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Preface

We would like to present, with great pleasure, the inaugural volume-10, Issue-10, October 2024, of a scholarly journal, *International Journal of Environmental & Agriculture Research*. This journal is part of the AD Publications series *in the field of Environmental & Agriculture Research Development*, and is devoted to the gamut of Environmental & Agriculture issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Environmental & Agriculture as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Environmental & Agriculture community, addressing researchers and practitioners in below areas.

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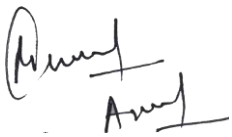
Agriculture, Biological engineering, including genetic engineering, microbiology, Environmental impacts of agriculture, forestry, Food science, Husbandry, Irrigation and water management, Land use, Waste management and all fields related to Agriculture.

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with *IJOEAR*. We are certain that this issue will be followed by many others, reporting new developments in the Environment and Agriculture Research Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOEAR* readers and will stimulate further research into the vibrant area of Environmental & Agriculture Research.



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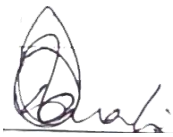

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Screening of Rice Genotypes for Bacterial Blight of Rice under Artificial Inoculation in South Gujarat Conditions

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Abstract— *The study was conducted at the Navsari Agricultural University's main rice research center in Gujarat, India, during the kharif season (July–November 2023) to assess the resistance of rice genotypes to bacterial blight using an artificial inoculation method. Thirty rice genotypes were evaluated along with two known susceptible varieties viz., GR-11 and TN-1, using the clip inoculation technique under field conditions. Among them, four genotypes viz., NVSR-996, NVSR-1065, NVSR-1127 and ISM showed moderate resistance. Fifteen genotypes viz., NVSR-936, NVSR-938, NVSR-941, NVSR-950, NVSR-951, NVSR-942, NVSR-1002, NVSR-1003, NVSR-1005, NVSR-1048, NVSR-1111, NVSR-983, NVSR-1130, NVSR-1064, and GNR-3 were found moderately susceptible. Eleven genotypes viz., NVSR-939, NVSR-952, NVSR-997, NVSR-956, NVSR-1001, NVSR-1007, NVSR-1031, NVSR-1033, NVSR-1128, NVSR-964, and NVSR-1052 were found to be susceptible. Whereas, the susceptible checks GR-11 and TN-1 were found highly susceptible against bacterial blight of rice. Among the screened genotypes, NVSR-939 exhibited the highest disease intensity (48.60%) followed by NVSR-1128 (48.57%) and NVSR-952 (46.20%). In contrast, ISM had the lowest disease intensity (7.28%) followed by NVSR-1065 (8.20%) and NVSR-996 (8.60%), respectively. The international susceptible check TN-1 showed a disease intensity of 76.00 per cent and the local check GR-11 showed 68.57 per cent, both indicating high susceptibility to bacterial blight of rice.*

Keywords— Screening, Clip inoculation, Bacterial blight, Disease intensity.

I. INTRODUCTION

Rice (*Oryza sativa* L) is considered as queen of the cereal crops because of its importance as staple food of about half of the world's population (Qudsia *et al.*, 2017). India has the world's largest area and is the second highest producer of rice. Rice is considered one of the most strategic commodities for the world; not only linked with global food security but also closely connected with economic growth, employment, social stability and regional peace (Yadev and Kumar, 2018). The production of rice worldwide in 2023-2024 was about 518.14 million metric tons which increases by 0.87 per cent, whereas the production in India during 2023-2024 was about 134 million metric ton changes by seven per cent as compared to production in previous five years. With a production of 118.87 million tonnes and a productivity of 2722 kg per hectares, rice is grown on an area of 43.66 million hectares in India (Anonymous, 2021). As opposed to Gujarat, where rice is grown on 0.90 million hectares, producing 2.14 million tonnes and yielding 2365 kg per hectare (Anonymous, 2022). In terms of its nutritional content, over two billion people in Asia alone derive 80 per cent of their energy needs from rice, which contains 80 per cent carbohydrates, 7–8 per cent protein, 3 per cent fat, and 3 per cent fibre (Chaudhary *et al.*, 2018). In tropical and subtropical rural and urban settings, rice accounts for between four per cent and 70 per cent of caloric intake (Hossain and Fischer, 1995). A report suggests that the history of domestication and cultivation of rice in China as old as 7700 years (Zong *et al.*, 2007). The bacterial leaf blight disease of rice caused by *Xanthomonas oryzae* pv. oryzae and causes a huge loss in terms of quantity and quality of rice. In world, due to this disease yield loss was estimated approx 50 per cent (Shekhar *et al*., 2020) and in India 81.3 per cent (Prasad *et al.*, 2018; Swati *et al.*, 2015). Bacterial leaf blight early symptoms appear on the leaf blades at tillering stage, starting from lower plant parts and then reaching to above ones (Goto, 1992, Cha, 1982). In most damaging cases, yellow to white stripes are seen just inside the margins of the leaf blades, turning yellow and at the end results in mortality of leaf tissues (Ou,

1985). At the seedling stage, the "Kresek" phase is the most damaging phase of bacterial blight (Chahal, 2005). Rice farmers worldwide experience significant yield losses due to bacterial blight. This disease, which is prevalent in the southern region of Gujarat, appears annually, causing substantial damage to rice crops.

II. MATERIALS AND METHOD

The screening trial was conducted from July to November 2023 at the Main Rice Research Centre, NAU, Navsari, Gujarat, India. The bacterial blight of rice (*Xoo*) is a highly disastrous disease that severely impacts rice yield, grain quality, and causes substantial economic losses. Each growing season, the pathogen affects millions of hectares of rice, particularly in certain environments. Therefore, identifying and using high-yielding, resistant, or tolerant rice genotypes is considered the most effective, environment friendly and economically viable method for managing this disease. This investigation aimed to identify sources of resistance to bacterial blight under artificial conditions.

Two rows of 2.1-meter length for each cultivar were taken and international susceptible check TN-1 and state susceptible check GR-11 were planted after 10th test entry. The artificial inoculation of bacterial leaf blight pathogen was done by standard clip inoculation technique after 30 days of transplanting by cutting the tip of leaves with the help of scissors. The diseased leaf area was observed and the percentage of infection was calculated and recorded from each tested entry or genotype. Twenty hills from each genotype were randomly selected and considered for the severity of disease on standing plants. The labeled plants were observed for disease rating by using 0-9 scale as per the Standard Evaluation System (SES) of Rice (IRRI, 2013).

TABLE 1
DISEASE RATING SCALE FOR BACTERIAL BLIGHT (IRRI, 2013)

Scale	Disease Reaction	Description
1	Resistant	1- 5 % leaf lesion area
3	Moderately Resistant	6-12 % leaf lesion area
5	Moderately susceptible	13- 25 % leaf lesion area
7	Susceptible	26- 50 % leaf lesion area
9	Highly Susceptible	51-100 % leaf lesion area

Formula for calculating per cent disease intensity is:

$$\textbf{PDI} = \frac{\textit{Sum of the score} \times 100}{\textit{No.of observations} \times \textit{highest number of rating scale}} \quad (1)$$

III. RESULTS AND DISCUSSION

Among the thirty-two genotypes screened, highest per cent disease intensity (48.60%) was recorded in NVSR-939 followed by NVSR-1128 (48.57%) and NVSR-952 (46.20%) and the lowest per cent disease intensity was observed in ISM (7.28%) followed by NVSR-1065 (8.20%) and NVSR-996 (8.60%). Whereas the international susceptible check TN-1 (76.00%) and local check GR-11 (68.57%) was found highly susceptible against bacterial blight disease.

Thirty genotypes along with two susceptible checks *viz.,* GR-11 and TN-1 were screened against bacterial leaf blight under field conditions. The results presented in Table-2 and depicted in Photo 1 and 2 revealed that, among all the tested genotypes, none were found immune and resistant. Out of them, four *viz.,* NVSR-996, NVSR-1065, NVSR-1127 and ISM were found to be moderately resistant. Fifteen genotypes *viz.,* NVSR-936, NVSR-938, NVSR-941, NVSR-950, NVSR-951, NVSR-942, NVSR-1002, NVSR-1003, NVSR-1005, NVSR-1048, NVSR-1111, NVSR-983, NVSR-1130, NVSR-1064 and GNR-3 were moderately susceptible. Eleven genotypes *viz.,* NVSR-939, NVSR-952, NVSR-997, NVSR-956, NVSR-1001, NVSR-1007, NVSR-1031, NVSR-1033, NVSR-1128, NVSR-964 and NVSR-1052 were found susceptible and two genotypes *viz.,* GR-11 and TN-1 were highly susceptible against bacterial blight of rice.

Screening of rice genotypes against bacterial blight was carried out on different varieties by earlier workers. Khan *et al*. (2009) screened 76 rice varieties/lines. Among them, none of the lines were found resistant against bacterial leaf blight. Whereas four varieties *viz*., IR-72102-3-107-1-1-2, P-52-9-2, Super-Bas and DM-1-30-3-99 were found moderately resistant. All other entries were showed in the range of moderately susceptible to highly susceptible reaction against bacterial leaf blight of rice. Banito *et al*. (2012) evaluated 21 rice varieties and near isogenic lines under screen house. Among them, four varieties *viz*., NERICA4, NERICA8, NERICA14 and Gigante were found moderately resistant against BLB of rice. Gangwar *et al*. (2021) screened 74 rice genotypes including two susceptible checks (1 National Check + 1 Local Check). Among the tested genotypes, none of the genotypes were found immune against the disease. Amin *et al.* (2022) tested 91 germplasm lines and revealed that, among the tested lines, none of the lines were recorded resistant against bacterial blight of rice. Jirankali *et al.* (2023) screened 102 rice genotypes for bacterial leaf blight resistance under open field conditions under artificial inoculation and revealed that no rice cultivar was found immune to the bacterial leaf blight disease. Srinivas *et al.* (2023) screened thirty genotypes along with two susceptible checks against bacterial blight under artificial inoculation condition and revealed that, no genotypes were found immune and resistant, whereas the genotypes *viz.*, GR-11 and TN-1 were found highly susceptible against bacterial blight of rice.

PHOTO 1: Nursery raising of different rice genotypes for screening against BLB

PHOTO 2: Artificial inoculation of rice genotypes by using clip inoculation method at panicle initiation stage in field condition

TABLE 2
SCREENING OF RICE GENOTYPES FOR BACTERIAL BLIGHT OF RICE UNDER ARTIFICIAL INOCULATION METHOD

Sr. No.	Genotypes	PDI (%)	Disease score (0-9 Scale)	Disease reaction
1	NVSR-936	15.22	5	MS
2	NVSR-938	23.25	5	MS
3	NVSR-939	48.60	7	S
4	NVSR-941	22.42	5	MS
5	NVSR-950	24.64	5	MS
6	NVSR-951	14.68	5	MS
7	NVSR-952	46.20	7	S
8	NVSR-996	8.60	3	MR
9	NVSR-997	45.73	7	S
10	NVSR-942	24.40	5	MS
11	NVSR-956	41.44	7	S
12	NVSR-1001	34.28	7	S
13	NVSR-1002	16.80	5	MS
14	NVSR-1003	13.44	5	MS
15	NVSR-1005	23.30	5	MS
16	NVSR-1007	45.71	7	S
17	NVSR-1031	33.20	7	S
18	NVSR-1033	42.22	7	S
19	NVSR-1048	21.22	5	MS
20	NVSR-1111	19.44	5	MS
21	NVSR-983	22.30	5	MS
22	NVSR-1065	8.20	3	MR
23	NVSR-1127	10.44	3	MR
24	NVSR-1128	48.57	7	S
25	NVSR-1130	24.41	5	MS
26	NVSR-964	31.30	7	S
27	NVSR-1052	37.22	7	S
28	NVSR-1064	22.22	5	MS
29	GNR-3	20.24	5	MS
30	ISM	7.28	3	MR
31	Check State- GR-11	68.57	9	HS
32	Check International- TN-1	76.00	9	HS

MR = Moderately Resistant, MS= Moderately susceptible, S = Susceptible, HS = Highly Susceptible

IV. CONCLUSION

The different rice genotypes were screened against bacterial blight of rice and concluded that, among the thirty-two genotypes screened, highest per cent disease intensity (48.60%) was recorded in NVSR-939 followed by NVSR-1128 (48.57%) and NVSR-952 (46.20%) and the lowest per cent disease intensity was observed in ISM (7.28%) followed by NVSR-1065 (8.20%) and NVSR-996 (8.60%). Whereas the international susceptible check TN-1 and local check GR-11 was found highly susceptible against bacterial blight disease with the per cent disease intensity of 76.00 per cent and 68.57 per cent, respectively.

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Exploring the Nutritional and Medicinal Significance of Underutilized Fruits: A Review

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Abstract— *Underutilized fruit crops encompass plant species traditionally utilized for various purposes such as food, fodder, fiber, oil, and their extensive medicinal attributes. Despite their multifaceted potential in ensuring food security, nutrition, health, income generation, and ecological benefits, these species remain underexplored. While commercially cultivated fruits like Mango, Banana, Papaya, Litchi, Guava, among others, dominate the market, wild edible fruits remain largely uncultivated and undomesticated. Many of these underutilized indigenous fruit crops serve as integral components of traditional medicine systems across India. Their value-added products present an opportunity for focused efforts to tap into both domestic and international markets. This overview primarily centers on elucidating the food, nutritional, and medicinal significance of these minor fruits. In India, prevalent underutilized fruits include Bael (Aegle marmelos), Jamun (Syzygium cumini), Karonda (Carissa carandas), Ber (Ziziphus mauritiana), Lasora (Cordia myxa L), Phalsa (Grewia subinaequalis), among others. Hence, this review paper primarily emphasizes the nutritional, therapeutic, and various other values associated with these diverse fruit crops.*

Keywords— Blood pressure, Cholesterol level and fats, Vitamins, Minerals, Antioxidants.

I. INTRODUCTION

India boasts diverse and favorable agro-climatic conditions, giving rise to a vast array of tropical and temperate fruits. These fruits are often referred to as "protective foods" due to their abundant reserves of vitamins, minerals, antioxidants, and phytochemicals. They are predominantly composed of water, typically ranging from 80 to 90 percent, with relatively low levels of protein, fat, salt, and sugar. Fruits also serve as a valuable source of soluble dietary fiber. In addition to forming an integral part of a well-balanced diet and a healthy, active lifestyle, a substantial intake of fruits and vegetables has been associated with several health benefits. This includes the reduction of blood pressure, cholesterol levels, and body fat, facilitating the maintenance of a healthy weight. Moreover, fruits contribute to regular bowel movements and bolstering the immune system. Their potent antioxidant properties aid in eliminating harmful free radicals from the body, offering protection against various chronic and infectious diseases Beluhan S and Ranogajec A 2010. Within India's fruit cultivation landscape, major crops such as Mango, Banana, Papaya, Litchi, Guava, and others are commercially cultivated, encompassing a significant portion, approximately 75 percent, of the total fruit cultivation area. In contrast, wild edible fruits comprise species that have not been subjected to cultivation or domestication. These underutilized indigenous fruit crops, such as Jamun (*Syzygium cumini*), Bael (*Aegle marmelos*), Karonda (*Carissa carandas*), Ber (*Ziziphus mauritiana*), Lasora (*Cordia myxa L*), and Phalsa (*Grewia subinaequalis*), originate from their wild natural habitats and have long served as a vital source of sustenance. They hold significant importance in traditional Indian medicinal systems like Unani, Ayurveda, and Homoeopathy, where they are recognized for their therapeutic properties.

Furthermore, it is well-established that a diet rich in fruits and vegetables can effectively reduce the risk of various non-communicable diseases, including cardiovascular diseases, type II diabetes, and certain types of cancer (4). These indigenous and underutilized fruit crops play a crucial role in the diets of many local inhabitants, serving as the primary source of essential vitamins and minerals in their otherwise modest diets, particularly in rural villages. In India, some of the most commonly underutilized fruits include Jamun, Bael, Karonda, Ber, Lasora, and Phalsa. Therefore, the focus of this review paper is

primarily directed toward highlighting the nutritional, therapeutic, and other valuable attributes of these underutilized fruit crops, shedding light on their significance in both traditional medicine and local diets.

II. JAMUN:

Jamun (*Syzygium cumini*) is a notable indigenous underutilized fruit crop with commercial value in India. It belongs to the Myrtaceae family and goes by various names such as Ram jamun, Indian black cherry, and black plum in different regions. This evergreen tree is commonly grown for shade in neglected areas, forest niches, marshy lands, and as staggered trees along roadsides. Although its original home is India and the East Indies, it can also be found in countries like Thailand, the Philippines, Madagascar, and others. Efforts have been made to introduce jamun into subtropical regions like Florida, California, Algeria, and Israel. Jamun trees are abundant in tropical and subtropical regions of India, extending from the Indo-Gangetic plains in the north to Tamil Nadu in the south. They can also be found in the lower range of the Himalayas, up to altitudes of 1,300 meters, and in the Kumaon hills, up to 1,600 meters. The importance of jamun fruit lies in its high nutritive value. It is not only a source of minerals, sugars, and proteins but also a good source of iron. Jamun is considered a medicinal plant in various conventional systems of medicine, and it is particularly celebrated for its potential benefits for diabetic patients. Additionally, it has proven effective in treating conditions such as diarrhea, ulcers, and inflammation. The fruit is rich in compounds like anthocyanins, glucoside, ellagic acid, isoquercetin, kaempferol, and myricetin, all of which contribute to its therapeutic properties. Jamun fruits also contain a variety of antioxidant compounds, including flavonoids, phenolics, carotenoids, and vitamins. These antioxidants are known for their ability to reduce oxidative stress and prevent macromolecular oxidation, making them beneficial for human health. The various parts of the jamun tree, including the seeds, are used in traditional medicine to treat a range of ailments, with a particular emphasis on diabetes mellitus. The gallic acid and ellagic acid found in the seeds play a crucial role in reducing blood glucose levels. The fruit pulp, with its high anthocyanin content, can serve as a natural food colorant for the food processing industry. The leaves and bark of the jamun tree are used to control blood pressure and address issues like bleeding gums. The seed powder is effective in reducing sugar content in urine. Consumption of jamun is considered a cost-effective way to manage diabetes because the glucosides in jamun inhibit the conversion of starch into glucose, helping to reduce blood sugar levels. The seeds are used to treat various ailments, including diabetes mellitus. Jamun pulp can lower blood sugar levels within about 30 minutes, while its seeds have a longer-lasting effect, lowering blood sugar levels within about 24 hours. Over time, jamun consumption can reduce thirst associated with diabetes and decrease urine output, sometimes reducing the need for insulin (Chandra, A *et al* 1995). Furthermore, jamun seeds have gastro-protective properties and are effective in promoting mucosal defensive factors, reducing lipid peroxidation, and even exhibiting anti-cancer and anti-viral properties. Jamun fruit extract has been found to control the growth and increase apoptosis of breast cancer cells. Jamun juice has carminative, mild astringent, stomachic, and diuretic properties, offering a soothing effect on the human digestive system. The seeds of the jamun fruit also have hypoglycemic, anti-inflammatory, antibacterial, anti-HIV, and anti-diarrhea effects. Lastly, the high anthocyanin content in jamun fruit pulp makes it a potential source of natural food colorants for the food processing industry. These pigments are known for their strong antioxidant capacity and health-protecting effects, reducing the risk of various diseases. Chaudhary B and Mukhopadhyay K 2012.

III. BAEL

Bael (*Aegle marmelos*) is a significant member of the Rutaceae family and is native to India. It holds a special place in various indigenous systems of medicine not only in India but also in China, Burma, and Sri Lanka. Bael is unique in that it is the only member of the monotypic genus *Aegle*. This tree is of moderate size and is known for its aromatic properties. It typically reaches a height of 6.0 to 7.5 meters with a girth ranging from 90 to 120 cm. Bael trees grow in scattered forest niches throughout India and are recognized by various names such as Bengal quince, golden apple, Japanese bitter orange, and stone apple. In different regions of India, it is also known as Kaitha, Maredu Pandu, Vilam Palam, Belada Hannu, Koovalam, Kothu, Koth Bel, and so on. The importance of bael fruit lies in its nutritional composition. Bael fruit contains approximately 29.07 grams of carbohydrates, 2.13 grams of protein, 0.3 grams of fat, 75 milligrams of ascorbic acid (vitamin C), 54.5 milligrams of carotene, 1.03 milligrams of riboflavin (Mala, R.2009) (vitamin B2), and various minerals including calcium, phosphorus, and iron. Notably, it is considered one of the richest sources of riboflavin among fruits. Bael fruit is processed into various products, such as dried slices of green bael fruit, pulp for making sherbet and syrup, marmalade for treating diarrhea and dysentery, and powders, preserves, nectar, and toffees. In addition to its nutritional value, bael is highly regarded for its medicinal properties. Different parts of the bael plant, including the leaves, roots, seeds, bark, and fruit, contain a variety of bioactive compounds such as coumarins, alkaloids, sterols, and essential oils. These compounds contribute to its wide range of therapeutic uses, including analgesic (pain-relieving), anti-inflammatory, antipyretic (fever-reducing), anti-microfilarial (against parasitic worms), antifungal, hypoglycemic (blood sugar-lowering), antidyslipidemic (regulating lipid levels),

immunomodulatory (modulating the immune system), antiproliferative (inhibiting cell growth), wound healing, antifertility, and insecticidal properties(Morton JF1987). Bael has been used in Ayurvedic medicine for a long time to treat specific disorders, including respiratory disorders, constipation, ulcers, diarrhea, dysentery, and more. Marmelosin, a therapeutically active compound found in bael fruit, is known for its stomach ailment remedies. The fresh leaf juice of bael fruit is considered beneficial, especially when taken in doses of 8 to 16 grams with honey. It acts as a mild laxative and is used in the treatment of fever and asthma. Fresh leaves and fruits are also used as a remedy for beriberi, a nutritional deficiency disorder. In summary, bael is a versatile fruit with both nutritional and medicinal value, and it has a rich history of use in traditional medicine systems for various health-related purposes.

IV. KARONDA

Karonda (*Carissa carandas* L.) is a short-stature evergreen shrub or tree that belongs to the family Apocynaceae. It is native to regions such as the Western Ghats and the Himalayas, where it grows at elevations ranging from 300 to 1800 meters. Karonda is also found cultivated in India, Malaysia, South Africa, and other regions. In India, it grows naturally in states like Bihar, West Bengal, Maharashtra, and Karnataka, and it is cultivated in Uttar Pradesh, Rajasthan, and Gujarat. Karonda is well-suited to arid climates and thrives in higher temperatures. The importance of karonda fruit lies in its nutritional content. Although the taste of karonda is sour and astringent, its nutritional quality is remarkable. Karonda fruits are a rich source of iron, B vitamins, and vitamin C. Vitamin C is known for its antioxidant properties and its ability to help flush out free radicals from the body. Karonda fruits also contain significant amounts of protein, carbohydrates, fat, dietary fiber, and calcium. Various products can be prepared from karonda fruits. These include pickles, chutney, sauces, jelly, carissa cream, and jellied salads. During the summer, ripe karonda fruit is used to make a refreshing cooling drink. Despite emitting sticky latex while being cooked, the fruit yields a rich red juice that becomes clear when cooled. In terms of medicinal uses, karonda fruits are used in many Ayurvedic formulations due to their nutritional value. Unripe karonda fruit is considered a good appetizer. The root extract is used for chest pain, while the leaves are used for fever. Leaf extract can also be applied externally for the treatment of leprosy. Additionally, two drops of plant oil can be given with half a cup of honey to control minor worm infestations. Karonda fruits contain antioxidants such as flavonoids, alkaloids, and tannins, which offer various health benefits, including analgesic (pain-relieving), anti-inflammatory, antipyretic (fever-reducing), and cardiotonic properties. Traditionally, karonda fruits have been used for medicinal treatments of conditions such as malaria, epilepsy, leprosy, nerve disorders, fever, pain relief, headaches, and as a blood purifier. Rahmatullah M. *et al* (2009)Reshu, V. *et al*. (2017). The major bioactive constituents in karonda fruits include alkaloids, flavonoids, saponins, cardiac glycosides, triterpenoids, phenolic compounds, and tannins. These chemicals make karonda effective in the treatment of conditions like scabies, intestinal worms, pruritus (itching), biliousness, and as an antiscorbutic (preventing scurvy) and anthelmintic Sagrawat H., *et al.,* (2006) Singh Jashbir. *et al.,* (2013) (expelling parasitic worms). In summary, karonda is a versatile fruit with nutritional, culinary, and medicinal value. It has been traditionally used in various forms for the treatment of a range of ailments, and its nutritional richness makes it a valuable addition to diets in regions where it grows.

V. BER

Ber (*Ziziphus mauritiana*) is an evergreen, spiny small tree or shrub native to Indo-China and India. It belongs to the family Rhamnaceae. The fruit of the ber tree varies in shape, which can be oval, oblong, or round, with sizes ranging from 2.5 to 6.25 cm long, (Spiller, G. A. 2007) depending on the variety of the plant. The flesh of ber fruit is white, crunchy, and juicy, with a pleasant aroma. The skin is tight, thin, smooth, and glossy. Ber is also known by various names, including Indian jujube, Indian plum, and poor man's fruit. The importance of ber fruit lies in its nutritional content. Ber fruits are a great source of energy and are easy to digest because they are rich in carbohydrates and dietary fibers. These properties help in curing constipation and are essential for boosting metabolism. Ber fruits also contain minerals such as iron, zinc, potassium, phosphorus, and manganese, making them highly nutritious. The combination of these minerals is required for maintaining a healthy heart and regulating blood circulation in the body. Various products can be prepared from ber fruit, including ber powder, ber candy, ber murabba (preserved ber), ber jam, ber preserve, ber pickle, ber beverages, ber wine, and ber ready-to-serve (RTS) items.In terms of medicinal uses, ber fruit has several health benefits:

- **Preventing Anemia:** The iron content in ber fruit helps prevent anemia by increasing hemoglobin levels in the blood.
- **Bone Health:** Dried ber fruits are rich in calcium and phosphorus, which are essential for developing and maintaining bone density.

- **Anti-Aging:** Ber fruits contain vitamin C and antioxidants, which help reverse the effects of aging by fighting free radicals and preventing cell damage.
- **Sedative Qualities:** Ber fruit contains antioxidants like flavonoids, phytochemicals, and saponins, which have sedative effects that help in treating anxiety by calming the nerves.

In summary, ber fruit is a nutritious and versatile fruit with various culinary uses and medicinal benefits. It is valued for its energy-boosting properties, role in digestion, and the array of essential minerals it provides. Additionally, its antioxidant content and potential sedative effects contribute to its importance in traditional medicine and wellness.

