:

Precision agriculture and IPM are incorporating drones more and more. Drones equipped with remote sensing technology (sensors) are used to map crop performance variations, monitor crop health, and spot insect outbreaks. While early identification and correction to inadequate abiotic conditions may avoid significant pest outbreaks, they could act as decision support aids. Different drones (actuators) could be used to deliver prompt treatments to pinpointed insect hotspots when outbreaks do happen. The future is automated pesticide spraying and/or biological control organism release via communication between sensor and actuation drones. Engineers, ecologists, and agronomists must collaborate on multidisciplinary research for this strategy, which has huge commercial potential.

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CURRENT SITUATION, ISSUES AND PROSPECTS OF INDIAN VEGETABLE SEED SYSTEM

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Abstract:

As a result, the country now has access to 357 grammes of vegetables per person per day. India is the world's top producer of peas and okra, while it comes in second place for tomatoes, cauliflower, potatoes, onions, and brinjal. For food and nutritional security, vegetables are crucial components of agriculture. Additionally, it has the capacity to create both off- and on-farm employment. One method of preventing malnutrition is to increase the accessibility, affordability, and consumption of nutrient-dense vegetables. India is blessed with an enormous variety of vegetables, and in 2017–18, it contributed the most (59.5%) of the nation's total horticultural output. Vegetable cultivation is expanding, primarily as a result of improved livelihoods brought about by increased productivity, shorter maturation cycles, high value, and increased income. Vegetable production sets new records every year, making it the farmers' preferred agricultural product. While it was less than 20 million tonnes during independence, production in 2017–18 was recorded at 184 million tonnes from 10.3 million hectares. To meet the demand of 1.5 billion people by 2030, this enormous increase must continue. The most crucial ingredient for successful vegetable cultivation is seed. The vegetable seed market in India is booming. Since India gained independence, the government has liberalised and promoted the trade in seeds. In India, a number of private seed companies with a global clientele are actively engaged in the production of vegetable seeds. Vegetable seed production has a positive impact on the Indian economy in terms of generating income, jobs, and foreign exchange on the global market. The vegetable seed industry in India faces a number of obstacles, including high seed production costs, technical issues, and strict legal requirements.

Keywords: India, Vegetable, Seeds, Vegetable Production, Seed Production

Introduction:

Vegetables and vegetable seed scenario in India

A wide variety of vegetables can be grown in India thanks to its diverse agro-climatic zones and distinct seasons. Vegetables are an excellent source of vitamins, phytochemicals, and dietary fibre. Farmers have seen greater financial gains thanks to vegetables with shorter growing seasons and higher productivity. According to reports, vegetables are a good source of minerals (leafy vegetables, drumstick pods), proteins, Vitamin-A (tomato, carrot, drumstick, leafy vegetables), Vitamin-B (garlic, tomato, and peas), Vitamin-C (drumstick leaves, Cole crops, leafy vegetables, green-chilli, and leaves of radish). India has a year-round growing season for vegetables. The majority of vegetables have medicinal qualities and are excellent sources of micronutrients that are beneficial to people with a variety of chronic health issues, particularly heart disease and diabetes. Additionally, it can aid in enhancing the health of the soil and serve as livestock feed.

India has a 357 gm/person/day per capita availability of vegetables, which aids in preventing malnutrition. It may also be grown in the house's backyard as a kitchen garden. A country's economy is improved by the production of vegetables because they are a great source of income and employment, in addition to their nutritional benefits. In horticulture crop productions over the past five years, vegetables continue to contribute the most, at 58.70 to 59.20%.

Vegetable production has increased in India over the past few years. Vegetable production, productivity, and area expansion have all advanced significantly. The area used for horticulture increased by 2.6% annually and production rose by 4.8% over the previous ten years. Between 2001-02 and 2017-18, vegetable production increased from 88.62 million tonnes to 184.40 million tonnes.

Vegetables are grown on 10.23 million hectares of land in India, where 184.39 million metric tonnes of produce were produced in 2017–18. By 2025, we'll need 225 million tonnes of vegetables, and by 2050, 350 million tonnes. There is an urgent need to increase vegetable production in India in order to guarantee food and nutritional security. All types of fresh vegetables are readily available thanks to India's varied climate. In terms of global vegetable production, it comes in second place to China. India is the world's top producer of okra (*Abelmoscus esculentus*) and pea (*Pisum sativum*), while it comes in second place for the production of tomatoes (*Solanum lycopersicum*), cauliflower (*Brassica oleracea*), potatoes (*Solanum tuberosum*), onions (*Allium cepa*), and brinjal (*Solanum melongena*), among other crops (Kumar *et al.,* 2017).

The Indian government recognized the need for horticulture sector diversification in the middle of the 1980s by emphasizing investment in this industry. Horticulture has currently proven to be effective in boosting income through increased productivity, creating jobs, and increasing export earnings. As a result, horticulture transitioned from a rural, subsistence-based industry to a commercial one. The nodal department for overseeing the development of horticulture in the nation is the Department of Agriculture and Co-operation (DAC) of the Ministry of Agriculture. It implements various programmes through the Departments of Horticulture and Agriculture in each State and acts as the central coordinator of initiatives to promote horticulture (Anonymous, 2018).

Among all the inputs needed to produce crops sustainably, seed is a crucial one. It is believed that 20–25% of productivity is influenced by the quality of the seeds. Mankind long ago realized the value of high-quality seed. The Rigveda of ancient India mentions the requirement for a good viable seed for the prosperity of the human race. The phrase "Subeejam Sukshetre Jayate Sampadyate," which roughly translates to "A good seed in a good field will win and prosper," is found in the Primeval Manusmriti. With the founding of National Seeds Corporation (NSC) in 1963, the growing of crops specifically for seeds in an organized manner to maintain quality in terms of genetic and physical purity is realized for the first time during the green revolution era, despite the fact that there have only been a few private seed industries dealing with production of vegetable seeds (Poonia, 2013). In order to develop the seed industry in India, the National Seeds Corporation was established. The main duties of NSC are to set up a sufficient system of quality control inspection for the storage, processing, and marketing of seeds. As of 2014, there were about 850 seed businesses operating in India, of which 50 had the capability to conduct crop breeding research. The responsibility of producing foundation seed for varieties that have been released as well as multiplying seed from pre-released varieties falls under the purview of National Seeds Corporation. Vegetable crop seed replacement rates (SRR) increased from 20% in the 1980s to >90% today. The current value of the traded seed market in India is Rs. 20,000 crores. There are 4000 crores of rupees worth of vegetable seed market overall, including open pollinated varieties. Sixty percent of the 110 hybrids published by the ICAR's All India Coordinated Research Project come from the private sector. In terms of global seed production, India currently ranks fifth. With a compound annual growth rate (CAGR) of 12% over the last five years, the Indian seed industry has outperformed the 6.7% global growth rate. The seed industry in India is experiencing new paradigms of growth and development, along with growing domestic demand and demand for high-quality seeds in many foreign nations, primarily South East Asian nations. Along with several other driving factors, such as the expanding middle class, rising disposable income, expansion of the food processing industry, rising seed replacement ratio, and other related factors, the use of hybrid seeds has quietly but steadily increased. Over the past few years, there has been an increase in demand for seeds due to increased farmer awareness of the advantages of using quality/certified seeds. Farmers are now more willing than ever to pay more for premium seeds as a result of this. India's share of the world's seed production is very small. In terms of the size of the global seed market, India lags far behind nations like the USA and China. Below are a few significant developments in the Indian government's seed policy:

1. The Seeds Act, 1966.
2. The Seeds Rules, 1968.
3. National Seeds Project.
4. New Seed Development Policy, 1988.
5. Act of 2001 Protecting Plant Varieties and Farmers' Rights.
6. National Seeds Policy, 2002.
7. Seed Bill (2004).

Vegetable seeds with a high commercial value in India:

From the start, the public sector of the country's seed industry dominated the private one. The majority of open-pollinated varieties (OPVs) have been the most abundant and valuable category of seeds on the market, followed by public hybrids and private hybrids. Right now, the situation is largely reversed. A sizeable portion of the market for vegetable seeds is made up of seeds from private hybrids. This resulted from the establishment of private seed businesses following the liberalization of the seed trade in 1988. Currently, the public sector primarily produces certified seeds for high yielding varieties of cereals, pulses, and cotton in high volume, low value segments, with a small share of high value hybrid cereals and cotton (Mazumdar, 2012). Private sector varieties and hybrids, whose seeds are produced solely by the specific manufacturers, have largely replaced public sector varieties and hybrids in the vegetable industry. Corporate seed companies are primarily focusing on vegetables like tomatoes, cabbage, brinjal, chillies, okra, and cucurbits because it is easier and more profitable to produce OPVs and hybrid seeds from these plants. The public sector's inability to generate significant revenue for research and development (R&D) in comparison to private seed companies and the lack of an appropriate market for varieties and hybrids produced by the public sector are both plausible explanations for the sector's current state of moribundity. Ten to twelve percent of the revenue of private seed companies is allocated to R&D. Investment in R&D by medium-sized seed companies is increasing by 20% yearly.

Vegetable seeds currently in demand and supply in India:

Since most of the farmers' certified/high-quality vegetable seed comes from the private seed industry, there isn't a regular assessment done to determine the demand and supply of these seeds in the nation. However, there is a well-established mechanism in place for field crops where each State in the nation creates a Seed Rolling Plan (SRP) based on the Seed Replacement Rate (SRR), which is typically maintained at 33% for self-pollinated crops, 50% for cross-pollinated crops, and 100% for hybrids. The state creates the seed rolling plan based on the crops sown during various seasons, the area under crops, and the seed replacement rate (SRR). As a result, the Ministry of Agriculture and Farmers Welfare, GoI, Department of Agriculture and Farmers Welfare, and other states calculate a rough estimate of the number of seeds that are needed. According to the Seed Rolling Plan, various seed-producing organizations working in the state are given production targets in order to meet the demand for seeds. Indicators are placed to the Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, GoI for compilation and subsequent submission to the Indian Council of Agricultural Research (ICAR) for the production of breeder seed. The requirement for breeder seed is assessed based on targets. Being a state subject, agriculture depends heavily on the State Government for the production, availability, and distribution of seeds. By coordinating seed availability and requirements among the states through Zonal Seed Review Meetings (ZSRM), which are held prior to each crop season, weekly video conferences, and National Campaign Meetings during the Zaid, Kharif, and Rabi seasons, the Government of India supports the efforts of the State Governments. The production and accessibility of certified seeds to farmers is significantly influenced by the National Seeds Corporation, State Seeds Corporations (SSCs), and other national and state level organizations involved in seed production.

India's current system for growing and distributing vegetable seeds:

In India, there are primarily two different kinds of seed systems: informal and formal. The formal seed system entails a series of processes that end in distinct products. In a formal system, organizations producing and marketing seeds in the public and private sectors, as well as organizations in charge of seed certification and quality control, are all included. Maintaining varietal identity, maintaining genetic purity, and producing seed with the best possible physical, physiological, and sanitary qualities are the guiding principles of the formal system (Reddy *et al.,* 2007).

In the informal seed system, also referred to as the farmer, village, or local seed system, farmers produce, distribute, and obtain seed directly from their own harvest, through trade with friends, neighbors, and relatives, or through regional grain markets. The widely distributed varieties are probably a heterogeneous mixture of various varieties and may be landraces or mixed races. Both seed systems have drawbacks that require creative solutions in order to overcome. Crop breeding research was primarily carried out by State Agricultural Universities and ICAR-affiliated institutes, such as the Indian Agricultural Research Institute (IARI), before the seed industry was liberalized in 1988. The National Seeds Corporation, State Seed Corporations, and a select number of private businesses all participated in the formal seed production process. The primary source of seed supply was local businesses, farmer associations, and farmers who produced open-pollinated varieties of seeds on a small-scale. The reform of the seed industry allowed for the unrestricted import of vegetable seeds (within the bounds of tariffs and phytosanitary laws) as well as the entry of both international and sizable domestic companies into the seed business. For crops where hybrid seed production was feasible, such as cotton, pearl millet, sorghum, maize, and many vegetables, the reform resulted in a rapid expansion of private seed production (Kolady *et al.,* 2012); however, other crops, like rice and wheat, saw a slower but steadier rate of growth in private seed production. The reform accelerated the growth of the private sector's research and development in the vegetable industry (R&D). Private crop breeding research was further boosted in 2001 by the introduction of the protection of intellectual property rights for new plant varieties (Kolady *et al.,* 2012). 850 seed companies (mostly seed producers) are currently active in India in 2014, and of those, 50 have capacity for crop breeding research (Reddy *et al.,* 2014).

Over the past fifty years, the quantity and value of the Indian seed industry have grown horribly. Production of high-quality seeds is a top priority for both public and private sector businesses. The Indian Council of Agricultural Research (ICAR) institutions, State Agricultural Universities, National Seeds Corporation (NSC), 16 State Seeds Corporations (SSCs), and other organizations make up the public sector component. In 1971, the Indian Council of Agricultural Research (ICAR) established the All India Coordinated Research Project on Vegetable Crops (AICRP-VC) at the Indian Agricultural Research Institute (IARI), New Delhi, to plan, coordinate, and monitor the research activities on vegetable crops. The Project Directorate of Vegetable Research (PDVR) was established in 1986 to boost vegetable research and address new challenges. The PDVR headquarters were moved to Varanasi in 1992 due to the North Eastern Plain being the main region for vegetable production. The Indian Institute of Vegetable Research (IIVR), a full-fledged organization, was founded in Varanasi in 1999 to further advance systematic vegetable research in the nation. AICRP-VC was also maintained, with its headquarters at the Indian Institute of Vegetable Research (IIVR) and a network of centers spread across the nation's various agro climatic regions. In 1979, the ICAR began the National Seed Project, an All India Coordinated Research Improvement project (AICRP) with 14 centres located at various ag universities, to improve seed production. The National Seed Project launched AICRP on the production of breeder seeds for vegetable crops in 1994. Quality control and certification activities are carried out by twenty-five State Seed Certification Agencies and 132 State Seed Testing Laboratories (Nandi *et al.*, 2013). There are 150 seed businesses in the private sector, both domestic and international. In the beginning, the private sector of the Indian seed industry used to be completely dominated. Open-pollinated varieties, public hybrids, and private hybrids have been the three types of seeds that have dominated the market in terms of quantity and price (APEDA, 2013). Right now, things are actually quite the opposite. A sizeable portion of the total vegetable seed market is made up of seeds from private hybrids.

The limited generation's system for seed multiplication is largely followed by the Indian seed programme in a phased fashion. The system recognizes three generations—breeder, foundation, and certified seeds—and offers sufficient protections for quality assurance in the seed-propagation chain to preserve the purity of the variety as it moves from the breeder to the farmer.

Breeder seed:

Breeder seed, which is created by the original breeder or a sponsored breeder, is the offspring of a variety's nucleus seed. Breeder seed production is ICAR's mandate, and it is carried out with the assistance of:

i. ICAR Research Institutions, National Research Centers, and All India Coordinated Research Project of different crops;
ii. State Agricultural Universities (SAUs), which have 14 centres spread across different States;
iii. Sponsored breeders who have been approved by specific State Seed Corporations; and
iv. Non-Governmental Organizations.

Through the National Seeds Corporation (NSC), State Seeds Corporations (SSCs), and Krishi Vigyan Kendras, the Indian Council of Agricultural Research (ICAR) also promotes the production of sponsored breeder seeds (KVKs). Breeder seed has been produced more and more frequently over time.

The Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture Cooperation and Farmers Welfare, Government of India collects the indents from various government seed producing agencies and that of private seed companies by State Departments of Agriculture, and then submits them to the department, which in turn compiles the information crop-wise, organises meetings to finalise the breeder seed indents with representatives. Following thorough discussion among all interested parties regarding the indents received, the finalized indents were sent to the Indian Council of Agricultural Research (ICAR), which forwarded them to the concerned Project Coordinator/Project Director of the respective crops (in ICAR) for final responsibility allocation to various SAUs/ICAR institutions for production of breeder seed in the crop-specific national workshop. The availability of nucleus seed of a specific variety and the facilities and capabilities offered by the centres are taken into consideration when official allocation orders are then made to various centres. At least 15 to 18 months before the start date, indents are compiled and sent to ICAR. The production of breeder seeds is being monitored by teams, and reporting forms have been developed in order to make the programme systematic and ensure proper evaluation. The members of the monitoring teams are the breeder of the variety, the concerned Project Director or his designee, a representative of NSC, and a representative from the State Seed Certification agency. At its Annual Seed Review Meeting, the ICAR-DAC evaluates the production of breeder seeds each year. The Indian Council of Agricultural Research informs the Department of Agriculture and Co-operation (DAC) of the actual production of breeder seed by various centres (ICAR). The available breeder seed is distributed fairly to all the indenters upon receiving information from the Indian Council of Agricultural Research (ICAR). Indents for breeder seed are placed with SAUs/ICAR institutions in the State by the concerned Director of Agriculture in the case of varieties that are only pertinent to that State. The Director of Agriculture or foundation seed-producing organizations under his authority directly harvest the breeder seed produced.

Foundation seed:

Breeder seed has a progeny known as foundation seed, and foundation seed must either be derived from breeder seed or from foundation seed that can be directly linked to breeder seed. The National Seeds Corporation (NSC), State Agriculture Departments, State Seeds Corporation, Other Central Seed Producing Agencies, and Private Seed Producers, who possess the required infrastructure facilities, have been given the responsibility for producing foundation seed. The minimum seed certification requirements outlined in the Indian Minimum Seeds Certification Standards must be met by foundation seed in both laboratory and field testing.

Certified seed:

The offspring of foundation seed is considered certified seed and is required to adhere to the Indian Minimum Seeds Certification Standards, 2013. If the crop is self-pollinated, certified seeds may also be produced from certified seeds as long as the number of generations from Foundation Seed Stage-I is not more than three.

Distribution systems and distributors:

Since the production and distribution of certified seeds falls under the purview of the State Governments because agriculture is a matter of State, it is their primary duty. The organization of certified seed production in the State is carried out by the State Seed Corporation, Departmental Agricultural Farms, Cooperatives, private seed businesses, and other seed producing organizations. The distribution of seeds is carried out via a variety of channels, including the block and village-level agricultural departmental outlets, cooperatives, seed company outlets, private dealers, etc. The National Seeds Corporation (NSC) and other central seed producing agencies, which produce certified seed of varieties of important national importance, support the efforts of the State Governments. These organizations sell their seeds either directly to consumers or through a dealer network. The National Seeds Corporation (NSC), various Central Seed Producing Agencies, and State Seed Corporations organize their certified seed production primarily through contract growing agreements with forward-thinking farmers. Additionally, National Seeds Corporation (NSC) produces seeds on its own farms. Additionally, the private sector has begun to play a significant role in the distribution of high-quality seeds for various fruits, vegetables, and crops, including hybrid maize, sorghum, pearl millet, cotton, castor, sunflower, paddy, and others.

Channels and stakeholders in import-export:

India's Export and Import (EXIM) Policy 2002-07 and its amendments regulate the export and import of seeds and planting materials. With the exception of the following, all cultivated seed export restrictions have been lifted as of April 1, 2002.

i. Breeder, foundation, and wild varieties;
ii. onion, clover, cashew, nux vomica, rubber, pepper cuttings, sandalwood, saffron, neem, forestry species, and wild ornamental plants;
iii. Niger exports, which are routed through TRIFED, NAFED etc.
iv. Groundnuts, whose exports are required to register a contract with APEDA.

These seeds can only be exported under special circumstances and with a license from the Director General of Foreign Trade (DGFT), who bases his decisions on the suggestions made by the Department of Agriculture and Cooperation. Following are the rules regarding the import of seeds and other planting supplies:

i. Importing seeds, tubers, bulbs, cuttings, and saplings of fruits, vegetables, and flowers is permitted without a license under the terms of the import permit issued under the Plant Quarantine (Order), 2003, and any amendments made thereto.
ii. Under certain conditions outlined by the Ministry of Agriculture, the Indian Council of Agricultural Research (ICAR), among others, is permitted to import seeds, planting supplies, and live plants without a license.
iii. The Plant Quarantine Order, 2003 permits the import of seeds and tubers of plants such as potato, garlic, fennel, coriander, cumin, and others with the appropriate import permits.
iv. Import of seeds of wheat, rye, barley, oat, maize, rice, millet, sorghum, pearl millet, finger millet, other cereals, soybean, groundnut, linseed, palmnut, cotton, castor, sesame, mustard, safflower, clover, jojoba, etc. is allowed without licensing subject to the New Policy on Seed Development, 1988 and in accordance with import permit granted under Plant Quarantine Order, 2003.

All imports of seeds and other planting materials will be subject to regulation under the Plant Quarantine Order, 2003, according to the Export and Import Policy (EXIM Policy). Directorate General of Foreign Trade (DGFT) would only issue import licenses based on DAC recommendations. For one crop season, a small sample of the seeds that were intended to be imported would be given to farms that have been approved by the Indian Council of Agricultural Research (ICAR) or to the ICAR itself for testing and evaluation. The trial/evaluation report on the seed's performance and resistance to seed- and soil-borne diseases would be taken into consideration by DAC upon receipt of applications for commercial import. Within 30 days of receipt, the Department of Agriculture and Cooperation (DAC) must either accept or reject the application for the issuance of an import licence to the Directorate General of Foreign Trade (DGFT). For testing and/or addition to the National Bureau of Plant Genetic Resources' gene bank, all importers are required to make a small specified quantity of their imported seeds available to the Indian Council of Agricultural Research (ICAR) at cost (NBPGR). After quarantine inspections, the Plant Protection Adviser (PPA) must approve or reject the import of seeds within three weeks. It is necessary to destroy the returned shipment. The cost of keeping the imported consignment in a bonded warehouse during quarantine will be borne by the importer. It must be ensured that there will be zero tolerance for any compromises in plant quarantine procedures when importing seeds and plating material. Every effort must be made to stop the entry of any weeds, diseases, or pests from abroad that could harm the nation's farmers.