VI. LASORA

Lasora (*Cordia myxa L.*), also known as Gonda or lehsua, belongs to the family Boraginaceae. It can be found in moist and dry forests of India, except in high hills and temperate climates. Lasora is a medium-sized, perennial tree with a crooked stem, and it bears smooth, small cherry-sized fruits in bunches from March to August. The importance of lasora fruit lies in its significant nutrient content, providing essential components for human health. Lasora fruits are a probable source of vitamins, minerals, and fiber. These fruits contain various nutrients such as proteins, carbohydrates in the form of starch and free sugars, oils, ascorbic acid (vitamin C), minerals, and antioxidants. Fruits, in general, are rich sources of natural antioxidants like carotenoids, ascorbic acid, phenols, and more.*Lasora* is considered a multipurpose plant with associations to nutrition, health, and various uses in treating human ailments. The tree has a role in the rural economy of arid regions by providing food (in the form of pickles and vegetables), fuelwood, and timber. Products of lasora fruit include ripe fruits, which are eaten fresh. Unripe fresh fruits are often used as vegetables and for making pickles, especially when conventional vegetables are scarce (typically in April and May). Sometimes, fruits are blanched and dehydrated to be used as a vegetable during the off-season. The gummy crush obtained from ripe fruits is generally used to prepare glue. In terms of medicinal uses, various parts of the lasora tree are utilized both internally and externally for medicinal purposes. The tree has traditionally been used in the treatment of conditions such as fever, dyspepsia (indigestion), ulcers, ringworm, headaches, lung diseases, spleen-related issues, and more. Different parts of the tree, including the bark, leaves, fruits, and seeds, have reported medicinal properties, including antidiabetic, anti-ulcer, anti-inflammatory, diuretic, immune-modulator, laxative, antidote, astringent, analgesic, and expectorant activities. In summary, lasora is a versatile tree with nutritious fruits and various applications in both food and traditional medicine (Trivedi, P. C 2007).It plays a significant role in providing sustenance and addressing health concerns in the regions where it grows.

VII. PHALSA

Phalsa (*Grewia subinaequalis*) is a large shrubby tree native to India and other parts of Southeast Asia, including Pakistan, Sri Lanka, and Bangladesh. It belongs to the Tiliaceae family and is cultivated for its edible fruits in India and many other tropical countries. Phalsa is also known as Indian Sherbet Berry. The ripe phalsa fruit is similar in appearance to grapes, with a thin layer of dark purple to black skin and greenish-white fleshy pulp surrounding the seeds. It has a sweet and sour taste and is typically found in branched clusters. Phalsa fruits have a very short shelf life, limiting their distribution mainly to local markets. They are primarily cultivated in the western and northern states of India for commercial purposes. The importance of phalsa fruit lies in its significant nutrient content. It is high in moisture and water content, making it a refreshing fruit. Phalsa consumption provides energy, as it is loaded with a good amount of carbohydrates and calories in the form of simple sugars, which are easily processed by the human body. Phalsa is also rich in vitamins, particularly Vitamin C, and contains abundant trace minerals, including iron. Iron is essential for the synthesis of hemoglobin, which is needed for circulating blood between tissues and organs. Adequate iron intake helps combat dizziness and fatigue. The seeds of phalsa contain approximately 5 percent oil, which is bright yellow in color and consists of 65 percent linoleic acid and 11 percent stearic acid. Phalsa fruits have a short shelf life and are best consumed quickly. In India, during the hot summer season, ripe phalsa fruits are enjoyed either fresh in desserts or processed into stimulating soft drinks like sherbet, squash, ready-to-serve beverages, and more. In terms of medicinal uses, phalsa fruit offers several health benefits:

- **Blood Pressure Regulation:** Phalsa fruits can help lower high blood pressure due to their potassium and phosphorus content, which play a role in maintaining healthy blood pressure levels.
- **Heart Health:** Phalsa consumption helps prevent cardiac ailments such as heart attacks, arrhythmia (irregular heartbeats), and atherosclerosis. Its anthocyanins, antioxidants, and tannins help prevent fat deposition and cholesterol accumulation in blood vessels.
- **Anti-Inflammatory:** Phalsa fruits have anti-inflammatory properties that can help reduce inflammation in the body.

- **Antioxidant Properties:** Phalsa is rich in antioxidants, which neutralize free radicals, alleviate bone pain (useful in conditions like arthritis and osteoporosis), and improve joint mobility.

In summary, phalsa is a nutritious fruit that provides energy, essential vitamins, and minerals. It also offers various health benefits, including blood pressure regulation, heart health support, anti-inflammatory effects, and antioxidant properties. Enjoyed during the hot summer months, phalsa is a refreshing and healthy addition to the diet.

The underutilized fruit crops or minor fruits discussed in the current investigations have been shown to possess significant value both in terms of medicinal and nutritional properties. These plant species have traditionally been used for their fruits, fiber, fodder, oil, or therapeutic properties, but they are considered underexploited resources with great potential for enhancing food security, nutrition, health, income generation, and environmental services. Despite being underutilized, these fruits also play a vital role in sustainable agriculture due to their adaptability and tolerance to unfavorable climatic conditions. Underutilized plants typically have local importance, but they often lack nationwide recognition. Therefore, it is crucial to prioritize research and development efforts aimed at the cultivation of underutilized fruit crops. This can help promote organized marketing systems for fresh fruits during surplus periods and encourage the processing of these fruits into value-added products. Such initiatives can have a positive impact on the nation's economy by diversifying agricultural production and providing new income opportunities for farmers. In summary, the cultivation and promotion of underutilized fruit crops hold promise for addressing various challenges related to food security, nutrition, and economic development. By recognizing the value of these lesser-known fruits and investing in their development, we can harness their potential benefits for both local communities and the broader agricultural sector.

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Strategies for Addressing Climate Change Impacts on Agriculture: Adaptation and Mitigation Approaches

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Abstract— *Climate change is expected to exert significant impacts on crop yields by altering temperatures and water availability. Mitigation and adaptation efforts aim to counteract these effects gradually while sustaining development. Effective strategies encompass various practices that fall into three main categories: crop and cropping system-based technologies, resource conservation-based technologies, and socio-economic and policy interventions. In the context of India, it is crucial to explore these measures and identify the most suitable strategies for combatting climate change. Crop and cropping system-based technologies involve the adoption of climate-resilient crop varieties and optimized planting practices. Utilizing drought-resistant seeds, implementing precision agriculture techniques, and adjusting planting calendars can enhance resilience to changing climatic conditions in India. Resource conservation-based technologies encompass sustainable water management and soil conservation practices. Implementing efficient irrigation methods, such as drip irrigation and rainwater harvesting, can help preserve precious water resources. Soil health improvement through organic farming, reduced tillage, and agroforestry can enhance soil fertility and mitigate climate-related risks. Socio-economic and policy interventions play a critical role in climate resilience. Promoting farmer education and awareness on climate-smart agriculture practices can empower rural communities to adapt effectively. Additionally, government policies that incentivize sustainable agriculture, provide insurance against climate-related crop losses, and support research and development of climate-resilient technologies are essential for long-term climate adaptation in India.*

Keywords— Agroforestry, Carbon, Food insecurity, Intercropping, Pollutants, Rainfed farming, Rice fields, Zero tillage.

I. INTRODUCTION

Climate change represents a multifaceted alteration of our planet's climate, characterized by its subtle and continuous nature, yet its consequences are of paramount importance, particularly for the diverse vegetation that thrives under stable or relatively unchanged climatic conditions. The effects of climate change have now reached a pivotal juncture, where we are deeply concerned about the potential for irreversible disruptions to the fundamental functioning of our planet. Over the past decade, particularly within the realm of agriculture and food production, we have observed a series of notable impacts. Firstly, there has been a marked increase in the occurrence of storms and floods, events that have become more frequent and severe. These extreme weather events wreak havoc on crops, causing soil erosion, waterlogging, and substantial damage to agricultural landscapes. Simultaneously, the incidence and severity of droughts and forest fires have heightened, posing significant threats to water resources, livestock, and overall agricultural productivity. Moreover, the gradual expansion of frost-free periods and growing seasons, while offering opportunities for extended crop cultivation, also introduces new challenges. These include managing pests and diseases that thrive in milder climates and addressing potential water resource issues. Concurrently, the frequency of diseases and insect pest attacks in agriculture has increased due to the changing climate conditions, impacting crop yields and food security. Additionally, climate change-induced alterations to ecosystems and habitats have led to the diminishing of critical environments for various plant and animal species. This disruption affects not only biodiversity but also the availability of pollinators and indigenous plants and animals that play vital roles in food production. These modifications in previously stable climates signal an undeniable warming trend and escalating climatic variability, demanding urgent action from the global scientific community to mitigate or reverse these trends. While efforts have been made in the past to reduce greenhouse gas emissions and curb climate change, the current pace of warming suggests that these measures may fall short of what is needed. The early impacts of climate change are already manifesting globally, affecting numerous human and natural

systems, including human health, food and fiber production, water resources, and various aspects of economic and social well-being. While certain impacts may confer short-term advantages to specific regions or activities, the long-term consequences are anticipated to be largely detrimental. In the context of agriculture, while carbon dioxide emissions are relatively low, significant greenhouse gases are emitted from this sector. Agriculture accounts for approximately 60% of nitrous oxide emissions, mainly due to fertilizer use, and about 50% of methane emissions, primarily from natural and cultivated wetlands and enteric fermentation. These emissions are projected to increase substantially in the coming years due to growing nitrogen fertilizer use and increased livestock production to meet rising food demands.

Changes in climate are expected to have substantial impacts on crop yields, influenced by shifts in both temperature and moisture patterns. These alterations may also disrupt the distribution of plant diseases and pests, posing additional challenges for agriculture. Nevertheless, agriculture has historically displayed a degree of adaptability to varying climate conditions, with short-term investments and the ability to adjust crops and cultivars to suit new conditions. Consequently, at the global level, agriculture may have the capacity to adapt to a moderate degree of global warming, up to 2.5°C above current levels, assuming no dramatic shifts in climate variability. It's worth noting that while agriculture in temperate regions may benefit from improved growing conditions, crops in low latitudes, such as tropical and sub-tropical areas, are often close to their heat tolerance limits. The relative distribution of adverse impacts will depend significantly on adaptive capacity across different regions and sectors, making it imperative for comprehensive, cooperative efforts to address and mitigate the extensive consequences of climate change. The evident alterations in formerly stable climates signify an unmistakable warming trend and a growing climatic variability that has far-reaching consequences for existing ecosystems. It is imperative for the global scientific community to harness all available knowledge and resources to halt or reverse this trend to the fullest extent possible. While past efforts have been made to reduce atmospheric greenhouse gases (GHGs) and slow down climate change, as documented by Boer et al. in 2000, the current pace of the warming trend suggests that these measures may soon prove insufficient. The early impacts of climate change are already being experienced on a global scale, with far-reaching effects on a diverse range of human and natural systems. These impacts encompass critical areas such as human health, food and fiber production, water supplies, and numerous other facets essential to economic and social well-being. While some impacts may yield short-term benefits to certain regions or sectors, it is crucial to recognize that in the long-term, the overall effects are anticipated to be predominantly detrimental. Therefore, concerted global efforts to mitigate and adapt to climate change are essential not only to address its current impacts but also to safeguard the well-being of present and future generations. While carbon dioxide emissions from agriculture are relatively small compared to other sectors, this sector plays a significant role in the release of other crucial greenhouse gases (GHGs). Agriculture is responsible for approximately 60% of global nitrous oxide emissions, primarily stemming from fertilizer usage, and about 50% of methane emissions, which predominantly originate from natural and cultivated wetlands and enteric fermentation processes. Projections indicate that methane and nitrous oxide emissions are expected to rise by 35 to 60% by 2030, driven by increased nitrogen fertilizer usage and heightened livestock production in response to the growing global demand for food. The shifting climate patterns resulting from climate change are expected to have profound impacts on crop yields, influenced by alterations in both temperature and moisture levels. These changes may also disrupt the distribution of plant diseases and pests, posing additional challenges to agriculture. Nonetheless, agriculture has consistently demonstrated adaptability to varying climate conditions. Investments are often short-term, and crops and cultivars can be swiftly adjusted to suit new conditions. Consequently, on a global scale, agriculture is likely capable of adapting to a moderate degree of global warming, up to 2.5°C above current levels, assuming there are no dramatic shifts in climate variability. It's noteworthy that crops in low latitudes, such as tropical and sub-tropical regions, are often operating near their limits of heat tolerance. Conversely, growing conditions in higher latitudes, characterized as temperate regions, are expected to improve, potentially providing agriculture with a competitive advantage. As with other sectors, the capacity to adapt is likely to be a critical factor in determining how the adverse impacts of climate change are distributed across various regions and sectors. Thus, a coordinated and adaptive approach is essential to effectively address the multifaceted challenges posed by climate change in the realm of agriculture. The primary purpose of mitigation and adaptation measures is to address and combat the progressively worsening effects of climate change while sustaining ongoing development efforts. It is crucial to recognize and understand the subtle yet critical distinction between these two approaches. Mitigation and adaptation differ primarily in their temporal and spatial effectiveness. Mitigation efforts, aimed at reducing greenhouse gas emissions and their impact, exhibit benefits over the long term, often taking several decades to manifest due to the extended residence time of these gases in the atmosphere. Conversely, adaptation measures are intended to provide immediate or near-future responses to the changing climate conditions. Furthermore, it's essential to note that mitigation efforts offer both global and local benefits, while adaptation typically takes place at the local or regional level. The vulnerability of global food security has escalated significantly, with climate change altering global and local patterns of vulnerability. Small-scale rainfed farming systems,

pastoralist communities, inland and coastal fishing and aquaculture industries, and forest-based systems are particularly susceptible to climate change impacts. To enhance preparedness and resilience to uncertain future impacts, preventive and planned adaptation and innovation are imperative. Technical adaptation measures encompass a range of strategies, from adjusting planting or fishing schedules, crop rotation, and diversification, to implementing crop- livestock pisciculture systems, agroforestry practices, soil and water conservation, and biodiversity development. These efforts also entail soil biomass building, land restoration, rangeland rehabilitation, water harvesting and recycling, tree planting, and the development of adapted crop varieties and breeds. Additionally, adaptation measures include the establishment of disaster risk management plans and risk transfer mechanisms like crop insurance, along with diversified livelihood systems. On the other hand, mitigation options involve carbon sequestration in agriculture and forestry, making it a global responsibility. Agriculture, forestry, and fisheries/aquaculture sectors hold significant potential for mitigating greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) estimates that agriculture alone has the potential to reduce between 5,500 and 6,000 Mt CO2-equivalent per year by 2030, with the majority of these reductions attributed to carbon sequestration in soils. Carbon sequestration offers several benefits: it removes CO2 from the atmosphere, enhances agroecosystem resilience through increased organic matter levels in the soil, and sustains income generation and livelihoods by improving soil fertility, ultimately leading to better yields. There is a growing opportunity to increase carbon sinks in soil, above-ground, and below-ground biomass, contributing to soil carbon sequestration as part of post-2012 climate change efforts. Organic agriculture and conservation agriculture play a vital role in this context, as they can help reduce greenhouse gas emissions and promote sustainable agricultural practices while addressing the pressing challenges of climate change.

II. ENHANCING CLIMATE RESILIENCE AND MITIGATING ENVIRONMENTAL IMPACT THROUGH ADVANCED TECHNOLOGIES

The Twin Pillars of Climate Resilience: Technological Advancements in Crop Management and Sound Governmental Policies. Mitigating and adapting to the challenges posed by climate change in agriculture rests upon two pivotal pillars. The first pillar focuses on harnessing innovative technologies to address the direct impacts of climate change on grain crops. This includes addressing issues such as reduced crop duration, embryo abortion, spikelet sterility, fluctuations in grain number and size, and variations in anthesis intervals. To combat these challenges, a strategic approach involves the efficient application of conventional breeding methods and cutting-edge biotechnological tools. This encompasses techniques like molecular and mutation breeding, aided by biotechnological tools such as marker-assisted selection, whole genome expression analysis, and subsequent gene discovery through bioinformatics. The second pillar underscores the critical role of government policies and political will in mitigating and adapting to the anticipated adverse effects of climate change in agriculture. These effects encompass not only direct impacts on crops but also indirect consequences, including dwindling water resources, heightened pest and disease incidence, and the loss of soil organic carbon. To address these indirect effects, a comprehensive strategy involves the conservation and efficient utilization of water resources, the implementation of integrated pest management practices, and the promotion of conservation farming techniques. Together, these twin pillars—technological advancements in crop management and supportive governmental policies—constitute a holistic approach to enhance climate resilience and mitigate the detrimental impacts of climate change on agriculture.

III. ADVANCEMENTS IN CROP AND CROPPING SYSTEM TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE

The focus of these efforts will primarily revolve around the promotion of crop cultivation and varieties that are well-suited to new cropping systems and changing seasons. This includes the development of crop varieties with altered growth durations that can withstand the transient effects of climate change. Special attention will be given to releasing varieties that exhibit tolerance to high temperatures, drought, and submergence, as well as those that respond positively in terms of growth and yield to elevated CO2 levels. Additionally, there is a need to emphasize the development of varieties with high fertilizer and radiation use efficiency. Novel crops and varieties that can thrive in coastal areas with high salinity and potential saltwater inundation are also essential for resilient agriculture. Preserving agricultural biodiversity and exploring crop germplasm for favourable traits is a critical area that demands extensive exploration. Collecting and conserving seeds, plants, and plant parts that demonstrate tolerance to temperature, water, and other atmospheric stresses resulting from climate change will aid crop breeding research significantly. A comprehensive reassessment of wild relatives, land races, existing varieties, modern breeding stocks, and previously overlooked traits can provide valuable insights for adapting to the current climatic challenges. Genetic resources are likely to be the most cost-effective foundational material for enabling agriculture to adapt to climate change. In India, notable progress has been made in understanding the genetic aspects of flowering time, inflorescence architecture, temperature tolerance, and drought tolerance in certain model plant systems, thanks to comparative genomics in crop plants. For instance, CRIDA (Central Research Institute for Dryland Agriculture) in Hyderabad has introduced a

transformed Sorghum bicolor L. Moench cv. SPV462 with the mtlD gene from E.coli, encoding mannitol-1-phosphate dehydrogenase. This genetic modification aims to enhance tolerance to water deficit and NaCl stresses, resulting in significantly improved germination potential and robust root systems when exposed to salt and water stress conditions. Furthermore, strategies for genetically enhancing heat-tolerant genotypes, especially in pulse crops, by identifying and validating markers for high-temperature tolerance coupled with high yield potential are essential technological advances. Another strategy involves taking advantage of the accelerated growth observed under higher temperatures. Consequently, new varieties, particularly those suited for the rabi cropping season, should possess traits such as early flowering, early maturity, and high productivity

IV. ENHANCING CROP PRODUCTION AND CLIMATE RESILIENCE THROUGH INNOVATIVE AGRONOMIC PRACTICES

To address the challenges posed by climate change and promote stable crop production, it is essential to adopt improved and novel agronomic and crop production practices. These strategies aim to mitigate the negative impacts of climate change and reduce yield instability. Some key approaches include:

1. **Adjustment of Planting Dates:** One effective practice involves modifying planting dates to minimize the adverse effects of increased temperatures, which can lead to spikelet sterility. By avoiding the hottest periods during flowering, this adjustment can help maintain more stable yields.
2. **Changing Cropping Calendars:** In regions prone to increased climatic variability, such as arid and semi-arid tropics, adaptation measures may involve altering the cropping calendar. This enables farmers to capitalize on wet periods and avoid extreme weather events during the growing season.
3. **Crop Variety Selection:** Choosing crop varieties that are resistant to lodging (bending or collapsing of plants) can help crops withstand strong winds, especially during vulnerable growth stages.
4. **Crop Management Practices:** Implementing improved crop management techniques, including crop rotations, intercropping, and integrated pest management, can enhance crop resilience and overall productivity. Agroforestry and afforestation schemes can complement these efforts.
5. **Grassland Improvement:** In grazing lands, pasture improvement through planned grazing processes, enclosures for recovery, or enrichment planting is crucial to combat impending changes brought about by climate variability.
6. **Intercropping:** Intercropping, particularly grain-legume intercrops, offers multiple benefits, including stable yields, efficient resource utilization, reduced weed and pest pressure, increased protein content in cereals, and lower nitrogen leaching compared to sole cropping systems.
7. **Seed Banks:** Establishing seed banks is vital in highly variable and unpredictable environments. These facilities provide a practical means to re-establish crops after major disasters and extreme climate events. They also contribute to plant community dynamics, helping buffer against inter-annual variability in growing conditions.

Additionally, the promotion of scientific agroforestry plays a pivotal role in the battle against climate change. Agroforestry systems offer several advantages, including:

- **Climate Resilience:** Agroforestry systems act as buffers against climate variability, helping farmers adapt to changing conditions.
- **Carbon Sequestration**: Trees in agroforestry systems can sequester carbon dioxide, mitigating the accumulation of greenhouse gases in the atmosphere.
- **Soil Improvement:** Trees in agroforestry systems enhance soil fertility by reducing erosion, maintaining soil organic matter, increasing nitrogen (N) accumulation, extracting nutrients from deep soil layers, and promoting closed nutrient cycling.
- **Economic and Environmental Benefits:** Agroforestry practices generate economic, environmental, and socio-economic benefits, improving the livelihoods of farmers while protecting the environment.

V. RESOURCE CONSERVATION TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE

Resource conservation-based technologies play a pivotal role in sustainable agriculture and contribute significantly to climate change mitigation. These technologies encompass a wide range of practices aimed at efficiently utilizing resources while reducing the environmental footprint of agriculture. Here are some key resource conservation technologies and strategies:

1. **In Situ Moisture Conservation:** Implementing techniques to retain soil moisture in the root zone, such as mulching and soil cover crops, to optimize water use efficiency.
2. **Rainwater Harvesting and Recycling:** Capturing and storing rainwater for agricultural use, reducing dependency on external water sources and mitigating the effects of water scarcity.
3. **Efficient Use of Irrigation Water:** Employing precision irrigation methods to minimize water wastage and enhance water use efficiency.
4. **Conservation Agriculture:** Embracing practices like no-till farming, cover cropping, and crop rotation to improve soil health, reduce erosion, and enhance resource conservation.
5. **Energy Efficiency in Crop Production and Irrigation:** Implementing energy-efficient technologies and practices in agricultural machinery and irrigation systems to reduce energy consumption and environmental impact.
6. **Utilization of Poor Quality Water:** Developing strategies to use poor-quality water sources for irrigation, reducing the demand for freshwater resources.

Additionally, suggested strategies to enhance resource conservation and climate resilience in agriculture include:

- **Characterization of Resources:** Utilizing Geographic Information Systems (GIS) and remote sensing to characterize biophysical and socio-economic resources, enabling informed decision-making.
- **Integrated Watershed Development:** Implementing comprehensive watershed management strategies to optimize water resources and minimize runoff.
- **Rainwater Use Efficiency:** Enhancing rainwater harvesting, storage, and reuse systems to maximize agricultural benefits.
- **Contingency Crop Planning:** Developing crop plans that account for potential production losses during drought or flood years.
- **Zero Tillage (ZT) Technology:** Utilizing ZT practices to reduce water demand and greenhouse gas emissions, while also improving soil organic matter.
- **Bed Planting:** Adopting bed-planting techniques for increased water use efficiency, reduced waterlogging, and improved crop management.
- **Doruvu/Kottai Technology:** Managing seawater intrusion in coastal areas by creating deep open wells to store and distribute fresh water efficiently for crop irrigation.
- **System of Rice Intensification (SRI):** Implementing SRI practices that optimize water use, enhance root growth, and improve rice plant resilience to climate-related stressors.
- **Integrated Nutrient Management (INM) and Site-Specific Nutrient Management (SSNM):** Applying these approaches to increase rice yields, reduce greenhouse gas emissions, and optimize nutrient use efficiency.
- **Zymogenic Bacteria and Inhibitors:** Using microbial agents and inhibitors to reduce methane (CH4) and nitrous oxide (N2O) emissions from paddy fields.
- **Neem-Coated Urea:** Promoting the use of neem-coated urea as a cost-effective method to improve nitrogen use efficiency and reduce environmental impact
- **Integrated Farming Systems:** Encouraging the adoption of integrated farming systems that combine multiple agricultural enterprises on a single piece of land, reducing risk and enhancing sustainability.These resource conservation-based technologies and strategies are vital components of sustainable agriculture, contributing to increased productivity, reduced environmental impact, and greater resilience in the face of climate change.

VI. POLICY INTERVENTIONS FOR CLIMATE-RESILIENT AGRICULTURE AND SUSTAINABLE DEVELOPMENT

Effective strategies for combating the impacts of climate change on crop production require more than just technological advancements; they demand a robust policy framework and unwavering political commitment from governments. A well-structured policy framework should address various aspects, including redesigning the social sector to prioritize vulnerable areas and populations, introducing innovative credit instruments with deferred repayment options, managing liabilities during extreme weather events, and promoting weather insurance as a key risk transfer mechanism.

Governmental initiatives should focus on identifying and prioritizing adaptation options across critical sectors such as storm warning systems, water storage and diversion, health planning, and infrastructure development. It is essential to integrate national development policies into a sustainable framework that complements adaptation efforts. Additionally, efforts should be made to mobilize financial resources to strengthen adaptation measures within countries. Local institutions, such as Self-Help Groups (SHGs), banks, and agricultural credit societies, should be promoted to enhance capacity building. The role of community institutions and the private sector in agriculture should be addressed through policy initiatives.

To navigate the challenges posed by climate change, policy considerations include:

1. **Mainstreaming Adaptations:** Incorporating climate impact assessments into all major development initiatives to ensure climate resilience.
2. **Scientific and Economic Pricing Policies:** Encouraging the adoption of scientific and economic pricing policies, particularly for natural resources like water, land, and energy.
3. **Financial Incentives:** Providing financial incentives and packages to promote improved land management and exploring Clean Development Mechanism (CDM) benefits for mitigation strategies.

Green Research Fund: Establishing a dedicated "Green Research Fund" to support research on adaptation, mitigation, and impact assessment.

In conclusion, while climate change is an undeniable reality in India, a comprehensive understanding of its impacts, vulnerabilities, and adaptation options across various warming scenarios, sectors, and regions is crucial. A proactive approach, supported by sound policy interventions and political will, is essential to prepare the nation effectively for the challenges of climate change.

Future research endeavors in the context of climate-resilient agriculture should focus on several critical issues to enhance crop production and mitigate the impacts of climate change. These researchable issues include:

1. **Breeding for Improved Crop Varieties:** Research efforts should aim to develop crop varieties that are specifically tailored to address growth and flowering phenology, photoperiod sensitivity/insensitivity, stability in response to inputs (e.g., lodging resistance, optimum tillering, harvest index), and other traits that enhance resilience to climate change.
2. **Efficient Water and Soil Management:** There is a need to identify and implement efficient water and soil management practices. Research should focus on crops and varieties with high water use efficiency, improved dry matter conversion ratios, positive responses to temperature extremes, and elevated levels of atmospheric carbon dioxide (CO2).
3. **Innovative Intercropping and Farming Systems:** Research should explore new intercropping combinations and innovative farming system approaches, including integration with livestock and fisheries. These systems should be designed to withstand the challenges posed by predicted climate change while remaining economically viable.
4. **Greenhouse Gas Emission Reduction:** Cost-effective methods for reducing greenhouse gas emissions from rice paddies and cropping systems with livestock components should be identified and promoted. Research should explore strategies to minimize emissions while maintaining agricultural productivity.
5. **Conservation Agriculture Practices:** Research efforts should emphasize the promotion of conservation agriculture practices. This includes research in areas such as water harvesting, nutrient management, and pest and disease control to enhance sustainability and climate resilience in agriculture.

Addressing these researchable issues is vital for ensuring food security, environmental sustainability, and resilience in agriculture under changing climate conditions. It requires collaborative efforts from the scientific community, policymakers, and stakeholders to develop and implement innovative solutions that can withstand the challenges posed by climate change.

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Evaluation of Cropping System for Rain Fed Agriculture

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Abstract— *Erratic and inadequate rainfall is one of the important factors for crop production under rain fed conditions. Crop grown as sole crop are found to be rather risky due to delayed monsoon accompanied with prolonged intermittent dry spells. A strategy for stabilizing production of dry-land crops through commonly recognized practice of intercropping of compatible crops is considered viable to overcome the situation. Mothbean and pearlmillet are important arid crop. So it is necessary to find out its intercropping proportion to resuce the risk of failure of sole crop. Therefore, an experiment was conducted at Dry Farming Research Station, Sardarkrushinagar Dantiwada Agricultural University, Radhanpur to evaluate of cropping system for rainfed agriculture in kharif season during 2010-11 to 2022-23. Significantly higher pearlmillet equivalent yield (3466 kg/ha) was recorded under Sole Mothbean which remained at par with pearl millet + moth bean (1:3) intercropping (3305 kg/ha).*

Keywords— Rainfed, Equivalent yield and Intercropping.

I. INTRODUCTION

Rainfed area occupies 58% of net cultivatable area in the India, have diverse farming systems, different potentials and constraints, which can only be addressed through development and application of location specific. Sole cropping is very risky in rainfed area because of erratic pattern and uncertainty of rainfall, there is a possibility of failure of sole crop. Researchers and farmers are developing different crop production systems to increase productivity and sustainability which includes intercropping, mix cropping, relay cropping and crop rotation since the Vedic times. There are several factors like variety, seeding ratios, planting pattern and competition between crop which affect the growth of species in mix cropping and intercropping.

Moth bean as arid legumes and Pearl millet as arid millets are largely grown in arid region. Due to the risk of failure of sole crop it is necessary to build up an insurance against total crop failure. So that the study on inter cropping of moth bean with pearl millet under rain fed condition is essential to find out the proportion of intercropping of moth bean and pearl millet and to increase the income by sowing the main crop with inter crop. Another objective of intercropping in rainfed area are to produce an additional crop by optimize the use of natural resources and to stabilize the yield of crops and to overcome the risk.

II. MATERIAL AND METHOD

A field experiment was conducted at Dry Farming Research Station, Sardarkrushinagar Dantiwada Agricultural University, Radhanpur to evaluate suitable cropiing system for rainfed agriculture during 2010-11 to 2022-23. But due to delayed monsoon accompanied with prolonged intermittent dry spells one or more treatment were failure in many years. So here successful four seasons *i.e.* 2011, 2016, 2020 and 2022 are considered for pooled results. The experiment was laid out in randomized block design with four replications. There were total eight treatments in which five intercropping of mothbean in pearlmillet *viz.*, pearlmillet + mothbean (1:2), pearlmillet + mothbean (2:1), pearlmillet + mothbean (1:3), pearlmillet + mothbean (3:1), pearlmillet + mothbean (2:2), two sole crop treatment (sole pearlmillet and sole mothbean) and one mix cropping taken for

study. Both the crop sown with 45 cm row spacing in all the treatments and 1:1 seed ratio is used in mix cropping treatment. Normal crop husbandry practices were followed for the successful raising of crop. Pearlmillet equivalent yield (PEY) was calculated in terms of pearlmillet yield of all intercropping treatments on the basis of prevailing market prices (Rs. kg^{-1}). It was calculated using formula suggested by Lal and Ray (1976). Pearlmillet Equivalent Yield (Kg ha^{-1}) = [Seed yield of mothbean (kg ha^{-1}) x Price of mothbean (Rs kg^{-1}) / Price of pearlmillet (Rs kg^{-1})] + Seed yield of pearlmillet (kg ha^{-1}). The statistical analysis of data of various characters studied in the investigation was done using analysis of variance techniques as suggested by Panse and Sukhatme (1985). The critical differences for comparing treatment means were worked out at 5 per cent level of significance.

III. RESULTS

Plant height, number of tillers per plant and length of ear head were unaffected by different intercropping systems. It might be due to no annidation effect were take place between intercrop and main crop with 45 cm row spacing. While Pealmillet grain yield (1021 kg/ha) were found significantly higher in sole pearlmillet. The reduction in grain yield of pearlmillet in the intercropping system was mainly due to replacement type of intercropping system was followed in the present study so reduction in plant stand of pearlmillet in different intercropping treatment. Pearlmillet fodder yield (2515 kg/ha) were found significantly higher with intercropping of pearl millet + moth bean (3:1) which remained at par with sole pealmillet cropping in pooled result.

TABLE 1
EFFECT OF INTERCROPPING ON GROWTH AND YIELD ATTRIBUTES OF PEARLMILLET UNDER RAINFED CONDITION (POOLED RESULTS)

Treatment	Plant height (cm)	Number of tillers per plant	Number of earhead per plant	Length of earhead (cm)	Grain yield (kg/ha)	Fodder yield (kg/ha)
Pearlmillet + Mothbean (1:2)	151.46	2.56	1.74	18.93	442	1267
Pearlmillet + Mothbean (2:1)	150.16	2.58	2.09	18.49	679	1927
Pearlmillet + Mothbean (1:3)	150.19	2.58	1.8	18.29	427	1075
Pearlmillet + Mothbean (3:1)	151.3	2.59	1.89	17.75	771	2515
Pearlmillet + Mothbean (2:2)	150.59	2.55	1.79	18.48	544	1743
Sole Pearlmillet	149.81	2.53	1.84	18.03	1021	2274
Mix Cropping	149.55	2.53	1.93	18.49	710	1689
S.Em.±	2.8	0.08	0.08	0.4	114.8	159
C.D. at 5 %	NS	NS	0.22	NS	341	473
Y X T	NS	NS	NS	NS	Sig.	Sig.
C.V. %	8.06	13.19	16.12	8.97	14.98	14.4

No significant effect was recorded in plant height (cm), number of branches per plant, pod per plant, pod length (cm) and seed per pod in mothbean by different intercropping systems. It might be due to no annidation effect were take place between intercrop and main crop with 45 cm row spacing. Sole Moth bean found significantly the highest moth bean seed yield (739

kg/ha) in pooled results. Mothbean fodder yield (3586 kg/ha) were found significantly the highest with sole moth bean in pooled results. The reduction in seed yield of mothbean in the intercropping system was mainly due to replacement type of intercropping system was followed in the present study so reduction in plant stand of mothbean in different intercropping treatment.

TABLE 2
EFFECT OF INTERCROPPING ON GROWTH AND YIELD ATTRIBUTES OF MOTHBEAN UNDER RAINFED CONDITION (POOLED RESULTS)

Treatment	Plant height (cm)	Number of branches per plant	Pod per plant	Pod length (cm)	Seed per pod	Seed yield (kg/ha)	Straw yield (kg/ha)
Pearlmillet + Mothbean (1:2)	43.19	4.44	36.35	3.74	5.19	425	2080
Pearlmillet + Mothbean (2:1)	40.85	4.11	40.04	3.7	5.26	238	1218
Pearlmillet + Mothbean (1:3)	41.78	4.63	38.53	3.69	5.18	523	2223
Pearlmillet + Mothbean (3:1)	40.99	4.13	39.69	3.76	5.3	151	679
Pearlmillet + Mothbean (2:2)	41.81	4.19	38.11	3.84	5.35	322	1488
Sole Mothbean	45.13	4.44	39.39	3.99	5.35	739	3374
Mix Cropping	42.88	4.02	37.94	3.76	5.21	329	1607
S.Em.±	1.3	0.19	1.68	0.08	0.13	60.61	125
C.D. at 5 %	NS	NS	NS	NS	NS	180	371
Y X T	NS	NS	NS	NS	NS	Sig.	Sig.
C.V. %	12.11	16.68	17.38	8.05	10.8	15.09	14.92

Apart from the competitive effects, prevailing price become an additional important factor in choosing the components of intercropping system and so mothbean yields were converted into pearl millet grain equivalent yield added with pearl millet grain yield in all the treatments for better interpretation of the results. Significantly higher pearlmillet equivalent yield (3466 kg/ha) was recorded under Sole Mothbean which remained at par with pearl millet + moth bean (1:3) intercropping (3305 kg/ha). Same way land equivalent ratio (LER) is considered as a measure of the efficiency of economic yield production of the crop mixture, compared with sole crops and based on land use. Here pearl millet + moth bean (1:3) gave higher peralmillet equivalent yield with LER more than one (1.13) which indicate that this intercropping system is beneficial. This is due to higher yield of mothbean and pearlmillet in the pearl millet + moth bean (1:3) intercropping system and thereby envisages effective utilization of the resources. Similar findings have been reported by Yadava *et al.* (2005), Yadava and Beniwal (2006) and Kandpal *et al.* (2015).

TABLE 3
EFFECT OF INTERCROPPING ON PEARLMILLET EQUIVALENT YIELD AND LAND EQUIVALENT RATIO UNDER RAINFED CONDITION

Treatment	Pearlmillet equivalent yield (kg/ha) (Pooled results)	Land Equivalent Ratio (LER)
Pearlmillet + Mothbean (1:2)	2973	1.01
Pearlmillet + Mothbean (2:1)	2421	0.99
Pearlmillet + Mothbean (1:3)	3305	1.13
Pearlmillet + Mothbean (3:1)	2165	1.37
Pearlmillet + Mothbean (2:2)	2629	0.97
Sole Pearlmillet	1589	-
Sole Mothbean	3466	-
Mix Cropping	2845	1.14
S.Em.±	257.66	-
C.D. at 5 %	758	-
Y X T	Sig.	-
C.V. %	9.6	-

**** Last year selling price (pearlmillet Rs 20/kg and mothbean Rs 70/kg) was considered for calculation of equivalent yield of all years***

Sole mothbean gave maximum net return (Rs. 44480) and BCR (2.44) followed by pearl millet + moth bean (1:3) intercropping (Rs. 35154 and 2.14). This could be due to higher yield of mothbean and peralmillet in pearl millet + moth bean (1:3) intercropping systems as compared to other systems. These results corroborated with the finding of Yadav and Jat (2005).

TABLE 4
ECONOMICS OF DIFFERENT INTERCROPPING SYTEMS UNDER RAINFED CONDITION

Treatment	PEY (kg/ha)	Gross return (Rs./ha)	Total cost of cultivation (Rs./ha)	Net return (Rs./ha)	BCR
Pearl millet + Moth bean (1:2)	2973	59460	30988	28473	1.92
Pearl millet + Moth bean (2:1)	2421	48420	31136	17284	1.56
Pearl millet + Moth bean (1:3)	3305	66100	30947	35154	2.14
Pearl millet + Moth bean (3:1)	2165	43300	31173	12127	1.39
Pearl millet + Moth bean (2:2)	2629	52580	31065	21515	1.69
Sole Pearl millet	1589	31780	31290	490	1.02
Sole Moth bean	3766	75320	30839	44480	2.44
Mix Cropping	2845	56900	30313	26587	1.88

IV. CONCLUSION

From the forgoing discussion it can be concluded that, rainfed pearlmillet should be grown as pearlmillet : mothbean (1:3) intercropping system with 45 cm spacing instead of sole pearlmillet for getting higher pearlmillet equivalent yield, net profit and insurance against failure of one crop.

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A Study on tribal Food Habits, Food Culture and Lifestyle of Changthang Region

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Abstract— *The district is located at a distance of around 430 km from Srinagar and 235 km from Kargil. The present study was conducted in the Changthang region of Leh District in UT Ladakh. The sample for the study was drawn from the Nyoma block of the Changthang region. The traditional food of Changthang people is based on animals, vegetables, and the cropping system of barley. Animal-based products (meat and dairy) are common. Most people eat dry yak and goat meat, which is sliced thinly and hung to dry after slaughter. By-products of livestock such as milk are used to make paneer, churpey (cottage cheese), butter (khakla maar), and ghee. Pastoral nomads consume only meat and milk from their livestock due to the absence of a cropping system, as they migrate in search of pasture for their livestock. During the winter, Changthang people sell livestock like goats, sheep, and yak in other parts of Leh. They face various challenges in life, especially regarding health and basic necessities, which impacts their social and economic life. Most people consume preserved products like dried meat and churpey. Traditionally, the agricultural system in the Changthang region was primarily for self-consumption. Krishi Vigyan scientists provide training on food preservation and value addition for milk products, vegetables, and barley, focusing on drying vegetables in a hygienic way without losing vitamins and minerals.*

Keywords— Changpa, Changthang, Livestock, Food, Agriculture.

I. INTRODUCTION

Changthang is a unique part of Ladakh, characterized by harsh climatic conditions with dryness and very low rainfall. The temperature varies from hot to extreme cold. This area is known as a Cold Himalayan Desert and has very low thermal and hydric indexes. July and August are the hottest months, while January is the coldest. In Changthang, average precipitation, mostly in the form of snow, is less than 10 mm, which can be fatal to livestock during the winter. The population predominantly leads a nomadic lifestyle, constantly moving in search of greener pastures for their livestock.

FIGURE 1: Changthang Location

The cropping system is agri-pastoral, with most of the area gross cropped. The average altitude of the region is around 14,600 meters above sea level. Changthang, covering an area of 21,000 square kilometers, occupies a strategic position, sharing borders with both China and Pakistan. It is home to thousands of Changpa nomads (Tashi Dolkar et al., 2017).

In Ladakh, women actively participate in all agricultural activities. In recent years, one of the notable features of the mountainous region of Ladakh has been the shift in the traditional subsistence economy towards livelihood diversification among genders. This diversification has had a direct impact on the dominant economic activities of the region (Tashi Dolkar et al., 2021).

Limited food resources and seasonal accessibility to vegetables and fruits make the population susceptible to nutritional deficiencies. However, like other isolated communities, Ladakhis have developed indigenous practices of food processing. As pastoralists, they incorporate milk and milk products to supplement their staples (Anup Raj et al., 2015).

The traditional food diets of the region are considered highly nutritious and healthy (Kala, Roy et al., 2004).

II. METHODOLOGY

The present study was conducted in the Changthang region of Leh District in UT Ladakh. Ladakh is divided into two main districts, Leh and Kargil. Leh District is located approximately 430 km from Srinagar and 235 km from Kargil. The sample for the study was drawn from the Nyoma block of the Changthang region. The information sources for the study were both primary and secondary. Secondary data was obtained from various published sources such as journals, magazines, books, and websites. The secondary data was used only after thorough scrutiny.

III. RESULT AND DISCUSSION

The way of life of the Changthang nomads shows their adaptability to the rugged cold desert environment. The nomads rely heavily on meat and dairy products to meet their nutritional needs, consuming very little other food. The traditional food of the Changthang people is based on animals, vegetables, and the cropping system of barley. Most people consume dried yak and goat meat after slicing it thinly and hanging it on threads to dry. By-products of livestock, such as milk, are used to make paneer, churpey (cottage cheese), butter (khakla maar), and ghee. Pastoral nomads consume only meat and milk, as they do not engage in farming due to their migratory lifestyle in search of pastures. Semi-nomads, however, cultivate green vegetables like cabbage, Swiss chard, spinach, potatoes, turnips, coriander, and mint.

Permanent settlers in Changthang villages cultivate a variety of vegetables and have a cropping system. After harvest, they dry dairy products, other food products, and vegetable leaves, storing them for the winter. Permanent settlers also rear cows, yaks, and dzomos. During the harsh winter, Changthang people consume more meat products than vegetables, as it fulfills their nutrient requirements and helps keep them warm. They slaughter yaks and goats before the onset of winter. Most people consume preserved products like dried meat and churpey.

Krishi Vigyan scientists have provided training and vocational courses on preserving and adding value to milk products, vegetables, and barley. They teach how to dry vegetables without losing essential vitamins and minerals in a hygienic way. Dried cottage cheese, or churpey, is a traditional fresh cheese widely consumed in the Ladakh region. Lactic acid bacteria (LAB) produce lactic acid through homolactic fermentation, causing milk to curdle and form churpey cheese.

Agricultural land in Changthang is primarily used to grow food crops such as grim (naked barley), wheat (in the Rong side of Changthang), peas, etc., which are conducive to the environment’s short growing season. Grim, locally known as "ne" or "nes," is one of the most important staple crops of Ladakh.

3.1 Cropping pattern:

The main crops grown in the Changthang region include barley, wheat (only in Liktsey village), mustard, peas, and other grains. Non-food crops mainly consist of fodder crops, especially alfalfa and oats.

3.2 Traditional Foods:

- **Tagi**: A type of bread that can be baked by covering it in ashes (Tagi Thaltak). Lighter versions of this bread are often eaten with tea.
- **Khambir (Skyurchuks)**: A sourdough bread made from yogurt and water, typically paired with butter tea.
- **Khura**: Fried biscuits, both salted and sweet, which are specially prepared for the Losar festival.
- **Chhang Kholak**: A fermented local drink made from barley, commonly consumed by travelers for refreshment.
- **Paba**: A pudding made from a mixture of grain and legume flours, widely eaten across Ladakh.
- **Zathuk**: A soup made from the leaves of the stinging nettle plant (*Urtica hyperboria*).
- **Tangthur**: A dish made with green leafy vegetables, served with buttermilk or yogurt.
- **Tsamik**: A sauce made from a blend of coriander, mint, radish, and onions.
- **Skyu**: A soup-based dish that includes vegetables and small dough balls.

FIGURE 2: Tagi Khamber

FIGURE 3: Khura

3.3 Traditional Drinks:

A. Butter Tea:

People of Ladakh drink butter tea throughout the day as it not only provides warmth but also keeps the body hydrated in the cold, high-altitude environment. Known locally as "gur-gur chai," the tea is prepared by boiling tea leaves and then churning them with butter, milk, and salt until thoroughly mixed.

B. Chhang:

Chhang is Ladakh's traditional local beer, commonly served to guests. It is made by fermenting barley and has an alcohol content ranging from 5% to 7%. Chhang is an important part of festivals, weddings, and other major events. In marriage proposals, a pot of chhang is presented to the girl's family; if accepted, it signifies their agreement to the marriage.

3.4 Common Wild Vegetables of Changthang:

TABLE 1
COMMON WILD VEGETABLES OF CHANGTHANG

Common Name	Local Name	Scientific Name	Part Used	Usage in Diet
Stinging nettle	Zatsot	*Urtica hyperboria*	Leaves	Zathuk is prepared and also mixed with various types of thukpa.
Wild onion	Skoche	*Allium przewalskianum*	Leaves	Used as an onion substitute for frying in curries; also mixed in thukpa.
Caraway	Ambuk/Konsnyot	*Carum carvi*	Leaves, Seeds	Mixed in thukpa and curries, also used as a condiment.
Chenopodium	Naval/Sniu	*Chenopodium foliosum*	Leaves	Mixed with thukpa, also used in preparing tangtur.
Sow thistle	Khala	*Sonchus oleraceus*	Leaves	Mixed with thukpa, also used in tangtur preparation.
Mallow	Suchili	*Malva neglecta*	Leaves	Mixed with thukpa.
Buckwheat	Dyat	*Fagopyrum tartaricum*	Leaves	Curry is prepared using the leaves.
Arnebia	Toma	*Arnebia euchroma*	Roots	Eaten raw or fried, often mixed with thukpa.
Gege	—	Bulb	Bulb	Eaten raw or fried, also mixed with thukpa.

3.5 Losar Festival:

The Losar festival marks the beginning of the New Year in Ladakh and is regarded as the most significant festival in the region. All respondents from various villages celebrate Losar, along with the birthday of the Dalai Lama. These celebrations include feasts and prayers at gompas (monasteries), and participants enjoy stage performances symbolizing the fight between good and evil. The date and location of the Losar festival change each year［Tashi Dolkar et al.］.

3.6 Health Status of Changthang People:

Most Changpa women suffer from anemia, and children are often deficient in vitamins due to the limited vegetative cover and low plant production, especially in remote areas. The diet is deficient in various important nutrients, leading to anemia and other deficiency diseases.

IV. CONCLUSION

The Changpa nomads of the Changthang region exemplify the traditional pastoral practices of the Himalayas. They use natural resources to shape their knowledge of making various foods. However, many women and children suffer from anemia and vitamin deficiencies due to poor vegetation and limited nutritional resources. The agricultural system is witnessing a shift, with an increasing focus on vegetable cultivation and a decline in the production of traditional crops.

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Contribution of Agroforestry Tree Species in Vindhyan Region of Uttar Pradesh, India

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Abstract— *As the population of India is increasing at a very fast rate; the land-holding size of farmers shrink at a very fast rate and agroforestry is the only way to optimize the farm productivity. The trees play an important role in fulfilling daily needs of people. The Eastern part of Uttar Pradesh in India is in great deficit of tree plantations on agriculture lands. Agroforestry is only way for growing trees on available lands in block/boundary plantations, thus, reducing pressure on forests for tree based needs in day-to-day life. As per latest report of FSI, 2021, only 9.23 % (6.18 % forest and 3.05 % Tree cover outside forests) area is covered with trees in the state of Uttar Pradesh. In Vindhyan region, total 15489782 trees were enumerated, where highest (2509795) number of trees were found in 121-150 cm girth class, followed by 2283850 trees in 151-180 cm girth class and 1996340 trees in 91-120 cm girth class Similarly, Eucalyptus tree possessed highest contribution (18.29%), followed by Mango(15.1%), Teak (14.34%) and Neem (13.83 %) .The smallest (629466) no. of trees were found in 271-300 cm followed by 756034 in 0-30 cm class. It clearly indicates that overall there is urgent need of time to plant these species in different agroforestry models to overcome wide demand supply gap of traditional tree species like, desi Mango, Neem, Teak, Eucalyptus, Mahua and Shisham. Similarly, new species, like Mahogany, Melia, Gamhar and Chironji may be planted in various agroforestry combinations in view of their great economic value. In recent past, Mahogany gave a good response in the region and 44358 no. of trees were found in 0-30 cm girth class in respective districts. Like Gamhar was also seen in some villages with 7747 no. of trees in 0-30 cm girth class in studied districts. The condition of Mahua planting is alarming as being a slow growing species, only 6798 no. of trees were found in 0-30 cm girth class. In new species, Melia dubia istaking good place, as 28646 trees were found in 0-30 cm class in villages. Chironji trees were rare in Mirzapur and Sonbhadra district and completely absent in Prayagraj district. In a total, only 4480 Chironji trees were recorded in the Vindhyan region. The girth class wise trees in Vindhyan region depicted that in 271-300 girth class, minimum number of trees were existing followed by 0-30 cm girth class and 31-60 cm class. This is clear that old trees were harvested at very fast rate for most of the species and less young plantations showed that these established and new tree species should be planted at fast rate in agroforestry so as to maintain their sustainable availability.*

Keywords— Agroforestry, ToFs, contribution, Vindhyan region, Eastern UP, sustainable availability.

I. INTRODUCTION

There are several challenges that reap the benefits of agroforestry in India. There is shortage of superior planting material and improved seed varieties (Verma *et al.,* 2017). In India, just as there is a great diversity in climate similarly there exists a large number of agroforestry systems of various forms and types (Dagar *et al*., 2014). As the population of India is increasing at a very fast rate; the land-holding size of farmers shrink at a very fast rate and agroforestry is the only way to optimize the farm productivity (National Agroforestry Policy, 2014). Growing trees outside forests (ToF) presents a significant environmental and economic opportunity in India. Nearly 80 million hectares (Mha) of these trees could sequester 3.4 gigatons of carbon dioxide-equivalent (Gt CO2e) by 2040 to help India achieve its international climate commitments. It can also support food and livelihood security for rural India, especially for its poor and vulnerable groups (Duraisami *et al.* 2022). The alternatives

of energy have been generated but still the wood energy is a prime energy source in domestic sector. The contribution of biomass is 14% of the world energy and 38% in developing countries (Dagar *et al.,* 2014). These changes in ecology and economics through on- farm trees are well documented and traditionally been followed. The wood demand has increased by over 60% and the output from forests has reduced to half in the same period. It is because of the dramatic rise of outputs from plantation and farm forestry, if has been reduced by over 50%. In the private sector, more than 50% of industrial timber is being contributed by agroforestry. The community lands share major part of the annual 250 million tons of fuel consumption (FSI, 2021). The trees play an important role in fulfilling daily needs of people. The Eastern part of Uttar Pradesh in India is in great deficit of tree plantations on agriculture lands. Agroforestry is only way for growing trees on available lands in block/boundary plantations, thus, reducing pressure on forests for tree based needs in day-to-day life. As per latest report of FSI, 2021, only 9.23 % (6.18 % forest and 3.05 % Tree cover outside forests) area is covered with trees in the state of Uttar Pradesh.

The Trees outside forests (TOFs) occur in natural and in cultivated landscapes and serve in a number of ecological and economic functions (Kleinn and Morales, 2005). Trees and other woody plants in the landscape serve also important ecological functions, particularly for the conservation of biodiversity, offering shelter and food, and nesting sites (Waltert *et al.,* 2005); other ecological functions are erosion control, water protection and carbon sequestration (Khadanga and Jaykumar, 2018; Bhardwaj and Panwar, 2003). It is now being increasingly argued that the role of TOF in providing food, wood and fuel to rural masses, carbon sequestration, prevention of soil erosion, biodiversity conservation, checking desertification, establishment of wildlife corridors and microclimatic stabilization, is quite substantial (Bhattarai, 2000) . The share of wood energy from non-forest land used for cooking in rural India is 59% while that of biomass energy is 90% (Saxena, 1997) . After the creation of Uttaranchal State, the forest cover including tree cover in Uttar Pradesh is only 9.20 % (FSI, 2021) of the total geographical area. This forest cover in the state is mainly confined to the Tarai and Vindhyan regions. In Eastern Uttar Pradesh, the forest cover is negligible and mostly in the form of small wood lots and plantations. In this region, due to population explosion, illiteracy, poverty and urbanization, the scope of increase in forest area is very limited. However, the vegetation cover may be increased by adopting social forestry, particularly the agro forestry.