In accordance with the New Policy on Seed Development and Export and Import Regulations, the Seeds Division established an Export and Import Committee to handle requests for the exports and imports of seeds and planting materials. The Committee discusses applications and provides recommendations to the Plant Protection Adviser (PPA)/Director General Foreign Trade (DGFT) for the issuance of an alternative licence for the import/export of seeds and planting material. The Committee meets once a month, subject to the trend of proposals for the import/export of seeds and planting material. Applications for export and import must be submitted in 20 copies in the specified formats by exporters and importers. The Export and Import Policy (EXIM Policy) Committee's meeting minutes are available on the Seednet Portal.

India has made the decision to join the Organization for Economic Co-operation and Development's (OECD) Seed Schemes for the following types of crops in order to increase seed exports:

i. Grasses and legumes,
ii. Crucifers and other oil or fiber species,
iii. Cereals,
iv. Maize and sorghum,
v. Vegetables

The Organization for Economic Co-operation and Development's (OECD) Seed Schemes are one of the international frameworks available for the certification of agricultural seeds moving in international trade. The Organization for Economic Co-operation and Development's (OECD) Seed Schemes seek to promote the use of seeds that are consistently of high quality in participating nations. For seeds that are grown and processed for international trade in accordance with established standards, the Scheme permits the use of labels and certificates. As the National Designated Authority, it has been proposed that the Joint Secretary (Seeds) of the Department of Agriculture & Cooperation serve in that capacity. Furthermore, the Designated Authorities under the Scheme to carry out certification work under Organization for Economic Co-operation and Development (OECD) Seed Schemes have been nominated to be the Heads of Seed Certification Agencies in the following states: Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Rajasthan, Uttaranchal, Uttar Pradesh, Haryana, Bihar, and Assam. Prior to beginning the certification process, the department is in the process of completing additional requirements under the OECD Seed Scheme guidelines.

Opportunities for vegetable seed

1. **Constantly growing demand:** Vegetable production has doubled globally over the last 25 years, and the value of vegetable trade now outpaces that of cereal trade. After China

(22.5 t/ha), India is now the world's second-largest producer of vegetables (17.3 t/ha). Vegetable production in India has increased 2.5 times over the past 20 years, from 58.5 m t in 1991–1992 to 146.5 m t in 2010–2011. Expanding areas planted with high yielding vegetable varieties and hybrids are primarily responsible for the increase in yield. Vegetable cultivation has expanded from 5.59 million ha in 1991–1992 to 8.49 million ha in 2010–2011. (Koundinya *et al.*, 2014). Finally, it causes the demand for high-quality vegetable seed to rise steadily. Furthermore, compared to crops grown from own saved seeds, replaced seeds result in higher crop yields. Compared to other cereals and oil seed, vegetables like tomato (99.3%) and cabbage (100%) have higher seed replacement rates. The total number of vegetable seeds produced in the nation is insufficient to meet the rising demand in the nation. Currently, only 30–35% of demand for quality seeds is being met. Framers use their own saved seeds to make up 60–65% of the total (Nandi *et al.*, 2013). The main vegetable seeds that India continues to import from other nations are radish, followed by cabbage and pea.

2. **Diverse agro-climatic situations:** India benefits from a wide range of agro-climatic conditions, from tropical to temperate, which enable the cultivation and seed production of nearly all vegetables from various temperature regimes. Warm-season vegetable seeds can be produced in the Indian plains and Deccan Plateau, while winter vegetables like cabbage, cauliflower, broccoli, beetroot, European carrots, and radish can be produced in the Himalayan range's hill stations. Some winter vegetables, such as onions, Asian carrots, Asian radishes, and tropical cauliflower, produce seeds during the winter months in the plains of North India, whereas legumes, solanaceous vegetables, and cucurbits do so all year long in South India.
3. **Accessible cheap labour:** Producing hybrid vegetable seeds, in particular, requires a lot of labour. For carrying out various cultural operations, labour is required. Although mechanization reduces human effort to some extent, full-scale mechanization is limited by high fuel and energy costs. Additionally, only human labour is used for the emasculation and pollination processes during the production of hybrid vegetable seeds. Some vegetables' smaller flower structures require more time and effort, which decreases productivity. These tasks call for labour that has been specially trained and skilled. India is Asia's second-largest producer of hand-pollinated vegetable seeds, after China. Average man-days per acre needed for producing hybrid seeds of different vegetables are as follows: Cucurbits range from 150 to 450, tomato 480, chilli 1800, okra 180, and brinjal 600. Huge human resources are available in India at comparatively lower costs. This is luring various corporate sectors with domestic and foreign roots to invest in the seed industry in India.
4. **Huge domestic and international market:** The area used for vegetable cultivation is growing astronomically each year as a result of the high profits in vegetable cultivation. Due to this, there is a huge market demand for vegetable seed. Vegetable seed demand is rising every year. Open pollinated vegetable seed requirements increased from 30550 tonnes in 2001-02 to 48000 tonnes in 2005, while hybrid vegetable seed requirements increased from 346.2 tonnes in 2001-02 to 994 tonnes in 2005. Due to the area increasing

to 8.49 mha in 2010–2011, this must have gone up even more. Due to their higher yield, uniformity, and improved quality, hybrids are increasingly replacing Open Pollinated Varieties (OPV). For example, India is the second-largest consumer of hybrid tomato seed after the United States. 70% of all seed exports are of the vegetable variety. Open pollinated varieties (OPV) or hybrid vegetable seeds from India are in high demand in other nations like Pakistan, Bangladesh, and Saudi Arabia.

Challenges and problems:

1. **Large price and uncertain market demand:** Due to the higher labour and other input costs associated with hybrid seeds, vegetable seeds are very expensive. The high cost of vegetable seeds is out of the reach of small and marginal farmers. Farmers must also buy hybrid seeds (F1 generation) each time because the seeds harvested in the previous season (F1) change genetically in the F2 generation as a result of segregation and recombination. Vegetable seed demand is hazy on the market. Contrary to cereal seeds, surplus cannot be eaten by humans. Therefore, the overproduction of vegetable seeds will result in significant economic loss (Sharma, 2011).
2. **The non-durable nature of seed:** Unlike fertilisers and chemicals produced in factories, seed is a living organism and a biological product. Therefore, depending on the genetic potential for survival and the storage conditions, it is subject to death (Sharma, 2011). A longer period of storage has a negative impact on the specified yield, ideal crop stand, and given germination percentage. Due to delays in marketing and the completion of complex export procedures, seeds occasionally reach their expiry date while being stored or transported. Vegetable seeds, in contrast to cereals, are not the majority of vegetables' edible parts (Sharma, 2011). Even in cereals, seeds are not meant to be eaten because they have been treated with a poison, or fungicide.
3. **Contract farming-related issues:** Multinational corporations in developed nations produce seeds in their own fields. But contract farming is used in India to produce seeds in the fields of farmers. In addition to providing farmers with credit benefits, it has a negative impact on the seed's quality. Since the majority of Indian farmers are small and marginal, it's possible that they lack the scientific and technical knowledge about floral biology that's essential for producing high-quality seeds, such as isolation distance, rouging, and pollination mechanisms. Furthermore, seed production spans a sizable geographic area. These not only cause the seeds to be uneven but also cause contamination (Mazumdar, 2012).
4. **Issues related to the environment, pests, and diseases:** The production of seeds is a seasonal endeavour. Seed crops are raised in open fields that are exposed to extreme weather conditions. Large losses result from crop failure due to extremes in temperature and rainfall. In addition, flowering is temperature-sensitive in most vegetables, including tomato, okra, cucurbits, and some temperate vegetables. Under a scenario of climate change, these vegetables' flowering and pollination will be hindered (Koundinya *et al.*, 2014). In order to prevent contamination, seeds are typically produced over a larger area

with the same variety, but this practise encourages the spread of epidemics of pests and diseases. The crop may completely fail due to pests like Helicoverpa, Leucinodes, and Earies, diseases like purple blotch in onions, powdery mildew in cucurbits, and bacterial and fungal wilts and rots. The cost of production is once more increased by the management of these pests and diseases.

5. **Strict seed laws and policies:** Varietal notification and registration are required and involve a time-consuming process. Another significant and time-consuming task is seed certification, even though seeds that are accurately labelled do not require certification (Sharma, 2011). These details are necessary for varietal registration. Despite the fact that the Protection of Plant Varieties and Farmers' Rights Act of 2001 safeguards the rights of these businesses by prohibiting farmers from reproducing branded seed, it still permits researchers to carry out their work with the exception of using these varieties as parents in hybridization programmes without the prior consent of the original plant breeder or institution. Regulations for export and import are still onerous. Vegetable seed pricing is unclear, and there is no way to predict market demand pricing for the coming season (Sharma, 2011). Arbitrary prices encourage cost-cutting, even in crucial operations that may be detrimental to seed quality.
6. **Climate-resilient seed production:** During the growing season, environmental factors play a significant role in determining how successfully plants reproduce. Moisture and temperature are two environmental factors that have a direct impact on reproduction. Early reproductive processes like pollination, fertilisation, anthesis, stigma receptivity, and early embryo development are all extremely vulnerable to moisture and/or temperature stresses. Any of these processes going wrong increases early embryo abortion, which causes poor seed set and lowers the seed yield. Unknown physiological mechanisms underlie reproductive failure in stressful situations. In order to develop appropriate crop management technologies and lessen the negative effects on the reproductive phase, it is important to study how climate change affects the seed production of different crops.
7. **Climate disruption in relation to climate change:** To effectively convert breeder seed into downstream classes and increase output, the seed production chain, which involves a number of stakeholders, most notably the Departments of Agriculture of various States, State and National Seed Corporations, farmer producer organizations, and the private sector, needs to be strengthened. Climate change has recently had a negative impact on the nation's agricultural production, and the seed production programme is no exception. Finding new niches or alternate locations in non-traditional seasons and locations for compensatory seed production is therefore urgently needed. Young people without jobs can receive training in the field of seed quality assurance, and with funding and laboratories for seed quality assurance, "seed clinics" could be established in important seed-growing regions. The physical and genetic purity of the seeds, their germination, viability, vigour, health, and appearance—such as size, shape, weight, and color—are all factors that contribute to the quality of the seed. Each of these factors is influenced by the climate during the crop growth phase and the subsequent seed processing. When climatic

conditions are unfavourable for crop growth, the resulting low-quality seeds have a lower market value, which results in financial loss for the farmers (Maity & Pramanik, 2013).

8. **Inconsistencies between standard operating procedures for seed testing and Regulations of the International Seed Testing Association (ISTA):** The International Seed Testing Association (ISTA) develops globally accepted standards for seed sampling and testing, accredits labs, fosters research, issues certificates for international seed analysis, and disseminates information about seed science and technology. This promotes national and international seed trade, ensures seed quality, and improves food security. For businesses that trade seeds internationally, the International Seed Testing Association (ISTA) offers testing services. North American nations abide by the Association of Official Seed Analysts (AOSA) regulations, which were tailored specifically for their market and differ from those of the International Seed Testing Association only slightly (ISTA). A joint committee on the harmonization of rules was formed by the International Seed Testing Association (ISTA) and the Association of Official Seed Analysts (AOSA). The International Seed Testing Association (ISTA) seed lot certificates, which also include the findings of other quality tests, are typically used in conjunction with the Organization for Economic Co-operation and Development (OECD) Seed Schemes, which offer a system for the assurance of varietal purity and identity for international seed trade. There are some differences between Indian seed testing practises and those used by the International Seed Testing Association (ISTA).
9. **Comparison of the 2013 Indian Minimum Seed Certification Standards (IMSCS) Seed programmes of the Organization for Economic Co-operation and Development (OECD):** To facilitate the seed trade by removing technical obstacles, the Organization for Economic Co-operation and Development (OECD) Seed Schemes offer a global framework for seed certification. The establishment of the seed scheme was motivated by the rapidly expanding seed trade, regulatory requirements in some nations, the development of off-season production, and the significant breeding and production potential of exporting nations. These programmes are designed to promote the use of "quality-guaranteed" seed in the participating nations. According to established guidelines, the schemes permit the use of labels and certificates for seed produced and processed for international trade. They are determined by two important factors: varietal identity and purity. There are seven unique, independent seed programmes, and enrollment in each programme is entirely optional. India currently takes part in five programmes: the vegetable, grass, legume, crucifer, and other oil or fibre species; cereal, maize, and sorghum; and, finally, vegetable. The Organization for Economic Co-operation and Development (OECD) seed certification are primarily meant to satisfy the needs of 59 member countries to meet the international seed standards and trade. In contrast, the IMSCS were developed, adopted, and updated in 2013 to cater to the needs of domestic seed certification system. The Indian Minimum Seed Certification Standards (IMSCS) also adhere to many of the regulations and guidelines established by the

Organization for Economic Co-operation and Development (OECD) for field inspections intended to guarantee varietal identity and purity. When a seed crop submits an application for Organization for Economic Co-operation and Development (OECD) certification, OECD rules and directives will be applied for a field inspection. This process is carefully supervised by a robust system of checks and balances. The standards and methods of operation between the two systems differ significantly. While there are six classes in the Organization for Economic Co-operation and Development (OECD) scheme, including two sub-classes of certified seed, there are only five recognized classes of seed in India. In terms of Organization for Economic Co-operation and Development (OECD) seed schemes, the nucleus, breeder, and foundation seed in Indian Minimum Seed Certification Standards (IMSCS) are equivalent to the breeder's maintenance material, pre-basic seed, and basic seed, respectively. The only varieties that qualify for seed certification in India are those that have been notified under the Seeds Act of 1966. However, under OECD schemes, varieties that have been accepted for Value for Cultivation and Use (VCU) in at least one country or are included in the national list after being checked for Distinctness, Uniformity and Stability (DUS) characters also qualify for certification.

System development suggestions:

1. In general, the seed trade is one of the most regulated industries in the world, with a multitude of seed laws, testing, and certification procedures. Globally, farmers' access to high-quality seed is being improved by the standardisation and simplification of testing and certification processes. When it comes to the Organization for Economic Co-operation and Development (OECD) scheme, non-official inspectors are permitted, whereas in the Indian system, a team of officials from public sector organisations only performs certification at the foundation and certified seed production stages. Additionally, it permits non-official laboratories to perform seed analysis, whereas under the Seeds Act of 1966, only accredited seed testing laboratories are permitted to do so. Other than general and crop-specific standards, the primary distinction between the Organization for Economic Co-operation and Development (OECD) seed scheme and the Indian Minimum Seed Certification Standards (IMSCS), 2013, is the use of designated authorities, laboratories, and non-official inspectors for seed sampling, analysis, and certificate issuance. For the Organization for Economic Co-operation and Development (OECD) Seed Scheme's varietal certification in India, ten State Seed Certification Agencies covering every region of the nation were designated as Designated Agencies.
2. Introduce Bar/QR codes are preferred for breeder seed source traceability in the chain of multiplication for high-quality seed production. The first step in facilitating high-quality breeder seed production is the development of variety-specific molecular markers to enable quick genetic purity testing, management of nucleus seed and its upkeep to replace or supplement grow-out tests, and a network on developing a national database of crop varietal DNA profile (fingerprinting).
3. To increase output, the chain of seed production, which involves a number of parties, particularly the Departments of Agriculture of various States, State and National Seed

Corporations, farmer producer organisations, and the private sector, needs to be strengthened. Climate change has recently had a negative impact on the nation's agricultural production, and the seed production programme is no exception. Finding new niches or alternate locations in non-traditional seasons and locations for compensatory seed production is therefore urgently needed. Establishing a "National Seed Grid" and identifying provenances for off-season seed production will help meet the demand for seeds and reduce the effects of climatic whims, along with developing a sustainable seed plan for backup in the event of natural disasters. Young people without jobs can receive training in the field of seed quality assurance, and with funding and laboratories for seed quality assurance, "seed clinics" could be established in important seed-growing regions.

4. Developing seed quality testing laboratories and transforming them into seed quality assurance hubs will be crucial to reviving the nation's high-quality seed industry. These laboratories ought to be staffed with qualified and well-trained individuals in addition to cutting-edge infrastructure. Additionally, the manual on seed testing needs to be regularly updated with all pertinent information, including infrastructure requirements like building work, tools, testing protocols/methods, and stewardship in seed quality assurance. The orange and blue international seed analysis certificates, which are essential for the world's seed trade, may only be issued by laboratories that have been accredited by the International Seed Testing Association (ISTA). India's seed testing facilities should be encouraged to take part in proficiency exams to gauge their level of proficiency. Many laboratories that issue ISTA's International Seed Analysis Certificates, which can be viewed as a passport for international seed trade, can help to promote the seed industry. The International Seed Testing Association currently has 134 accredited seed testing laboratories from 60 nations, six of which are in India. A favourable environment for seed export will be created by increasing capacity and establishing more accredited laboratories for seed quality assurance.
5. In order to ensure long-term seed vigour and viability, the development of seed-post-harvest technologies through the dry chain concept needs special attention. India should investigate the viability of producing high-quality seeds of popular varieties in other South Asian Association for Regional Cooperation (SAARC) nations in addition to setting up a crop-specific advisory body and referral lab for the implementation of a quality control system. India is one of the major players in the SAARC seed market.
6. In conclusion, the much-anticipated second green revolution can be ushered in by bolstering the quality seed production chain in the age of climatic vagaries through off-season seed production and utilising the inherent potential of rice fallow cropping systems, especially for pulse and oilseed crops.
7. International Seed Testing Association (ISTA) standards and Organization for Economic Co-operation and Development (OECD) seed schemes are developed specifically to promote international seed trade, whereas Indian Minimum Seed Certification Standards (IMSCS) standards were developed and adopted since 1974 to cater to the needs of various stakeholders of the Indian seed industry. Due to the fact that these two streams are distinct,

there are some discrepancies in the varietal certification processes and standards, which must be properly addressed in order to expand the global market for Indian seeds. Two choices are available. Organization for Economic Co-operation and Development (OECD) Rules and Guidelines only apply when a variety is being registered or offered for the Organization for Economic Co-operation and Development (OECD) Seed Schemes and International varietal registry. Indian Minimum Seed Certification Standards (IMSCS), OECD, and International Seed Testing Association (ISTA) standards be harmonized to facilitate seed trade. India has been a member of the OECD's seed programmes since 2008, and it would seem appropriate to internationalize the rapidly developing Indian seed market by harmonizing seed standards, seed testing, and the establishment of accredited seed testing laboratories by the International Seed Testing Association (ISTA).

Conclusion:

Conclusion: Vegetable seed businesses will always have a great chance of success and will be crucial to the economies of nations like India where the majority of people work in agriculture. It is more important than ever to give farmers access to high-quality seeds at fair prices and in a timely manner. To guarantee the supply of quality seeds and to safeguard farmers from fake seeds, seed laws must be strictly enforced. The formulation and execution of policies must be based on current circumstances and should take into account the needs of both the nation and its farmers. In order to compete with private seed companies and offer farmers high-quality seeds at lower prices, the public sector must be strengthened in research and development. The collaboration of the public and private sectors could undoubtedly aid in the production of high-quality vegetable seeds in India. Between the public and private sectors, there should be an exchange of germplasm and other inputs. Due to their established R&D wings and in-house technical staff, the massive seed companies may not be interested in such deals. However, such a covenant may offer a better option for young seed companies with a moderate level of staffing and establishment. India, like many other nations, has made significant investments in public agricultural research. Within this framework, developing, testing, and disseminating pertinent technologies have been the main priorities. However, the public sector's dominance of agricultural research is changing. A sizable enough portion of the benefits from research can now be appropriated by innovators thanks to new technologies and strengthened intellectual property rights. As a result, the private sector has expanded to have a sizable presence in many crops, which has completely changed the seed industry. The investment of private capital in agricultural research will also contribute to economic development as the payoff to research and higher agricultural productivity is high in developing countries.

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FRUIT AND VEGETABLES PROCESSING – AN OVERVIEW

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Abstract:

Indian horticulture sector has been growing at a phenomenal pace, surpassing the crop sector and presently its production is around 307 million tonnes consisting of fruits (about 100 million tonnes) and vegetables (about 207 million tonnes). India is also the second larger producer of fruit and vegetables in the world after China. Fruit and vegetables are an elemental part of cuisines and play a vital role in providing fresh nutrition and healthy food to consumers of all ages around the world. These are highly perishable and have a very short life resulting in 20-30 percent post-harvest losses due to a lack of proper harvesting, processing and poor cold chain and storage facilities. Value addition is the easiest way to reduce these losses. The aim of doubling the farmers income cannot be fulfilled without the efficient post-harvest management of agri-horti crops. Processing and value addition not only help in minimizing the wastes but it will also create ample opportunities for employment and add several income avenues. Advances in processing technologies of fruit and vegetables will help to curb post-harvest losses and results in giving a boost to the food processing industries. This book chapter proposes to show the status of the processing industries, the need for processing, government initiatives, modern technologies, challenges, technological impact and alternatives for product development. The future tasks involve interdisciplinary and cross-border collaboration and the fruit and vegetables production and processing needs are global but their application will require different approaches in different regions.