This study shall be helpful in collecting the information regarding needs and suggestions about forestry in eastern U.P. To identify deficit Agroforestry species *viz. Melia dubia* (Barma drek), *Gmelina arborea* (Gamhar), *Neolamarckia cadamba* (Kadamb), *Swietenia macrophylla* (Mahogany), *Dalbergia sissoo* (Shisham), *Acacia nilotica* (Babool*), Mangifera indica* (Mango), *Azadirachta indica* (Neem), *Madhuca indica* (Mahua), *Eucalyptus sp.* (Safeda), *Poplar deltoids* (Poplar), *Buchanania lanzan* (Chironji) and *Artocarpus heterophyllus* (Kathal) in Vindhyan region of Uttar Pradesh for incorporating them in Agroforestry/ afforestation programmes, this study has been conducted. As forest cover in the districts of Vindhyan region, Prayagraj, Mirzapur and Sonbhadra is 2.36, 18.25 and 36.79 % respectively. In these districts, tree cover area is very negligible and green cover of the region can be increased well by increasing Agroforestry in the rural region. Thus, for making suitable choice of species on the basis of assessment of trees outside forests in the rural area may also give a clear picture of girth class-wise number of existing trees.

II. STUDY AREA

2.1 Vindhyan region:

The Vindhya region of Uttar Pradesh lies between 22° 45′ to 24° 34′ North latitude and 82° E to 83° 23′ East longitude. The forest of Vindhya region is tropical dry deciduous type. The rainfall varies from 1200-3720 mm in July-August. The Vindhyan region consists of the Vindhyan plateau and hills in the state. The topography consists mainly of plateau lands but has lot of local variations too.The soil of this region has red lateritic soils with often-pronounced nodules locally called “Murram”. Three districts - Prayagraj, Mirzapur and Sonbhadra existing in Vindhyan region were selected for study. Vindhyan region was with dense forests, but now depletion of this resources is increasing very fast due to developmental activities, agricultural land expansion and, of course, spurt in forest offences, like-illicit felling, encroachment, poaching etc. Factors, like- abiotic and edaphic, have also played a key role in determining and also restraining the growth of plant species in this area.

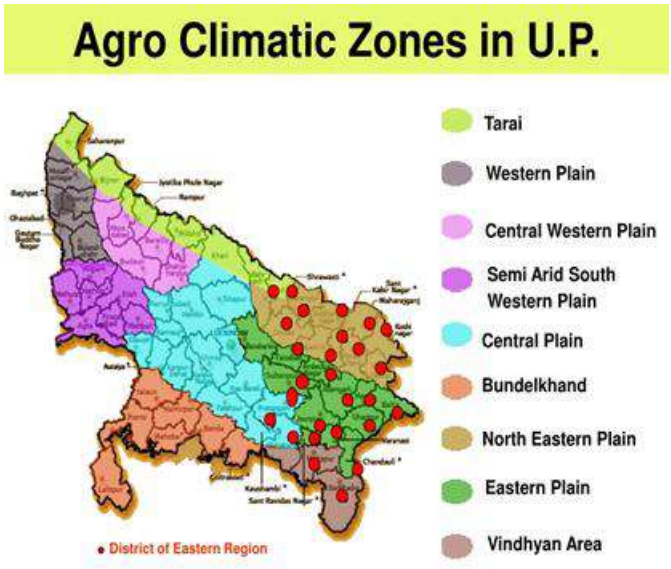

FIGURE 1: Vindhyan region in agro-climatic zones of U.P.

2.2 Prayagraj:

It is located in the southern part of the state, at between 24° 47′ to 25° 47′ North latitudes and 81° to 82° 21′ East longitudes, and stands at the confluence of the Ganga (Ganges), and Yamuna Rivers. Prayagraj division consists of Prayagraj, Kaushambi and Fatehpur districts. Prayagraj District consists of 8 Tehsils and 20 development blocks. It has an area of 5482.10 sq. km and borders the state of Madhya Pradesh. The district falls under the central Ganga alluvial plain. It has 23 developmental blocks.

2.3 Mirzapur:

Mirzapur is located at 23.52° & 25.32° North latitude and 82.7° and 83.33° East longitude. It is a part of Varanasi Division. This District is surrounded by the Varanasi, Sonbhadra, Prayagraj districts. Mirzapur is enriched with natural beauty and is located at a distance of about 60 km both from Varanasi and Prayagraj. It has an average elevation of 265 feet or 80 meters from sea level. South of Mirzapur is Sonbhadra district, on its north-west is Prayagraj district. Sandstone, red sand and ordinary sand are found aplenty in Mirzapur. Trees like mahua, neem, saal, teak, mango and guava are commonly found throughout the district.

2.4 Sonbhadra:

Sonbhadra lies between 23° 52′ to 25° 32′ North latitudes and 82° 72′ to 83° 33′ East logitudes. It is surrounded by Mirzapur, Chandauli, Kaimur and Rohtas District districts.The district headquarters is Robertsganj. Sonbhadra's major part of land is classified as forest land. But, very less no. of trees exist in the forest and in 40 percent of the land, urbanization led for crop cultivation.

III. METHODOLOGY

The districts Mirzapur, Sonbhadra and Prayagraj, located in Vindhyachal Region (Zone-9) were in study area. List of districts villages were compiled from population census records of U.P. One percent villages selected in each district- Prayagraj, Mirzapur and Sonbhadra, through purposive random sampling representing each block (with high population and tree growers). A total of 10 households of each selected village following stratified random sampling (Progressive - 04, Medium -03 and Lower -03) were taken. The demand and supply of selected species and socio-economic studies conducted for villages of selected districts in their respective tehsils through developed questionnaire. The data were collected through structured questionnaire for tree species existing in villages especially on farm bunds/block plantations, village road side, pond side and other locations.With the help of villagers locations were verified for tree orchards, agroforestry plantations The observations were grouped on the basis of the development blocks of the districts covering 1% of the total villages. In all three districts, species wise number of trees were tabulated in respective girth classes *viz.* 0-30, 31-60, 61-90, 91-120, 121-150, 151-180, 181-210, 211-240, 241-270 and 271-300 cm. After combining data in blocks of respective districts, the number of TOFs in rural area of district was assessed. The species wise percent contribution of trees for respective districts in Vindhyan region was

calculated (Manhas *et al.,* 2006; Explorable.com, 2009; Kothri, 2012; Cochrein, 1977; National Statistical Office (NSO); Anand *et al.,* 2016).

IV. RESULTS AND DISCUSSION

The tree species selected for the study were very common as Trees Outside Forests (TOFs) in rural area of the districts of Vindhyan region *viz.* Prayagraj, Mirzapur and Sonbhadra. The species as *Mangifera indica, Tectona grandis, Azadirachta indica* and *Dalbergia sissoo* were most demanded species of the region. The total enumerated tree species with respective girth classes in these districts of Vindhyan region had been depicted in results.

In Prayagraj, the results clearly depicted (Table 1, Fig. 2) complete picture of enumerated trees of selected fourteen species in the villages of the district. Out of total 7994888 number of trees, the highest no. of species was for Mango (17.42 %) followed by Neem (17.11 %), Eucalyptus (16.63%), Mahua (10.97%), Teak (10.35%), Babool (9.76 %), Shisham (9.62 %), Kathal (3.44%) and Kadamb (2.47%). The other new species as Melia, Mahogany, Gamhar and Poplar contributed 0.85%, 1.14%, 0.12% and 0.11% respectively. The Chironji trees were not found in the district. For Teak, young plantations in girth class of 0-30 cm were very less (21249 in the district). Similarly young plantations of Shisham was also negligible with 5540 number of trees. The young plantations of Neem and kalmi Mango was found in the district. In Mirzapur, the results clearly showed (Table 2, Fig.3) complete picture of enumerated trees of selected fourteen species in the villages of the district. Out of total 5739415 number of trees, the highest no. of species was for Eucalyptus (22.49 %) followed by Babool (16.93 %), Teak (16.07%), Mango (12.06%), Shisham (9.19 %), Neem (8.86) and Mahua (6.84%). The other new species as Melia, Mahogany, Gamhar, Chironji and Poplar contributed in very negligible number respectively. The young plantations of timber species were less, thus, needs to be planted in form of agroforestry/orchards /afforestation programmes of tree growers.In Sonbhadra, the results clearly depicted (Table3, Fig 4) complete picture of enumerated trees of selected fourteen species in the villages of the district. Out of total 1755479 number of trees, the highest no. of species was for Teak (26.85 %) followed by Neem (16.10 %), Mango (14.51 %), Eucalyptus (12.09%), Shisham (9.81 %) and Mahua (8.26 %). The other new species as Melia, Mahogany, Gamhar, Chironji and Poplar contributed in very negligible number.

In Vindhyan region, Table 4 and Fig. 5 indicated that out of total 15489782 trees enumerated in Vindhyan region, highest (2509795) number of trees were found in 121-150 cm girth class, followed by 2283850 trees in 151-180 cm girth class and 1996340 trees in 91-120 cm girth class. The smallest (629466) no. of trees were found in 271-300 cm followed by 756034 in 0-30 cm class. Similarly, Eucalyptus tree possessed highest contribution (18.29%), followed by Mango (15.1%), Teak (14.34%) and Neem (13.83 %) (Fig. 6, 7 & 8). It clearly indicates that overall there is urgent need of time to plant these species in different agroforestry models to overcome wide demand supply gap of traditional tree species like, desi Mango, Neem, Teak, Eucalyptus, Mahua and Shisham. Similarly, new species, like Mahogany, Melia, Gamhar and Chironji may be planted in various agroforestry combinations in view of their great economic value. In recent past, Mahogany gave a good response in the region and 44358 no. of trees were found in 0-30 cm girth class in respective districts. Like Gamhar was also seen in some villages with 7747 no. of trees in 0-30 cm girth class in studied districts. The condition of Mahua planting is alarming as being a slow growing species, only 6798 no. of trees were found in 0-30 cm girth class. In new species, Melia dubia istaking good place, as 28646 trees were found in 0-30 cm class in villages. Chironji trees were rare in Mirzapur and Sonbhadra district and completely absent in Prayagraj district. In a total, only 4480 Chironji trees were recorded in the Vindhyan region. The girth class wise trees in Vindhyan region depicted that in 271-300 girth class, minimum number of trees were existing followed by 0-30 cm girth class and 31-60 cm class. This is clear that old trees were harvested at very fast rate for most of the species and less young plantations showed that these established and new tree species should be planted at fast rate in agroforestry so as to maintain their sustainable availability (Table 5 and Fig 9).

The girth class distribution of Mahua is very much wide and young plantations are not taking up by the villagers. Mostly trees of Mahua were old aged and results indicated that an important species of timber was found occasional in villages. Majority of the farmers have adopted Teak on their farm bunds as agro forestry species. Most of the Teak trees are too young to be harvested. It is clear from tree enumeration studies that young plantations of desi Mango, Neem, Mahua and Shisham were less. Some other tree species as Jamun (*Syzygium cumini*), Arjun (*Terminalia arjuna*), Ashok (*Saraca asoka*), Sahjan, Aonla, Shahtoot, Siras, semal and Karanj (*Pongamia pinnata*) were seen occasionally in all three districts of the region.

TABLE 1
GIRTH CLASS WISE TOFS IN PRAYAGRAJ

PRAYAGRAJ																
S. No.	**Girth class (cm)**	**Teak**	**Shisham**	**Mahua**	**Eucalyptus**	**Melia**	**Mango**	**Neem**	**Gamhar**	**Mahogany**	**Chironji**	**Poplar**	**Kadamb**	**Kathal**	**Babool**	**Total**
1	0-30	21249	5540	4464	55356	15450	115647	61967	980	32682	0	2350	15620	8675	24234	364214
2	31-60	60761	11581	16680	91180	19170	74092	101181	1050	12924	0	3890	16980	26909	62222	498620
3	61-90	151041	57463	18737	205452	21340	98330	157420	5400	26722	0	1200	64097	43070	163831	1014103
4	91-120	158646	78533	29359	233898	12045	89338	194800	1290	18822	0	765	44119	78849	146761	1087225
5	121-150	153321	198358	143629	244927	0	212152	194454	1210	0	0	840	36212	66015	125135	1376253
6	151-180	104966	141411	159283	224205	0	192792	179906	0	0	0	0	9766	25451	67486	1105266
7	181-210	78425	117307	163751	136375	0	151044	171901	0	0	0	0	8056	13381	61945	902185
8	211-240	41631	83827	123895	79664	0	236820	175834	0	0	0	0	2370	5510	95092	844643
9	241-270	25819	54481	111204	34014	0	121499	101200	0	0	0	0	0	3014	25578	476809
10	271-300	31641	20717	106098	24669	0	100956	29437	0	0	0	0	0	3836	8216	325570
Total no. of trees		**827500**	**769218**	**877100**	**1329740**	**68005**	**1392670**	**1368100**	**9930**	**91150**	**0**	**9045**	**197220**	**274710**	**780500**	**7994888**
Mean		82750	76921.8	87710	132974	17001.25	139267	136810	1986	22787.5		1809	24652.5	27471	78050	799488.8
± SD		±	±	±	±	±	±	±	±	±	-	±	±	±	±	±
		55504.07	61457.16	63568.49	87205.47	4105.8	56362.22	59057.31	1912.47	8687.06		1325.05	21389.08	27006.02	53473.53	361524.69

TABLE 2
GIRTH CLASS WISE TOFS IN MIRZAPUR

MIRZAPUR																
S. No.	**Girth class (cm)**	**Teak**	**Shisham**	**Mahua**	**Eucalyptus**	**Melia**	**Mango**	**Neem**	**Gamhar**	**Mahogany**	**Chironji**	**Poplar**	**Kadamb**	**Kathal**	**Babool**	**Total**
1	0-30	58899	9508	2334	70949	12316	31133	38752	2800	3180	0	457	10127	8050	75680	324185
2	31-60	83765	47550	19001	107040	20899	36705	24472	3877	3710	0	1267	11774	9605	87678	457343
3	61-90	108080	44518	12261	132384	30569	51072	58934	4726	2650	0	590	17778	15902	151840	631304
4	91-120	127308	55646	27466	142333	29206	88357	63906	4748	1060	195	0	18846	11729	109563	680363
5	121-150	146897	71753	63403	204725	23636	100427	71875	7258	0	0	0	11073	25402	110073	836522
6	151-180	146225	101229	63866	149440	20215	138126	69786	2551	0	380	0	24865	18903	135596	871182
7	181-210	62082	80083	77954	162814	0	99121	80853	0	0	0	0	16673	28918	86613	695111
8	211-240	110070	85037	34926	181067	0	57631	39705	0	0	0	0	17715	13393	69760	609304
9	241-270	63705	18365	60870	66698	0	49635	25299	0	0	0	0	1909	5309	68229	360019
10	271-300	15369	13826	30319	73330	0	39713	17918	0	0	0	0	0	7139	76468	274082
Total no. of trees		**922400**	**527515**	**392400**	**1290780**	**136841**	**691920**	**491500**	**25960**	**10600**	**575**	**2314**	**130760**	**144350**	**971500**	**5739415**
Mean		92240	52751.5	39240	129078	22806.83	69192	49150	4326.67	2650	287.5	771.33	14528.89	14435	97150	573941.5
± SD		±	±	±	±	±	±	±	±	±	±	±	±	±	±	±
		42839.1	31922.37	25589.23	48337.28	6667.88	35289.18	22635.9	1709.71	1144.93	130.81	434.38	6604.44	7896.33	28802.52	210686.99

TABLE 3
GIRTH CLASS WISE TOFS IN SONBHADRA

SONBHADRA																
S. No.	**Girth class (cm)**	**Teak**	**Shisham**	**Mahua**	**Eucalyptus**	**Melia**	**Mango**	**Neem**	**Gamhar**	**Mahogany**	**Chironji**	**Poplar**	**Kadamb**	**Kathal**	**Babool**	**Total**
1	0-30	27720	2849	0	6250	880	7061	1716	3967	8496	1111	150	5398	220	1817	67635
2	31-60	39025	1376	0	2440	1720	1817	9864	4361	7516	1160	280	6029	80	5767	81435
3	61-90	76745	35931	1430	23775	2950	16471	39657	7756	1265	1114	190	6272	11628	25799	250983
4	91-120	72547	32515	640	25642	2928	16479	34880	1027	0	620	0	5178	16656	19646	228758
5	121-150	77768	21760	2548	58538	1342	61062	44539	5257	0	300	0	4578	11204	8124	297020
6	151-180	56023	34775	32527	54995	0	45672	65956	0	6139	0	0	3753	3296	4266	307402
7	181-210	63100	23747	34102	27038	0	48450	31779	0	1809	0	0	0	5846	0	235871
8	211-240	9150	12314	35004	13590	0	24184	34782	0	612	0	0	3197	510	0	133343
9	241-270	49300	4765	24163	0	0	24698	15215	0	5077	0	0	0	0	0	123218
10	271-300	0	2186	14556	0	0	8846	4226	0	0	0	0	0	0	0	29814
Total no. of trees		**471378**	**172218**	**144970**	**212268**	**9820**	**254740**	**282614**	**22368**	**30914**	**4305**	**620**	**34405**	**49440**	**65419**	**1755479**
Mean		52375.33	17221.8	18121.25	26533.5	1964	25474	28261.4	4473.6	4416.29	861	206.67	4915	6180	10903.17	175547.9
± SD		±	±	±	±	±	±	±	±	±	±	±	±	±	±	±
		23552.85	14213.47	15230.93	20710.44	938.48	19837.6	20290.75	2425.71	3184.8	383.64	66.58	1140.19	6301.67	9581.62	100311.79

TABLE 4
GIRTH CLASS WISE TOFS IN VINDHYAN REGION

GIRTH CLASS WISE TOTAL TREES IN VINDHYAN REGION																
S. No.	**Girth class (cm)**	**Teak**	**Shisham**	**Mahua**	**Eucalyptus**	**Melia**	**Mango**	**Neem**	**Gamhar**	**Mahogany**	**Chironji**	**Poplar**	**Kadamb**	**Kathal**	**Babool**	**Total**
1	0-30	107868	17897	6798	132555	28646	153841	102435	7747	44358	1111	2957	31145	16945	101731	756034
2	31-60	183551	60507	35681	200660	41789	112614	135517	9288	24150	1160	5437	34783	36594	155667	1037398
3	61-90	335866	137912	32428	361611	54859	165873	256011	17882	30637	1114	1980	88147	70600	341470	1896390
4	91-120	358501	166694	57465	401873	44179	194174	293586	7065	19882	815	765	68143	107234	275970	1996346
5	121-150	377986	291871	209580	508190	24978	373641	310868	13725	0	300	840	51863	102621	243332	2509795
6	151-180	307214	277415	255676	428640	20215	376590	315648	2551	6139	380	0	38384	47650	207348	2283850
7	181-210	203607	221137	275807	326227	0	298615	284533	0	1809	0	0	24729	48145	148558	1833167
8	211-240	160851	181178	193825	274321	0	318635	250321	0	612	0	0	23282	19413	164852	1587290
9	241-270	138824	77611	196237	100712	0	195832	141714	0	5077	0	0	1909	8323	93807	960046
10	271-300	47010	36729	150973	97999	0	149515	51581	0	0	0	0	0	10975	84684	629466
Total		**2221278**	**1468951**	**1414470**	**2832788**	**214666**	**2339330**	**2142214**	**58258**	**132664**	**4880**	**11979**	**362385**	**468500**	**1817419**	**15489782**
Mean		222127.8	146895.1	141447	283278.8	35777.67	233933	214221.4	9709.67	16583	813.33	2395.8	40265	46850	181741.9	1548978.2
± SD		±	±	±	±	±	±	±	±	±	±	±	±	±	±	±
		115138.84	97896.54	99907.76	145694.89	13270.31	98404.83	96792.87	5388.52	15820.05	387.42	1924.63	25792.73	36280.76	84631.15	662410.42

TABLE 5
SPECIES-WISE CONTRIBUTION OF TREES OUTSIDE FORESTS IN DISTRICTS OF VINDHYAN REGION

Species	Prayagraj (a)		Mirzapur (b)		Sonbhadra (c)		Vindhyan region (a+b+c)		Score in region
	Number	Contribution (%)	Number	Contribution (%)	Number	Contribution (%)	Number	Contribution (%)	
Teak	827500	10.35	922400	16.07	471378	26.85	2221278	14.34	3
Shisham	769218	9.62	527515	9.19	172218	9.81	1468951	9.48	6
Mahua	877100	10.97	392400	6.84	144970	8.26	1414470	9.13	7
Eucalyptus	1329740	16.63	1290780	22.49	212268	12.09	2832788	18.29	1
Melia	68005	0.85	136841	2.38	9820	0.56	214666	1.39	10
Mango	1392670	17.42	691920	12.06	254740	14.51	2339330	15.1	2
Neem	1368100	17.11	491500	8.56	282614	16.1	2142214	13.83	4
Gamhar	9930	0.12	25960	0.45	22368	1.27	58258	0.38	12
Mahogany	91150	1.14	10600	0.18	30914	1.76	132664	0.86	11
Chironji	0	0	575	0.01	4305	0.25	4880	0.03	14
Poplar	9045	0.11	2314	0.04	620	0.04	11979	0.08	13
Kadamb	197220	2.47	130760	2.28	34405	1.96	362385	2.34	9
Kathal	274710	3.44	144350	2.52	49440	2.82	468500	3.02	8
Babool	780500	9.76	971500	16.93	65419	3.73	1817419	11.73	5
Total	**7994888**	**100**	**5739415**	**100**	**1755479**	**100**	**15489782**	**100**	**-**

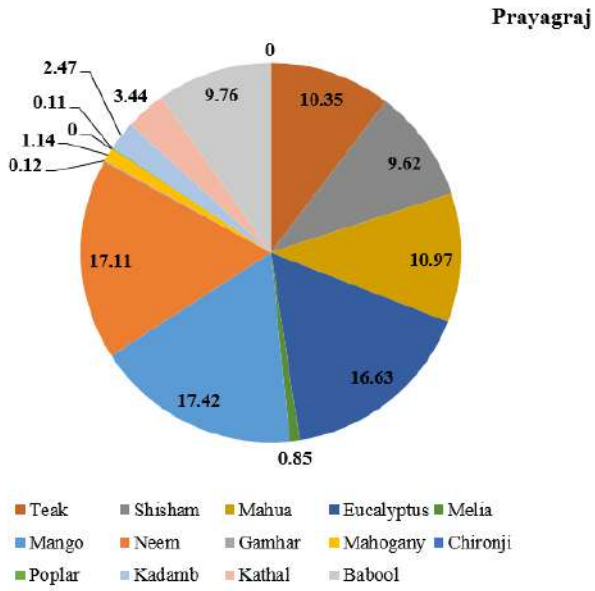

FIGURE 2: Contribution (%) of Tree species in Prayagraj

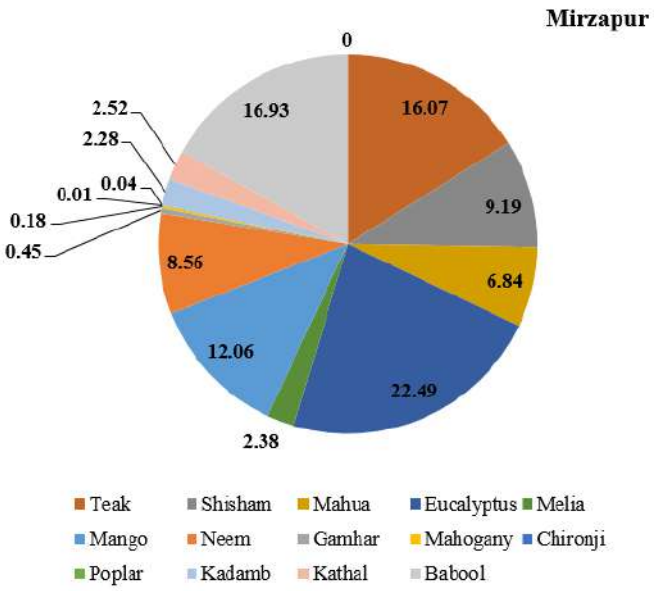

FIGURE 3: Contribution (%) of Tree species in Mirzapur

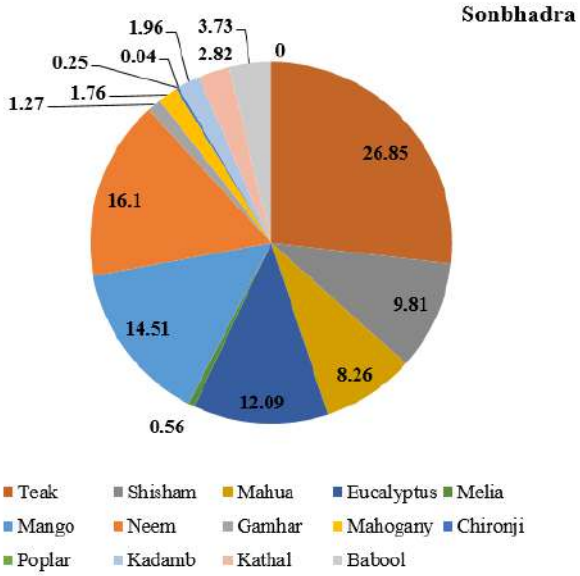

FIGURE 4: Contribution (%) of Tree species in Sonbhadra

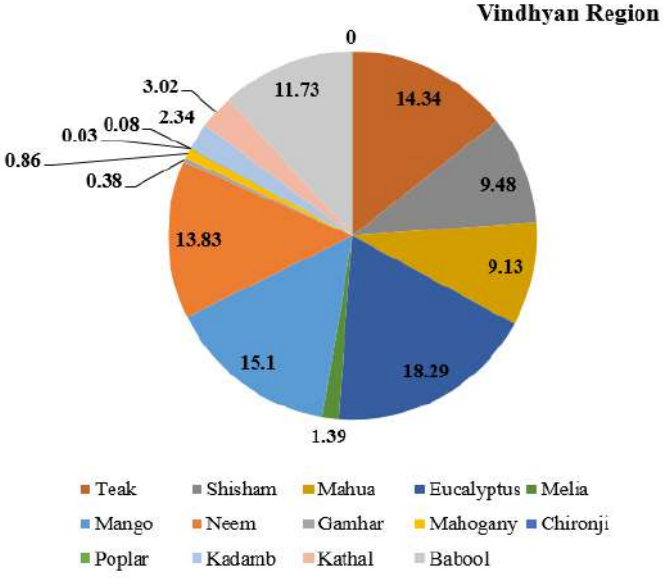

FIGURE 5: Contribution (%) of Tree species in districts and Vindhyan region

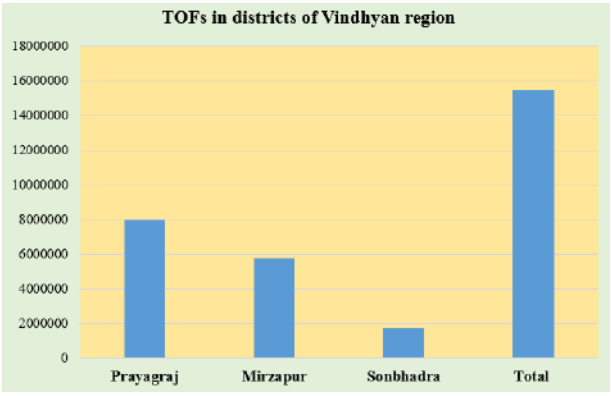

FIGURE 6: TOFs in districts of Vindhyan region

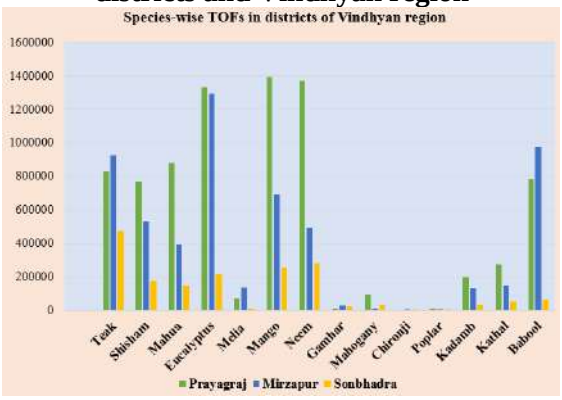

FIGURE 7: Species-wise TOFs in districts of Vindhyan region

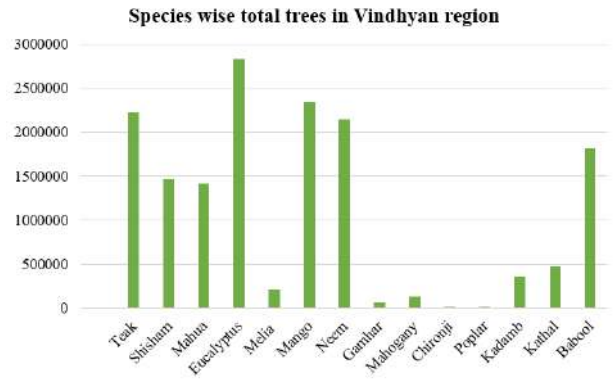

FIGURE 8: Species wise ToFs in Vindhyan region

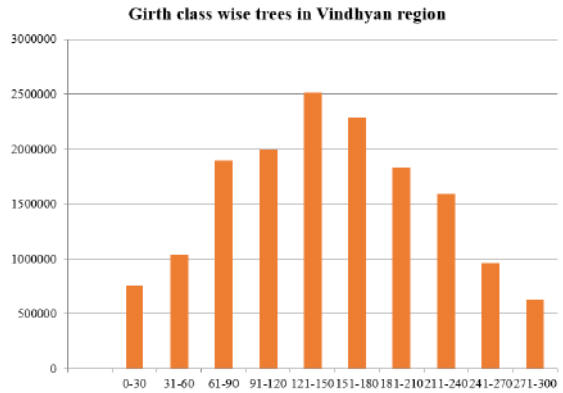

FIGURE 9: Girth class wise trees in Vindhyan region

The farmers have little opportunities to select the tree species and therefore, they accept whatever is available on their land. Bhatt *et al.,* (2010); Dadhwal *et al.,* (1989) and Toky *et al.,* (1989) have recognized three agroforestry systems with their multifarious benefits. The various problems and constraints of agroforestry can be overcome through policy and institutional reforms (Smith *et al.*,1998). Moreover, there is deficiency in the understanding of biophysical concerns correlated with productivity, water-resource sharing, soil productivity and plant interactions in agroforestry systems, since most of the research is site-specific, observational in nature and not process-oriented (Puri and Nair, 2004). In almost all tropical and subtropical eco zones, agroforestry is represented by the homestead farming, essentially the mixed cropping of annual and perennial crops around the farmer's dwelling houses. Home gardens are recognized worldwide as an epitome of sustainable agroforestry systems (Torquebiau, 1992; Kumar & Nair, 2004). Thus, agroforestry practices can be an important tool to get four per cent sustainable growth in agriculture (National Agroforestry Policy, 2014). The upgradation of agroforestry is possible through agroforestry policy, industries, NGOs and participation of different stakeholders (Verma *et al.*, 2017). The Farmers with major land holdings will get more benefit by the agroforestry related schemes than other catefory of farmers. So, there is need to introduce special programmes on agroforestry models for marginal and small farmers (Verma *et al.,* 2017) because 2/3rd farmers of Indian farmers are small and marginal farmers (Kumar *et al.*, 2017; Singh & Pandey, 2011). Jain & Singh (2000) stated that it is needed to strengthen the agroforestry practices by identifying successful models that can be adopted by the farmers on a wide scale. Advancement of contemporary agricultural technology would also be helpful in increasing the yield of sole crops as well as intercrops.

V. CONCLUSION

The systematic pattern in tree planting needs to be improved for the region. It is well known that western part of U.P. is more flourished than Eastern part for adoption of agroforestry. It is now urgent need of time to adopt tree plantations in massive way in districts of Vindhyan zone to increase green cover in the region and decrease pressure on forests. Agroforestry is the only way for progress of farmers and rural people, leading to sustainable development, food and nutritional security. Agroforestry adoption with suitable recommended species of economic value will improve state / country forest and tree cover to the 33 percent as desired in national forest policy. The foresters, researches, NGOs, tree growers and traders are needed to coordinate for successful implementation of tree plantation in agroforestry at large level. Further, to enhance the efforts of farmers, sale of end products should be strengthened with the involvement of project planners and wood based industries.

VI. ACKNOWLEDGMENT

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Land Conversion: An Economic Boon or Bane in Central Luzon's Agricultural Sector

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Abstract— *This study explores the economic impact of land conversion on the agricultural sector in Central Luzon from 1981 to 2021, using the Cobb-Douglas production function as the analytical framework. Employing key econometric tools—such as the Augmented Dickey-Fuller (ADF) test for stationarity, Johansen cointegration for long-term relationships, and Ordinary Least Squares (OLS) regression—the analysis shows that all variables are stationary. Farm size is positively correlated with rice output, while labor use and the man-land ratio negatively affect production. The findings highlight the vital role rice production plays in the household income of Central Luzon, indicating that while it has contributed to modest but steady economic growth, land conversion has acted as an economic boon, promoting development opportunities in the region. The study concludes by urging policymakers to craft strategies that enhance agricultural productivity and ensure sustainable income for farmers, contributing to broader economic prosperity. Future research should examine the specific types of land being converted from agriculture, assess the long-term impacts on different crops, and consider how land conversion affects the region's overall agricultural sustainability. This will provide a more comprehensive understanding of the broader implications of land use changes on Central Luzon's economy.*

Keywords— Arable Land, Central Luzon, Employment Rate, Man-land Ratio, Land Conversion.

I. INTRODUCTION

Urbanization has proven to be a vital tool for ensuring a healthy economy in every country (Pradhan et al., 2021). In a study by Magazzino and Mele (2021), improving transportation by putting road-building projects across western counties in more than 15 areas is one strategy to support economic growth in China. However, Shaban et al. (2022) assert that the impact on economic growth may differ depending on the degree of urbanization and economic development of a particular nation. The possible causes of urbanization include a natural increase in the man-land ratio, which refers to the number of farmers who have lost their jobs due to land conversion, rural-to-urban migration, which affects the employment and income opportunities of the people, and the productivity of the land that determines the capability of the farmland to be transformed. Because there is a hope of having a better standard of living in the urban areas, people are starting to migrate, causing a continuous increase in the population.

As a result, it is necessary to meet the needs of the people in terms of housing, work, and educational prospects, in addition to providing easier access to social services and more chances for social and cultural activities (OLCreate, n.d.). However, while civilization causes towns and cities to thrive, it also has negative implications regarding agriculture since it affects the lands, particularly in the rural areas, through land conversion. For this to occur, urbanization considers the farmland values and their determinants, such as location, distance, travel time, size, farm income, soil productivity, and the like (Tavares et al., 2022).

Transforming agricultural lands into non-agricultural or manufacturing ones is considered as industrialization. According to Harini et al. (2018), demand for land rises along with population growth and socioeconomic activity. Without keeping pace with land supply, agricultural land will decline, leading to decreased agricultural production in an area. Hence, it is evident how it typically occurs in less-developed countries such as the Philippines since there is a need for commercial, residential,

and industrial development, especially in the country's rural areas (Fulgar, 2023). However, it also mentioned how it affected the food security and livelihoods of the people relying on the agricultural sector. In a study by Bravo (2017), significant land conversion brought about by urbanization and industrialization altered the agricultural environment of the Metropolitan Manila area. It substantially decreased the amount of land used for crop production. Additionally, it put pressure on the periphery of cities, which made land use conversion in cities inevitable.

According to a study by Dait (2023), because rice, or palay, has always been at the core of Philippine agricultural policy, it is regarded as a highly political commodity in the nation. The country's rice basket, which is located in Region III, or Central Luzon, and is made up of the provinces of Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales, is often the site of farmland conversion because it is a thoroughfare and a popular destination for real estate developers seeking more reasonably priced housing outside of Metro Manila (Fair Finance Asia, 2021). Based on the report of the Department of Agriculture (DA), from several years ago up to now, Central Luzon is classified as the top producer of palay in the Philippines, specifically in Nueva Ecija. The province is known as the "Rice Granary of the Philippines" since it is the country's number one producer of palay, producing 13,499.54 thousand metric tons from 4006.4 in 2003 (Santos et al., 2018). Also, in an article by Tecson (2023), the region has been a consistent top producer during recent years by producing 867,084 metric tons of palay, contributing 18.1 percent to the country's agricultural output. However, since farm inputs are continuously increasing in price, farmers tend to use chemical fertilizers and pesticides and, worse, sell their lands to commercial developers, which are privately owned, just like in Candaba Swamp in Pampanga, leading to a threat to biodiversity and food security (Costamero, 2023).

In an article written by Navales in 2019, he said land use conversion projects such as roads and industrialized areas have been covering productive lands in the region, threatening the livelihood of the farmers, food security, and self-sufficiency of the people in the area. Moreover, the presence of the North Expressway during 1981 was very noticeable in that it transformed 9.07 hectares of land into asphalted or cemented streets. In 1991, an average of ten percent (10%) of agricultural land in Plaridel, Bulacan, was converted to residential, commercial, or institutional areas per year, covering 361.27 hectares of total land area to roads and built-up areas (Nantes, 2011). Large national real estate firms have developed and are currently developing several housing developments and subdivisions in Bulacan, including three San Jose del Monte subdivisions and a 300-hectare residential property in Malolos (Arceo-Dumlao et al., 2021).

Therefore, it will be difficult for recognized beneficiaries of land-use conversion to get a statewide ban on it in order to conserve the rice fields of Central Luzon. An act from the Office of the Secretary of the DA (2019), regarding land conversion in the country, the "2002 Comprehensive Rules on Land Use Conversion," states that conversion of agricultural land to non-agricultural uses shall be strictly regulated and may be allowed only when certain conditions are met. As approved by the Department of Agrarian Reform (DAR), land use conversion alludes to the act or process for converting a piece of agricultural land from its existing physical use—such as cultivating soil, planting crops, or growing trees—to another usage or for an agricultural purpose other than farming and reaping its produce.

Cobb and Douglas' (1928) production theory shall serve as a foundation for this study. It states that there is a relationship between the units of factors of production and the units of output of goods and services. It also demonstrated that if the number of inputs used changes, the units of output produced will likewise change. In this research, it explores how the independent variables will cause a change in the dependent variable.

Several studies have been conducted regarding the relationship of several factors of the agricultural sector such as arable land, employment opportunities, and man-land ratio on how it influences rice output. Most of these studies are focused primarily on the national level, with a few focusing on Central Luzon. In addition, only a limited number of studies have concentrated on whether the agricultural sector, through rice production, is beneficial to the economy.

This study will benefit society and agricultural communities since they will know whether land conversion boosts economic growth and productivity. Moreover, the current undertaking hopes to contribute to the existing knowledge in the academe pertinent to the effects of land conversion on agricultural production and consequently to people, specifically to the farmers' average income. As a business economics student, this research will allow the researcher to apply the principles and theories learned inside the classroom and apply them on a vital sector of the economy that significantly impacts the nation as a whole. Lastly, this will benefit municipal and national policymakers as they will have information intended for the agricultural sector in the region. The researcher will further explore the relationship between the variables involved in this study. Hence, this educational endeavor hopes to provide an extensive and exhaustive perspective on the effects of land conversion in the agricultural sector in Region III.

This research aims to identify and explore the presence of Cobb-Douglas production theory in the Philippines, specifically in Central Luzon's agricultural sector. It investigates the effects of (IV1) quantity of arable land available, (IV2) employment rate, and (IV3) man-land ratio to (DV1) rice output and (DV2) average income earned. Specifically, this study seeks: To determine how the quantity of arable land, employment ratio, and man-land ratio affect rice output in Central Luzon; To determine whether the changes in the level of rice output is a boon or bane in Central Luzon as measured by the average income earned by the farmers. This data analysis will be carried out across all the provinces in the region to ensure thorough analysis and conclusion.

This study limits itself to the Philippines, particularly Central Luzon (Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales), as the country's notable palay producer. Data will come from secondary sources and publicly available statistics. This study will only validate the impact or relationship between the three (3) independent variables, quantity of arable land, employment rate, and man-land ratio on rice output. The effects or consequences of these independent factors will not be covered. The question of whether or not land conversion benefits the local economy, based on its agricultural sector, will also be covered. Furthermore, the data covered in this study spans 41 time periods, commencing from 1981 to 2021. Hence, the study's findings might only partially reflect the present situation or effectively anticipate future trends.

II. REVIEW OF RELATED LITERATURE

Industrialization through land conversion is one way to boost the economic growth of a country; hence, understanding the factors influencing it will help determine whether it is advantageous to the economy or not. This proposal shall be anchored on Cobb and Douglas' (1928) production theory, which explains how production factors affect the output units. This study will focus on agricultural production factors such as land and labor such as arable land, employment rate, and man-land ratio. Specifically, this aims to identify how the three factors, the farm size, labor use, and man-, will affect rice output and, consequently, the average income earned by the farmers in Central Luzon.

2.1 Rice Output:

The agriculture industry is under pressure to supply the growing demand for food due to the growing population (Shah and Wu, 2018). Chen et al. (2019) emphasized that to guarantee food security in China, 120 million hectares of arable land—the so-called "red line" for food security—must be preserved, and crop yield must be increased to assure domestic production and self-sufficiency. Various elements affect crop productivity, but different approaches affect the crops differently (Ochieng et al., 2016). Porciuncula et al. (2015) state that rice production, with onion, corn, and vegetables grown as supplementary crops, is the most productive crop in the provinces of Nueva Ecija, Pampanga, and Zambales. Based on the findings of the study by Gollin et al. (2014), world income inequality can only be fully understood by first recognizing agricultural productivity.

2.2 Arable Land:

A range of factors, including soil quality, construction quality, space quality, eco-environmental quality, and beauty and cultural quality, can be categorized as arable land quality, according to Du et al. (2016). The quality of arable land is determined by the interplay of the natural system, the use system, human demand, and it also represents the full range of services performed by the farmland ecosystem (Ye et al., 2022). A study by Pozza and Field (2020), land access is essential in rural communities and that soil health is necessary to prevent land degradation. Since soil erosion is one cause of degradation that impacts around 20% of the world's arable systems (Prăvălie et al., 2021).

2.2.1 Quantity of Arable Land Available on Rice Output:

Arable land is the most critical agricultural output component (Tsue et al., 2014). However, as development demands rise, competition for land has resulted in the conversion of many agricultural lands. In addition, even if there is an increase in agricultural land, various issues have arisen such as a million hectares of land being converted into urban use in such a short period of time (Kong, 2014). A study by Han et al. (2020) noted that one of the most critical tools for macro-controlling urban expansion has always been land use regulation, which can directly impact a city's land values and subsequently influence the linked urban economic well-being. Land demand rises with population growth and socioeconomic activity, potentially resulting in arable land and productivity decline as economic and physical factors drive most land conversions (Kong, 2014; Harini et al., 2018; Farah et al., 2019). For instance, in Shanghai, China, industrial land grew from 1947 to 1993 but declined from 2002 to 2016 because of land prices, existing industrial land, distance to the central transport station, and economic development level (Fan et al., 2020). Also, from 1987-2010, there was a reported 34.8% of total cropland loss due to built-up land expansion

(Ju et al., 2018). Lastly, (Abubakari, Anaman, & Ahene-Codjoe, 2022) established that 48.7% of Ghana's accessible land area in 2020 was made up of built-up areas.

Urbanization and industrialization are economic growth drivers typically involving land conversion (Pradhan et al., 2021; Opoku & Yan, 2018). It caused many tensions and complaints among those affected, such as agricultural workers, while other stakeholders, such as government agencies and state-owned enterprises, found it profitable (Phuc et al., 2014). Converting agricultural land to urban areas can pose social, cultural, environmental, and economic challenges due to the need to accommodate more people in a smaller space while meeting their demands for resources and services (Peerzado et al., 2019; Kovács et al., 2019). As such, it is essential to weigh the benefits and drawbacks of both rural and urban growth, as arable land is essential for livelihoods (Tavares et al., 2022).

Since land availability is limited, it is a must for efficient land use. In European Union (EU) countries, the population continues to expand, which means more food is needed in the future, a reason to maintain arable lands needed for crop production (Némethová et al., 2022). Furthermore, in a study by Nilsson (2018), more crops can be grown if enough land is available. There are instances where agricultural land is situated in highly inappropriate and unsuitable places, which results in low productivity and environmental impact such as small farm sizes, slow growth rates, poor access to financing, post-harvest losses, and low levels of mechanization and commercialization, preventing cropland from expanding to boost output. (Mesgaran et al., 2017; Ngowi 2022). Negative implications of this agricultural and industrial land conversion, such as issues between the State, investors, and farmers whose land is acquired, show unfair benefit-sharing among the stakeholders, making farmers the least benefited (Nguyên et al., 2016). This demonstrates how industrialization can conflict with people's needs, goals, and preferences (Utami et al., 2022).

As Pia (2021) reported, 89.031 agricultural lands in Butuan City, Philippines, from 2014 to 2016 were converted into non-agricultural use. Furthermore, more arable lands in Central Luzon were being transformed into commercial and residential areas due to urbanization and industrialization, according to reports by German et al. (2022). In Ifugao rice terraces, mountainous agricultural landscapes tend to undergo frequent land cover changes which includes agricultural abandonment and afforestation (Estacio et al., 2022). A reason for this is when the area has been urbanized, and the land would have a higher economic value for residential, commercial, or industrial uses, or when the land is no longer economically viable and sound for agricultural purposes (Arceo-Dumlao et al., 2021). Accordingly, the study by Navarro (2023) comes to the conclusion that implementing a National Land Use Agreement (NaLUA) through a suitable institutional mechanism can aid in resolving land use issues in the country.

2.3 Employment Rate:

Sustainable farming should maintain natural ecosystems and services while simultaneously producing nutritious meals and a means of livelihood for farmers (Giller et al., 2021). But even in cases where population growth is low, research by Tschirley et al. (2015) and Yeboah and Jayne (2020) indicates that the percentage of employment in farming is steadily declining. In most developing countries, it is evident how the agricultural output due to the workforce is seriously decreasing, which potentially harms the price and availability of food for the poverty (Alston & Pardey, 2014).

Preparing the youth, aged 15 to 24, for the workforce is one of the Philippines' biggest developmental concerns, where the leading industry is agriculture (Budhrani et al., 2017). A study by Palis (2020) mentioned that most farmers do not want the same type of job for their children, which can result in unemployment in the farming sector.

2.3.1 Employment Rate on Rice Output:

It is necessary to use inputs such as land, labor, capital, and entrepreneurship when producing output. Traditional agricultural production relies on two main inputs: land and labor, which are the primary tools for increasing output. As a result, farmers' work and their land are essential for crop production. The production style, crop variety, and previous land usage affect direct employment and may help prevent smallholder farmers from being forced out of the market (Nolte & Ostermeier 2017). However, despite their crucial role in production, the quantity of farmlands is decreasing, and farmers are not adequately compensated. For instance, in the barangay of Lumbia in Cagayan De Oro, farmers face economic difficulties such as poverty, income, education, and housing tenure that lead to land conversion (Navarro et al., 2017). A study by Ghatak and Mookherjee (2014) mentioned that farmers lease land from private wonders or local governments with a sharecropping contract before ownership.

Most jobs are in the non-farm sector, such as civil-service employees (Jayne et al., 2016). Das and Paul (2021) employed a thorough literature review to determine the possible impacts on urban growth, followed by charts and graphs to illustrate and OLS test using R Programming for necessary recommendations. So, it has always been a global issue as employment shifts away from agriculture as the world's population grows. Although agriculture employs most people in Asian countries, it decreased by 20.68% in South Asia and 28.82% in East Asia between 1991 and 2019 (Das & Paul, 2021).

Nguyen et al. (2016) estimated the degree of variability in economic benefits among stakeholders and analyzed changes from conversion through a bottom-up approach, finding that agricultural land conversion for urban development is a significant process in many cities' surrounding areas. However, numerous landless farmers are a significant part of the rapidly expanding urban population (Tang et al., 2016). Such developments provide unequal benefits among different stakeholders, with farmers benefiting the least from urban development due to the many difficulties associated with transitioning from agricultural to non-agricultural livelihoods, such as sustaining non-agricultural activities, finding stable alternative income activities, and using compensation for capital investments. Also, it causes a threat to the livelihood of individuals leaving the farming industry because they have to deal with a higher workforce, and factors of knowledge and expertise make non-agricultural employment more challenging for farm workers, causing a decline in agricultural employment (Suharyanto et al., 2021). It increased the number of land-lost farmers at risk of unemployment; a few continue to work in agriculture, but the well-being primarily become unemployed (Yong, 2019; Siciliano, 2013).

The shift in employment structures in rural areas has caused non-agricultural labor incomes to increase because of the increase in non-agricultural employment opportunities for farmers as a result of the urbanization process (Coulibaly & Li, 2020). Overall, the increase in urban land expansion diminishes the availability of land among farmland households near urban areas, consequently negatively affecting their livelihood and overall well-being.

According to Sims et al. (2019), using panel regression models and estimated with heteroskedasticity robust standard errors, found that land protection positively affects employment. Similar to Zambia, where policies related to land administration and agricultural spending have resulted in the emergence of 95% of farming households (Sitko and Jayne, 2014). As a result, Ge et al. (2020) stated that it is critical to support the rural transformation to provide employment opportunities that are appropriate for meeting the needs of the area and attracting rural migrants to return and establish businesses in the area.

According to Das and Paul (2021), when a country is heavily urbanized, a declining employment in agriculture will be observed and this is observed in Asian countries which contribute to most of the agricultural sector. During the past two decades, urbanization in the Philippines has reached and increased more in rural areas, resulting in significant land conversion of agricultural lands and decreased employment in the agricultural sector due to shift of sectors (Bravo, 2017).

2.4 Man-land Ratio:

Man-land ratio, a key metric in our study, represents the quantity of land production per person. It serves as a measurement of agricultural wealth and conversion's social and economic impacts on the conditions of any particular region, particularly those agrarian (Meena and Gadekar, 2020). In the rural man-land relationship system, the two main components are population and residential land use and this study by Liu et al. (2022) of the man-land relationship in rural regions dramatically depends on the link between the rural people and residential land. Furthermore, the man-land ratio demonstrates a negative relationship with total fallow land, implying that the higher the availability of the workforce, the less the area of arable land (Kshettry et al., 2020).

2.4.1 Man-Land Ratio on Rice Output:

Land depends on man for survival and protection; man can also affect land (Tope, 2022). Man-land relationship is deeply affected by externalities, such as social, economic, and geographical factors (Meena and Gadekar, 2020). The relationship between natural and human resources was determined by dividing the efficiency of man by the efficiency of land, which is the formula used to calculate the man-land ratio. Man and land have a substantial link, as evidenced by the degree of land cover, the pattern of land use, and the demographic composition of the people in the area, as analyzed by (Bindu & Jayapal, 2017). For instance, rapid population growth led to an imbalance in the man-land ratio, human activities, and changes in land usage (Santra et al., 2018). Similar to the study of population explosion, urbanization, and industrialization, the rapid growth of the regional economy, agricultural structure adjustments, environment degradation, market, and globalization are the significant drivers of the man-land ratio (Zhao et al., 2023). In addition, specific government initiatives brought upon by industrialization resulting in agricultural to non-agricultural land, rural-to-urban migration, and regional disparities in rural areas have affected the man-land ratio (Peng et al., 2016). Numerous factors influenced the man-land ratio estimates based on mean and mapping

using modern methods, yet land conversion remains prominent. This is because as time progresses, the population grows, and the demand for land increases (Chakraborty & Ghosh, 2016). As a result, land degradation and conversion rates increase, affecting the man-land ratio.

Cultivated land not used for agriculture, food, or abandonment reflects changes in land-use structure and way (Liu, Hu, & Li, 2014; Tu & Long, 2017). Long et al. (2018) argue that urbanization alters man-land interactions and land use transitions through the per capita construction land area (PCCA - m2 /person) and per capita farmland area (PCFA - ha/person) and three (3) times standard deviation test. It also demonstrates how land use shifts are triggered, causing a dramatic loss in farmland and resulting in threats to man-land connections. For example, urbanization has converted farmland in developing countries into various non-agricultural uses. This leads to a loss of agricultural production and challenges the man-land ratio, as farmers face job losses and land expropriation (Yong, 2019).

2.5 Average Income Earned:

The agricultural sector plays a significant role in the economy of emerging countries and its priority is to increase agricultural productivity through achieving sustainable yield improvements, advancing agricultural technology and management, enhancing groundwater, and post-harvest management (Irvan and Yuliarmi, 2019). Also, Arifin et al. (2021) stated how farmers' income also makes way for the quality of food, and these foods are mainly produced on small lands. Nevertheless, due to either landlessness or inadequacy of land owned or leased, people are experiencing poverty due to agricultural revenue received from seasonal wage employment (Abas, 2016). As a result of low yield, poor food quality, and significant post-harvest losses, low income is the main problem that millions of farmers in the Philippines, who cultivate 4.81 million hectares, are dealing with.