Keywords: Fruits, Vegetables, Losses, Processing, Value addition, Nutrition, Food security

Introduction:

The most perishable goods are fruit and vegetables, also crucial components of the human diet. Fruit and vegetables are seasonal in nature, and during the glut time, prices drop significantly, making production unprofitable owing to distressed sales. Therefore, if fruit and vegetables are not handled, processed, or used appropriately, an increase in production will be of little use. Processing has recently received more attention because the expenses associated with minimizing losses are always lower than the cost of production. India's business for processing fruit and vegetables is incredibly unstructured. Fruit pulp and juice, ready-to-serve beverages with fruit as the main ingredient, canned fruit and vegetables, jams, squash, pickles, chutneys, dehydrated veggies, etc. are some of the popular and commercial goods. More recently, the sector has also begun to make items like canned mushrooms and mushroom products, frozen pulps and vegetables, frozen dried fruit and vegetables, fruit juice concentrates, and vegetable curries in re-sealable pouches. Real-world preservation conditions involve various techniques including physical, physicochemical, chemical and biological processes, these phenomena never operate alone. The procedures for preserving fruit and vegetables, the equipment needed and other information for a unit that processes fruit and vegetables are explained.

The agricultural sector is the backbone of the economy in developing nations. It should therefore come as no surprise that a sizable amount of their output can be accounted for by agricultural enterprises and allied activities. Fruit and vegetables processing is one of the most significant agriculturally based activities among the many different activities. Both current and future fruit and vegetables processing initiatives seek to address a specific development issue. This is because the grower suffers significant losses due to low demand, shoddy infrastructure, poor transportation, and the perishable nature of the commodities. The loss is significant during the post-harvest glut and frequently some of the produce must be fed to animals or allowed to perish. The fruit and vegetables processing primary goals are to offer consumers year-round access to wholesome, secure and nutritious food. In addition to generating foreign cash by exporting finished or semi-processed goods, fruit and vegetables processing projects also aim to replace imported goods like squash, yams, tomato sauces, pickles etc.

Fruit and vegetables processing are among important businesses in developing nations as it helps in:

- Reduction of imports and meeting export demands;
- Government industrialization policy;
- Diversification of the economy to lessen current dependence on one export commodity;
- Stimulation of agricultural production by obtaining marketable products;
- Creation of rural and urban employment;
- Reduction of fruit and vegetables losses;
- Improvement of farmers' nutrition by allowing them to consume their own processed fruit and vegetables during the off-season;
- Creation of new sources of income.

Fruit and vegetables processing aims at:

1) **To lessen wastage and losses:** The fruit and vegetables sector is the backbone of the horticulture industry since it handles all potential waste that may occur despite advancements in fresh product marketing and distribution.
2) **To manage glut:** The produce generated during the glut season is used to produce a variety of processed goods, therefore fruit processing aids in minimizing waste and managing excess produce during the glut.
3) **To maintain agricultural revenue and prices:** It maintains farm prices by using extra produce to add value and give farmers more money.
4) **To make use of marketable surplus:** Processing makes use of cull and malformed produce, as well as marketable surplus, to ensure that growers receive a profit.
5) **To create jobs:** Processing of fruit and vegetables requires much labour and it helps to provide both direct and indirect jobs for the general public.
6) **To add diversity to the diet:** Food is made more appetizing and appealing by value addition and processing.

7) **To address nutritional security**: Fruit and vegetables are the sources of nutrients including vitamins and minerals, which adds to managing undernourishment.
8) **To generate foreign currency:** Since, both fruit and vegetables are high-value crops, it helps to earn foreign currency by exporting fresh, processed and value-added products of fruit and vegetables.

Status of fruit and vegetables in India

In India, the green revolution and subsequent initiatives to increase food production or apply science and technology have led to food independence. Increased food production results from the impetus provided by the government, state agricultural universities, state departments of agriculture and other organizations through the development and introduction of numerous hybrid varieties of fruit and vegetables as well as improved management techniques. Among the perishable goods are fruit and vegetables. They are crucial components of the human diet. Due to their great nutritional value, they significantly contribute to human well-being in terms of nutrition. They are the better, more affordable source of foods that offer protection. The agricultural sector is the backbone of the economy in developing nations. Processing of fruit and vegetables is among the most significant process nowadays. Planning and policymakers have therefore been paying close attention to the processing of fruit and vegetables since it can help the rural population's economy grow. Utilizing resources, both human and material is one technique to raise a family’s economic situation. India is blessed with a region that is remarkably varied and distinguished by a wide variety of agro-climatic zones. A variety of horticultural crops including fruits, vegetables, flowers, spices, plantation crops, root and tuber crops, as well as medicinal and aromatic crops can be produced and processed. Because of India varied environment, various kinds of fresh fruit and vegetables are available around the year. After China, India is the second largest producer of fruit and vegetables. India ranks second in the production of potatoes, onions, cauliflower, brinjal, cabbages and other vegetables, while it tops the list for ginger and okra. The nation leads the world in the production of three different types of fruits: bananas (25.7%), papayas (43.6%) and mangoes including mangosteens and guavas (40.4%). While onions, mixed vegetables, potatoes, tomatoes and green chilies make up the majority of the vegetable export basket. Grapes, pomegranates, mangoes, bananas and oranges make up the majority of the fruits exported from the nation. India produce is primarily exported to Bangladesh, the United Arab Emirates, the Netherlands, Nepal, Malaysia, the United Kingdom, Sri Lanka, Oman and Qatar. India's share of the global market is still only about 1 percent, but its horticulture products are becoming more and more popular. According to the United Nations Food and Agriculture Organization (FAO), India is the world's second-largest producer of both fruit and vegetables in 2019. The amount of produce produced in the country in the years 2018–19, 2019–20, and 2020–21 (Third Advance Estimates) and the average amount produced during these three years are listed below (Table 1):

Table 1: Production of fruit and vegetable from 2018-21 in India

Production of Fruit and vegetables (Million Tonnes)				
Year	**2018-19**	**2019-20**	**2020-21**	**Average**
Fruits	97.97	102.08	103.03	101.02
Vegetables	183.17	188.28	197.23	189.56

Andhra Pradesh, Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Karnataka and Tamil Nadu are the major Fruits producing States, whereas Uttar Pradesh, West Bengal, Madhya Pradesh, Bihar, Gujarat, Maharashtra and Odisha are the major Vegetables producing States of the country (in order of production, as per the Third Advance Estimates of 2020-21). The vast production base offers India tremendous opportunities for export. As per the APEDA database, during 2021-22, India exported fresh fruit and vegetables worth Rs. 11,412.50 crores/1,527.60 USD millions which comprised fruits worth Rs. 5593 crores/750.7 USD millions and vegetables worth Rs. 5745.54 crores/767.01 USD millions. The processed fruit and vegetables including pulses exported to be Rs. 12,858.66 crores/USD 1,724.88 million which comprised of processed vegetables including of pulses Rs.8308.04 Crore/USD 1114.19 million and processed fruits and juices Rs.4550.62 crores/USD 610.69 million in 2021-22. Record horticulture production is estimated at 342.33 million tonnes in a 28.08-million-hectare area.

- Fruit production is estimated to be 107.24 million tonnes.
- Vegetable production is estimated to be 204.84 million tonnes.
- During the Year 2021-22, India exported fruit and vegetables worth Rs. 11,412.50 crores/ 1,527.60 USD millions in which Fruits were exported of worth Rs. 5593 crores (750.7 USD millions) & Vegetables worth Rs. 5745.54 crores (767.01 USD millions).

Government initiatives for the promotion of food processing and value addition

I. Establishment of specialized institutions

National Institute of Food Technology Entrepreneurship and Management (NIFTEM)

The Ministry of Food Processing Industries, Government of India, founded NIFTEM. The Ministry of Human Resource Development, Department of Higher Education, also recognised NIFTEM as a Deemed-to-be University under the De Novo category. NIFTEM's primary responsibilities include providing high-quality management, research, and education programmes tailored to the food industry, as well as providing facilities for business incubation and information dissemination in the food industry. The undergraduate and graduate programmes that NIFTEM will offer have been approved by the All-India Council for Technical Education (AICTE) as of April 2013. The Indian Institute of Food Processing Technology (IIFPT) in Thanjavur, Tamil Nadu, and the National Institute of Food Technology, Entrepreneurship and Management (NIFTEM) at Kundli, Haryana, which are currently under the administrative control of the Ministry of Food Processing Industries (MoFPI), were both approved by the Union Cabinet for inclusion in the National Institutes of Food Technology, Entrepreneurship and Management (NIFTEM) Bill, 2019 (Institute of National Importance).

II. Government initiative through Operation Greens

In the Union Budget 2018-19, the finance minister stated about Operation Greens. Currently, the Ministry of Food Processing Industries (MoFPI), is where Operation Green is located. The Nodal Agency for putting in place price stabilization measures is NAFED. In keeping with Operation Flood, the Operation Greens program intends to advance FPOs (Farmer Producer Organizations) processing facilities, agri-logistics and skilled management of agricultural output. The goal of Operation Greens is to provide fair rates for farmer’s produce. It tries to guarantee that farmers receive the appropriate compensation for the resource they produced. By linking farmers and consumers, the program focuses on the structured marketing of top vegetables such as tomatoes, onions and potatoes.

Objectives of operation greens:

- By producing clusters with good planning and introducing dual-use types, prices for consumers and producers can be stabilized.
- Increasing the value that farmers realize by focusing interventions to support FPOs and production clusters and connect them to the market.
- Reducing post-harvest losses through the construction of farm gate infrastructure, adequate storage space, acceptable agro-logistics and connections between consuming hubs.
- Increasing the capacity for food processing and adding value along the value chain with business ties to production clusters.
- Establishing a market intelligence network to gather data in real-time on crop prices, demand and supply.

The need for operation greens:

- The goal of Operation Greens is to increase farmers incomes by a factor of two by the end of 2022. It is modelled after Operation Flood and aims to reinforce the benefits of milk in fruit and vegetables.
- Vegetable commodities prices plummet when production spikes since there is not enough modern storage space. Consequently, the plan aims to address the storage capacity issue.
- Frequently, the farmers get less than one-fourth of what customers pay for the product. Operation Greens would concentrate on these issues for fundamental ingredients and not on extra commodities in agriculture, as processing and organized retailing in India have weak and limited links.

Efforts of operation greens during the year 2021-22:

- Onion Production is estimated to be **31.27 million tonnes** (as compared to 26.64 MT in the year 2020-21);
- Potato Production is estimated to be **53.39 million tonnes** (as compared to 56.17 MT in the year 2020-21);
- Tomato production is estimated to be **20.33 million tonnes** (as compared to 21.18 MT in the year 2020-21.

Processing of fruit and vegetables

According to third-advance projections, horticultural production will likely reach a record 314.7 million tonnes (MT) in 2018–19, up from 311.71 MT in production the year before. Even with a modest fall in the production of tomatoes and onions, vegetable production was predicted to have increased to 185.88 MT in the year due to productivity advances. However, it was predicted that potato production would increase by 3.4 percent to 53.03 MT. India is the world's second-largest fruit producer, and production there is projected to reach 98.57 MT in 2018–19, up from (97.36 MT) in 2017–18. Due to its diverse agro-climatic variability, India has the ability to grow all varieties of temperate, subtropical and tropical fruit and vegetables. Due to inadequate infrastructure for mechanical harvesting, processing, value addition and integrated storage, losses are estimated to be between 20 and 30 percent. Beverages, foods with intermediate levels of moisture, preserves, canned and dehydrated fruit and vegetables, pickles, soup bases, sauces and ketchup are a few of the widely consumed goods made from fruit and vegetables. India exports a large amount of varied processed and value-added goods. The nation exported 253276.97 MT of vegetables worth Rs. 2760.53 crores in 2019–20. Mango pulp exports a total of 85725.57 MT during the same time period for a value of Rs. 584.31 crores.

The most perishable goods are fruit and vegetables, which are also crucial components of the human diet. Fruit and vegetables are seasonal in nature and during the glut time, prices drop significantly, making production unprofitable owing to distressed sales. Therefore, if fruit and vegetables are not handled, processed or used appropriately, an increase in production will be of little use. Processing has recently received more attention due to the fact that the expenses associated with minimizing losses are always lower than the cost of production. India business for processing fruit and vegetables is incredibly unstructured. Fruit pulp and juice, ready-to-serve beverages with fruit as the main ingredient, canned fruit and vegetables, jams, squash, pickles, chutneys, dehydrated vegetables etc. are popular commercial goods.

More recently, the sector has also begun to make items like canned mushrooms and mushroom products, frozen pulps and vegetables, frozen dried fruit and vegetables, fruit juice concentrates and vegetable curries in re-sealable pouches. Real-world preservation conditions involve various techniques, including physical, physicochemical, chemical, and biological processes; these phenomena never operate alone. The procedures for preserving fruit and vegetables, the equipment needed, and other information for a unit that processes fruit and vegetables are explained in the paragraphs that follow.

According to Food and Agriculture Organization (FAO), processed foods can be classified into three types:

- **I. Primary processing:** The primary processing includes basic cleaning, grading and packaging as in the case of fruit and vegetables.
- **II. Secondary processing:** Secondary processing includes the alteration of the basic product to a stage just before the final preparation as in the case of milling of paddy to rice.
- **III. Tertiary processing:** Tertiary processing leads to high value-added ready-to-eat food like bakery products, instant foods, health drinks, jam, jelly, etc.

Modern food processing has three major aims:

1. To make food safe (microbiologically, chemically).
2. To provide products of the highest quality (flavour, colour and texture).
3. To make food into forms that are convenient (ease of use) and long-lasting.

The significant benefits for different stakeholders involved in food processing are:

- **Farmer** – higher yield, better farm realization, lower risk.
- **Consumer** – greater variety, lower prices, new products.
- **Companies** – new business opportunities, demand growth.
- **Economy/Government** – employment generation, reduced rural migration.

Need for food processing

Once the food is harvested, it begins to deteriorate immediately due to various factors like the effect of micro-organisms (yeast, mould, bacteria); impact of intrinsic enzymes; temperature; moisture and insect damage. It's crucial to remember that no kind of food processing can improve on inferior basic ingredients. Use the best raw materials possible, establish good processing procedures and stick to them and maintain a suitable product environment after processing to guarantee that the product satisfies high standards. Not all food processing techniques are used to preserve food. Some are also employed in the texturization or stabilization of food. Microorganisms require water, nutrient, oxygen and a suitable temperature for optimal growth and reproduction. The microorganism can only survive in conditions with optimum pH and solute concentration as these will not destroy them. Food can be preserved by destroying the microorganism present in the food or by stopping the activities of these microorganisms. Food that has been processed is preserved to be consumed after the harvest season, making it more delicious, safe and edible. Food processing is another method that promotes variety in food plates and attracts the consumer attention by providing more choices.

Salient opportunities for stakeholders in fruit and vegetables processing:

For equipment & technology supplier	For F&V processor
● New technology in F&V processing ● Cold chain & packhouses- Farm level, logistics, end product storage and at point of retail ● Packaging technology ● Food testing labs with the latest equipment and technology	● New product development: Health food, traditional food, nutraceuticals ● Convenience foods ● Beverages: Traditional Indian beverages like nimbu paani, coconut water etc. ● Processed ingredients for ice creams, yogurt, beverages etc.

Key market challenges in fruit and vegetables processing:

- Getting volume and quality vegetables as raw material at competitive pricing irrespective of seasonal variations.
- Political and legal complications during start-up (GMO, Standards and specifications, licensing etc).
- Production line stabilization (line vs batch processing).
- Assessment of market competition.
- Getting qualified/trained manpower (managers/ workers for all plant departments).
- Initial slow rate of popularity of products.
- Identifying customers.

Approaches in processing of fruit and vegetables

In addition to being dried, canned, frozen or juiced, fruit and vegetables can also be kept in various ways. The creation and use of many techniques and procedures for the preservation of fruit and vegetables were affected by modern lifestyle and diet, which encouraged people to store a range of fruits and other plant organs properly. Fruit and vegetables technological processes can be categorized into a few processing techniques:

- **Traditional processing techniques:** include drying, concentrating, heating (cooking, baking, frying), cooling and adding chemicals.
- **Improved conventional processing techniques:** include aseptic packaging, controlled atmosphere (CA), freeze-drying, microfiltration and membrane processes, application of high temperatures (sterilisation, pasteurisation), application of low temperatures (cooling, freezing) and modified atmosphere (MA) and vacuum.
- **Modern approaches:** High voltage pulse approaches, photodynamic inactivation, microwave processing - heating, high-pressure treatment, ionizing radiation, heating of electrical resistance effect and induction are some of the techniques under investigation.
- **Low and high-temperature processing:** Fruit and vegetables that are frozen (low temperature), canned, or dried (thermally processed) have many advantages, such as a longer shelf life, convenience, year-round availability, the majority of their vitamins are retained because they are typically processed and packaged shortly after being picked, ease of storage and preparation etc.

Basic steps in fruit and vegetables processing:

- Harvesting and packaging
- Pre-treatments: Cleaning, Sorting, Blanching
- Preparing for processing
    - Fresh fruit and vegetables
    - Canned vegetables (cut/whole)
    - Brining/pickling
    - Thermal processing
    - High Temperature: Drying and dehydration
        - Low Temperature: Frozen fruit and vegetables (IQF)
        - Minimally processed F&V (shredded, sliced, diced, cubed)
    - Tertiary processed products (juices, powders, concentrates etc.).

Key segments in fruit and vegetables processing:

- Dehydrated or dried fruit and vegetables;
- Jam, jellies and marmalades;
- Frozen fruit and vegetables (peas, corns, cauliflowers, fruit chunks, etc);
- Candied, crystallized and glazed fruit and vegetables;
- Ready-to-eat and minimally processed fruit and vegetables;
- Thermally processed products;
- Sauces, ketchup, culinary pastes;
- Juices, pulp and concentrates.

Some of the fast-growing segments of food processing industries are:

Tomato concentrate & ketchup, dehydrated garlic powder, banana & its by-products, jam, jelly, chutney, pickles & squashes, tutti fruity from papaya fruit, cashew fruit juice from the cashew apple, fresh processed frozen vegetable puree, dry ginger to green ginger, ginger powder, onion powder, canning and preservation of fruit and vegetables, cold storage for fruits & vegetables, deep freezing of vegetables like pea, tomato & potato etc., dehydration & canning of fruit & vegetables, dehydration and canning/packing of fruits & vegetables, dragon fruits farming, dry fruits processing, drying of tropical fruits (by heat drying process), freeze-dried vegetables, frozen foods, fruits & vegetables, frozen vegetables (potato, cauliflower, peas, bhindi & parwal), growing of fruits & manufacturing of natural juices, processed fruit and vegetables) etc.

Salient categories and business opportunities processed fruit and vegetables:

Apart from traditional food processing methods of making pickles, brined products, jams, and canning, modern approaches to bringing good quality fresh produce with enhanced shelf life in the market, use of technology like high-pressure processing, aseptic packaging, membrane filtration, freeze drying, minimal processing are gaining popularity as it is capable of offering a high-quality product to the consumer. Some of such projects are shared below.

I. **Value addition through Primary processing**

- **Grading of fruit and vegetables:** The fruit and vegetables (intact/ whole) are sold in markets around the world. Size, shape and weight grading help in bringing uniformity in physical attributes of the fruit and vegetables and helps to follow set market standards for fetching better prices.
- **Fresh-cut fruit and vegetables:** This group includes slicing, dicing, shredding and trimming of fruit and vegetables. For example: lettuce (cleaned, chopped, shredded), spinach/leafy greens (washed and trimmed), broccoli and cauliflower (florets), cabbage (shredded), carrots (baby, sticks, shredded), celery (sticks), onions (whole peeled, sliced, diced), mushrooms (sliced), jicama/zucchini/cucumber (sliced, diced), garlic (sliced) etc.

Key equipment for primary processing and fresh cut

Washers, blowers, sizers, grader, colour sorters, trimming line and packaging units or shrink wrap units etc.

II. **Frozen products:** This low-temperature preservation method freezes the food at -38^{O}C and stores it at -18^{O}C. The metabolic activity and deterioration brought on by post-harvest chemicals are slowed down by freezing, which is less expensive than canning and produces items that are closer to fresh products and of higher quality. The main drawback of the procedure is that a low temperature must be maintained during handling, transit, and storage before the product is finally consumed, even though the product preserved by freezing preserves its quality to a significant extent. Mango slices, pulp, pineapple slices, guava slices, orange segments, peas, carrots, cauliflower, beans and other produce are suitable for freezing.

Key equipment for frozen products: (peas/corn)

Depodder, winnower, elevator, washing machines, blower, blanching machine, boiler, chiller, fan, vibrator machine and inspection belt

III. **Dehydrated products:** Dehydration is the process of intentionally producing heat under controlled conditions of temperature, relative humidity and air movement in order to remove moisture from fruit and vegetables. Dehydration removes enough moisture from the product to prevent deterioration, but it must be done carefully to save as much of the product's nutritional value as feasible.