However, most agricultural output in developing nations is linked to low productivity and low income because of a heavy reliance on low-tech subsistence farming and limited market access (Nguyen et al., 2015). Paul (2018) mentioned that despite generating income in this sector, some still need to earn a living wage enough for a particular household. Income of local non-farm jobs and tourism income dividend accounts for 70.8% and 17.8%, while agriculture just plays a slight role in improving household income (Zhang et al., 2019)

2.5.1 Average Income Earned on Industrialization and Land Conversion:

According to Haraguchi et al. (2019), there are several reasons to continue pushing industrialization, particularly in low-income nations. According to Davis et al. (2014), it is because of adequate employment opportunities. The decline in part-time employment led to increased work hours in places where salaries were lower (Bhorat et al., 2014). Sustainable agricultural productivity, such as non-farm activities providing a household's income and a source of investment capital, reduces the income gap between rural and urban areas (Adelekan & Omotayo, 2017), 2017; Yao & Jiang, 2021). Newfarmer et al. (2018) stated that approximately 50% of the productivity gains made by developing nations, primarily in East Asia, between 1950 and 2006 came from increased manufacturing productivity and structural shifts away from agriculture. This was supported by Arouri et al.'s (2017) study, stating that salaries have increased in non-farm activities, increasing total household income and consumption expenditure.

The income of the affected farmer households, using the test of difference between paired sample means, has been negatively and significantly impacted by land conversion, and this decline in household income is related to the reduction in farming land (Nurpita et al., 2017; Wang et al., 2019). Smallholder farmers' income needs to be increased to support their families; in the absence of credit constraints, households' income may rise to 7.3 and 5.1 (Amanullah & Wang, 2022). In that case, they might have to engage in other income-generating activities rather than depending entirely on traditional agricultural methods (Debela et al., 2020). Hence, a study by Su et al. (2015), with the utilization of Kuznets theory, Breush and Pagan's (1980) Lagrange test for cross-sectional dependency, slope homogeneity test, and panel causality test using Granger causality proved that urbanization significantly impacts the urban-rural income gap. Also, Research by Poulsen et al. (2015) suggested that, despite low harvests, urban agriculture can be a significant source of income for households. Lastly, aside from urbanization, "townization" is concluded to improve and promote farmers' income, especially farmers' transfer income (Huang et al., 2021).

However, because of a decline in agricultural operations, the overall loss of agricultural revenue in India during 2008 amounted to 3.9 billion (Azadi et al., 2018). After deducting the cost of inputs and hired labor wages, farmers' revenue from farming activities has grown at varying rates, from low to high growth throughout the previous three decades, based on the Tendulkar methodology (Chand et al., 2015). A study by Davis et al. (2017) mentioned that most countries consider specialization in farming activities rather than focusing on industrialization. Likewise, rapid urbanization and the transfer of labor from the low-

productivity agricultural sector to the productivity in other sectors brought about challenges such as progress in well-paying jobs, poverty and inequality, and food security (Woldemichael et al., 2017; Popkin, 2014). As cited by Simon Kuznets (1955), Kuznets' hypothesis supported these various theories by mentioning that income disparity rises and then declines in industrializing nations.

Raising wages in the agricultural sector or finding them better-paying jobs outside of it are two ways to increase the income of Filipino farm laborers (Briones, 2017). Notwithstanding the ongoing increase in agricultural income, the primary source of income for agricultural households is and has always been nonfarm revenue (Briones, 2022). According to a study by Quimba and Estudillo (2021), there are four (4) modernizing forces at work in Central Luzon: increasing urban influences, land reform implementation, population pressure on the closed land frontier, public infrastructure expansion, and growing urban influences accelerated by advancements in transportation and telecommunications. These factors, combined with modern technology, have raised household income and prevented poverty from rising in the region. Thus, to avoid both low-level rural economic development and an extensive property income gap between citizens and farmers, it is recommended that urban and rural development be balanced (Wu et al., 2019).

The agricultural sector has been correlated with the number of lands available, the employed persons in this industry and the man-land ratio. For instance, numerous studies have reported a limited number of lands that need to be maintained for crop production since it has a positive correlation. Consequently, more crops can be grown if enough land is available (Nilsson, 2018). In addition, if there is arable land, there must be farmers. Based on studies, the labor force tends to sell their lands because of rising difficulties in maintaining lands and income generation. This proves that the workforce tends to leave the agricultural industry as the land decreases. Lastly, as man depends on land for survival, man also affects the land (Tope, 2022). Studies mentioned that various elements contribute to the man-land ratio and that land degradation and conversion values have affected the relationship of man-land and agricultural production. Central Luzon has been classified as a notable palay producer, giving its residents excellent crops.

In this proposal, the researcher hopes to determine how the level of rice output affected Central Luzon's agricultural sector based on the average income earned by the farmers. Studies show that depending on the type of country, income earned shall be generated in various circumstances. In most developing countries, such as the Philippines, income has been associated with farming (Davis et al., 2017). However, it is still important to note that there is more income outside the farming sector.

Certain factors forced land conversion to take over the world. Due to the continuous increase in population, more housing, infrastructure, and facilities are needed, leading to issues regarding agricultural lands and production. Studies have mentioned that population growth and socioeconomic activity increase the demand for land, which may reduce productivity and arable land since most land conversions are driven by physical and economic factors (Harini et al., 2018; Farah et al., 2019). Because of this, several studies have noted the issues that arise if this conversion is advantageous to the economy or not. For example, conflicts may emerge regarding food security, affecting the condition of food provided for the people (Costamero, 2023). Still, it was noted that one of the primary drivers of economic expansion is land transformation (Pradhan et al., 2021; Opoku & Yan, 2018).

2.6 Theoretical Framework:

The Cobb-Douglas Production Function will be used by the researcher to demonstrate how variations in the inputs impact the amount of output generated. According to Kamanga et al. (2000), selecting a function and determining which elements to use, including selecting the inputs that influence a production function's output, requires some judgment. As a result, a general form of the Cobb-Douglas Production Function will be utilized for this study:

$$Y = AX_1^{a1}, X_2^{a2}, X_3^{a3}, \ldots X_n^{bn} \quad (1)$$

Where Y is the quantity of output, X_i are the inputs or the vectors of variable resources with i being 1, 2, 3,...,n. Lastly, A and a_i with i = 1,2,3,...,n where a_i estimates the elasticity or transformation ratio for the inputs X_i.

In this study, Y is rice output, which is Palay Production in Central Luzon as the output. While the X_i are the levels of inputs that affect the level of corresponding output or crop productivity. Specifically, these will be the Quantity of Arable Land, Employment Rate, and Man-land Ratio.

The basis of using the Cobb-Douglas production function stems from its reasonable simplicity and ease of interpretation. Moreover, Cobb-Douglas production function bias can be eliminated by transforming the equation by calculating both sides' logarithms (Muraya, 2017).

$$\log Y = \log A + a_1 \log X_1 + a_2 \log X_2 + a_3 \log X_3 + \cdots + b_n \log X_n \quad (2)$$

III. MATERIALS & METHODS

Cobb and Douglas' (1928) production theory states that there is a relationship between production factor units and output units of goods and services. It also demonstrated that as the number of inputs changes, so do the units of output produced. The positive signs in the variables, arable land as measured by farm size and employment rate through the labor use for rice production, indicate a positive relationship with the dependent variable, rice output. Additionally, the negative sign in the man-land ratio suggests a negative relationship with the dependent variable. Rice output, therefore, affects the household income earned from rice production, justifying whether land conversion is beneficial to the people in the agricultural sector of Central Luzon.

This theory shall serve as the foundation for the proposed research topic, including a time-series analysis for 41 periods from 1981 to 2021. The proposed research framework examines the relationship between farm size, labor use for rice production, man-land ratio, rice output, and household income from rice production. It would investigate the effects of farm size, labor use, and man-land ratio on agricultural productivity, focusing on Central Luzon. It would assess whether land conversion has been beneficial or detrimental to the economy based on household income earned.

Since the man-land ratio, employment rate, and amount of arable land all impact Central Luzon's agricultural production, the researcher will examine how these independent factors vary. Here, the movement of the data collected from the average farmer's income will help decide whether or not land conversion are economically advantageous.

3.1 Data:

The data to be used in this proposal will be secondary data with 52 observations for each variable. This is to align with the 42 time period from 1981-2021. Data for the IV1 or the Quantity of Arable Land, measured by Farm Size (Hectares), and the IV3 or the Man-Land Ratio, were collected from the Central Luzon Loop Survey by the International Rice Research Institute (IRRI) which can be found on the book Emerging-Economy State and International Policy Studies. Data for IV2 or the Employment Rate measured by the labor use for rice production as well as the earlier years (1981-2004) of DV1 or Average Income Earned were collected in Changes in rice farming in the Philippines: Insights from five decades of a household-level survey by IRRI. DV1 or Crop Production, measured through Palay Production in Metric Tons, as well as DV2 or Average Income, measured by estimated monthly per capita income and percentage distribution income, was collected from the PhilRice website by the Department of Agriculture, wherein data sources are from the Philippine Rice Information System, PSA, PalayStat, World Bank, and DOST-FNRI.

3.2 Research Design:

Quantitative research will be employed in this proposed study. Using the time-series analysis, this study will examine the impact of the farm size, labor use for rice production, and man-land ratio on the rice output in Central Luzon, which will aid in identifying its effect on the average income earned by Filipino farmers in region three.

3.3 Model:

This study aims to determine the relationship between the indicated production factors and the output, as well as the impact of the quantity of arable land, employment rate, and man-land ratio on rice output. This will also determine how agricultural output will affect the average income earned of the farmers. Thus, the researcher employed the following econometric models:

$$RO = \beta 0 + \beta 1 FS + \beta 2 LU - \beta 3 ML + e \quad (3)$$

$$HHI = \beta 0 - \beta 1 RO + e \quad (4)$$

Where RO refers to rice output, FS refers to farm size, LU refers to labor use for rice production, ML refers to man-land ratio, and HHI refers to household income from rice production.

This study will now employ an ordinary least squares model, specifically a multiple linear regression, following the completion of the augmented dickey fuller test. Muraya (2014) states that determining the individual or combined contribution of inputs to outputs necessitates the establishment of a production function. The general neoclassical production function: Y = F (X1, X2, X3,….Xn) where Y is the output level, Xs are the inputs; in this study it is the arable land, employment rate and man-land ratio, respectively for the first model while rice output will be the input in the second model.

Moreover, Muraya (2014) states that the formula can be transformed by taking the logarithm of both sides in order to remove the bias from the Cobb-Douglas production function. The Cobb-Douglas production function is less flexible than the transcendental logarithmic function or trans-log. It is, therefore, better suited for evaluating intricate production relationships. The ordinary least squares (OLS) method can estimate this converted function. Now that the model's parameters are linear, it may be estimated by ordinary least squares (OLS). This creates a double log model with all the variables in logs, as the theoretical framework specifies.

A double logarithmic regression will be used to determine the theoretical framework. This will allow it to confirm the percentage change in the output or DV for rise and decrease for each 1% increase in the input (IV). As a result, the double logarithmic regression will look like this:

$$Log\ Rice\ Output = \beta 0 + \beta 1 \log Farm\ Size + \beta 3 \log Labor\ Use\ for\ Rice\ Production - \beta 2 \log Man - land\ Ratio + e \quad (5)$$

The study by Muraya (2014) and Ameh et al. (2017), which investigated the effect of agricultural input on agricultural productivity and is similar to the current study, will be used as a reference for the tests that will be performed.

3.3.1 Augmented Dickey Fuller Test:

A time series test will be employed in this study because it can be used to identify and address non-stationarity in a time series. In particular, the Augmented Dickey Fuller (ADF) test will be used in this investigation. Here it will determine whether rice production is stationary or non-stationary throughout the years. Furthermore, the relationship between the independent variables and the dependent variables within the time series will be determined by means of this time series test. Artlova & Fedora (2016) studies the unit root test, specifically the formulation of ADF test to come up with the equation as follows:

$$\Delta Y_t = (\emptyset_1 - 1) Y_{t-1} + \sum_{t=1}^{p-1} Y_i \, \Delta y_{t-1} + \varepsilon_t \quad (6)$$

Where ϕ_1 is the autoregression parameter, ε_t is the random error term, assumed to follow a white noise process. However, a key problem with this test is selecting the appropriate number of lags p. With this, Schwert (1989) recommends using the maximum lag length, as choosing p too small may introduce autocorrelation, while selecting p too large can reduce the statistical power of the test.

3.3.2 Johansen-Granger Cointegration:

The Johansen Cointegration method will be employed to estimate the long-term relationship between agricultural production and the relevant variables. However, as noted by Ameh et al. (2017), cointegration itself does not reveal the direction of causality between the variables. To address this, Granger causality analysis will also be used to assess whether one variable can predict another. The Johansen Cointegration approach is based on a vector autoregression (VAR) model of order p, expressed as:

$$Y_t = \mu + A_1 + Y_{t-1} + \cdots + A_p Y_{t-p} + \beta x_t + \varepsilon_t \quad (7)$$

Where A represents the autoregressive matrices, while Y_t is a vector of endogenous variables. The parameter matrices are denoted by B and X_t refers to the deterministic vector.

3.3.3 Test for Autocorrelation:

Autocorrelation test is used to validate the regression analysis as presented in a study by Suphannachart and War (2011) in their study investigating the effects or impact of inputs on agricultural production or productivity. This test will be determined through assuming that the model has no serial autocorrelation and the alternative hypothesis is that the model has a serial autocorrelation. If the value exceeds the p-value, then the null hypothesis is accepted, however, if it is less than the p-value, null hypothesis is rejected, while alternative hypothesis will be accepted. This is to verify that the errors in the model are unrelated or that the error for one observation does not influence the error of another observation (Burton, Mladenoff, & Forrester, 2011). Breusch-Godfrey Test has been shown superiority to other autocorrelation tests for models with lagged dependent variables. The equation will be:

$$Y_t = \beta_1 + \beta_2 X_t + u_t \quad (8)$$

3.3.4 Test for Heteroskedasticity:

The heteroskedasticity test was also employed in the previously described studies to confirm the validity and reliability of the regression analysis. Heteroskedasticity will be determined by whether the null hypothesis states that the model is homoscedastic

or not, and the alternative hypothesis states that the model is heteroskedastic. The null hypothesis can be rejected if the log of the error term and the explanatory variable show a statistically significant relationship.

Classical linear regression assumes that the error terms should have a constant spread across all data points, a condition known as homoskedasticity. However, when this assumption is false, and the spread of errors varies across different levels of the data, it results in heteroskedasticity. Mills (2014) explored this phenomenon, presenting heteroskedasticity in the following manner:

$$V(u_i) = E\ (u_i^u)\sigma^2 \tag{9}$$

3.3.5 Test for Multicollinearity:

The alternative hypothesis, which claims that the model has multicollinearity, will be compared to the null hypothesis, which claims that the model has no multicollinearity. This will allow for the determination of multicollinearity. If the value is less than five, the null hypothesis will be accepted since the VIF method's strictest rule will be followed. When the value is more than five, the alternative hypothesis is accepted and the null hypothesis is rejected. In a study by Sanaullah et al. (2020), Variance Inflation Factor (VIF) was utilized in their study with an equation as follows:

$$VIF = \frac{1}{1-R_j^2} \tag{10}$$

The coefficient of multiple correlation, denoted as R_j, represents the strength of the relationship between variable j and the other regressors in the model. When a variable has little to no correlation with the other variables, the minimum value of R_j is 1.0. According to Neter, Wasserman, and Kutner (1983), a VIF exceeding 10 typically indicates a high degree of collinearity. Therefore, it is advisable to examine the highest VIF as a diagnostic measure for potential collinearity issues.

3.3.6 Test for Specification Error:

The Ramsey RESET Test will be used in this study. There is no specification error in the null hypothesis, but there is one in the alternative hypothesis. The null hypothesis is accepted if the value is greater than the p-value. The alternative hypothesis is accepted, and the null hypothesis is rejected if the value is less than the p-value. Prabowo, Suhartono, and Prastyo (2020) presented the equation in this test as follows:

$$Y_i = \lambda_i + \lambda_2 X_i + u_i \tag{11}$$

IV. RESULTS & DISCUSSION

TABLE 1
JOHANSEN COINTEGRATION TEST RESULTS

Rank	EigenValue	Trace Test	p-value	Lmax test	p-value
0	0.36372	33.281	0.5457	16.276	0.6489
1	0.24096	17.005	0.6479	9.9253	0.7538
2	0.11964	7.08	0.5746	4.5871	0.7902
3	0.066904	2.4929	0.1144	2.4929	0.1144

The Johansen Cointegration test, conducted for both the linear and double-logarithmic models, produced identical results. In both cases, the alternative hypothesis was accepted across all ranks, indicating the presence of cointegration. This suggests that the variables in the models have a long-term relationship. Even if short-term shocks cause temporary deviations, the variables are expected to eventually converge over time.

TABLE 2
AUGMENTED DICKEY FULLER TEST RESULTS

Variable	t-statistics	Prob.*
(First-Difference) Rice Output	-8.25589	8.76E-14
(First-Difference) Farm Size	-4.52301	0.0001739
(First-Difference) Labor Use for Rice Production	-3.9863	0.001488
(First Difference) Man-land Ratio	-6.14301	5.38E-08

The long-run regression analysis begins with conducting unit root tests to assess the stationarity of each model variable using the Augmented Dickey-Fuller (ADF) test. The results from the ADF test indicated that both models produced consistent findings. Specifically, the test showed that none of the variables were non-stationary at their levels, and as such, the null hypothesis of non-stationarity could not be rejected. This implies that the variables remain stable and do not exhibit changes in response to shifts over time or across different conditions.

TABLE 3
MODEL 1: OLS LINEAR RESULTS AND DOUBLE LOG RESULTS ON RICE OUTPUT, FARM SIZE, LABOR USE, AND MAN-LAND RATIO FROM 1989-2020 (T = 32)

	coefficient	std.error	t-ratio	p-value
const	21.498	1.78225	12.06	1.32e-012 ***
Farm Size	1.84766	0.582814	3.17	0.0037 ***
Labor Use	-0.584891	0.296437	-1.973	0.0584 *
Man-land Ratio	-1.16772	0.325202	-3.591	0.0012 ***

Mean dependent var	14.70661	**Schwarz criterion**	5.141973	**P-value(F)**	0.000287
Sum squared resid	1.426649	**rho**	0.640963	**Akaike criterion**	-0.720971
R-squared	0.485223	**S.D.dependent var**	0.298998	**Hannah Quinn**	1.222429
F (3, 28)	8.797484	**S.E. of regression**	0.225725	**Durbin Watson**	0.718774
Log-likelihood	4.360486	**Adjusted R-squared**	0.430068		

The Ordinary Least Squares (OLS) analysis yielded several significant insights regarding the factors affecting rice output. The intercept (y0) value of 21.4980 suggests that, in the absence of the key variables—farm size, labor use, and man-land ratio—rice output would still amount to 21.4980 metric tons. Notably, an increase of 1 hectare in farm size leads to an additional 1.84766 metric tons of rice output, highlighting the positive impact of land area on production. However, the study reveals that for every 1% increase in labor used for rice production, there is a corresponding decline of 0.584891 metric tons in output. Similarly, a 1% increase in the man-land ratio results in a reduction of 1.6722 metric tons of rice output.

These results partially validate the initial hypotheses. As expected, farm size has a positive impact on rice production, underscoring the importance of maintaining and efficiently managing arable land to optimize yields. This finding is consistent with previous studies by Nemethova et al. (2022), Nilsson (2018), and Tavares et al. (2022), all of which emphasize the critical role of farm size in enhancing agricultural productivity. The positive relationship between farm size and output reflects the need for policies that support the preservation and sustainable use of agricultural lands, particularly in regions where rice is a staple crop.

Contrary to expectations, labor use exhibited a negative effect on rice output, which can be attributed to multiple challenges within the agricultural sector. As noted by Ghatak & Mookherjee (2014), Navarro et al. (2017), and Suharyanto et al. (2021), farmers face numerous obstacles, including labor shortages, limited access to technology, and inefficiencies that inhibit productivity. Additionally, Das & Paul (2021) highlight the growing trend of workers transitioning from farm-related jobs to non-farm sectors, further exacerbating labor constraints in agriculture. This shift likely explains the observed negative relationship between labor use and rice output, as the diminishing agricultural workforce struggles to maintain productivity.

The negative impact of the man-land ratio on rice output is also aligned with findings from Santra et al. (2018) and Chakraborty & Ghosh (2016), who emphasize that urbanization and population growth are contributing to the reduction of farmland. As land resources become more limited, managing the balance between agricultural productivity and competing land uses becomes

increasingly vital. These results point to the need for strategic land management practices to ensure that rice production can meet growing demand while addressing the challenges posed by demographic and spatial changes.

TABLE 4
DIAGNOSTIC TEST ON RICE OUTPUT, FARM SIZE, LABOR USE, AND MAN-LAND RATIO

	Breusch-Godfrey	White's Test	Breusch-Pagan	Normality of Residual	RESET
Test Statistic: Chi-square (2)	20.7866	6.486	1.00485	1.06945	3.287196
p-value	0.0136	0.690463	0.800079	0.585832	0.0534

Diagnostic tests are crucial for evaluating the model to ensure unbiased and more accurate results. Several tests were conducted to assess the model, including the Breusch-Godfrey test for autocorrelation, White's and Breusch-Pagan tests for heteroscedasticity, normality tests, and Ramsey's RESET test (Table 4). The Breusch-Godfrey Serial Correlation LM test yielded a value greater than the alpha level of 0.01, indicating no significant first-order autocorrelation in the regression output. Similarly, the Durbin-Watson statistic, being higher than the alpha threshold, confirms the absence of correlation errors.

Moreover, the p-values from White's and Breusch-Pagan tests were both greater than 0.01, signifying that heteroscedasticity is not present in the model. Regarding the normality of residuals, the alpha level exceeds the test statistic, confirming that the residuals are normally distributed. Lastly, the RESET test's p-value, being above the alpha level, indicates no evidence of misspecification errors in the model.

TABLE 5
OLS LINEAR RESULTS ON HOUSEHOLD INCOME AND RICE OUTPUT FROM 1981-2020 (T = 41)

	coefficient	std.error	t-ratio	p-value
const	−12.4942	2.84743	−4.388	0.0001 ***
Rice Output	0.79952	0.195639	4.087	0.0003 ***

Mean dependent var	−0.860207	**Schwarz criterion**	34.31797	**P-value(F)**	0.000252
Sum squared resid	4.480947	**rho**	0.687366	**Akaike criterion**	31.15093
R-squared	0.329405	**S.D.dependent var**	0.436939	**Hannah Quinn**	32.25631
F (1, 39)	16.70123	**S.E. of regression**	0.363032	**Durbin Watson**	0.626545
Log-likelihood	-13.57547	**Adjusted R-squared**	0.309681		

The Ordinary Least Squares (OLS) analysis on the relationship between household income and rice output revealed several critical insights. The intercept (y0) coefficient of -12.49 indicates that, in the absence of rice output, household income decreases by 12.49%. Conversely, a 1% increase in rice output results in a modest 0.79% increase in household income. With p-values of 0.0001 and 0.0003, these results are statistically significant, confirming the reliability of the model.

These findings highlight the crucial role that rice production plays in supporting household income in rural areas. Without rice output, household income experiences a marked decline, underscoring the importance of maintaining agricultural productivity. This aligns with Arifin et al. (2021), who stress the critical connection between farmers' income and the quality of food produced, suggesting that income stability in farming is key to ensuring food security and sustainability. Similarly, Nurpita et al. (2017) and Wang et al. (2019) link the reduction in household income to a decrease in farming activities, reinforcing the idea that lower agricultural output has direct financial consequences for rural households.

The results further resonate with Davis et al. (2014), who emphasize that many countries prioritize agricultural specialization over industrialization, particularly in rural economies, where farming remains a vital source of livelihood. However, while rice output continues to positively impact household income, several studies (Woldemichael et al., 2017; Popkin, 2014; Briones, 2017; Arouri et al., 2017) suggest that non-farm income opportunities are increasingly significant in rural regions. As a result, although rice production remains essential, there is growing recognition that diversifying income sources beyond agriculture could offer more stable and potentially higher earnings for households.

TABLE 6
DIAGNOSTIC TEST ON HOUSEHOLD INCOME AND RICE OUTPUT

	Breusch-Godfrey	White's Test	Breusch-Pagan	Normality of Residual	RESET
Test Statistic: Chi-square (2)	17.128428	3.97166	1.48434	15.5925	3.44308
p-value	0.0349	0.137267	0.223096	0.0004	0.0425276

The second model was subjected to several diagnostic tests to ensure its validity and accuracy. The Breusch-Godfrey test for autocorrelation yielded a result greater than the alpha level of 0.01, indicating no significant autocorrelation. Similarly, both the White's and Breusch-Pagan tests produced p-values exceeding 0.01, confirming the absence of heteroscedasticity in the model. However, the normality test indicated that the residuals are not normally distributed, as the p-value was below the 0.01 threshold. Additionally, the Ramsey's RESET test revealed no evidence of model misspecification, and the Durbin-Watson statistic confirmed the absence of correlation errors. In summary, the model passed most diagnostic tests, with the exception of the normality of residuals.

V. CONCLUSION

Rice remains a staple food for over half of the global population, with Asia accounting for 90% of its production (Fukagawa & Ziska, 2019). In 2010, the Philippines allocated 4.4 million of its 10 million hectares of agricultural land to rice cultivation. Despite this, the country still relies heavily on rice imports to meet the growing demand from its rapidly increasing population, earning it the recognition as the world's largest rice importer. This study aimed to assess the effects of farm size, labor usage, and the man-land ratio on rice output and their subsequent impact on farmers' household income, particularly in Central Luzon. Additionally, it applied the Cobb-Douglas production function to explore how these factors influence production and income generation.

Findings of this study highlights that farm size has a positive impact on rice output, emphasizing the critical role of maintaining arable land for agricultural productivity. The preservation and effective management of farmland are essential to ensuring food security and addressing the rising demand for rice in the Philippines. On the other hand, labor usage showed a negative effect on rice output, contrary to expectations. This can be attributed to the various challenges farmer's face, such as labor shortages, inadequate access to technology, and inefficiencies that hinder productivity.

In addition, man-land ratio was also found to negatively impact rice production, supporting the hypothesis that imbalances in land distribution and increasing urbanization reduce available farmland. This trend is exacerbated by population growth, which increases demand for land for non-agricultural purposes. The shrinking of farmland underscores the need for efficient land management practices to sustain agricultural productivity and prevent further declines in rice output.

In conclusion, the results suggest that rice production still serves as an economic boon in some areas of Central Luzon. In regions where rice output is absent, household incomes decline significantly, while areas with rice production experience a modest but important increase in farmers' income. However, the economic benefits are limited, and the region's heavy reliance on rice farming may contribute to economic stagnation rather than growth, making it an economic bane for many farmers. This highlights the need for a balanced approach that supports both agricultural productivity and diversification of income opportunities.

Hence, it is recommended that the government take proactive measures to secure farmers' incomes and make farming a more viable and attractive occupation, especially for younger generations. Policies should be developed to address income security, improve access to resources, and encourage sustainable agricultural practices. Additionally, future research should focus on investigating the types of land being converted from agriculture and examining the broader impacts of land conversion on various crops and regions. By promoting effective land management and prioritizing agricultural preservation amidst increasing urbanization, the Philippines can enhance the sustainability of its farming sector and strengthen its contribution to the country's economic development.

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Effect of different organic nutrition combination on growth and yield of Moong bean (*Vigna radiata* L. Wilczek)

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Abstract— *The present investigation was carried at Organic Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Bundelkhand University, Karguanji, Jhansi, Uttar Pradesh during the Kharif-2023 with a view to identify the effects of different combinations of organic nutrition and its role in growth, yield and economics of moong bean variety Samrat. The experiment was laid in Randomized block design with 8 treatments and 3 replications with different combination of organic nutrition. Under this experiment, overall, 8 treatment was taken T_0 Control (water spray), T_1 (100% Farmyard Manure), T_2 (100% Vermicompost), T_3 (100% Neem cake), T_4 (50% Farmyard + 50% Vermicompost), T_5 (50% Farmyard Manure + 50% Neem cake), T_6 (50% Neem cake + 50% Vermicompost) and T_7 (33.33% Farmyard Manure + 33.33% Neem cake + 33.33% Vermicompost). From the above experimental finding it may be concluded that the treatment T_3 (100% Neem cake) was found to be best in the terms of growth parameters like plant height (61.81cm); number of branches (16.48 branches); number of root nodules (15.41 nodules); fresh shoot weight (195.45 gram) at 60 DAS, earliness in flowering (41.00 days) and maturity (61.67 days). T_3 also performed best in terms of yield like highest number of pods per plant (50.48 pods); number of seeds per pod (11.33 seeds); pod weight (5.86 gram); longest pod (11.48 cm) and seed yield per hectare (13.60 q/ha).*

Keywords— Moong bean, Farmyard Manure, Neem cake, Vermicompost, Benefit cost ratio.

I. INTRODUCTION

Pulse cultivation holds immense importance in the realm of global agriculture, making a substantial contribution to both food security and nutrition. The leading pulse-producing nations across the globe include India, Canada, Myanmar, China, Australia, the United States, Russia, Brazil, Ethiopia, and Turkey. Collectively, these countries are responsible for more than 85% of the total global pulse production. The increasing demand for pulses, driven by their nutritional advantages and their potential to enhance soil quality, has spurred research, development, and investments in this sector. The production of pulses can be influenced by various factors, such as weather conditions, pest infestations, diseases, and market fluctuations. Efforts are currently underway to advance farming practices and promote both the cultivation and consumption of pulses. Notably, India stands as the largest producer and consumer of pulses on a global scale, covering 37% of the world's pulse-growing area and contributing 20% of the total production. In India, pulse cultivation encompassed 26.28 million hectares of land, resulting in a production of 23.01 million metric tonnes in the 2020-21 fiscal year. (*Source:* **DES, Ministry of Agriculture & Farmers Welfare, Government of India, 2021-22**). India produces a wide range of pulses, including chickpeas, pigeon peas, lentils, mung beans, black gram, and kidney beans. Chickpeas and pigeon peas are the most widely cultivated pulses in India, accounting for around 60% of the total pulse production. Mungbean, also known as green gram, is a pulse crop with a short

growth duration that is cultivated throughout India. It holds the position of being the third most significant pulse crop, following chickpeas and pigeon peas, and accounts for approximately 12-13% of the total pulse acreage in the country. From a botanical perspective, Mungbean is scientifically referred to as *Vigna radiata* L. Wilczek, and it belongs to the Leguminosae family, specifically the sub-family Papillionaceae. It is a diploid, self-pollinating species with a chromosome count of 2n=22, as determined by **Karpechenko** in **1925**. The origins of Mungbean are believed to be in India, as suggested by **De Candole** in **1986**. This crop is predominantly grown in regions such as China, India, Burma, and other parts of Southeast Asia. The wild progenitor of Mungbean is *Vigna radiata* sub; *Sublobata*. In the year 2020-21, Mungbean production in India covered an area of 38.32 lakhs hectares, yielding a total production of 17.84 lakhs tonnes, according to data from the Department of Economics and Statistics (**DES**), Ministry of Agriculture & Farmers Welfare, Government of India. Rajasthan emerged as the leading state in both the area and production of Mungbean in the year 2021-22, followed by Maharashtra and Karnataka. In Uttar Pradesh, the Mungbean production area amounted to 0.54 lakhs hectares, resulting in a production of 0.29 lakhs tonnes for the same year. Mungbean is highly regarded for its quality as a pulse due to its outstanding digestibility and high protein content, ranging from 25% to 28%. The application of FYM enriches the soil with nutrients, contributing to improved soil fertility. On average, well-decomposed farmyard manure contains approximately 0.5% Nitrogen (N), 0.2% Phosphate (P_2O_5), and 0.5% Potassium (K_2O). Additionally, FYM enhances the availability of soil phosphorus. Furthermore, when FYM is used in conjunction with fertilizer phosphorus, it can impact the solubility and potential availability of applied phosphorus. It's essential to recognize that neither the sole use of organic manure nor chemical fertilizers in isolation can ensure sustainable and productive yields in modern intensive farming. A balanced approach that combines both organic and chemical inputs is often necessary to achieve long-term agricultural sustainability (**Singh, 2019**). Vermicompost is the result of a decomposition process that employs various types of earthworms, including red worms, white worms, and other earthworm species. This process, known as worm composting, involves breaking down a mixture of vegetable or food waste, bedding materials, and vermicast (worm castings). Raising earthworms for the purpose of creating this nutrient-rich mixture is often referred to as worm farming, and the final product is known as Vermicompost. Vermicompost boasts significant mineral content, including nitrogen (2-3%), potassium (1.85-2.25%), and phosphorus (1.55-2.25%). In addition to these primary nutrients, it also contains micronutrients, beneficial soil microbes, and is rich in 'plant growth hormones and enzymes.' Scientifically, Vermicompost has been proven to act as a remarkable growth promoter for plants and serves as a protective agent against pests and diseases. This makes it a valuable and multifaceted resource for improving soil health and supporting plant growth in agricultural and horticultural practices. Neemcake, a by-product of neem seed oil extraction, is a nutrient-rich organic fertilizer. Packed with nitrogen, potassium, phosphorus, and micronutrients, it enhances soil health, improves water retention, and boosts plant growth. Its high nitrogen content fosters robust plant development, while potassium aids in flowering and fruiting. Phosphorus promotes root growth. Additionally, Neemcake acts as a natural pest repellent due to its azadirachtin content. Environmentally friendly and beneficial, it serves as a valuable resource in sustainable agriculture practices. On average, Neemcake has a nutrient composition of about 5.03 percent nitrogen (N), 3.63 percent phosphate (P_2O_5), and 1.03 percent potassium (K_2O). Numerous studies have demonstrated that the application of neem cake can enhance production efficiency with protective features. A sufficient supply of nitrogen is particularly critical for achieving robust vegetative growth in crops. This highlights the importance of neem cake, which provides an enriched source of essential nutrients, including nitrogen, that can promote the vigorous growth of millet and, by extension, other crops. (**Ayub *et al.*, 2009**). Mung bean holds a significant position in agriculture due to its economic importance. Organic substances like Farmyard Manure (FYM), Vermicompost, and Neem cake not only enhance crop yields and quality but also unlock the genetic potential of plants. The presence of these nutrients contributes to root development, fruit formation, and overall plant vigour and health. Furthermore, they improve soil quality and its biological diversity. Nutrients are essential for a well-rounded plant diet and serve as valuable tools for farmers seeking to boost both quantity and quality in their yields. This study aimed to investigate the impact of various organic fertilizers on the growth and yield attributes of mung bean. The combined use of organic materials has the potential to increase mung bean productivity in terms of both quantity and quality, making the plants more resilient to stress conditions, be they biotic or abiotic. This, in turn, can enhance market prices and profitability. Therefore, the objective of this research is to assess the growth and yield parameters of mung

bean. Keeping these above point the present investigation was carried out with objective to determine effect of organic manures on growth and yield of Moongbean *cv.* Samrat.

II. MATERIALS AND METHODS

The current investigation was carried out in *Kharif*-2023 at the Karguan ji Organic Research Farm, Jhansi Department of Agronomy, Institute of Agricultural Sciences, Bundelkhand University, Jhansi, U.P. The experimental design employed was a Randomized Block Design (RBD) with three replications and nine treatments. The **Fisher and Yates, 1963** method was used to statistically analyse the data. The software used for analysis was INDOSTAT. The Moong bean variety used was Samrat. In the study, the height of randomly chosen plants from each plot was assessed in centimetres using a meter scale. Stem diameter was measured at last harvest stage using meter tape in random selected five plants. Additionally, the number of branches and leaves per plant, emerging from the main shoot, was counted, and the values were averaged. TSS was measured using refractometer. The details of treatments comprised of T_0 Control (water spray), T_1 (100% Farmyard Manure), T_2 (100% Vermicompost), T_3 (100% Neem cake), T_4 (50% Farmyard + 50% Vermicompost), T_5 (50% Farmyard Manure + 50% Neem cake), T_6 (50% Neem cake + 50% Vermicompost) and T_7 (33.33% Farmyard Manure + 33.33% Neem cake + 33.33% Vermicompost).

III. RESULTS AND DISCUSSION

There was significant difference present for plant height at 60 DAS among different treatment combinations. The tallest plant (61.81 cm) at 60 DAS was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 57.31 cm. Plant with minimum height (49.78 cm) was observed in T_0 (control), while the remaining treatments were moderate in their growth habit. The highest number of branches (16.48 branches) at 60 DAS was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 12.82 branches. Plant with minimum number of branches (8.67 branches) was observed in T_0 (control). The improved performance of the treatment combining 100% neem cake followed by a combination of 50% vermicompost and 50% neem cake, in contrast to other treatments for moong bean's plant height and number of branches per plant, likely arises from the rich nutrient composition of neem cake. Its organic richness aids in stimulating lateral branching and foliage growth. Additionally, the combined treatment offers a balanced nutrient amalgamation, fostering robust branch development and plant height. This harmonious blend of neem cake's nutritional benefits and the balanced composition likely promotes increased branching in moong bean plants. Similar findings were reported by **Armin *et al.*, (2016); Patel *et al.*, (2019)** in Moong bean.

The highest number of root nodules (15.41 nodules) at 60 DAS was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 14.79 nodules. Plant with minimum number of root nodules (9.11 nodules) was observed in T_0 (control). The enhanced performance of the treatment sequence utilizing 100% neem cake followed by a combination of 50% vermicompost and 50% neem cake, over other treatments in moong beans concerning the number of root nodules per plant, likely arises from neem cake's bioactive compounds. Neem cake fosters rhizobial activity, aiding nitrogen fixation and nodule formation. The combined treatment's balanced nutrient mix supports symbiotic interactions, encouraging increased nodulation. This synergistic effect between neem cake's properties and the balanced nutrient blend likely augments root nodule formation in moong bean plants. Similar findings were reported by **Raj and Mehera (2022)** in Moong bean.

The highest fresh shoot weight (195.45 gram) at 60 DAS was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 188.68 gram. Plant with lowest fresh shoot weight (142.93 gram) was observed in T_0 (control). The highest dry shoot weight (59.62 gram) at 60 DAS was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 57.56 gram. Plant with lowest dry shoot weight (37.29 gram) was observed in T_0 (control). The superior performance of the treatment sequence, starting with 100% neem cake and followed by a mixture of 50% vermicompost and 50% neem cake, in comparison to other treatments for dry shoot weight in moong beans, likely stems from neem cake's nutrient richness. Neem cake provides slow-release nutrients, fostering robust shoot growth. The combined treatment offers a balanced nutrient amalgamation, promoting vigorous foliage. This synergy between

neem cake's nutrient profile and the balanced blend likely supports enhanced shoot growth in moong bean plants. Similar findings were reported by **Kumar *et al.*, (2021); Tadewos *et al.*, (2021)** in Moong bean.

The minimum days to 50% flowering (41.00 days) was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 44.67 days much earlier compared to T_0 (control) with 51.00 days. The minimum days to maturity (61.67 days) was observed with treatment T_3 (100% Neem cake) at par with T_6 (50% Vermicompost + 50% Neem cake) with 63.67 days much earlier compared to T_0 (control) with 72.00 days. The earlier maturity of moong bean in the treatments with 100% neem cake and a combination of 50% Vermicompost and 50% neem cake, compared to other treatments, can be attributed to the multifaceted benefits of these components. Neem cake's natural pest-repelling properties protected the plants, preventing potential damage and stress, which often delays maturity. Simultaneously, the Vermicompost supplied essential nutrients and organic matter, ensuring optimal plant development. This combined approach enhanced the plant's overall health and vigour, enabling it to reach maturity more swiftly. The synergy of pest resistance and nutrient provision in these treatments expedited the maturation process, potentially resulting in earlier, more efficient seed and grain production. Similar conclusions were drawn by **Patel *et al.*, (2019); Gurjar *et al.*, (2022)** in Moong bean.

Number of pods per plant varied significantly among different treatment combinations. The highest number of pods per plant (50.48 pods) was observed with treatment T_3 (100% Neem cake) at par with T_6 (50% Vermicompost + 50% Neem cake) with 49.62 pods making better over T_0 (control) with 36.48 pods. The highest number of seeds per pod (11.33 seeds) was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 9.57 seeds better over T_0 (control) with 6.43 seeds. The maximum pod weight (5.86 gram) was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 4.75 gram better over T_0 (control) with 3.25 gram. The longest pod (11.48 cm) was observed with treatment T_3 (100% Neem cake) followed by T_6 (50% Vermicompost + 50% Neem cake) with 9.29 cm better over T_0 (control) with 6.65 cm. The highest seed yield per plant (10.88 g/plant) was observed with treatment T_3 (100% Neem cake) at par with T_6 (50% Vermicompost + 50% Neem cake) with 10.05 g/plant which was better than T_0 (control) with 7.49 g/plant. The highest seed yield per hectare (13.60 q/ha) was observed with treatment T_3 (100% Neem cake) at par with T_6 (50% Vermicompost + 50% Neem cake) with 12.56 q/ha. Lowest seed yield per hectare was observed in T_0 (control) with 9.36 q/ha. The enhanced seed yield in the treatment combination of 100% neem cake followed by a 50% vermicompost and 50% neem cake blend, in contrast to other treatments in moong beans, likely stems from the combined impact of neem cake's nutrient richness and vermicompost's organic composition. Neem cake's essential nutrients fortify plant health, fostering robust growth and reproductive vigour. The balanced nutrient synergy in the combined treatment sustains optimal conditions for seed development, promoting larger and more numerous pods. This collaborative effect between neem cake's nutrients and the organic richness of vermicompost likely contributes to an increased seed yield in moong bean cultivation compared to alternative treatments. Similar findings were reported by **Shariff *et al.*, (2015); Patel *et al.*, (2019); Raj and Mehera (2022) and Kumar *et al.*, (2023)** in Moong bean.

The highest biological yield per hectare (29.09 q/ha) was observed with treatment T_1 (100% Farmyard manure) at par with T_3 (100% Neem cake) with 29.06 q/ha which was better than T_5 (50% Farmyard manure + 50% Neemcake) with 25.00 q/ha. The highest harvest index (46.85 %) was observed with treatment T_3 (100% Neem cake) at par with T_6 (50% Vermicompost + 50% Neem cake) with 46.35 % which was better than T_0 (control) with 35.09 %. The highest harvest index in the treatment combination of 100% neem cake followed by a 50% vermicompost and 50% neem cake blend, compared to other treatments in moong beans, likely stems from an optimized resource allocation strategy. Neem cake's nutrient richness, coupled with the balanced nutrient blend in the combined treatment, promotes robust reproductive structures—more pods and seeds—relative to vegetative biomass like straw. This efficient utilization of resources directs more energy towards yield-producing parts, increasing the ratio of edible or harvestable parts to total biomass. The synergistic effect of these treatments likely enhances the harvest index, resulting in a more efficient utilization of resources for yield in moong bean cultivation. Similar findings were reported by **Shariff *et al.*, (2015); Patel *et al.*, (2019); Raj and Mehera (2022) and Kumar *et al.*, (2023)** in Moong bean.

TABLE 1
EFFECT OF ORGANIC NUTRITION ON GROWTH AND EARLINESS PARAMETERS OF MOONG BEAN

Treatment Details		Plant height (cm) [60 DAS]	No of branches per plant [60 DAS]	No of root nodules per plant [60 DAS]	Fresh shoot weight of plant (g) [60 DAS]	Dry shoot weight of plant (g) [60 DAS]	Days to 50% flowering	Days to Maturity
T_0	Control	49.78	8.67	9.11	142.93	37.29	51	72
T_1	100% Farmyard Manure	51.06	10.65	11.45	180.22	47.1	46.33	69
T_2	100% Vermicompost	52.92	12.55	11.76	176.7	46.03	47	68
T_3	100% Neem cake	61.81	16.48	15.41	195.45	59.62	41	61.67
T_4	50% Farmyard Manure + 50% Vermicompost	52.48	12.19	11.88	175.51	46.03	48	71.33
T_5	50% Farmyard Manure + 50% Neem cake	54.58	11.05	11.87	175.49	46.22	50.67	70.33
T_6	50% Vermicompost + 50% Neem cake	57.31	12.82	14.79	188.68	57.56	44.67	63.67
T_7	33.33% Farmyard Manure + 33.33% Vermicompost + 33.33% Neem cake	54.54	12.24	12.42	183.37	47.99	45	65.17
'F' test		**S**	**S**	**S**	**S**	**S**	**S**	**S**
CV.		**1.45**	**10.21**	**8.25**	**8.36**	**9.25**	**2.7**	**2.86**
SE. m (±)		**0.45**	**0.71**	**0.59**	**8.93**	**2.59**	**0.73**	**1.12**
CD. at 5%		**1.36**	**2.14**	**1.76**	**26.79**	**7.76**	**2.18**	**3.35**

TABLE 2
EFFECT OF ORGANIC NUTRITION ON YIELD PARAMETERS OF MOONG BEAN

Treatment Details		No of pods per plant	No of seeds per pod	Average pod weight (g)	Average pod length (cm)	Seed yield per plant (g/plant)	Seed yield per hectare (q/ha)
T_0	Control	36.48	6.43	3.25	6.65	7.49	9.36
T_1	100% Farmyard Manure	34.5	8.03	3.45	7.76	8.81	11.01
T_2	100% Vermicompost	39.83	9.34	4.75	8.61	8.98	11.24
T_3	100% Neem cake	50.48	11.33	5.86	11.48	10.88	13.6
T_4	50% Farmyard Manure + 50% Vermicompost	39.83	6.77	3.45	7.19	8.41	10.52
T_5	50% Farmyard Manure + 50% Neem cake	28.24	7.39	4.05	8.76	8.69	10.85
T_6	50% Vermicompost + 50% Neem cake	49.62	9.57	4.75	9.29	10.05	12.56
T_7	33.33% Farmyard Manure + 33.33% Vermicompost + 33.33% Neem cake	48.36	9.13	4.55	8.96	9.95	12.44
'F' test		**S**	**S**	**S**	**S**	**S**	**S**
CV.		**8.05**	**6.19**	**5.27**	**8.15**	**8.82**	**8.81**
SE. m (±)		**1.9**	**0.3**	**0.13**	**0.4**	**0.47**	**0.58**
CD. at 5%		**5.71**	**0.91**	**0.39**	**1.21**	**1.4**	**1.75**

TABLE 3
EFFECT OF ORGANIC NUTRITION ON YIELD PARAMETERS OF MOONG BEAN

Treatment Details		Biological yield per hectare (q/ha)	Harvest Index (%)
T_0	Control	26.76	35.09
T_1	100% Farmyard Manure	29.09	37.89
T_2	100% Vermicompost	28.55	39.36
T_3	100% Neem cake	29.06	46.85
T_4	50% Farmyard Manure + 50% Vermicompost	25.84	40.86
T_5	50% Farmyard Manure + 50% Neem cake	25	43.44
T_6	50% Vermicompost + 50% Neem cake	27.14	46.35
T_7	33.33% Farmyard Manure + 33.33% Vermicompost + 33.33% Neem cake	27.88	44.56
'F' test		**S**	**S**
CV.		**9.36**	**2.26**
SE. m (±)		**1.48**	**0.55**
CD. at 5%		**4.44**	**1.64**

IV. CONCLUSION

From the above experimental finding it is concluded that the treatment T_3 (100% Neem cake) was found to be best in the terms of growth, and yield of Moong bean.

ACKNOWLEDGEMENT

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Consumption Trends of WSF and its Future Prospects in Gujarat

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Abstract— *This study explores the usage and market potential of water-soluble fertilizers (WSF) in the agricultural sector, with a specific focus on Gujarat, India. The research emphasizes the Indian market scenarios for WSF, considering factors such as population growth and the adoption of drip irrigation. The study also delves into the scope of WSF, analyzing consumption trends, farmers' awareness, and satisfaction levels in the Anand, Sabarkanta, and Katch regions of Gujarat. The research methodology involves a descriptive study design, convenience sampling, and data collection from both primary sources. The findings indicate a growing awareness & adoption of WSF among farmers, with a positive impact on crop yields.*

Keywords— Water Soluble Fertilizers, Soil fertility, Crops yield, Farmer's perception.

I. INTRODUCTION

1.1 Water Soluble Fertilizer:

Water Soluble Fertilizers are commonly used as chemical fertilizers in sprinkler/drip irrigation systems or for foliar spraying to enhance yield and improve the quality of fruits/vegetables and improve nutrient use efficiency. These fertilizers are mostly a combination of nitrogen/phosphorus/potassium/calcium/magnesium/sulphur/micro-nutrients in various ratios. High analysis fertilizers are developed according to matrix of soil fertility status, crop type, water quality, climatic conditions, etc. It is easy to determine the exact nutrient solution for the plants. Water solids should meet the following criteria: 100% Soluble in water No Inert matter High Purity Driven By R&D Nutrients in readily Available Form Sodium and Chloride Free Low Salt Index (EC = 0.9 - 1.2) Acidic pH = 5.5 - 6.5 Suitable for festination/foliar application Improve crop yields and improve product quality and nutrient use efficiency.

Fertilizer use in India is not as extensive as in developed countries. In the USA, water soluble fertilizers consumed 17% of the total fertilizers consumed in all crops in 2009 (Patel, 2011). With the adoption of drip irrigation system, fertilizers are applied through festination. In India, 100% water soluble fertilizers are mostly imported; some of the Indian companies have started to import water soluble fertilizers or liquid fertilizers, but some of the Indian manufacturers have started to produce water soluble fertilizers. There are many water soluble fertilizers developed and included by the Government of India (GOI) in Fertilizer Control Order, 1985 (FAI 2013), which can be used alone or in combination with NPK (Nitrogen-Potash-Coated) fertilizers for growth in medium stage and mono-Potassium Potash-Coated fertilizers for sugar conversion as well as disease resistance. Up to this point sixteen grades of 100 percent water solvent composts has been informed table 1 FCO endorsed supplement arrangement of 100 percent water-dissolvable manures.

Product name (Grade) Composition of nutrients (%) NPK:

- 2O5K2O S CaMgO Zn
- Potassium nitrate (13-0-45) 13 :0 :45
- Mono potassium phosphate (0-52-34) 0: 52: 34
- Calcium nitrate 15.5 18.8
- NPK (13-40-13) 13: 40: 13
- NPK (18-18-18) 18: 18 :18

- NPK (13-5-26) 13 :5 :26
- NPK (6-12-36) 6: 12: 36
- NPK (20-20-20) 20: 20: 20
- NPK (19-19-19) 19: 19 :19
- Potassium magnesium sulphate 22: 20 :18
- Mono ammonium phosphate (12-61-0) 12 :61: 0
- Urea phosphate (17-44-0) 17 :44: 0
- NPK (12-30-15) 12: 30: 15
- NPK (12-32-14) 12: 32 :14
- Urea phosphate with SOP (18-18-18) 18 :18 :18
- NPK Zn (7.6-23.5-7.6-3.5) 7.6 23.5 7.6 3.5s

Source: Fertilizer (control) order 1985 (FAI 2013).

1.2 Global Market Potential of WSF:

Water solvent composts are utilized as substance manure in sprinkler or trickle water system frameworks and for foliar splash to expand to increment yield and to work on nature of leafy foods crops. Water dis-solvable manures are for the most part thought of. The worldwide water dis-solvable manure market size was esteemed at USD 12.5 billion out of 2015 and is supposed to enlist a CAGR of 6.5% with regards to income over the gauge period. Product demand is likely to be influenced positively by rising demand for food crops, food grains, vegetables, and fruits in emerging economies like China, India, and Brazil. Flood in populace, alongside rising tendency of buyers toward sickness free and solid new leafy foods, will fuel market development throughout the next few years. There has been expanding interest for and reception of dribble water system as it saves water and is appropriate for all grounds, including undulating territory, fruitless terrains, moving geography, and regions with shallow soil layers. Rising government drives zeroed in on expanding rural result, combined with execution of different sponsorship to advance the utilization of dribble water system will emphatically affect the business. Simple application, alongside high yield efficiency, will spike item interest throughout the next few years. In leading agricultural nations, land availability has been decreasing due to rapid industrial and infrastructure development. Nations like India, China, and U.S. are seeing a critical decrease in arable land attributable to soil disintegration, urbanization, and framework improvement. Diminishing accessibility of arable land is supposed to fuel interest for water dis-solvable composts over the estimate period.

Over the forecast period, market expansion will be hampered by feed-stock price volatility. By and by, expanding speculations by key market members for improvement of climate amicable and proficient manures will set out development open doors over the course of the following couple of years.

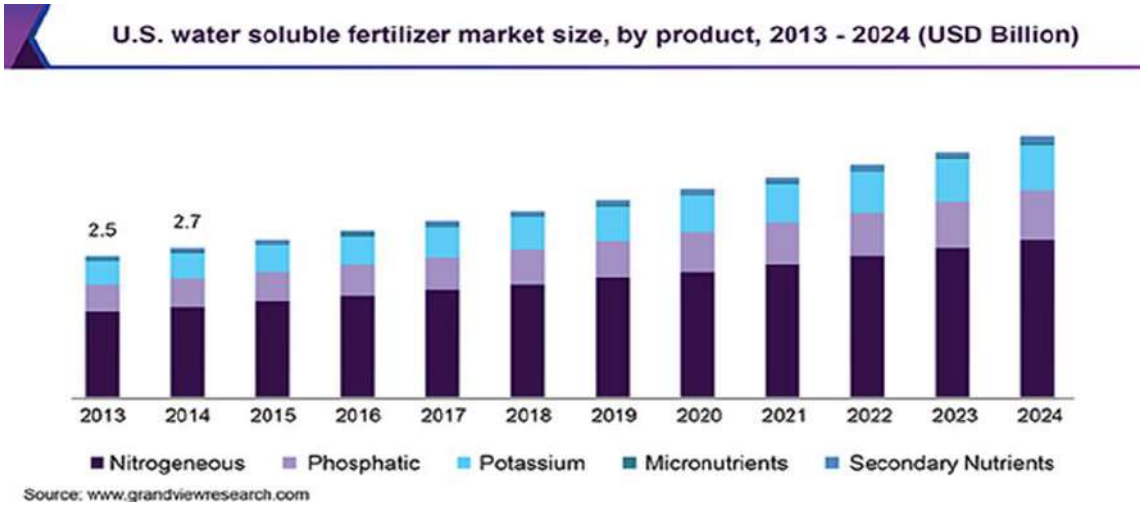


FIGURE 1: U.S Water Soluble Fertilizer Market

The worldwide water solvent manure market was esteemed at $12.52 billion of every 2016 and is estimate to develop at a consistent CAGR of 8.4% somewhere in the range of 2017 and 2024, finishing in 2024 worldwide income of $21.07 billion. Populace extension combined with rising interest for food security in creating locales is expected to stay the essential driving variable for market development over the figure period.