Key equipment for the dehydration unit

- **Blanching unit:** This unit can be used to steam blanch produce as a pre-treatment before processing.
- **Dryers:** Continuous conveyer belt for products like purees and liquids; belt trough for pieces; airlift dryers for granules, spray dryers for liquid products to get converted into powders, vacuum dryers for purees, liquid and cut pieces; cabinet/tray drier for f&v pieces, fluidized bed driers for fragments of F&V etc. Fruit and vegetables can be dried in a vacuum drier without losing any of their sensory qualities.

IV. **Canning:** Canning is the process of cooking and sealing food in a container that is hermetically sealed. The preparation, packaging, and hermetic sealing of a commercially sterile product in sterilized containers.

Key equipment for the canning unit

Washing and cleaning line, canning unit, 'can' assembly line, exhaust line**,** labelling unit etc.

V. **Cut or minimally processed and packaged fruits**: Produce that has been cut up, hardly processed, or packaged, including fruit and vegetables that have been cleaned, sanitised, peeled or cut up and sent to market. This requires the presence of a cold chain in handling the minimally processed products.

VI. **Fruit and vegetables pulp:** This refers to the first stage of volume reduction and high-value product creation from raw fruit and vegetables. The pulp so obtained is used to prepare products like concentrates, sauces, jams, fruit-based beverages etc.

Key machines used in a tomato pulp processing line

Washing unit

Drying unit

Pulper

Mixing tank

Boiling & Concentration unit

Filling & Bottling unit

Capping & Sealing unit

Labelling unit

Table 2: The estimated cost of various equipments for a tomato pulp processing unit.

Sr. No.	Equipment	Approx cost. (capacity 200 kg/hr)
1	Inspection conveyor and feed hopper	1.5-3.0 lakh
2	Fruit vegetable washer and dryer conveyor	3.5-5.0 lakh
3	Inspection/sorter conveyor	1.5-3.0 lakh
4	Hydraulic juice press	1.5-3.5 lakh
5	Steam Jacket kettle	0.5-1.50 lakh
6	Pulper	0.5-2.0 lakh
7	Baby boiler	2.5-4.0 lakh
8	Plastic trays, hand trolly etc.	0.5-2.0 lakh

Table 3: Salient fruit & vegetables business and approximate cost

Sr. No.	Raw Material	Total Project Cost (lakh) (Approx including land, civil work and machine etc.)	Machinery and equipment's cost (lakh) excluding land and civil work)
1	Drying and dehydration of seasonal fruit and vegetables	30.00	18.00
2	Frozen peas	60.00	35.00
3	Frozen sweet corn	36.00	28.0
4	Fruit pulp processing business	30.00	22.00
5	Ripening chamber business	36.00	24.00

Conclusion:

Fruit and vegetables have been part and parcel of the life of human beings since time immemorial. India is the world's second-largest producer of fruit and vegetables but hardly 2.0 percent of the produce is processed. Post-harvest management of fruit and vegetables is important to improve food availability and provide nutritional security to the nation. A wide range of physical and chemical treatments exists for maintaining and enhancing shelf life. The idea of the model act is to vertically, integrate farmers producing fruit and vegetables with agro-processing units for better price realistic. Modern technologies for fruit, vegetables processing and storage are essential for reducing post-harvest losses and increasing the profitability of the farmers. Achieving the goal of sustainable development of the fruit and vegetables value chain is highly dependent on processing at both the global and local levels. Future research in the development of delivering systems will not only improve the efficacy of post-harvest systems but may also address safety issues.

Acknowledgment:

The information offered in this chapter was compiled from secondary published sources, including journals, books and research papers. Various websites, data collection efforts and other sources are also highly acknowledged. The compiled and presented information has an educational purpose for sharing innovative practices in the sector of fruit and vegetables processing.

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Website resources:

Agricultural and Processed Food Products Export Development Authority (*APEDA*); https://apeda.gov.in/apedawebsite/

Food Safety and Standards Authority of India (FSSAI); https://www.fssai.gov.in/

Ministry of Food Processing Industries; https://www.mofpi.gov.in/

National Centre for Cold-chain Development (NCCD); https://www.nccd.gov.in/

National Horticulture Board; https://www.nhb.gov.in/

Pradhan Mantri Formalisation of Micro Food Processing Enterprises *Scheme;* https://pmfme.mofpi.gov.in/pmfme/#/Home-Page

Pradhan Mantri Kisan Sampada Yojana; https://www.mofpi.gov.in/Schemes/about-pmksy-scheme

STORAGE CHALLENGES OF RECALCITRANT SEEDS WITH SPECIAL REFERENCE TO SEEDS OF *MYRISTICA* SPS.

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Abstract:

The storage of recalcitrant seeds, including those of Myristica species, presents several challenges due to their high-water content, low desiccation tolerance, and rapid deterioration under conventional storage conditions. This article reviews the current state of knowledge on the storage challenges of recalcitrant seeds, including the physiological and biochemical factors that influence their storage behaviour, the effects of storage conditions on seed quality, and the strategies employed to improve seed storage and longevity. Myristica species are valuable trees that produce economically important spices such as nutmeg and mace. However, their seeds are highly recalcitrant, making them difficult to store for long periods. The storage behaviour of recalcitrant seeds is influenced by several physiological and biochemical factors, including seed water content, storage temperature, and the presence of antioxidants and free radicals. The loss of seed viability during storage is associated with several metabolic processes, including lipid peroxidation, protein degradation, and DNA damage. Understanding the physiological and biochemical factors that influence seed storage behaviour is critical for developing effective storage strategies that can improve seed longevity and preserve genetic diversity recalcitrant seed producing plants.

Keywords: Recalcitrant seed, *Myristica* sps., Myristica swamps, *Ex-situ*, desiccation, fatty acids, Dormancy.

Introduction:

Seeds are the unique characteristic reproductive body of both angiosperms and gymnosperms and they are the most important way of survival of their species. Seeds are essential for plants as reproductive structure and animals as the major source of food. Generally, seeds can be categorised into two major groups, recalcitrant and orthodox seeds. Recalcitrant seeds are characterized by their inability to tolerate desiccation, and lower temperature whereas orthodox seeds can. These seeds are commonly found in tropical and subtropical regions and have unique features that distinguish them from orthodox seeds, which can be stored for long periods under low humidity conditions. In addition, recalcitrant seeds have a short lifespan and are highly sensitive to environmental stresses, such as changes in temperature and humidity (Farrant *et al.*, 2015).

Myristica sps. of the family Myristicaseae are the main components of the Myristica swamps of southern Western Ghats, which are one of its kinds, ecologically and evolutionarily. Being traded as medicinal plants, as per IUCN report, all wild species of Myristica are on the verge of extinction. Apart from habitat destruction and fragmentation, as many other tropical plant species seed recalcitrance is also a major problem in the regeneration of Myristica sps. All these constraints make the conservation of tropical ever green trees which reproduce by recalcitrant seeds, a herculean task and eventually it will lead to genetic erosion of many tropical trees from the forest ecosystem.

Traditionally, the field gene bank has been the *Ex-situ* method of choice for those species which produce recalcitrant seeds or that propagated vegetatively. Genetic resources in the field gene bank remain exposed to pest, diseases and natural calamities such as drought, fire, and flood. Furthermore, cost of maintaining the germplasm as collection are also very prohibitive in terms of land and cost. Propagation solely by vegetative method may also close the door for pursuance of genetic variation. In this review, we will focus on the storage challenges of recalcitrant seeds with special reference to Myristica seeds.

Challenges

The storage of recalcitrant seeds presents a number of challenges such as high sensitivity to desiccation, vulnerability to fungal and bacterial infections, limited storage life, limited options for storage, High costs and logistical challenges, Lack of standardized storage protocols, etc.

1. **Sensitivity to desiccation**

The intolerance of recalcitrant seeds towards desiccation can be attributed to several reasons, including their high water content, lipid peroxidation, scarcity of LEA proteins, production of more ROS, degradation of vital protein molecules, accumulation of DNA damage and the lack of protective mechanisms against oxidative stress.

High water content: Recalcitrant seeds have a high water content, which can range from 30% to 60% or even higher (Walters *et al.,* 2013). This high water content is essential for the proper functioning of the seed's metabolism, but it also makes the seeds susceptible to damage upon drying and so cannot be stored in dry conditions for long periods of time without losing their viability. When the water content of the seed decreases, the proteins and enzymes that are necessary for germination can become denatured, leading to loss of viability The high moisture content is due to the presence of a large number of living cells and tissues, as well as high levels of lipids and proteins, which act as sources of energy for the developing embryo. The high moisture content of recalcitrant seeds makes them vulnerable to fungal and bacterial infections, which can further reduce their viability and lead to seed decay (Ferreira *et al.,* 2011; Hong and Ellis, 1996).

Myristica seeds, which are commonly known as nutmeg and mace, are a good example of recalcitrant seeds. These seeds are characterized by their high moisture content, which is around 50-60% (Singh *et al.,* 2019). Higher level moisture content has been reported in many mature fresh seeds of recalcitrant seeds such as *Quercus suber* L. (40% to 60%) Vieitez and Vieitez (1995)., *Theobroma cacao* L. (42% - 59%) Dias *et al.* (2006), *Durio zibethinus* Murr. (35% -

55%) Pongsathorn and Pongjanta (2018)., *Mangifera indica* L. (30% - 45%) Sharma and Singh (2005)., *Annona cherimola* Mill. (38% -51 %) Beltrán *et al.* (2009).

Lipid peroxidation: The degradation of lipids is an important factor in seed viability loss. Orthodox seeds contain low levels of free fatty acids (FFAs), which are hydrolysis products of storage lipids, and this is because their storage lipids are enclosed in a stable matrix of proteins and carbohydrates (Kader, 2005). During seed germination, the hydrolysis of storage lipids releases FFAs, which are then used as a source of energy for seedling growth. The hydrolysis of storage lipids is a complex process that involves several enzymes, including lipases and phospholipases (Hernandez-Sebastia *et al.,* 2005). Recalcitrant seeds contain unsaturated fatty acids in their membranes, which are prone to oxidation upon desiccation. The presence of high levels of FFAs, which are due to the presence of a low amount of storage compounds and high levels of unsaturated fatty acids (Walters *et al.,* 2013). The high levels of FFAs make recalcitrant seeds susceptible to lipid peroxidation, which is the oxidative degradation of lipids. The peroxidation of lipids generates free radicals, which can damage cellular structures and cause cell death (Bailly *et al.,* 2019). The susceptibility of recalcitrant seeds to lipid peroxidation is one of the main reasons for their short lifespan.

The degradation of lipids is a major contributor to the loss of seed viability. In orthodox seeds, lipid degradation is a slow process, and the low levels of FFAs protect the seeds from lipid peroxidation. In contrast, the high levels of FFAs in recalcitrant seeds make them vulnerable to lipid peroxidation, leading to the loss of seed viability. This is supported by studies that have shown that lipid peroxidation is a major cause of seed deterioration in recalcitrant seeds (Bailly *et al.,* 2019; Walters *et al.,* 2013). Sreenivasan and Shylaja (2013) have reported presence of high lipid content in Myristica seeds, which provides a source of energy for the developing embryo. Orthodox seeds contain low levels of FFAs, which protect them from lipid peroxidation, while recalcitrant seeds contain high levels of FFAs, which make them susceptible to lipid peroxidation. The susceptibility of recalcitrant seeds to lipid peroxidation is one of the main reasons for their short lifespan.

LEA Proteins: LEA (Late Embryogenesis Abundant) proteins are a group of proteins that are highly accumulated during late embryogenesis and help plants tolerate abiotic stresses such as drought, salinity, and low temperature. Studies have shown that LEA protein production is higher in orthodox seeds compared to recalcitrant seeds. One study by Dure et al. (1989) analysed the accumulation of LEA proteins in developing and mature seeds of several plant species and found that the accumulation of LEA proteins was higher in orthodox seeds than in recalcitrant seeds. Another study by Vertucci and Farrant (1995) also found that orthodox seeds contained more LEA proteins than recalcitrant seeds. Furthermore, a study by Ribeiro et al. (2015) compared the accumulation of LEA proteins in orthodox and recalcitrant seeds of the same plant species, *Jatropha curcas* L. The study found that LEA proteins accumulated to a much higher level in orthodox seeds than in recalcitrant seeds of *J. curcas.*

In summary, several studies have shown that LEA protein production is higher in orthodox seeds compared to recalcitrant seeds. This is likely due to the ability of orthodox seeds to withstand desiccation and maintain protein stability during long-term storage.

Reactive oxygen species: Reactive oxygen species (ROS) are highly reactive molecules that can cause oxidative damage to cells. ROS are produced as a by-product of cellular respiration, and their production is tightly regulated in living organisms. Seeds are unique structures that can exist in a dormant state for extended periods, and their viability is critical for successful plant propagation. The production of ROS in seeds is a complex process that is influenced by several factors, including the seed's type, age, and environment.

Studies have shown that the production of ROS differs significantly between orthodox and recalcitrant seeds. Orthodox seeds produce relatively low levels of ROS, whereas recalcitrant seeds produce high levels of ROS. For example, a study by Bailly *et al.* (2004) found that the production of ROS was significantly higher in recalcitrant seeds of *Quercus suber* L (cork oak) than in orthodox seeds of *Arabidopsis thaliana* (L.) Heynh. Similarly, another study by Ray *et al.* (2012) found that recalcitrant seeds of *Citrus sinensis* (L.) Osbeck. (sweet orange) produced more ROS than orthodox seeds of *Brassica napus* L. The high levels of ROS production in recalcitrant seeds are thought to be related to their high water content and limited ability to enter a state of metabolic dormancy. ROS are produced as a byproduct of cellular respiration, and the high metabolic activity of recalcitrant seeds may lead to increased ROS production. Additionally, the high water content of recalcitrant seeds may lead to increased ROS production through the activation of ROS-generating enzymes. In summary, the production of ROS differs significantly between orthodox and recalcitrant seeds, with recalcitrant seeds producing significantly higher levels of ROS. The high levels of ROS production in recalcitrant seeds are thought to be one of the major factors leads to loss of seed viability.

Degradation of protein molecules: Protein degradation is a critical factor affecting the longevity of seeds, and the degradation rate is different in orthodox and recalcitrant seeds. Protein degradation in orthodox seeds is relatively slow, and the degradation products are recycled or utilized during germination. (Walters, 2015). The proteins in recalcitrant seeds are also more susceptible to degradation, and the degradation products accumulate in the seed, leading to reduced viability (Berjak and Pammenter, 2013).

The difference in protein degradation between orthodox and recalcitrant seeds can be attributed to the difference in their moisture content and metabolic activity. Orthodox seeds have a low moisture content and a low metabolic rate, which helps to protect the proteins from degradation. In contrast, recalcitrant seeds have a high moisture content and a high metabolic rate, which makes them more susceptible to protein degradation. Several studies have investigated the impact of protein degradation on seed viability in both orthodox and recalcitrant seeds. For example, a study by Walters *et al.* (2005) showed that protein degradation is a major factor affecting the longevity of orthodox seeds during long-term storage. In another study, Berjak *et al.* (2001) showed that the accumulation of degradation products in recalcitrant seeds leads to reduced viability.

Accumulation of DNA damage: One consequence of seed storage is the accumulation of DNA damage, which can lead to a loss of seed viability. Both orthodox and recalcitrant seeds can accumulate DNA damage during storage, leading to a loss of seed viability. However, the nature and extent of DNA damage may differ between these two types of seeds due to differences in their storage behaviour.

Orthodox seeds can be stored for extended periods under suitable conditions. However, during storage, DNA damage can accumulate, leading to a loss of seed viability. Several studies have investigated the DNA damage that occurs during seed storage in orthodox seeds. For example, Zhang *et al.* (2018) studied the DNA damage in soybean seeds stored for up to two years and found that DNA damage increased with storage time. These studies suggest that DNA damage accumulates during seed storage in orthodox seeds, which can lead to a loss of seed viability.

Recalcitrant seeds cannot withstand desiccation and must be stored under moist conditions. During storage, recalcitrant seeds can also accumulate DNA damage, leading to a loss of seed viability. For example, during storage, recalcitrant seeds may be more susceptible to oxidative stress due to the presence of high levels of water and oxygen. Several studies have investigated the DNA damage that occurs during seed storage in recalcitrant seeds. Dussert *et al.*, (2018) have reported the DNA damage in cocoa seeds stored for up to 18 months and found that DNA damage increased with storage time. Similarly, Ribeiro *et al.* (2021) investigated the DNA damage in guarana seeds stored for up to 24 months and found that DNA damage increased with storage time. These studies suggest that DNA damage also accumulates during seed storage in recalcitrant seeds, which can lead to a loss of seed viability.

Lack of protective mechanisms: Unlike orthodox seeds, which have developed protective mechanisms to survive desiccation, recalcitrant seeds lack such protective mechanisms (Berjak and Pammenter, 2013). For example, orthodox seeds accumulate protective solutes such as sugars and amino acids, which can stabilize cellular components and prevent damage upon drying. Recalcitrant seeds, however, do not accumulate these protective solutes and therefore are more susceptible to damage upon drying.

2. **Limited storage life**

Recalcitrant seeds have a very limited storage life and can lose viability within a few weeks or months, making it difficult to maintain their genetic diversity over long periods of time (Hong and Ellis, 1996; Pritchard and Tompsett, 2000). Recalcitrant seeds are highly sensitive to desiccation and must be stored under moist conditions to prevent them from drying out (Berjak and Pammenter, 2008; Walters and Pammenter, 1993). Myristica seeds also have a short lifespan and are highly sensitive to environmental stresses, such as changes in temperature and humidity (Parthiban *et al.*, 2014).

3. **Limited options for storage**

There are limited options for storing recalcitrant seeds, as they cannot be stored under dry conditions like orthodox seeds. Cryopreservation, which involves the preservation of seeds at ultra-low temperatures, is an option, but it is not always successful and can be expensive (Pritchard and Tompsett, 2000; Walters and Pammenter, 1993).

Cryopreservation of recalcitrant seeds is a challenging task due to their inherent sensitivity to desiccation and low-temperature storage. Recalcitrant seeds are defined as those that cannot withstand drying to low moisture content without losing viability. This limitation makes their conservation a difficult task since traditional methods like seed banking are not effective. Cryopreservation is an attractive option for preserving recalcitrant seeds due to its potential to maintain the genetic diversity of plant species. However, several hurdles must be overcome for successful cryopreservation of recalcitrant seeds.

Cryoinjury: Recalcitrant seeds are prone to cryoinjury due to their sensitivity to low temperatures. The formation of ice crystals during freezing can cause physical damage to cells and tissues, resulting in a loss of viability. Several studies have reported the occurrence of cryoinjury in recalcitrant seeds during cryopreservation (Wesley-Smith *et al.*, 2001; Walters *et al.*, 2005).

Dehydration sensitivity: Recalcitrant seeds are sensitive to dehydration, and therefore, conventional cryopreservation protocols that involve dehydration steps are not suitable for these seeds. Attempts to cryopreserve recalcitrant seeds by directly plunging them into liquid nitrogen have been made, but these methods have yielded limited success (Farrant *et al.*, 2003).

Genotypic variability: Recalcitrant seeds show a wide range of genotypic variability in their response to cryopreservation. Therefore, it is essential to evaluate the responses of different genotypes of a species to cryopreservation (Berjak *et al.*, 2011).

Post-thaw recovery: The post-thaw recovery of cryopreserved recalcitrant seeds is often low due to the high levels of cryoinjury. Several factors, including the initial quality of the seeds, the rate of cooling and warming, and the use of cryoprotectants, can influence the post-thaw recovery of recalcitrant seeds (Walters *et al.*, 2013).

4. **High costs and logistical challenges**

The storage of recalcitrant seeds can be expensive, as it often requires specialized facilities, equipment, and expertise. Additionally, the transportation and distribution of recalcitrant seeds can be challenging due to their sensitivity to desiccation and potential for seed decay during transit (Berjak and Pammenter, 2008).

5. **Lack of standardized storage protocols**

There is currently no standardized protocol for the storage of recalcitrant seeds. Storage methods vary depending on the species, location, and storage conditions, which can make it difficult to compare and replicate results. Many recalcitrant seed species are found in remote or difficult-to-access locations, making it challenging to collect and store their seeds.

6. **Inability to enter a state of dormancy**

Another unique feature of recalcitrant seeds is their inability to enter a state of dormancy. Dormancy is a state of suspended growth and development that allows seeds to survive adverse environmental conditions, such as drought or extreme temperatures. However, recalcitrant seeds do not enter a state of dormancy and continue to develop even when conditions are unfavorable (Berjak and Pammenter, 2013). This makes it difficult to store recalcitrant seeds for long periods of time, as they will continue to develop and eventually lose viability.

Conclusion:

Overcoming these hurdles requires a thorough understanding of the biology and ecology of the seed species, as well as the development of specialized storage facilities and protocols that can maintain the high moisture content of the seeds while preventing fungal and bacterial infections. In conclusion, recalcitrant seeds are characterized by their high moisture content, short lifespan, sensitivity to environmental stresses, and inability to enter a state of dormancy. Myristica seeds are a good example of recalcitrant seeds, with a high moisture and lipid content, short lifespan, and sensitivity to environmental stresses. These unique features make it difficult to store recalcitrant seeds for long periods of time, and pose significant challenges for conservation efforts.

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TRADITIONAL KNOWLEDGE: A TREASURE OF KNOWLEDGE

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Introduction:

Traditional knowledge refers to the knowledge, skills, practices, and beliefs developed by indigenous and local communities over generations through their interactions with their natural environment. It includes knowledge of the natural environment, such as the properties of plants and animals and how to use them for food, medicine, and other purposes. It also includes knowledge of social and cultural practices, such as traditional ceremonies and rituals. The history of traditional knowledge dates back to the beginning of human civilization, and it has been passed down orally from one generation to the next. Indigenous and local communities around the world have developed unique knowledge systems that enable them to sustainably manage their natural resources and cope with environmental changes. This knowledge is often deeply rooted in cultural and spiritual traditions and reflects a holistic understanding of the interconnectedness of all living things.

Over time, traditional knowledge has been threatened by a variety of factors, including colonialism, globalization, and climate change. As a result, there has been a growing recognition of the value and importance of traditional knowledge, both for the communities that hold it and for broader society. Today, efforts are underway to document, preserve, and promote traditional knowledge, and to recognize the rights of indigenous and local communities to control and benefit from their knowledge systems. These efforts are seen as a key part of building a more just and sustainable future for all.

Importance of traditional knowledge

Traditional knowledge refers to the knowledge, skills, practices, and beliefs that have been developed by a community over time through experience and observation. This knowledge is often passed down from generation to generation through oral tradition and has played a crucial role in shaping human societies and cultures. The importance of traditional knowledge can be seen in various fields, including agriculture, medicine, ecology, and conservation.

Traditional knowledge has played a significant role in shaping agricultural practices in various parts of the world. For example, in the Amazon rainforest, indigenous communities have developed agroforestry systems that combine crop cultivation with the management of forest resources. These systems are based on the traditional knowledge of the communities and have been found to be ecologically sustainable (Chazdon, 2008).

Traditional knowledge has also been instrumental in the development of traditional medicine systems, which are still used in many parts of the world. For example, traditional

Chinese medicine (TCM) is based on the concept of balance and harmony between the body and the environment. TCM has been used to treat various ailments for over 2000 years and is still used by millions of people today (Chen *et al.,* 2017).

Traditional knowledge has played a critical role in the conservation of biodiversity and ecosystems. For example, in the Arctic, indigenous communities have developed a deep understanding of the ecological systems and the migratory patterns of animals. This knowledge has been used to develop conservation strategies that are effective in protecting the region's biodiversity (Berkes *et al.,* 2018).

Traditional knowledge in India

India has a rich tradition of traditional knowledge that has been developed and passed down by indigenous communities over centuries. This knowledge covers a range of areas, including agriculture, medicine, and spirituality.

Agriculture: Traditional knowledge has played a significant role in shaping agriculture in India. For example, the practice of mixed farming, which involves the cultivation of multiple crops in the same field, has been used in India for centuries. This practice is based on the traditional knowledge of the communities and has been found to be ecologically sustainable (Bandyopadhyay *et al.,* 2017).

Health care: Traditional medicine is an essential part of healthcare in India, with many people relying on it for primary healthcare. Ayurveda, which is an ancient Indian system of medicine, is based on the use of natural herbs and plants to treat various ailments. This system has been used for over 5000 years and is still used by millions of people in India today (Singh & Singh, 2017).

Yoga is a traditional practice that originated in India over 5000 years ago. It involves physical postures, breathing exercises, and meditation to promote physical, mental, and spiritual well-being. Yoga has been shown to have numerous health benefits, including reducing stress, improving flexibility, and boosting immunity. Traditional knowledge has also played a crucial role in shaping spirituality in India. For example, yoga, which is an ancient Indian practice, is based on the traditional knowledge of the body and mind. This practice has been found to have numerous health benefits, including reducing stress and anxiety (Telles *et al.,* 2017).

Siddha medicine is a traditional healing system that originated in South India over 2000 years ago. It is based on the concept of balance between mind, body, and spirit and uses natural remedies such as herbs, minerals, and animal products to treat various ailments (Balaji and Govindarajan, 2018).

Ecology and conservation: Traditional knowledge are essential for conservation efforts because it can provide valuable insights into the ecological systems and the ways in which they can be managed sustainably. Indian traditional knowledge is deeply rooted in ecology and conservation. For centuries, Indigenous communities in India have relied on their understanding of the natural world to sustain themselves and their environment. Here are some examples of how Indian traditional knowledge has contributed to ecology and conservation:

Sacred Groves: In India, there are numerous sacred groves, which are patches of forest that are protected by communities for their spiritual and ecological significance. These groves act as biodiversity hotspots and serve as a refuge for endangered species (Gadgil and Vartak, 1976).

Traditional Agriculture: Indian farmers have developed various farming techniques that promote biodiversity and soil health. For example, the practice of intercropping, where different crops are grown together, helps to reduce soil erosion and increase crop yield (Jat and Gupta, 2008).

Ethnomedicine: Traditional Indian medicine systems, such as Ayurveda and Unani, rely on natural resources and have a deep understanding of the ecological relationships between humans and the environment. This has led to the conservation of numerous medicinal plants (Jain and Sastry, 1983).

Traditional Livelihoods: Indigenous communities in India have developed sustainable livelihoods that are based on the principles of conservation. For example, the Bishnoi community in Rajasthan is known for their conservation efforts, including protecting the blackbuck antelope (Sankhala, 1966).

Conservation efforts based on traditional knowledge have been successful in many parts of the world. For example, in India, traditional knowledge has been used to conserve forests and manage wildlife for centuries. The Bishnoi community, for instance, is known for its commitment to protecting trees and wildlife, and their traditional practices have helped to conserve forests in Rajasthan for generations (Saberwal, 2001).

Despite the value of traditional knowledge, it is often threatened by modernization and globalization. Many traditional communities are under pressure to adopt modern agricultural practices and abandon their traditional knowledge. In addition, the loss of traditional languages and the migration of younger generations to urban areas are also contributing to the erosion of traditional knowledge (Oviedo, 2016).

To address these challenges, it is important to recognize the value of traditional knowledge and to work with traditional communities to promote its preservation and use. This can be done through education and training programs that help to pass on traditional knowledge to younger generations. In addition, efforts can be made to incorporate traditional knowledge into conservation policies and programs, ensuring that traditional communities are involved in the management and conservation of natural resources (Berkes, 2009). Traditional knowledge is a valuable resource for conservation efforts. It provides valuable insights into the ways in which ecological systems can be managed sustainably and has been used successfully by many traditional communities around the world.

Traditional knowledge in Kerala

Kerala, located in the southern part of India, is known for its rich cultural heritage and traditional knowledge systems and it refers to the knowledge, practices, and beliefs of the indigenous communities of the state.

Ayurveda: Ayurveda is an ancient Indian system of medicine that has been practiced in Kerala for thousands of years. It is based on the principle of balancing the three doshas - Vata, Pitta, and Kapha - to maintain health and prevent disease. The Charaka Samhita, Sushruta Samhita, and Ashtanga Hridaya are some of the classical texts that form the foundation of Ayurveda (Nair, 2014).

Panchagavya is a traditional Ayurvedic preparation made from five cow products, namely milk, curd, ghee, urine, and dung. It is widely used in Ayurvedic medicine for its medicinal and therapeutic properties. Panchagavya has been used for centuries in India and has gained popularity in recent years due to its natural and sustainable nature.

According to a review article by Kulkarni (2015), Panchagavya has a rich historical background and has been used in Ayurvedic medicine for various purposes such as rejuvenation, immunity boost, and detoxification. The five cow products used in the preparation of Panchagavya are known to contain various bioactive compounds that exhibit antimicrobial, antioxidant, and anti-inflammatory properties. These properties make Panchagavya a promising alternative to synthetic drugs.

Gaurav *et al.* (2017) highlighted the cultural and spiritual significance of cow products in Indian tradition. Cows are revered as sacred animals and are considered a symbol of wealth, strength, and purity. The use of cow products, including Panchagavya, is believed to bring spiritual and physical well-being.

Panchagavya has been found to be effective in the treatment of various diseases. Raut and Tare (2016) reviewed the scientific evidence supporting the therapeutic properties of Panchagavya. The review article found that Panchagavya exhibits significant antibacterial, antifungal, antiviral, and anti-cancer properties. It also boosts the immune system and helps in the prevention and treatment of metabolic disorders such as diabetes.

Martial Arts: Kerala has a rich tradition of martial arts, which includes Kalaripayattu, a style that is believed to be one of the oldest surviving martial arts in the world. Kalaripayattu emphasizes physical fitness, self-defence, and mental discipline. (Zarrilli, 1998; Bhagyalakshmi and Kaimal, 2016).

Architecture: Traditional architecture in Kerala is known for its unique style and use of natural materials such as wood, bamboo, and mud. The Nalukettu style of architecture, which features a central courtyard and four halls, is a classic example of Kerala's traditional architecture. (Vikramaditya Prakash, 2010).

Folklore and Mythology: Kerala has a rich tradition of folklore and mythology, which includes stories about gods and goddesses, demons and monsters, and other supernatural beings. Folklore includes songs, stories, and rituals. Folklore is an essential part of the cultural heritage of an area and it reflects the beliefs and practices of the local community. Many of these stories and songs are passed down from generation to generation, and they play an important role in preserving the cultural identity The Ramayana, Mahabharata, and Puranas are some of the classic texts that form the foundation of Kerala's mythology. (Padmanabha Menon, 2012; Gopalakrishnan and Velayudhan, 2017).

Traditional Food: Kerala's cuisine is known for its spicy and flavourful dishes, which feature coconut, curry leaves, and other local ingredients. Some of the classic dishes include Appam, Puttu, and Fish Curry (Lathika George 2012).

Traditional agricultural practices: Palakkad has a rich tradition of agriculture, and many farmers still use traditional agricultural practices. These practices include the use of natural fertilizers, crop rotation, and intercropping. Traditional agricultural practices are believed to be more sustainable and environmentally friendly than modern farming methods (Kumar and Veeraraghavan, 2016).

Rao and Reddy (2015) discussed the potential use of Panchagavya in sustainable agriculture. Panchagavya has been found to increase soil fertility, enhance plant growth, and provide protection against pests and diseases. The use of Panchagavya in agriculture can lead to sustainable and eco-friendly farming practices.

Traditional dance forms: Palakkad has a rich tradition of dance, and several traditional dance forms are practiced in the city. These include Mohiniyattam, Kathakali, and Thiruvathirakali. Traditional dance forms are an essential part of the cultural heritage of Palakkad, and they are performed during festivals and other cultural events (Narayanan, 2014).

Handicrafts: Kerala is well known for its traditional handicrafts, which include textiles, pottery, and woodwork. These handicrafts are made using traditional techniques and tools, and they reflect the artistic skills and cultural heritage of the local community. Many of these handicrafts are sold in local markets and exported to other parts of the world.

Aranmula Kannadi one of the iconic symbols of traditional knowledge prevail in Kerala. Aranmula Kannadi is a unique and traditional mirror that holds a significant place in the cultural heritage of Kerala. Its handmade process, symbolism, and recognition have made it a popular and valuable item for both locals and tourists alike (Pillai, 2015). Aranmula Kannadi is a unique and traditional mirror that is handmade in Aranmula, a village in the state of Kerala, India. It is considered as one of the eight auspicious items or Ashtamangalyam in Kerala, and it holds a significant place in the cultural heritage of the region. The history of Aranmula Kannadi dates back to the 16th century. It is believed that the mirror was first made by a family of craftsmen in Aranmula who belonged to the Viswabrahmin community. The traditional mirror-making process has been passed down through generations, and it is still practiced by the descendants of the original craftsmen.

Aranmula Kannadi is made using a unique process that involves several stages of polishing and heating. The raw materials used for making the mirror include copper, tin, and lead. The mirror is not made of glass but is a reflective surface created by polishing the metal surface to a high degree of smoothness. The craftsmen use natural materials such as sandstone, clay, and herbs to achieve the required smoothness and shine.

Aranmula Kannadi is considered as a symbol of prosperity and good luck in Kerala. It is believed that the mirror brings good fortune to the owner and wards off evil spirits. It is also considered as a sacred object and is often given as a gift during auspicious occasions such as weddings and housewarming ceremonies. In 2004, Aranmula Kannadi was granted the Geographical Indication (GI) tag, which is a certification that recognizes the traditional craft of a specific region. The GI tag ensures that only the mirrors made in Aranmula using the traditional method are marketed as Aranmula Kannadi. Aranmula Kannadi has become a major tourist attraction in Kerala. Visitors can witness the traditional mirror-making process and purchase the mirrors from local craftsmen. The Aranmula Parthasarathy Temple, which is located in the village, is also a popular tourist destination.

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SUSTAINABILITY AND DAIRY FARMING IN INDIA: THE POSSIBILITIES

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Abstract:

Dairy farming is an alternative source of income and employment generation in a developing country like India where the land holding decreases at geometric ratio average. It is a all-season business. At the same time Animal Husbandry practice gives higher remuneration compared to other agricultural practices in short duration of time and also a practice which can easily be managed by unskilled labour. In spite of efficient management of a dairy farm, sustainable dairy farming is considered to be a need of the hour. India ranked seventh in area-wise, second populous country in the world. India has been the leading producer and consumer of dairy products worldwide since 1998 with a sustained growth in the availability of milk and milk products. It's also has the largest bovine population in the world, but productivity per animal is significantly low as compared to the other major dairy producing country. Sustainable agriculture farming is the ways meeting societies present food needs without compromising the current or future generation's ability to meet their needs. The Sustainable dairy farming in India is a new concept that previses the current generation to practice the proper and efficient usage of the resources, without over-exploitation. It is important to understand that good management of a farming system constitutes the base of the farming system's economic, environmental and social sustainability. In India due to the variations in agro-climatic condition, biodiversity & ecology, socio-economic and cultural background of people and types of cattle breed reared, causes challenges in sustainable dairy farming. Animals contribute in climate change as they produce methane and carbon dioxide gases but changing climate also is also adversely affecting the livestock production and reproduction. Thus there is need to reduce the adverse impact of the climate change and this can be possible by identify proper feeds to the animals. For making the dairy sector more profitable there is need to have bulk milk coolers, refrigeration systems and also to develop the organized markets in rural areas which further can help in rural development. The focus should be given on small dairy farmers who lack availability of nutritious feed, timely institutional credits, fodder availability in off season of year, timely quality veterinary and AI services etc.

Milk and milk products are considered to have a good balance of protein , fat and carbohydrate and essentially the important source of nutrients calcium, riboflavin, phosphorous, vitamins A and B12, potassium, magnesium, zinc, iodine. Thus, it has a crucial role in bone health. Dairy foods like milk, yoghurt and cheese are not a threat to good health if had as part of a well-balanced nutritious diet. Therefore, it is considered as an essential good. Now a day's people from every sections of society have become more conscious about their health and milk to a great extend fulfills the deficiencies of human body as well as other animal's body. In Hindu culture female cow is worshipped as "Gou-mata" or cow mother as it serves as mother to her babies. Thus, the increasing market demand of milk in turn induces new and more investment in the field. The volume of cow milk produced worldwide has risen steadily over the last several years. It has increased from 497 million metric tons in 2015 to 532 million metric tons in 2020. Liquid milk is the largest share of dairy market in terms of market value. India is the world's largest milk producer, with 22 percent of global production, followed by the USA, China, Pakistan and Brazil. The milk surplus countries are New Zealand, USA, Germany, France, Australia and Ireland. India in not only the highest producer but it is also the highest consumer of milk. Its annual production was 186 million tons as of 2018 and as of 2020, approximately 4.2% of India's Gross domestic product is contributed from the dairy sector. The dairy sector in the country gained ground after the world largest dairy development program and a landmark project of India's National Dairy Development Board known as the Operation Flood Project was launched in the year 1970; that transformed India from a milk deficient nation into the world's largest milk producer nation in 1998. The per capita availability of milk in India was 394 gram per day in 2018-19.

Dairy farming is an alternative source of income and employment generation in a developing country like India where the land holding decreases at geometric ratio average. It is a all season business. At the same time Animal Husbandry practice gives higher remuneration compared to other agricultural practices in short duration of time and also a practice which can easily be managed by unskilled labour. In spite of efficient management of a dairy farm, sustainable dairy farming is considered to be a need of the hour. The dairy sector in the country gained ground after the world largest dairy development program and a landmark project of India's National Dairy Development Board known as the Operation Flood Project was launched in the year 1970; that transformed India from a milk deficient nation into the world's largest milk producer nation in 1998. The per capita availability of milk in India was 394 gram per day in 2018-19.

To mitigate risks and uncertainties associated with agriculture productivity, dairy farming is considered as a good option. Livestock faming system in India is different from other developed nations. It depends upon the locality of farming. In rural areas, usually small holder farms are cultivated and animals are largely fed on crop residues, whereas in peri-urban areas cross bred and highly productive animals are reared and the animals are supplemented with concentrate feed. Moreover, in India with higher percentage of landless person or higher proportion of marginal land holders, modern dairying is a suitable job for survival (Kumar & Parappurathu, 2014).

Dairy sector in India

India ranked seventh in area-wise, second populous country in the world. India has been the leading producer and consumer of dairy products worldwide since 1998 with a sustained growth in the availability of milk and milk products. It's also has the largest bovine population in the world, but productivity per animal is significantly low as compared to the other major dairy producing country. It is contributing 23 percent of global milk production. Milk production in the country has grown at a compound annual growth rate of about 6.2 percent. The production level has reached 209.96 million tons in 2020-21 from 146.31 million tons in 2014-15. As of 2020, the contribution of dairy sector to GDP was approximately 4.2 percent. As per 2019 livestock census, India has a population of over 300 million bovines, of which 192.49 million cattle and 109.85 million buffaloes. Half of the total milk produced in India comes from buffaloes. The numbers of indigenous breed of cattle in the country are decreasing steadily while the numbers of more productive exotic and cross bred cattle has been increasing continuously.

The most basic feature of Indian dairy sector is that it is still predominantly unorganized. Only 18-20 percent of total milk production is channelized through organized sector. India is neither a active importer nor exporter of milk. Most of the produced milk consumed domestically. Still the eastern part of the country is milk deficient.

Dairy act as an important source of employment and income and it's from an essential part of rural India economy. Most of the produce milk in the country is consumed domestically, with majority of being sold as fluid milk. Thus, Indian dairy industry has tremendous potential for value addition and overall development.

Table 1: value of milk group output at current prices (in Rs. crore) (Source: Central Statistical Organization, GoI)

Year	Value
2011-12	3,27,767
2012-13	3,72,228
2013-14	4,23,150
2014-15	4,95,835
2015-16	5,60,823
2016-17	6,29,259
2017-18	7,07,607
2018-19	7,75,556
2019-20	8,38,797

Milk consumption levels are not uniformly distributed across India. The consumption level in northeastern states is less whereas in northwest India it is higher. States with higher consumption of meat and egg are consuming less quantity of milk. Milk is also consider as having income elasticity of demand greater than one, consumption increase more as income increases.

Table 2: State-wise milk production in India (Thousand tonnes)

State	2015-16	2017-18	2019-20
Arunachal Pradesh	50	54	61
Manipur	79	82	90
Assam	843	872	920
Himachal pradesh	1283	1392	1531
Uttar Pradesh	26387	29052	31864
Rajasthan	18500	22427	25573
Madhya Pradesh	12148	14713	17109
Gujarat	12262	13569	15292
Andhra Pradesh	10817	13725	15263

Bihar	8288	9242	10480
Chhattisgarh	1277	1469	1676
Goa	54	55	61
Gujarat	12262	13569	15292
Haryana	8381	9809	11735
J & K	2273	2460	2506
Jharkhand	1812	2016	2321
Karnataka	6344	7137	9031
Kerala	2650	2576	2544
Madhya Pradesh	12148	14713	17109
Maharashtra	10153	11102	12024
Meghalaya	84	85	88
Mizoram	22	25	24
Nagaland	77	74	62
Orissa	1903	2088	2370
Punjab	10774	11855	13348
Sikkim	67	59	84
Tamil Nadu	7244	7742	8759
Telangana	4442	4965	5590
Tripura	152	174	199
Uttarakhand	1656	1742	1845
West Bengal	5038	5389	5859
A & N island	15	17	19
Chandigarh	43	42	49
D & V Haveli	9	8	
Daman & Diu	1	1	1
Delhi	281	279	
Lakshadweep	3	3	4
Pondicherry	48	49	50

Source: Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture and Farmers Welfare, GoI

Sustainable agriculture farming is the ways meeting societies present food needs without compromising the current or future generation's ability to meet their needs. The Sustainable dairy farming in India is a new concept that previses the current generation to practice the proper and efficient usage of the resources, without over-exploitation. It is important to understand that good management of a farming system constitutes the base of the farming system's economic, environmental and social sustainability. While people inherently know about dairy's nourishing strength, the dairy sector contributes more than just tasty goodness to the world's population.

Nearly one billion people globally earn livelihood in dairy sector. It sustains and revitalizes rural communities in all corners of the world. Dairying makes farmers responsible for livestock and makes land better for next generation. Moreover dairying helps to meet up world food crisis both safely and sustainably.

Table 3: Trends in the per capita consumption of milk and milk products in India (kg/annum)

States	1983	1993-94	2004-05	2009-10
Andhra Pradesh	34.7	39	43.5	46.7
Assam	24.6	17.2	22.1	20.8
Bihar	25.8	31.9	38.3	34.9
Chhattisgarh	17.7	22.6	13.4	14.5
Gujarat	68.6	77.2	74.7	84.6
Haryana	130.4	164.6	161.5	160.5
Himachal Pradesh	92.2	96.8	111.7	121.4
Jharkhand	16	29.7	24.1	26.6
Karnataka	38.8	42.5	48	53.3
Kerala	27.9	34.7	41.4	41
Madhya Pradesh	42.6	41.1	53.9	53.7
Maharashtra	38.3	41.8	44.5	49
Odisha	11.8	12.5	13.6	16.4
Punjab	132	161.7	141.7	140.7
Rajasthan	86.4	128.6	119.4	125.4
Tamil Nadu	29.1	34	42.6	49.7
Uttar Pradesh	46.6	69.8	60.5	59.3
Uttarakhand	71.2	92.7	84.4	83.9
West Bengal	25.8	24	23.2	21.9
India	44.7	54.3	55	57.1

The dairy sector of India has grown massively in last few decades and has topped in milk production and has largest livestock in the world. It is noted that dairy farming requires a large amount of feed, meal supplements and other drugs. Thus the sector is now facing many challenges.

In the present system of intensive dairy farming, the quantity of milk directly and proportionately depends on concentrate feedings. Acute feed and concentrate price with low quality too, increases the cost of dairy farmers and therefore decrease profit earned which is recognized as a major constraint in dairy farming in India. Moreover, the system prevails at present produce milk loaded with chemicals and unnatural nutrients. Because, in intensive farming the cattle are keeps in a confined areas with confined facilities for optimal productivity. As many cows are keeping together, it promotes spread of disease. The tightly packed facilities are too stressful to animals.

Thus, the modern dairy farming method seems sophisticated in nature, whereas most of its key elements are derived from traditional farming method. The dairy farming can be a sustainable if we take care of some aspects like animal care, earth care and energy care.

The first step in dairy farming is the choosing of right breed. The animal breed is mainly choose based on milk yield without considering their suitability to the local climate, soil, feed availability, resistance to diseases & pests and environmental conditions. The exotic breeds Holstein Friesion, Jersey cows are very sensitive to hot and dry climate. On the other hand, 'desi' breeds like, Sahiwal, Gir, Sindhi cows and Murrah Buffalo could be more suitable for the Indian climate condition. Apart from the breeds, hygienic cowshed is another important aspect to be considered. Along with protection from adverse weather conditions, the cowshed must have enough space for feeding. The regular health check-up of animals is also necessary to prevent them from falling ill. Thus, proper health management of animals of herd is a important aspect of sustainable dairy farming. Open grazing which is a concept of traditional dairying can be opt but its need higher labor.

Beyond animal care, the proper care of earth is also another important aspect of sustainable dairy farming. In the modern dairying system the high milk yielding animals need higher and steady supply of feed and fodder. To meet these need farmers should try to cultivate feed and fodder locally by growing green grasses in the farm itself and availing dry feed locally. High yielding Bajra Napier hybrids can be grown by using cow dung itself, whereas Guinea grass can be grown in barren rain fed land. Apart from growing organic fodder, it is important to ensure the manure urine and other waste are disposed off in compost pit. Another benefit of dairying is biogas that is used as safe and best alternative in place of LPG for cooking. It solves both problems of waste disposal and also provides ready manure for fertilizing crops.

Even though dairying is not an energy-intensive activity, but it some amount of electricity to run some machine that are use for cleaning and providing some facilities in the herd. And the farmers are relying mainly on generators which is very costly too, due to non-steady power supply in the villages. On the other hand, biogas is use for cooking process and it can be use for milk heating and chilling purposes as well. Biodiesel is another alternative that can be considered for running a diesel generator in remote places where electricity is not available. Farmer can also opt for solar panels to lighting up farm and run fans.

Challenges in sustainable dairy farming in India

Even though india is in highest position in world milk production accounting 18.5 percent of global milk production, the per capita availability of milk is still beyond the world average. Thus inadequacies in milk supply pose a serious health issue which needs to be addressed immediately. In India due to the variations in agro-climatic condition, biodiversity & ecology, socio-economic and cultural background of people and types of cattle breed reared, causes challenges in sustainable dairy farming.

The foremost challenges in dairying are regarding feed and fodder. Inadequate supply and poor quality feed supply is the major problem in dairying in india. Food and fodder is the challenge that become more severe with increment in population, decrease in arable land for crop production, water shortage, food-feed-fuel competition, limited supply of phosphourus, frequent climate extremes. In modern diary system a good quality feed and fodder is requires to fulfill the dietary necessity of milking animals. The excessive number of unproductive animals also causes shortage in feeds. The grazing area being reduced drastically every year due to industrial development resulting in shortage of supply of feeds and fodder to the total requirement. Moreover, provision of poor quality of forage to dairy cattle restricts animal production system.

Lack of proper breeding infrastructure health care centre is another important challenge in the country's dairy sector. The success of the sector was mostly due to rising number of animals not productivity. Late maturity, in most of Indian cattle breeds, is a common problem. The artificial insemination centre and veterinary health care centers are located in far off places, the ratio between cattle and center is wider. And resulting inadequate breeding and health services to animals. No regular and periodical vaccination schedule is followed. Therefore the mortality rate in calves is very high.

It was also observed that many cattle owners do not provide proper shelter to their cattles leaving them at market place or roadside that expose them to extreme climate conditions. Unsanitary conditions of cattle shed and milking yards leads to mastitis conditions. Unhygienic milk production leads to a reduction in storing quality and spoilage of milk and other products.
Another problem in achieving sustainable dairy farming is unavailability of effective market and pricing policy. Dairy farmers are not getting remunerative price for milk. Involvement of middle man also causes lower payment for milk at farm-gate and market. Lower prices for milk and higher prices of feeds and fodder cause economically unviable situation for dairy farmers.

Animals contribute in climate change as they produce methane and carbon dioxide gases but changing climate also is also adversely affecting the livestock production and reproduction. Thus there is need to reduce the adverse impact of the climate change and this can be possible by identify proper feeds to the animals. For making the dairy sector more profitable there is need to have bulk milk coolers, refrigeration systems and also to develop the organized markets in rural areas which further can help in rural development. The focus should be given on small dairy farmers who lack availability of nutritious feed, timely institutional credits, fodder availability in off season of year , timely quality veterinary and AI services etc.

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CHANGING AGRI-BUSINESS LANDSCAPE THROUGH USE OF ICT TOOLS – A CASE STUDY OF A WOMAN FARMER IN DISTRICT BUDGAM, J&K

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Summary:

Technology has taken the world by storm. Business, news, entertainment and education are facilitated by internet and e-applications. Information flow is facilitated in a flick of a second and at bare minimal cost. While it has wide usage, the actual picture at grassroots presents a rather dismal picture. Our primary producer – the humble farmer, stays blissfully ignorant about its utility and benefits.

Introduction:

The internet has largely shaped the world economics in the last three decades. More recently, its importance got underlined in times of Covid-19 Pandemic, when physical distancing was an imperative and all endeavors sought execution on-line for all practical purposes. Children were able to achieve their academic targets only because of electronic applications like Google Classrooms and other of the ilk. Our own clientele, the primary producer – farmer, was accessed through electronic applications like Zoom and Telegraph for most awareness programmes, lectures, and several demonstrations on processing of fruits and vegetables.

Information and Communication Technologies [ICT] are important elements in promoting connectivity among the community in contemporary society (Bin-Abbas and Bakry, 2012). Farmers in developing countries constitute economically and geographically marginalised groups (Cecchini and Scott, 2003). These vulnerable rural populations are at risk of digital exclusion and thereby social exclusion (Warren, 2007). Several ICT initiatives face challenges like affordability, simplicity, accessibility, scalability, relevant and localised content in inappropriate language and form (Keniston, 2002; Dossani *et al.*, 2005; Glendenning *et al.*, 2010). However, current mobile usage pattern is leapfrogging in developing countries such as India (Watkins *et al.*, 2012) and ensure use of the affordable mobile internet, utilisation of social media by information poor, particularly older, less educated, less affluent people. This, a new wave of ICT innovations had a lesser barrier in terms of skills and cost to the farmer and can be the decisive factor of ICT adoption process in agriculture. The use of smartphones in agriculture becomes even more important as farmers are constrained to travel in gaining necessary information or for using available public services in their disposition (Chatzinotas *et al.*, 2006; Ntaliani *et al.*, 2008). The access to a smartphone has a positive significant influence on gaining agricultural knowledge among farmers by smallholder farmers in India (Landmann *et al.*, 2017).

Social network sites may be defined as electronic based services that allow individuals to (Boyd and Ellison, 2007) construct a public or semi-public profile (Babu *et al.*, 2012) articulate a list of other users with whom they share a connection, and (gakuru *et al.*, 2009) view and traverse their list of connections and those made by others within the system. These sites however differ in nature and nomenclature. In nut-shell social media enable people to create, publish, share, collaborate, discuss and network through a wide range of new, mainly digital, formats and platforms. Different types of social media are Blogs, Microblogs (Twitter), Conversational threads (WhatsApp), Social Photos, Social Networking (Facebook, LinkedIn), Video Sharing (YouTube).

In developing countries, ICT in agriculture provides farmers with vital information pertaining to sowing, crop protection, and improving soil fertility that enables them to improve agricultural productivity (www.cropin.com)

In a random sampled data of farmers registered during these on-line and off-line trainings, it surfaced that nearly 65% of farmers use smart phones. This usage was primarily for communicating with friends, family and relatives or for seeking news and entertainment through social network sites. None of the farmers accessed were found to be using social media applications like FaceBook or Instagram for purposes to highlight/showcase their farm endeavors or sell their produce through these media. While 85% of these are illiterate, a mere ease of buttons, multi-language use, user-friendly interface is an edge that favors use of these apps by even a semi-literate person.

Insha Rasool – A case study of a woman farmer effectively using ICT for agri-business in J&K

Insha Rasool, is a promising agri-preneur who started organic farming in 2018 on her ancestral land as an experiment after quitting her job as a Research Associate at POSTECH, South Korea. She wanted to translate her international experience at her native place working with own people using the local resources.

Organic farming

To begin with, she used the ancestral land (25 kanal) that her family used for vegetable cultivation. Insha observed that the farmers in her vicinity were not growing cash value exotic and heirloom vegetables which were in high demand markets of India. She then began to invest money accumulating lesser-known seed varieties from local and international seed banks and her maternal grandmother's collection and aimed to create a seed bank for Kashmir. She established an experimental plot for exotic vegetables like like parsley, broccoli, lettuce that went up for sale through her official Facebook/Instagram page, Homegreens on daily basis – mostly in urban areas of Srinagar, Budgam and Pulwama Districts. Insha also made a foray into floriculture by curating succulents and cacti arrangements for home and office décor.

The stark public response to these organic exotic vegetables and succulents led Insha diversify her venture further. She spent months experimenting with different varieties of vegetable seeds in Kharif and Rabi seasons. She also connected to nearby farmers about what varieties they sowed, purchased heirloom and hybrid seeds from other countries and friends in Kashmir and hired staff to do the sowing, tilling, and other field jobs.

Simultaneously, she continued vegetable cultivation at her farm using Natural Farming techniques. Inter-Cropping plantation plan was use where pest repellent or attractant plants are grown between the crops of interest. Plantations like garlic, traditional marigold, common nettle, artemisia, and neem oil extracts are some of her most utilized options.

Post-Harvest management through value-addition

At Home Greens, gourmet pickles were the first line of product that we standardized right from growing the ingredients on the farm, processing the produce in the facility built, and having the value-added product sent directly to the homes. They undertook several trials before the clients purchased the product, and at times it took a year to standardize the recipe and fix the variables. So far, with their small team, they have been able to process 20-25 tonne into pickle. The raw material for these is partly procured from GreenSpace Organics farm from District Pulwama.

The long term goal is to fully standardize an in-farm fermentation unit where they can convert most organically grown farm produce into countless varieties of slow-fermented pickles using traditional recipes. The idea is to devise post-harvest management strategy in order to increase the produce shelf-life and also be able to provide pesticide-free products any time of the year.

Home Greens, now a brand, sells value-added products curated out of farm-grown organic veggies across India. They have become the first point of contact from dealers from Mumbai for purchase of superior quality exotic vegetables. For this, farmers practicing organic farming in District Pulwama have been taken on board to fulfill those orders.

Syngenta Hi Brix 55 is a Sweet Corn Variety that Homegreens procured from Switzerland and has collaborated with District Uri based farmer who cultivates it on 20 kanals. At their own farm, 15 kanals have been sown under this variety of sweet corn. The USP of this Sweet Corn variety is the sweetness index (Brix 55) as against the common sweet corn (Brix 30). Homegreens helps him to sell his produce through their brand on custom based orders through home delivery. Both fresh and Frozen batches are doled out for sale as per customized orders.

Challenges

Insha Rasool has been an agripreneur since 2018 and she has had her own challenges at every step of the journey. Quoting verbatim, *"We failed more than we succeeded. Sometimes the seed wouldn't germinate, inadequate fertilization yielded poor results, faulty irrigation etc."* She and her team learnt through their mistakes till they undertook vegetable cultivation on Commercial lines through organic means. Organic farming in India has enormous potential to uplift small-scale farming units. It uses pest controls and biological fertilizers mainly derived from natural resources such as animal and plant wastes.

As time passed and farm operations streamlined, Homegreens unit realized that one could do simple, successful agribusiness without heavy technology to begin with. Key learning in this process is strategic planning in order to avoid resource wastage. Also, there were not many successful farmers in her vicinity with whom she could connect and get encouragement from, for cultivation of organic vegetables.

Income and Assets

S. No.	Year	Gross Income from Enterprise	Labor
1	2020	2 Lakh from Pickle (500 kg)	One full time labor @ Rs. 5500 per month
2	2021	5 Lakhs from Pickling (1100 kg)	8500/Month 2 Man Days
		Sweet Corn Sale (12000)	60 daily wagers @ Rs 500 per person amounting to Rs.30,000
3.	2022	Pickle estimate 1500 kg @ Rs.500 per kg	2 Man Days @ Rs. 4500 per person per month

Assets:

- Eco Van for transporting orders (5 Lakhs)
- Constructed 2 storey production unit
- 2 large deep freezers

Conclusion:

Insha Rasool's Homegreens is the emerging new face of an educated, female agri-preneur. While there are a million women working in agriculture and allied activities at the grassroots, Insha has shattered the glass ceiling and marked her presence in a male dominated field by taking the lead. Though the profit margins are low, she has been able to carve a niche for herself and livelihood for the men and women who are associated with her farm.

There have been, in this journey of the family of Homegreens, Inter-district collaborations that have yielded fruitful results. Farmers from Uri in District Baramulla are able to find market for their Sweet Corn through her social media page on Facebook and Instagram. This case rightly endorses the practical use of technology for connecting with like-minded people for cross-learning and marking visibility in the sector of agri-preneurs for other young people to emulate.

There is a strong need to raise awareness about social networking sites among farmers. These are an important tool to enable them identify their niche areas and products for wider market and therefore economic returns. A digital profile of a local farmer, growing organic, farm fresh produce, eliminating the risk of middleman stands a larger chance of fetching economic remuneration than a local grocer if dealt in an organized manner.

Farmers need to identify their farms market and set their farm apart in terms of farm sanitation and idyllic appeal. They need more exposure visits to other aspiring agriprenuers in order to emulate their experience. These will subsequently broaden their vision and ultimately culminate into an experience that will enable them to develop their farm and enterprise in a commercially viable enterprise. A strong hand-holding from stakeholders like Krishi Vigyan Kendras, Department of Agriculture and other Non-Profit Organizations can build their capacities in these domains and enable progressive farmers to create farm logo, have a tag-line, launch a website, join Farmers Producer Organizations, attend farm related events and finally begin advertising their produce. A main benefit of social media in agricultural marketing is ability to gain wealth of knowledge and ideas, opportunity to establish key partnership, opportunity to reach wider consumers, experts in agricultural field.

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EFFECT OF THE REPEATED HERBICIDE RESIDUES IN RICE CULTIVATED FIELD AND THEIR RELATIONSHIP WITH MICROBIAL INOCULANTS ON THE GROWTH OF GREEN GRAM (*VIGNA RADIATA* (L.) CROPS

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Abstract:

Agriculture plays an important role in our economy. Active research is directed towards improving the agricultural productivity. As we entered into the new millennium, the world is seeking a greater demand of agricultural outputs. Herbicides have become an integral part of modern agriculture. Which was essential part for economically controlling of weeds in the rice – rice pulses system. The present study evaluates the beneficial effects of the formulations on the growth of Green gram (*Vigna radiata*). It was concluded that the herbicide residues soil in rice – rice pulses system does not affect the crop growth and their development. The microbial inocula such as *Rhizobium* sp and *Trichoderma viride* were also perform better as in normal soils. The observation was suggested that the application of commercial Pretilachlor and Oxadiargy rice herbicides at normal dose in the improvement of rice - rice pulses system. Modern agriculture is highly dependent on the use of herbicides to control weeds and plant pathogens, whereby continuous usage of herbicides highly affects the microbial antagonists. The *Rhizobium* sp and *Trichoderma viride* is the indigenous soil microflora to increase soil fertility, plant growth promoters and also acted as biocontrol agents of plant diseases.

Keywords: Green gram, Pretilachlor, Oxadiargy herbicide, *Rhizobium*, *Trichoderma viride*

Introduction:

Green gram, also known as mungbean (*Vigna radiata*), is the most widely produced pulse crop in India after rice. It can be grown during both rainy and summer seasons. Being a short duration crop, it fits well in traditional rice cropping systems and provides farmers with additional income. Being a leguminous crop, it can play a major role in nitrogen fixation from 20-80 kg/ ha (Hayat *et al.*, 2008), thus improving system sustainability. Green gram grains contain 22-28% protein, 60-65% carbohydrates, 1.0-1.5% fat, 3.5- 4.5% fibre and 4.5-5.5% ash (USDA 2019). It is also a rich source of aromatic amino acids, viz. leucine, isoleucine and tryptophan (Bhatty, 1982).

Green gram is not very competitive against weeds and productivity often suffers from weed competition, thus requiring herbicides to be used widely. The plants are threatened by the growth of weeds, therefore, weed control is essential to ensure proper crop growth, especially in early stages. The yield losses in green gram caused by weeds depend upon weed species, their densities and crop-weed competition period. (Pandey and Mishra 2003; Raman and Krishnamoorthy, 2005; Mirjha *et al.*, 2013). Herbicides have also been demonstrated for their negative effect on green gram – microbial interactions that either directly or indirectly on the growth of and grain yield of green gram (Anderson *et al.,* 2004; Ahemad and Khan 2011; Guriqbal singh *et al.,* 2015). In addition, microbial inoculants are applied to the seeds or soil to ensure effective growth, productivity of agricultural byproducts and subsequent nodulation and nitrogen fixation in green gram plants. Several studies have shown that some of these chemicals are incompatible with *Rhizobium* (Singh and Wright, 2002; Aamil *et al.,* 2004).

The legume–rhizobia symbiosis has a unique importance in agriculture. The symbiosis results in huge quantities of nitrogen fixation throughout the world and any adverse effect on rhizobia results in reduced rates of biological nitrogen fixation. Many factors influence the growth of nitrogen-fixing rhizobia. The effects of temperature, light, moisture, soil pH and nutrition on rhizobia are well documented (Dart, 1977; Gibson, 1977; Munns, 1977; Gibson and Jordan, 1983). In addition, herbicides may also influence the growth of rhizobia. Herbicides may have negative effects on the growth of rhizobia (Clark and Mahanty, 1991; Martensson, 1992), although other reports have shown no adverse effects (Martensson and Nilsson, 1989; Sprout *et al.,* 1992; Yueh and Hensley, 1993; Gonzalez *et al.,* 1996).

Rhizobium is a genus of Gram-negative soil bacteria that fix nitrogen. *Rhizobium* species form an endosymbiotic nitrogen-fixing association with roots of legumes and other flowering plants. Rhizobia bacteria play a significant role in provision of agricultural ecosystem services due to their ability to form symbiotic association with a wide range of leguminous plants that results in biological nitrogen fixation (Orrell and Bennett, 2013). Some of the rhizobia strains are reported to enhance the production of phytohormones, mineral uptake and reduce toxic effects of metals, thereby, indirectly promoting plant growth and development (Karthik, *et al.,* 2017) in polluted soils.

Trichoderma viride are microscopic soil borne filamentous fungi belonging to the division *Ascomycota*, widespread in the world and described for the first time in 1794. It can colonize aboveground and belowground plant organs, and are present between living cells. They are used as biopesticides because of their ability to destroy other fungi and certain nematodes, induce resistance to plant pathogens, impart abiotic stress tolerance, improve plant growth and vigor, solubilize plant nutrients, and bioremediate heavy metals and environmental pollutants. Nowadays, 60% of registered bio-fungicides are based on *Trichoderma viride.*

Trichoderma harizianum in diatomaceous earth with molasses for the control of *Sclerotium rolfisii* was the first successful attempts in biological control of plant diseases in 1975. *Trichoderma viridae* is effective against many diseases viz., damping off of vegetables, root rot of pulses, oil seeds and cotton. *Trichoderma* species are known to produce large quantities of fungistatic metabolites such as trichodermin, trichoviridin, dermin, and trichobruchin against soil borne plant pathogens. They do produce chitinase β-1,3, gluconase that acts on the cell walls of the pathogen and degrade the same.

Pretilachlor and oxadiargyl are the most commonly used pre-emergence herbicides in rice-growing regions of South India. Consumption of pretilachlor and oxadiargyl was 1530 kilo-liters and 31 tons respectively during 2018 (PMA, 2018). These pre-emergence herbicides are mixed with sand and normally applied as broadcast application at 3-5 days after transplanting

(DAT). Among the rice pesticides, pretilachlor is one of the most applied in the flooded rice fields to control weeds through inhibition of photosynthesis (Mitsou *et al.,* 2005).

Pretilachlor [2-chloro-2,6-diethyl-N-(2-propoxyethyl) acetanilide] is a chloroacetanilide herbicide which is widely used in transplanted and direct seeded rice (*Oryza sativa* L.) for the control of several grasses, broad-leaved weeds and sedges. Oxadiargyl (3-[2,4-dichloro-5-(2-propynyloxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2 (3H)- one), is an oxadiazolone class selective herbicide used in transplanted and direct seed rice for broad-spectrum control of weeds (Ramprakash and Madhavi, 2019).

Primary biochemical mechanism of action of chloroacetamide (pretilachlor) is linked to disruption in the formation of very long chain fatty acids located in plasma membranes of the plant cells. Loss of these very long chain fatty acids stops the biosynthesis and function of the plasma membrane, loss of cell integrity which leads to the death of the plant (Boger and Matthes, 2001). The herbicide activity of oxadiargyl lies in binding to the protoporphyrinogen oxidase IX as an inhibitor, preventing light-induced peroxidation and interrupting photosynthesis as a result. This herbicide has been mainly used in the prevention of certain perennial broadleaved and grass weeds during the pre-emergence of rice. Presence of herbicide residues in surface water, soil leads to potential risk for aquatic plants. Paddy herbicides are of high-risk concern for aquatic plants, because they easily flow out from paddy fields into rivers, with toxic effects (Nagai *et al.*, 2011). Residues of chloroacetanilide herbicides are extremely toxic to the aquatic organism caused the long-term adverse effects on the aquatic environment. Pretilachlor dissipated to below detectable limit at 10 DAA in flood water. The half-life of pretilachlor varied from 3.9-10.0, 3.4-8.5, 0.87-1.52 days for soil, rice plant and flood water, respectively (Dharumarajan *et al.,* 2011). Pretilachlor has higher adsorption on the sediment suggest that pretilachlor disappearance from the water was mainly the result of degradation during the period of 18 to 27 days after pesticide application under field conditions (Vidotto *et al.,* 2004). Pretilachlor is a relatively non-persistent herbicide with 50% degradation time values of 3.5 and 7 to 10 days in paddy water and sediment, respectively (Fajardo *et al.,* 2000).

The present study was conducted to determine the plant growth – promoting activities of *Rhizobium* sp. and *Trichiderma viride* grown in the presence and absence of the selected herbicides, Pretilachlor and Oxadiargyl. The herbicide tolerant *Rhizobium* sp. and *Trichiderma viride* were further tested for the plant growth promoting potential using greengram as a test crop, grown in soils treated with Pretilachlor and Oxadiargyl at both recommended and higher dose rates.

Materials and Methods:

Soil sampling and analysis

The soil sample from the field where herbicides (pretilachlor, oxadirgyl) were repeatedly applied for rice- pulse system of two year cycle was collected at 30 cm deep for about 50 bags and analyzed for initial status of pH, EC, available N, P, K standard analytical method adopted by soil testing laboratory, Government of Tamilnadu.

Inoculum preparation

Rhizobium culture was made into slurry using sugar solution (10%) and green gram seeds were mixed with the slurry and then air dried for 3 hours in shade and used for sowing. Similarly10g of seeds were inoculated with 290 CFU/g of *Trichoderma viride* culture.

The seeds inoculated with *Rhizobium* as stated above, once again treated with *Trichoderama viride* culture at 1g/10g seeds. This was used as dual culture.

Experimental design

Soil samples from the field, where herbicide (Pretilachlor and Oxadiargyl) were repeatedly applied for rice –pulse system of two year cycle, stored in polythene bags with pretilachor 50%, and oxadiargyl 80% .

Pot culture

The collected soil samples were used for potting and sown greengram seed (*Vigna radiata*) as for standard pot culture technique at nine seeds / pot. The relative humidity has maintained at 70%. The experiment was conducted with bacterial and fungal inoculants. The study was undertaken to evaluate the biological preparation system like *Rhizobium* on green gram crops. These seeds were obtained from Tamilnadu agricultural university, Madurai, Tamilnadu. Soil collected from rice fields was used to grow the seedlings. There were two experiments, one for each cultivar. Each experiment consists of their biological preparations (*Rhizobium*, *Trichoderma viride* and combination of both) and an untreated control. Each of these biological preparation was thoroughly mixed with field soil a depth of approximately lcm below the soil surface at a rate of 1:40 (v/v).The herbicides inoulated or uninoulated soil containing the biological preparation was placed into plastic pot (330g of soil/pot). Non – amended soil severed as untreated control. Nine seeds were sown into each bag. Each treatment and controls were replicated two times in the presence and absence of herbicides. Seedlings were watered regularly. The relative humidity was maintained at 70%.

Posts containing pertilachor as herbicides

Rhizohium and *Trichoderma viride* treated nine seeds and seeds treated with both *Trichoderma viride* and *Rhizobium* were selected and seeds that are not treated herbicide were seeded separately in each pot at equal distance.

Posts containing oxadiargyl as herbicide

Rhizohium and *Trichoderma viride* treated nine seeds, seeds treated with both *Trichoderma* and *Rhizohium*, seeds that are not treated with *Rhizobium* and *Trichoderma* were seeded separately in each pot at equal distance. Each pot with herbicides pertilachor treated soil contain the nine number of seeds treated with *Trichoderma viride* and *Rhizobium* individually and in a combined form were seeded separately. Similar experiment was followed in oxadiargyl herbicide treated soil. Another pot containing only *Rhizohium* and *Trichoderma viride* without herbicide treatment as microbial control and free soil as control without herbicide treatment and microbial inoculum were analysed.

Sampling and analysis

The growth of the seedlings was monitored at different day intervals for a period of 7 weeks. The bags were harvested and the following plant measurements were made: the plant shoot and root height, Root weight, length of each root, number of leaves, number of nodules and the nodules dry weight. Shoot length of the seedlings were recorded at the end of the second, fourth and fifth weeks. At the end of the second week, for seedlings were carefully pulled from each bag with adequate precautions to prevent any damage to the roots, and the roots lengths of the seedlings were also recorded. The same experiments were conducted at the end of fourth and sixth week. Remaining seedling was retained in each bag in order to record the short length at the end of the sixth week. Each experiment was conducted three times. The data were analysed separately for each experiment and subjected to analysis of variance.

Isolation and characterization of soil microbes

A 1g fresh root sample was taken from each replicated and macerated in 9ml of sterile distilled water using a mortar and pestle one gram of rhizosphere soil from each replicates were also suspended in 9ml of sterile distilled water. mple experiments was conducted at the end of fourth and sixth week. The fungal populations were quantified by plating a 10 fold dilution series of each root macerate or soil suspension onto SDA medium containing 100µg g-1 streptomycin. Plates were incubated at 20°C for 5 days. After incubation, the fungal growth was observed and enumerated. YEMA medium was used for the enumeration of root indigenous *Rhizobium.* Plates were incubated at 25°C and enumerated after 7days.

Statistical analysis

Data was analysed using SPSS for windows subsequently the differences between treated posts of herbicides and its effect were determined.

Results:

Seed germination rate

No significant differences in seed germination due to herbicidal residues containing soil and free soil sample with slight increased germination among microbial inoculated cases. Germination ranged between 92-96% (pretilachor) and 88-92% (oxadiargyl) and 96% (free soil).

Germination was observed at various concentrations of pretilacor and oxadiargyl have been noticed (Table I) and herbicide free soil sample were also have influenced very high; there is a increase of 96% germination in green gram. The germination has reduced about 82 – 96% in pretilachlor and 88-92% in oxadiargyl, these results clearly indicates that, when the seeds were treated with both the herbicides were inhibitory effect on germination. In the absence of microbial application, significantly decreased the efficiency of green gram seedling was compared with the control.

Plant height (cm) and number of leaves per plant

Increased plant height is shown in microbial application (*Rhizobium* sp. and *Trichoderma viride*) from 19.0 – 19.8 cm on 30 DAS, 23.0 – 23.5 cm on 45 DAS in pretilachlor residues containing soil. Dual application of *Rhizobium* and *Trichoderma viride* was found superior from 19.8 – 19.9 cm plant height on30 DAS than its individual application. The same trend was observed in soil containing oxadiargyl herbicide. The plant height was measured by 11.3 cm on 30 DAS and 23 cm on 45 DAS respectively.

Conversely, Herbicidal residues did not affect the leave production, where dual application of *Rhizobium* and *Trichoderma viride* had 4 leaves increased when compared to control. The leaves per plant ranged between 14.6 – 18.0 numbers on 45 DAS in pretilachlor containing soil. 14.0 – 16.0 leaves on 45 DAS in oxadiargyl containing soil against 14.6 leaves in herbicide free soils (Table – 2).

Root growth

Root growth was enhanced in microbial inoculated soil with both herbicides. The root length ranged between 12.0-13.0 cm in pretilachor residues soil against 12.4 cm in free soil on 45 DAS. The root weight ranged between 0.024-0.027 g/plant in pretilachlor residues soil against 0.021 g/plant in control soil in 45 DAS. While dual culture showed superiority (0.029g/plant) over (0.029g/plant) individual inoculation. The root length was measured between 12.5 – 12.6 cm in oxadiargyl residues soil against 12.6cm in tree soils in 45 days, while dual cultures were also showed by 12.5cm on 45DAS (Table – 3).

Dry matter production (DMP)(g/pl)

DMP of microbial cultures showed 0.024-0.051 g/pl in pretichlor containing soil and 0.031 g/pl in free soil on 45 DAS. Higher DMP was recorded in combined inoculation (0.051 g/pl) against 0.031 g/pl in free soils on 45 DAS when compared to control soil (0.042 g/pl). The same measurement was observed between 0.032-0.037 g/pl in oxadiargyl residues containing soil (Table – 4).

Number of branches per plant

No major difference among the treatment in this character. However in pretilachlor range was about 2.3-2.7 residues soil, 2.0-2.7 in oxadiagyrl residues soils against 2.7 numbers in residues of free soil (Table – 4).

Nodulation

Herbicides significantly reduced the nodules and inoculation with the microbial preparation significantly increased the number of modules / plant.

The combination of *Rhizobium* with *Trichoderma viride* was superior as it has 17.3 nodules, 14.7 with *Rhizobium,* 13 with *Trichoderma viride* individually. In control was recorded as 9.9 nodules per plant on 45 DAS in pretilachlor residues soil while free soil recorded 10.3 nodules per plant. Same observation was recorded in oxadiargyl residues containing soil. The combined microbial population was superior as it has 9 nodules/plant, 19 with *Rhizobium,* 18 with *Trichoderma viride* and 12 nodules / plant on 45 DAS in oxadiargyl containing soils.

Nodule dry weight ranged between 0.006 and 0.011g/pl in pretilachor residues soil and 0.006 and 0.012g/pl in oxadiargyl residues soil against 0.007 in free soil on 45 DAS (Table – 5).

Number of pods per plant

Ultimately no difference was found in number of pods per plant between herbicide residues containing soil and free soil. Microbial inoculum was recorded higher pods per plant. However combination of both microbes was superior as it has 7.7 pods/plant in pretilachor residue soil and 7.2 pods/plant in oxadiargyl soil when compared to individual inoculation (Table – 6).

Grain yield (g/pl)

Grain yield almost same among herbicide residues soils and free soil. Microbial application of the *Rhizobium* and *Trichoderma viride* was found superior than its individual inoculation (Table-6).

Soil nutrient status

Rhizobium inoculum had saved N by 98 kg per ha while in combination with *Trichoderma viride* by 99 N/ha. *Trichoderma viride* inoculum had saved about 4.8kg phosphorus and 35kg potassium / ha of soil 92 kg nitrogen,4.8 kg phorphous and 302kg of potassium/ha of pretilachlor residue soil. In oxadiargyl residue soil, *Rhizobium* had saved 100kg N/ha, while in combination with *Trichoderma viride* by 100 kg N/ha, 4.7 kg P/ha and 305kg of K/ha of soil. *Trichoderma* inoculum had saved about 98kg of N/ha, 4.6kg of P/ha and 305kg of K/ha of soil (Table – 7).

Table - 1: Seed germination study of Green gram on pretilachlor and oxadiargyl residues soil (%)

SI. No.	Treatments	Pretilachlor				Oxadiargyl			
		RI	RII	RIII	M	RI	RII	RIII	M
1.	*Rhizobium* treated	100	88	88	92	100	88	88	92
2.	*Trichoderma viride* treated	88	100	100	96	88	88	100	92
3.	*Rhizobium* & *Trichoderma viride* treated	100	100	88	96	88	100	88	92
4.	Microbial control	88	100	88	92	88	88	88	88
5.	Free soil (check)	88	100	100	96	-	-	-	-

R – Replication, M – Mean.

Table – 2: Effect of microbial inoculation on crop growth – plant height and number of leaves

SI. No.	Treatments	15 DAS								30 DAS								45 DAS							
		Plant height (cm)				No. of leaves/pl				Plant height (cm)				No. of leaves/pl.				Plant height (cm)				No. of leaves/pl			
		I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M
I	**Pretilachlor**																								
1	*Rhizobium*	12.5	12.7	13.0	12.7	4	4	4	4	19.2	19.7	19.8	19.6	10	12	10	10.6	23.2	22.8	24.4	23.5	16	16	18	16.6
2	*T.viride*	12.4	12.5	13.2	12.7	4	4	4	4	19.1	19.7	19.6	19.5	10	14	10	11.3	23.8	22.9	22.9	23.2	16	16	16	16.0
3	*Rhizobium + T. Viride*	12.5	12.7	13.2	12.8	4	4	4	4	19.9	19.8	19.9	19.9	12	12	14	12.6	24.2	24.0	23.8	24.0	18	18	18	18.0
4	Control	12.1	12.8	11.9	12.3	4	4	4	4	18.9	18.7	18.6	18.7	10	12	10	10.7	22.0	23.0	23.0	22.7	14	16	14	14.6
II	**Oxadiargyl**																								
1	*Rhizobium*	12.2	12.4	12.7	12.4	4	4	4	4	19.2	19.4	19.1	19.2	12	10	12	11.3	23.2	23.0	23.2	23.1	16	14	18	16.0
2	*T. viride*	12.1	12.5	12.9	12.4	4	4	4	4	19.2	19.4	19.4	19.3	12	10	12	11.3	23.8	22.7	23.0	23.0	16	14	16	15.3
3	*Rhizobium + T.viride*	12.2	12.3	12.5	12.3	4	4	4	4	19.2	19.8	19.4	19.5	12	12	10	11.3	23.2	23.2	22.8	23.0	16	14	18	16.0
4	Control	12.2	12.8	12.3	12.2	4	4	4	4	19.0	18.4	18.9	18.8	10	12	10	10.7	22.1	22.8	22.4	22.4	14	16	12	14.0
III	Free soil sample	12.1	12.8	12.3	12.4	4	4	4	4	18.7	18.6	18.9	18.7	12	11	9	10.7	22.7	22.1	22.0	22.3	15	14	15	14.6

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Table – 3: Effect of microbial inoculation on crop growth parameters – root growth

SI. No.	Treatments	15 DAS								30 DAS								45 DAS							
		Root length(cm)				Root weight(g/pl)				Root length(cm)				Root weight (g/pl)				Root lenth (cm)				Root weight (g/pl)			
		I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M
I	**Pretilachlor**																								
1	*Rhizobium*	4.7	4.4	4.8	4.6	.003	.003	.002	.003	7.5	2.6	7.2	7.4	.009	.009	.010	.009	11.2	12.2	12.5	12.0	.023	.022	.027	.024
2	*T. viride*	4.2	4.7	4.5	4.6	.002	.002	.002	.002	7.2	7.6	7.2	7.3	.009	.009	.011	.010	12.2	12.7	12.8	12.6	.027	.026	.028	.027
3	*Rhizobium +T.viride*	4.6	4.7	4.5	4.6	.002	.002	.002	.002	7.4	7.7	7.4	7.5	.010	.011	.011	.011	13.0	12.8	13.2	13.0	.029	.029	.028	.029
4	Control	4.5	4.4	4.2	4.4	.002	.002	.002	.002	7.0	7.3	7.0	7.1	.008	.008	.008	.008	12.7	12.2	12.4	12.4	.020	.022	.022	.021
II	**Oxadiargyl**																								
1	*Rhizobium*	4.4	4.3	4.2	4.3	.002	.002	.002	.003	6.8	6.2	6.7	6.6	.008	.009	.02	.009	12.7	12.3	12.8	12.6	.020	.021	.027	.023
2	*T. viride*	4.2	4.7	4.5	4.6	.002	.002	.002	.003	6.7	6.9	6.2	6.6	.008	.008	.007	.008	12.4	12.4	12.6	12.5	.027	.026	.028	.027
3	*Rhizobium+ T.viride*	4.4	4.6	4.7	4.6	.002	.002	.002	.002	7.0	7.1	0.9	7.0	.009	.008	.008	.009	12.2	12.8	12.4	12.5	.028	.028	.028	.028
4	Control	4.3	4.5	4.4	4.4	.002	.002	.002	.002	6.7	6.2	6.4	6.4	.007	.006	.007	.007	12.6	12.7	12.4	12.6	.024	.025	.027	.025
III	Free soil sample	4.3	4.5	4.4	4.4	.002	.002	.002	.002	6.7	6.2	6.4	6.4	.007	.006	.007	.007	12.6	12.7	12.4	12.6	.024	.025	.027	.025

Table – 4: Effect of microbial inoculation on crop growth – Dry matter production and Number of branches.

SI. No.	Treatments	15 DAS								30 DAS								45 DAS							
		DMP (g/pl)				No. of branches/pl				DMP (g/pl)				No. of branches/pl				DMP (g/pl)				No. of branches/pl			
		I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M
I	**Pretilachlor**																								
1	*Rhizobium*	.010	.012	.012	.011	-	-	-	-	.023	.027	.026	.025	1	1	2	1.3	.048	.047	.049	.046	3	2	3	2.7
2	*T. viride*	.012	.010	.012	.011	-	-	-	-	.027	.024	.023	.025	1	2	1	1.3	.051	.052	.049	.050	3	2	3	2.7
3	*Rhizobium +T.viride*	.010	.011	.013	.012	-	-	-	-	.028	.029	.027	.028	1	1	2	1.3	.049	.052	.053	.051	3	3	2	2.7
4	Control	.009	.008	.009	.009	-	-	-	-	.021	.022	.024	.023	1	1	2	1.3	.041	.042	.043	.042	2	3	2	2.3
II	**Oxadiargyl**																								
1	*Rhizobium*	.011	.011	.012	.012	-	-	-	-	.023	.022	.027	.024	1	1	1	1.0	.038	.036	.037	.037	3	2	3	2.7
2	*T. viride*	.010	.012	.011	.011	-	-	-	-	.026	.024	.025	.025	1	2	1	1.3	.033	.034	.030	.032	2	2	2	2.0
3	*Rhizobium +T.viride*	.012	.010	.012	.012	-	-	-	-	.024	.028	.027	.026	1	1	1	1.3	.037	.036	.038	.037	3	2	3	2.7
4	Control	.008	.007	.006	.007	-	-	-	-	.023	.022	.023	.023	1	1	1	1.3	.031	.034	.031	.032	2	3	3	2.7
III	Free soil sample	.008	.006	.007	.007	-	-	-	-	.024	.023	.026	.024	1	1	1	1.0	.033	.030	.030	.031	3	3	2	2.7

Table – 5: Effect of microbial inoculation on crop growth – Root nodulation

SI.No.	Treatments	15 DAS								30 DAS								45 DAS							
		No. of nodules/pl				Nodules dry weight (g/pl)				No.of nodules/pl				Nodules dry weight (g/pl)				No. of nodules/pl				Nodules dry weight (g/pl)			
		I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M	I	II	III	M
I	**Pretilachlor**																								
1	*Rhizobium*	1	2	1	1.3	Tr	Tr	Tr	Tr	8	7	9	8.30	.003	.002	.002	.002	17	12	15	14.7	.009	.008	.009	.009
2	*T. viride*	1	1	1	1.0	Tr	Tr	Tr	Tr	9	8	7	8.0	.002	.002	.001	.002	15	12	12	13.0	.008	.007	.009	.008
3	*Rhizobium* +*T.viride*	2	1	2	1.6	Tr	Tr	Tr	Tr	10	11	12	11.0	.002	.002	.003	.002	19	14	19	17.3	.010	.011	.012	.011
4	Control	1	2	1	1.3	Tr	Tr	Tr	Tr	5	6	6	6.0	.001	.002	.001	.001	9	9	11	9.9	.007	.006	.006	.006
II	**Oxadiargyl**																								
1	*Rhizobium*	1	3	2	2.0	Tr	Tr	Tr	Tr	9	8	9	8.7	.002	.002	.002	.002	17	12	19	16.0	.009	.010	.011	.010
2	*T. viride*	1	2	1	1.3	Tr	Tr	Tr	Tr	10	11	11	10.7	.002	.002	.001	.002	19	17	18	18.0	.012	.011	.010	.011
3	*Rhizobium* +*T.viride*	3	2	2	2.3	Tr	Tr	Tr	Tr	12	11	12	11.7	.002	.002	.002	.002	14	19	19	19.0	.011	.013	.012	.012
4	Control	1	2	2	1.7	Tr	Tr	Tr	Tr	7	6	7	6.7	.002	.002	.001	.002	9	11	12	10.6	.006	.007	.006	.006
III	Free soil sample	2	1	1	1.3	Tr	Tr	Tr	Tr	6	7	6	6.3	.002	.002	.001	.002	9	12	10	10.3	.006	.007	.007	.007

Tr - trace

Table – 6: Effect of microbial inoculation on crop yield parameters – number of pods and grain yield

SI. No.	Treatments	45 DAS							
		No. of pods/pl				Grain yield (g/pl)			
		I	II	III	M	I	II	III	M
I	**Pretilachlor**								
1	*Rhizobium*	6	7	9	7.3	21	18	19	19.3
2	*T. viride*	7	7	6	6.7	19	19	17	18.3
3	*Rhizobium +T.viride*	9	7	7	7.7	20	21	20	20.3
4	Control	5	5	6	5.3	19	16	18	17.7
II	**Oxadiargyl**								
1	*Rhizobium*	7	6	6	6.3	24	23	19	22.0
2	*T. viride*	6	6	6	6.0	18	20	19	19.0
3	*Rhizobium + T.viride*	7	7	8	7.2	24	22	24	23.3
4	Control	4	4	5	5.0	19	18	18	18.3
III	Free soil sample	4	6	5	5.0	20	19	19	19.3

Table – 7: Available nutrients status of soil (Kgs/ha)

S.No	Treatments	Initial nutrient status of soil					Post – soil nutrient status				
		Ec	**pH**	**N**	**P**	**K**	**Ec**	**pH**	**N**	**P**	**K**
I	**Pretilachlor**										
1	*Rhizobium*	0.3	8.2	11.2	4.9	320	0.3	8.2	98	4.2	300
2	*T.viride*						0.3	8.2	92	4.8	302
3	*Rhizobium +T.viride*						0.3	8.2	99	4.8	305
4	Control						0.3	8.2	90	4.0	295
II	**Oxadiargyl**										
1	*Rhizobium*	0.3	8.2	110	4.7	310	0.3	8.2	100	4.4	305
2	*T.viride*						0.3	8.2	98	4.6	305
3	*Rhizobium + T.viride*						0.3	8.2	100	4.7	305
4	Control						0.3	8.2	91	4.7	297
III	Free soil sample						0.3	8.2	91	4.1	297

Ec and pH : 2 : 1 ratio of water and soil mix.

Ec : $ds^{-1}m$

N,P,K : Kgs/ha. as available N,P and potassium.

Discussion:

Green gram may provide the dual benefit of pulse grain and can be used as green manure. Agronomists desire to maximize the green gram production without compromising the use of herbicides. Although reports have suggested a negative impact of herbicides on field-grown legumes, these chemicals are still widely used during greengram cultivation to prevent losses due to broad and narrow leaf weeds. However, there is relatively little information available on the herbicidal impact on greengram productivity. The present study, assess the effects of soil applications of two herbicides, Pretilachlor and Oxadiargyl along with microbial inoculants such as *Rhizobium* sp. and *Trichoderma viride* on plant growth, nodulation, N content, grain protein and yield of green gram, grown under controlled conditions in clay pots.

Efficacies of *Trichoderma viride, Rhizobium* sp individually and/or their mixtures were tested in herbicide residues soil. The ability of tested *Rhizobium* sp and *Trichodermia viride* to exhibit plant growth promoting rhizobacteria (PGPR)-properties including ability to solubilize-P and production of IAA, as well as production of siderophores, hydrocyanic acid (HCN) and secretion of cell-wall degrading enzymes (chitinase and protease). study the singly effect of seed soaking in *T. viride*, *Rhizobium* sp or their mixtures with the herbicide residues soil in pots after sowing of green gram seeds. Significant increase of seed germinations, plant height, number of leaves, root growth, number of branches and nodulation of green gram plants were recorded.

The toxicity of various herbicides to nodule bacteria in vitro or legume plants varies widely, and often compounds with the greatest herbicidal activity are the most damaging to both *Rhizobium – Trichoderma viride* and legume plants. The present study, Herbicides did not affect the viability of biofertilizers and the mechanism involved in greengram – microbial symbiosis. Herbicide is, however, applied to reduce the competition from weeds and consequently to augment the yield of agronomic crops: but their use may be incongruous regarding the establishment of an effective symbiotic relationship between nodule bacteria and legume host plant. In the study, the trend observed suggests that the lower dose rates of herbicides in general did not affect the growth and dry matter production negatively, but rather stimulated the growth parameters in greengram. These studies, therefore, suggest that the lower rates might have persisted in the soil for only a short time period, after which the viable cells of *Rhizobium* and *Trichoderma viride* were recovered and multiplied rapidly. This is possible because the soil environment can act as a buffer, reducing the potentially toxic effect by dilution of these chemicals (Castro *et al.,* 1997). The higher concentrations of the tested herbicides, on the other hand, reduced the total dry matter production in greengram crops, possibly due to inhibition of aromatic amino acid biosynthesis (glyphosate), photosynthesis, the microtubule morphogenetic process and the premature senescence of the plants (2,4-D) (Almas *et al*., 2005).

Herbicides may influence nodulation and biological nitrogen fixation in legumes either by affecting rhizobia, the plant or both. There is a need to study and thus separate the possibility of the direct effects of herbicides on rhizobia. The effects of herbicides on nodulation and nitrogen fixation by examination of the effects of these chemicals on plant growth have been reported previously (Singh and Wright, 1999), showing that herbicides adversely affected nodulation, nitrogenase activity and plant growth.

The toxicological effects of various herbicides on legumes have been reported (Khan *et al*., 2004). The toxic effects of herbicides are always depends primarily on the type and dose of compounds, duration of exposure, species and age of plants, and other environmental factors. Thus herbicides, when applied under field conditions, can affect both the Rhizobia and their symbiosis with legume crops, e.g., metribuzin affects the *Rhizobium* sp. (Heinonen-Tanski *et al*., 1982), the plant (Rennie and Dubetz, 1984) and the legume – *Rhizobium* symbiosis (Malik and Tesfai, 1985).

Preemergence application of pendimethalin at 0.9 kg ha^{-1} + post-emergence application of oxadiagryl at 90 g ha^{-1} 60 DAT and weed free treatment remain at par and recorded significantly higher plant height, leaf area index, bulb diameter, fresh and dry bulb weight and bulb yield during individual years and in pooled results over unweeded check. Weed free treatment produced 87.2, 60.6 and 73.0%higher bulb yield and pre-emergence application of pendimethalin @ 0.9 kg ha^{-1} + post emergence application of oxadiargyl at 90 g ha^{-1} produced 85.6, 58.7 and 71.4% higher bulb yields over unweeded control during 2007-08, 2008-09 and on pooled basis, respectively (Rathod *et al*., 2014).

Both pretilachlor (1μg kg $^{-1}$ soil (recommended dose) and Oxadiargyl (0.5μg kg $^{-1}$ soil (recommended dose)) increased the growth of *Rhizobium* sp. and *Trichoderma viride* inoculated and uninoculated plants. Both herbicides at high concentrations showed more phytotoxicity and affected the growth in terms of nodulation, total dry biomass, nutrients (nitrogen and phosphorus) uptake and seed yield compared to uninoculated control. When the inoculants strain was used with any concentration of the two herbicides, the growth and nodulation parameters of the plants were relatively better compared to the plants grown in soils treated solely (without inoculants) with the recommended concentration of each herbicide after 15, 30 and 45 DAS from sowing.

The present findings suggest that the *Rhizobium* sp. and *Trichoderma viride* were showed with multiple properties could be used to facilitate the productivity of green gram under herbicide stressed soils.

Conclusion:

Herbicide has become essential part for crop protection. The increasing world population will require increased crop production and this will require the use of new environmentally safe, effective agro-chemicals. Thus, we must step up forward into the new millennium with the site-specific agricultural management for sustainability of green gram production system in South India keeping in view of our eco-system.

Our study was concluded that the herbicide residues due to application of herbicides in rice – pulses system do not affect the crop growth and development. Microbial inoculation such as *Rhizobium* and *Trichoderma viride* was perform better as in normal soils. Hence, we can use pretiachor and oxydiargyl rice herbicides at normal doses in rice- pulses system.

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CHALKING NEW PATHWAYS IN AGRICULTURE - RENDERING FARMERS SUPPORT THROUGH FARMERS PRODUCER'S ORGANIZATIONS, SOIL TESTING AND SKILL DEVELOPMENT TRAININGS AT KRISHI VIGYAN KENDRA - BUDGAM

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Indian economy is predominantly agrarian in nature with nearly 70% dependant on it for their livelihood. A significant contributor to GDP, it is currently pegged at 7.0% (FICCI, Economic Outlook Survey 2022-2023). Agriculture and allied sector presents a broad spectrum of activities ranging from crop production of cereals, fruits and vegetables mainly coupled with livestock rearing and utilization of by-products there of. Rightly, called the backbone of Indian Economy, agriculture today is facing newer challenges than ever before. With a regional urban-rural divide, and bulk of agricultural activities being undertaken in rural and peri-urban areas, stakeholders like NGOs, Department of Agriculture, Corporates under Corporate Social Responsibility (CSR initiative) and Krishi Vigyan Kendras are making emergent strides for farmer welfare.

Krishi Vigyan Kendras or Farm Science Centres

The Krishi Vigyan Kendras or Farm Science Centres District Level support centres for farmers that operate under State Agricultural Universities. This team is led by the Senior Scientist and Head (Programme Co-ordinator) under whom six Subject Matter Specialists, from different agriculture and allied sciences disciplines operate along with other supporting staff. Here, the support offered to farmers are of different dimensions, ranging from basic to complex. Awareness Programmes on improved scientific techniques for practices on cultivation to harvest of fruits, vegetables, cereals and pulses are carried out for farmers, farm women and rural youth. Similar programmes are rendered for nutrition management of livestock.

Taking stock of disease outbreaks in crop or livestock in the District, the Subject Matter Specialists team undertake Disease Diagnostic Visits to identify the same and and subsequently suggest remedial measures. The scientists also execute Front-line Demonstrations (FLDs) that are massive, large scale cultivation of improved varieties of seed/crop among farmers to demonstrate exemplary yield in order to be emulated by other farmers in the District. Another endeavor of KVK is On Farm Trials (OFTs) that are essentially refinement of a Farmers Agricultural practice through Scientific interventions in order to bring about effective results. Similarly, Kissan melas and Fairs are also held in order to showcase technologies of the Kendra, sell improved seed and planting material and facilitate a Farmer-Scientists interface from time to time.

New Strides in Farmers Welfare

Apart from already discussed mandated activities of KVKs, the KVK Budgam has made remarkable strides in the field of farmers support/welfare. What follows is a brief account of endeavors undertaken by them more recently for farmers of the district.

Farmers Producers Organisation (FPO)

In India, the total horticulture production in 2021-22 is estimated to be 341.63 million tonnes (MT), an increase of about 7.03 MT over 2020-21. This is an increase of 2.10%, according to the second advanced estimates of area and production of various horticultural crops. Last year, the total horticulture cultivation was in 27.48 million hectares and according to the second advanced estimates, in 2021-22, it could be 27.74 million hectares. (The Hindu, 14th July, 2022). More than 6,400 hectares of land is under vegetable cultivation in Budgam and last year 20,952 metric tonnes of vegetables were cultivated in the district fetching more than 52 crores as revenue (Hindustan Times, 19th June, 2022). Despite huge production, there are problems faced by Vegetable Growers of District Budgam names Lack Lack of training of scientific vegetable production technology, unavailability of quality seed, fertilisers, Farm Yard Manure, Tedious process of obtaining finance for investment in farm enterprise, high rates of interests on loans, nonavailability of Transport facility, Non-availability of labour at the time of harvesting, Non-availability of skilled labour, cold storage facility, lack of information about Package of Practices, menace of the middle-men in mandis that lead to non-remunerative prices. A systemmatic solution to all of these problems that can facilitate aggregation of resources of small and marginal farmers with better scale of operation and operational efficiency are Farmers Producers Organisation (FPOs).

This Kendra is the first among the KVKs of the Kashmir region that was empanelled with the responsibility of establishing two Farmers Producers Organization in the domain of vegetable production in February 2021 by Indian Council of Agricultural Research (ICAR) with the National Co-operative Development Corporation (NCDC) as the Implementing Agency. The KVK-Budgam, acts as the Cluster Based Business Organization (CBBOs) that shall offer continued support in inception of FPOs, capacity building of the members, identifying market led linkages in order to ensure minimal loss and maximum wage for produce for a period of two years/18 months.

Two FPOs have been established namely Umeed ki Kiran FPO Co-operative Ltd. and Sheikh-Ul-Alam FPO Co-operative Ltd. are primarily run by a Board of five members. They are, both, primarily vegetable based FPOs comprising of small and marginal farmers. The idea of assimilating farmers into these common interest groups is to negotiate maximum price for their produce and ensure optimum returns. Similarly, in event of glut, the excess may be processed by scientific techniques of value-addition (purees, pickles, dehydrated vegetables, dried herbs etc) by scientific technologies endorsed by SKUAST-K.

Details of FPOs with KVK Budgam as CBBO

Name of the FPO	Umeed Ki Kiran
Location	Block B.K.Pora, Budgam
USP	Vegetables
Registration	Reg. No: RCS/J&K/2302-FPO;
Date of Incorporation	Dated: 04^{th} Feb. 2022
Registered Under Act	Co-operative Act 1999.
Composition of Board	Nominated Board of Directors (05)
Value of each Share	Rs.2000/-

Name of the FPO	**Sheikh Ul Alam FPO Co-operative Ltd.**
Location	Block Budgam
USP	Vegetables
Registration	Reg. No: RCS/J&K/2303-FPO;
Date of Incorporation	Dated: 04^{th} Feb. 2022
Registered Under Act	Co-operative Act 1999.
Composition of Board	Nominated Board of Directors (05)
Value of each Share	Rs.2000/-

The KVK intends to form FPOs that emerge as successful model of a market driven Co-operatives that are purely run by the farmers who are primary producers and therefore must have the final say in the price of their produce. The idea is to eliminate the cost expansion at various stages of the selling chain and establishing a direct linkage between the producer and the consumer. The aim is to build on the FPO strength by mobilizing more and more farmers gradually with an equity share of Rupees 2000/- each. Subsequently, the implementing agency (NCDC) will release additional grant (amount equal to equity generated by member farmers) which shall roll out as

While the fundamental focus in is to vest negotiating power of produce with the producers – all this is intended to be achieved through adopting scientific methods of vegetable production to ensure healthy farmers field in terms of soil fertility, pest free robust produce while also keeping in view environmental sanitation. The FPOs under the tutelage of KVK shall also be apprised about Seed production, utilization of waste land for cultivation of aromatic and medicinal plants and Value addition of fruits and vegetables in order to ensure minimum wastage.

Soil Sampling and Soil Testing through Rapid Soil Testing Device - Bhu-Parishak

Soil is the basic natural resource on which Agri-Horti production is dependent. Since the development of agriculture, the most important concept of soil has been as natural medium for plant growth. Soil testing is widely used practice for soil fertility evaluation and fertilizer recommendations. It is equally helpful in understanding its potential and limitations. Diagnosis of soil-related problems involving poor tree performance and other related physio-chemical characteristics, i.e. acidity, salinity, alkalinity, water retention etc. which influence plant growth and adaptability. Diagnosis of soil-related problems involving poor tree performance and other related physico-chemical characteristics, i.e. acidity, salinity, alkalinity, water retention etc. are critical for plant growth and adaptability.

Soils of Budgam are Deep, imperfectly drained, calcareous, fine-silty soils on nearly level slopes withy loamy-surface and slight flooding and comes under order Inceptisols. In order to identify soil deficiency across the district, KVK Budgam renders service for soil sampling and testing in the first of its kind through rapid soil testing device - Bhu Parikshak. The AgroNext Services Pvt. Ltd and SKUAST-K have signed an MoU regarding the use of device for soil testing in the District. The USP of the device is its cost effectiveness and rapid nature. Bhu Parikshak is able to detect soil status in less than 90 seconds. The device is compact and portable that requires 5 gms sample with less than 5% moisture to go in for soil testing.

Skill Training for Youth

Skill training for youth is the new buzz in development sector across all domains. More so for youth in rural areas where most are primarily associated with agriculture and often have no access to both information and education. There is thus a need to for knowledge of agricultural production and processing techniques and the relative know-how among them coupled with information on availing finance, land and market.

There are great opportunities in education, training in agriculture inputs, farming processes and technology, agriculture output processing and other agriculture allied sectors like dairy development, poultry, horticulture, sericulture etc. The KVK Budgam has from time to time organised these trainings jointly with Directorate of Extension, to aid Skill Building in Rural Youth. Since 2019, the Kendra has organised 16 trainings and trained about 448 rural youth. These trainings provide experiential learning for rural youth in agriculture and allies sciences that sensitizes, trains and equips rural youth with generic skills for Entrepreneurship Development in Agriculture and allied sectors. This has high potential of generating employment, removing income disparity, balanced regional development, protection and promotion of creative heritage.

Sharing Experiences – Grass root Heroes
Mushroom production

Name: Santnam Singh Bali

R/O: Ompora, Budgam

Qualification: Post-Graduate

Contact No: 9419237829

Role of KVK Budgam	Resources
• The KVK Budgam build his capacity to undertake this task through training and awareness programmes. • The grower was provided all types of technical guidance regarding the cultivation of White Button Mushroom. • Follow up visits were made to the trainees mushroom unit.	•Started with 350 polythene bags and produced 650 kg mushroom within 2 months and earned Rs.1,17000/- (@ Rs. 180/kg weighing). •Total expenditure was Rs. 50,000 thereby resulting in a saving of Rs67,000 in two months.

Satnam Singh quit his job at at MNC outside valley to pursue his desire of farming. The visuals are at his low-cost venture at the time of establishment

Fish farming (Trout)

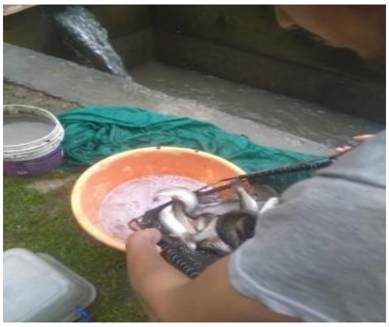
Name: Bilal Ah. Parray

R/O: Bon-Zanigam, Beerwah

Qualification: 10 + 2

Contact No: 6006381913

Role of KVK Budgam	Resources
• With technical assistance by KVK Budgam farmer started with 2500 fingerlings of Rainbow Trout and got an annual yield of 4 qtls during the first year. • Production of the farm has increased considerably and the current production stands at 50 qtls per year and sells his produce in the local market, sends to the hotels of the valley.	•During the current year, he has generated a revenue of Rs. 25 lakh with cost of production Rs. 7 lakh per year. •His net profit for the year is Rs. 18 lakh.



Integrated Farming System

Name: Bilal Ah. Parray

R/O: Bon-Zanigam, Beerwah

Qualification: 10 + 2

Contact No: 6006381913

Role of KVK Budgam	Resources
• The grower has 50 kanals of land with vegetables, paddy and orchard as major enterprise. • With the technical guidance of KVK Budgam he was able to develop an Integrated Farming System which also housed dairy farming, fish farming, poultry and vermincompost unit.	•At his 20 kanal land, the farmer undertakes cultivation of hybrids as well as high yielding varieties of all the major vegetable crops. Similarly, he has a planned orchard on 20 kanals of land and paddy in 10 kanals. •A revenue of Rs. 20 lakhs per annuum through sale of vegetables and 12 lakhs from orchard. •Paddy and forage grasses produced are sown for sustenance of family and livestock owned by him. •His sheer hard-work led to his nomination for award of appreciation during *Kissan Samman Diwas* organised by Directorate of Extension ,SKUAST-K Shalimar.

Nursery raising

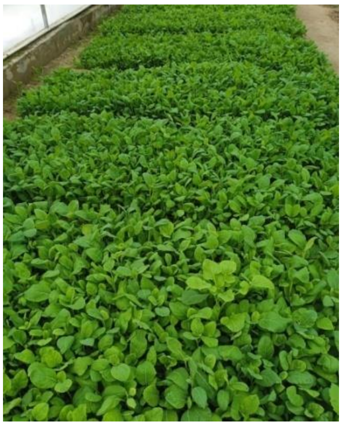
Name: Aijaz ahmad Wani

R/O: Galwanpora budgam

Qualification: Graduate

Contact No: 9797859672

Role of KVK Budgam	Resources
• Received Skill training programmes at KVK regarding Vermicomposting, Mushroom production etc.	•Established Venture Gulshan Nursery. •Started production of seedling of vegetables like tomato, cabbage, cauliflower, broccoli, lettuce, capsicum. •Started Flower nursery raising also •Has an enterprise worth Rs 2 lakh in a span of 1 year.


Integrated farming system

Name: Mushtaq ahmad

R/O: Aripanthan Beerwah

Qualification: Graduate

Contact No: 9906101030

Role of KVK Budgam	Resources
• Farmer received Skill training on Scientific Production of different crops at KVK. • The farmer was allotted vermicompost unit after receiving week long training on vermicompost production	•The Farmer has been able to integrate his farm resources into an efficient Integrated Farming System utilizing his poultry birds, seeds of high yielding quality field crops, viz paddy and maize • Currently he undertakes vegetable production on 5 kanals of land that fetches him a net return of 1.6 lakhs annually.

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About Editors

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