1.3 Indian market potential of WSF:

1) Indian water dissolvable composts market remained at $ 12.7 billion of every 2018 and is projected to reach $ 20.6 billion by 2028. Expected development in the market can be credited to expanding urbanization which is bringing about rising development exercises because of which arable land for development is diminishing. Additionally, soil deficiency of essential micronutrients and subsequent rise in demand for micronutrients like Zn, Fe, and others, to help plant development is emphatically impacting the interest for water solvent manures in the country.

2) Moreover, ranchers are leaning toward trickle water system as it lessens cost of harvest development by practically 30% other than expanding the typical efficiency of products of the soil by practically 40%. This element is further liable to push the interest for water solvent manures before very long.

The Indian water solvent composts market is constrained by these significant producers and merchants, to be specific, Coromandel Worldwide Restricted, DCM Shriram Homestead Arrangements, Indian Ranchers Manure Agreeable Restricted (IFFCO), Nagarjuna Manures and Synthetics Ltd., Gujarat State Manures and Synthetic compounds Ltd., Zuari Agro Synthetic substances Ltd., Aries Agro Restricted, Rashtriya Synthetics and Manures Restricted, Yara Manures India Pvt Ltd, and Deepak Composts and Petrochemicals Organization Ltd.

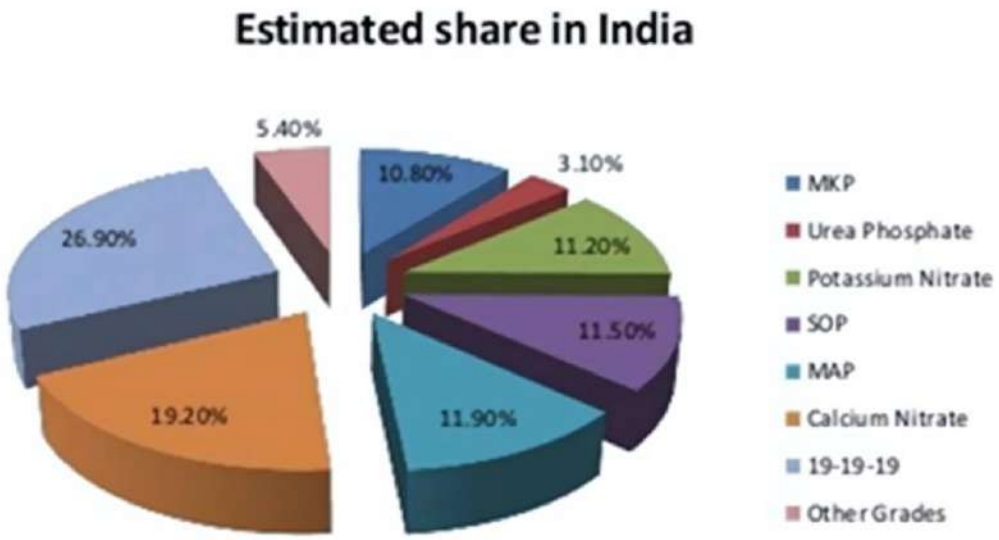


FIGURE 2: Pan India Estimated Share of important grades of WSF in total consumption

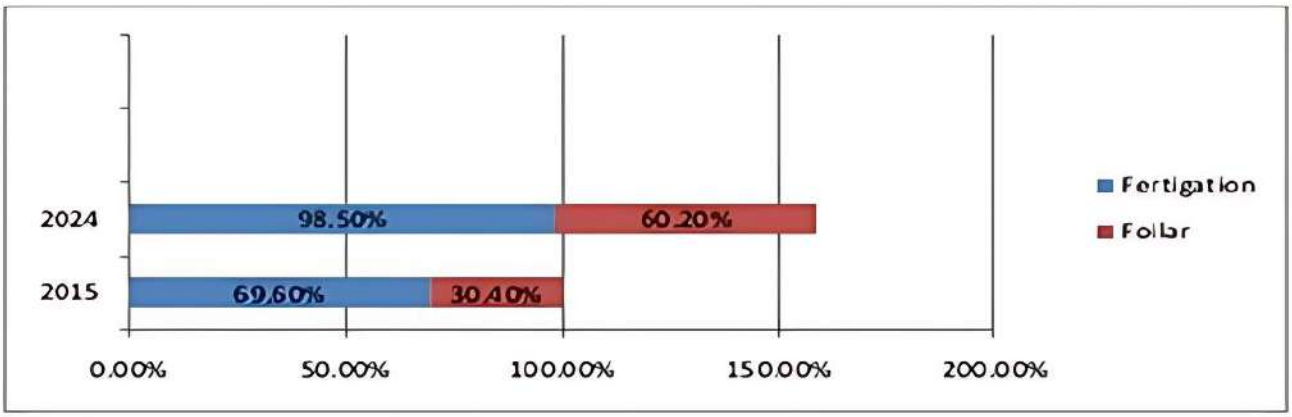


FIGURE 3: WSF market application movement analysis

FIGURE 4: Some of the WSF fertilizers

II. SCOPE OF THE STUDY

The scope of the study to consumption trends and future market towards WSF and farmer's perception and satisfaction level towards WSF in Anand, Sabarkanta, katch region of Gujarat.

2.1 Objectives:

- To know consumer awareness towards WSF in Gujarat.
- To identify the uses of WSF in Gujarat.
- To study the consumption trends of WSF in Gujarat.
- To study the factors which are influencing on purchase decision of WSF.
- To study the scope Micronutrient in Gujarat state.
- To study the problems regarding WSF consumption in Gujarat
- To study the suggestions of Dealer/retailers & farmers for increase market potential of WSF.

III. RESEARCH METHODOLOGY

Following a methodical and scientific approach to presenting and interpreting the study's or investigation's findings is crucial to achieving the study's goals. This section on system comprises of the subtleties of the portrayal of the review region, the testing strategy, nature and wellsprings of information, the scientific devices and methods utilized and other data to help the current outcomes like auxiliary wellsprings of data expected to keep the per user gathered for reference and documentation. The approach section is examined under the accompanying heads.

3.1 Methodology Used:

The descriptive study design was used, and the Random Convenience Sampling Method was used for the sampling. The review directed has been finished by addressing ranchers and sellers both.

- For essential information assortment around 301 ranchers and 71 Vendors and Retailers were addressed.

- In the wake of meeting both essential and auxiliary wellsprings of information, examinations was finished
- After examination discoveries and idea were planned.

3.2 Nature and wellsprings of information:

To assess the targets of the review, information was gathered from both essential and auxiliary sources.

3.2.1 Primary Data:

The essential information frames a significant part of any exploration examination. As the review centers on utilization patterns of WSF and its future possibilities in Gujarat and conduct of ranchers towards the reception of brands, the faithfulness of ranchers. Subsequently, more noteworthy push was given to gather data at rancher's level. Nevertheless, the number of farmers, their issues, and so on were also significant, and the primary data were absolutely necessary to collect. The essential information was gathered utilizing an organized survey enveloping various factors/boundaries which could make sense of their mindfulness and fulfillment of the ranchers.

3.2.2 Secondary Data:

As the exploration study centers around the perspectives, for example, assessing of Brand mindfulness and furthermore a portion of the data connecting with the quantity of ranchers in each Locale, amounts took care of, the job of divisions, the factual information and so on. Were especially expected to take a portion of the examination cycle. As a result, the necessary secondary data were gathered from company representatives, books, magazines, and the internet.

3.3 Sampling design:

Test populace was chosen haphazardly from various harvests for the most part vegetable and plant crops developing in Gujarat district. A multistage irregular inspecting as well as comfort testing was taken on as proper examining method for the review.

3.3.1 Sample Size:

An example size of 301farmer was taken from various district of Gujarat like Sabarkanta, Anand, Katch and all out 71 wholesalers and retailers were consulted. The area of venture fruition in Gujarat locale

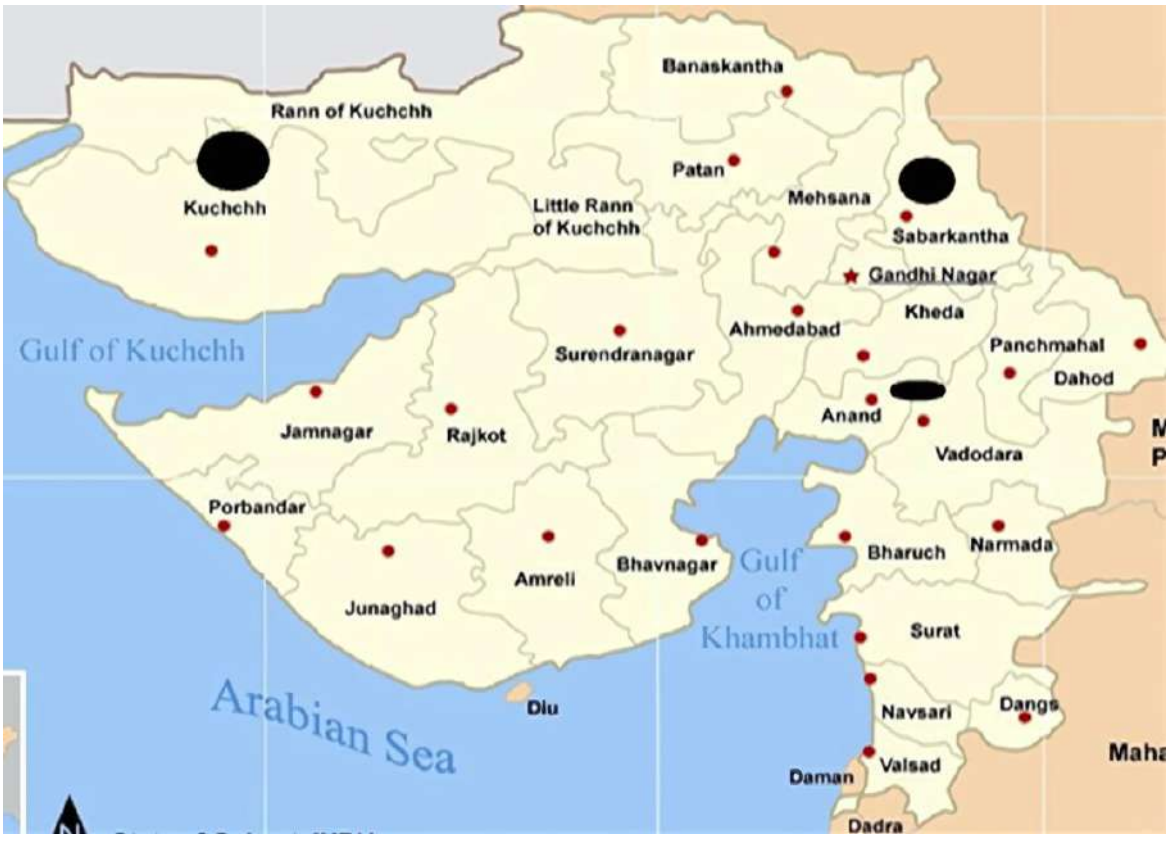


FIGURE 5: Depiction under concentrate on region.

a) **Research Design:** Nature The research design was created with the intention of collecting qualitative and quantitative data.

b) **Data Sources:** Essential Wellspring of information was Ranchers and vendors. Optional Wellspring of information was through true sites, research papers and Perusing material given by Task guide, Head of exposure and special divisions.

c) **Research Instrument:** Very much organized shut and unconditional poll and direct meeting technique is followed.

d) **Instrument of Data collection:** Questionnaires.

e) **Sample units:** Data is collected from Farmers

f) **Sample area:**

TABLE 1
SAMPLE AREA

District	Tahsil	Village
Sabarkatha	Himmatnagar, Idar, Prantij, Kapadganj, Bayad	10
Gandhinagar	Dehgam	4
Mehsana	Vijapur	4
Anand	Anand, Sojitra, Petlad	13
Kutch	Bhuj, Bachhau, Nakhatrana	5

g) **Sampling Method:** Random type of convenient sampling method for farmer is followed.

- **Sample size: Farmers –** 301, Dealers - 71
- **Period of study –** 3 months

3.4 Assumption:

- Respondents will reaction accurately.
- Respondents will answer with practically no inclinations and they will co-work at every single level of the meeting and the study.
- The administrations given by organizations make an impact on stock kept up with by seller of items.
- The perception of farmers is influenced by the services provided by various businesses; like prompt delivery, no billing disputes, and regular meetings.

3.5 Limitations of the review:

- The study was finished in restricted topographical region. As a result, the results cannot be considered representative of the district as a whole.
- Farmers and sellers who answered the inquiries might not have been valid in responding to different inquiries and might be one-sided to specific different inquiries. Some of ranchers and sellers were not able to share their perspectives on certain inquiries.

IV. DATA INTERPRETATION AND INFERENCES

Information examination and surmising's is a significant stage in report composing. The information after assortment must be handled and examined as per the blueprint set down for the reason at the hour of fostering the examination plan. This is

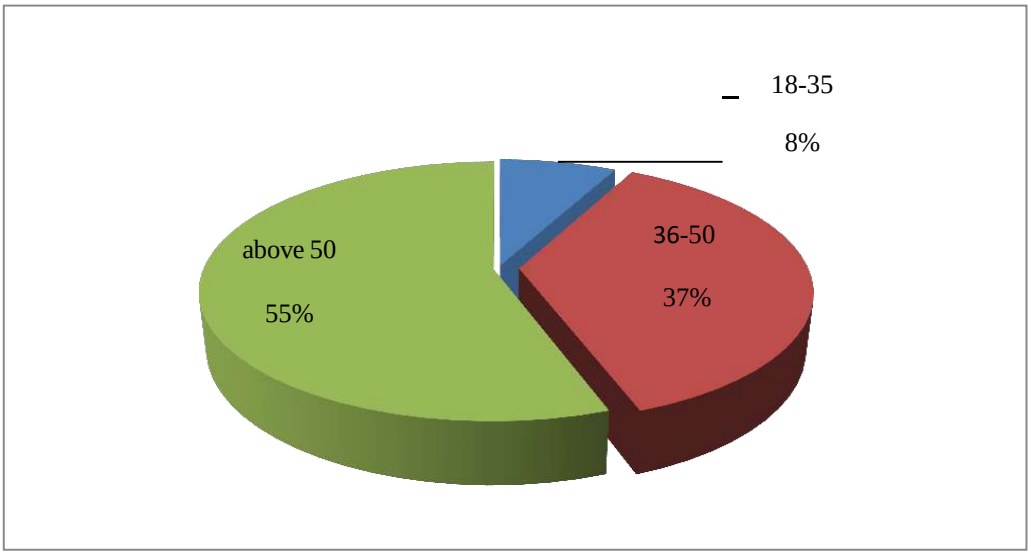
fundamental for a logical report and for guaranteeing that we have all significant information for making mulled over correlation and examination. In fact talking handling suggests altering, coding, order and classification of gathered information with the goal that they are manageable to examination.

4.1 Age of farmer:

From the below graph 4.1, 55% of the farmers are above 50 years old and 37% of between 36- 50 years while young farmers are about 8% between 18-35 years old. From above graph the middle age 36-50 years old farmers are quite increasing while youngster that is between the ages of 18-35 attracted towards farming.

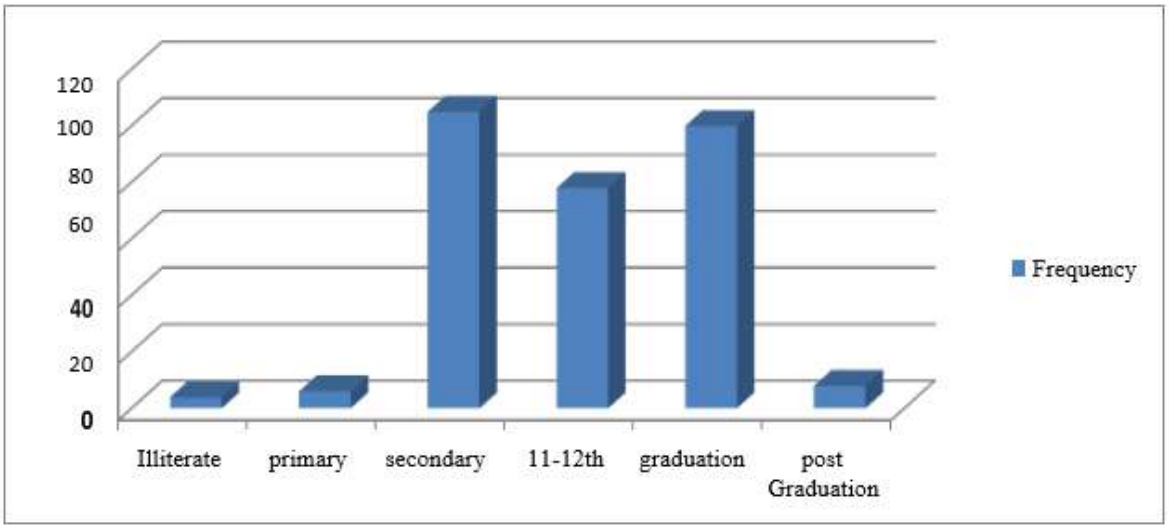
TABLE 2
AGE OF FARMER

Particular	Frequency	Percentage
18-35	23	8
36-50	111	37
above 50	167	55



GRAPH 4.1: Age of farmers

4.2 Education:



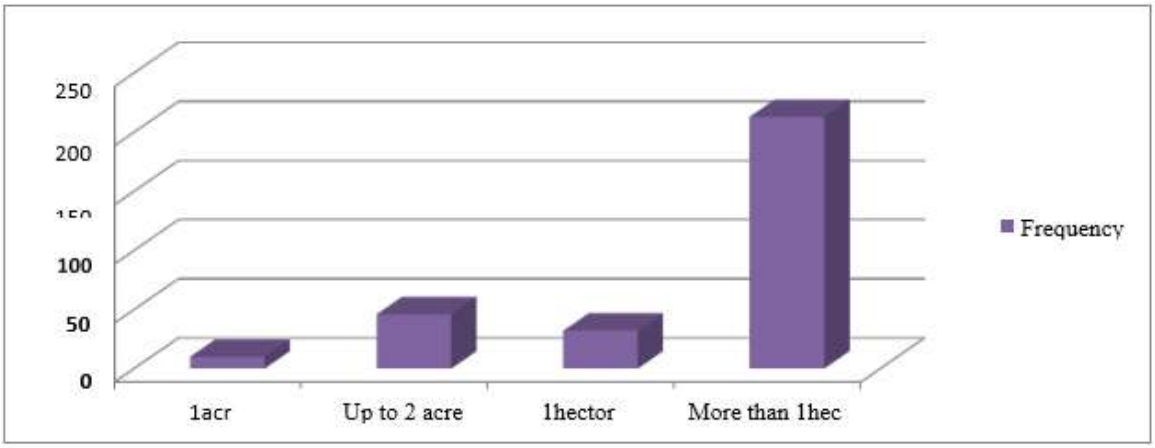
GRAPH 4.2: Education

TABLE 3
EDUCATION

Particulars	Frequency	Percentage
Illiterate	4	1
Primary	6	2
secondary	105	35
11-12th	78	26
graduation	100	33
Post-graduation	8	3

Literacy level of farmer always helps to increase his standard of living, he is ready to accept new technology in farming system. From above graph 4.2, 35% of farmer did secondary education, 33% are graduates, 26% farmers did higher secondary education, 3% are post graduate, 2% did primary education and 1% are illiterate. From this sample size its good literacy level ratio, farmers are always willing to accept new farming techniques.

4.3 Total land holdings:



GRAPH 4.3: Land Holding

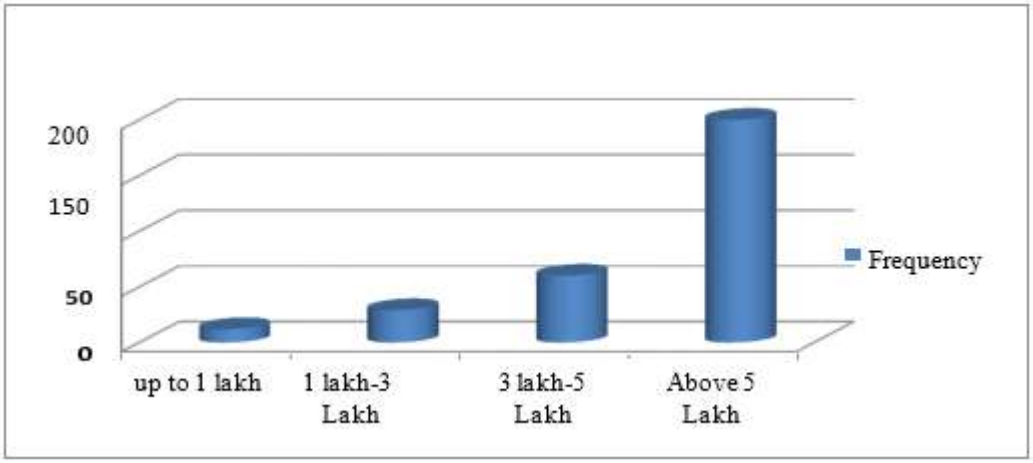
From the above graph 4.3. From the sample size most of the farmers have large land 71% farmers have more than 1hec land specially in kutch side most of the farmers are very big land.15%farmers have upto 2 crore land, 11% farmers have 1hec land and 3% farmers have 1acre of land. From sabarkantha, Anand, Kutch region all type of that is small farmer, marginal farmer, large farmers are seen

In that all three regions various cropping pattern are followed by the farmers in sabarkanta region mostly vegetable crops are taken by farmers from that small and marginal farmer make their benefits. In Anand region mostly chilly, Banana, paddy and others crop taken by most of thesmall and marginal farmers. While in kutch region most of the farmers have big land they mostlycultivate horticulture crops like mango, pomegranate, date palm etc.

TABLE 4
TOTAL LAND HOLDINGS

Particulars	Frequency	Percentage
1acr	10	3
Upto 2 acre	46	15
1hector	32	11
more than 1hec	213	71

4.4 Annual Income of the Farmer:



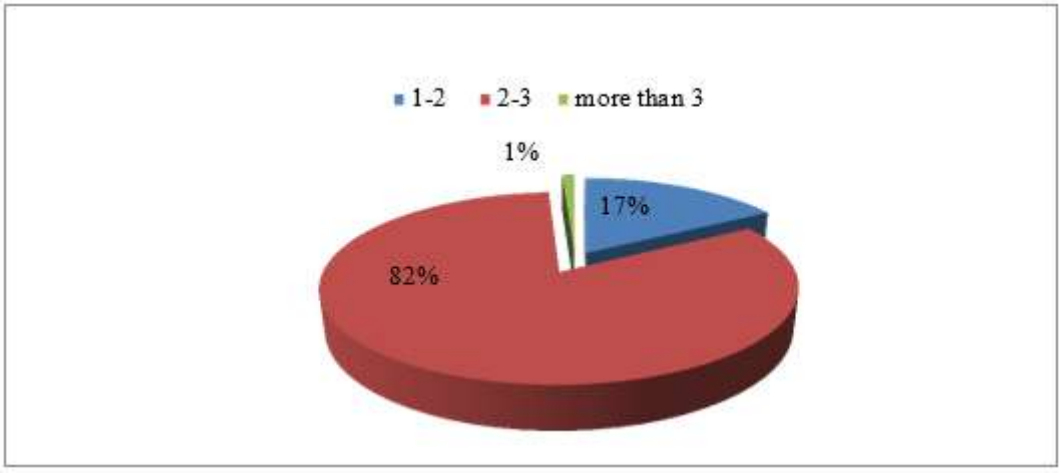
GRAPH 4.4: Annual Income

From the above graph 4.4, the income of the farmer is quite good mostly high income from vegetable and horticulture crops. 4% farmers have low income i.e. upto 1lakh, 10% farmers have 1lakh-3lakh income, 20% have 3lakh-5lakh and 66% farmer have more than 5 lakh income from the farming.

TABLE 5
ANNUAL INCOME

Particulars	Frequency	Percentage
upto 1 lakh	12	4
1 lakh-3 lakh	29	10
3 lakh-5 lakh	60	20
above 5 lakh	200	66

4.5 How many crops grows in a year?



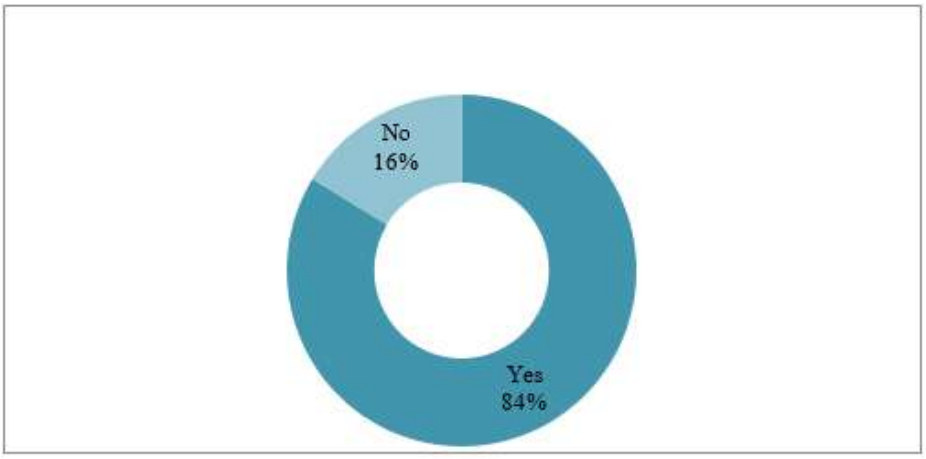
GRAPH 4.5: Crop Growth

From the above graph 4.5, 1% of the farmers cultivate more than 3 crops in year, 17% farmerscultivate 1-2 crops in a year and 82% of farmers cultivate 2-3 crops in a year because of enough source of irrigation mostly from bore well.

TABLE 6
CROP GROWTH

Particulars	Frequency	Percentage
2-Jan	50	17
3-Feb	248	82
more than 3	3	1

4.6 Do you use WSF fertilizer?



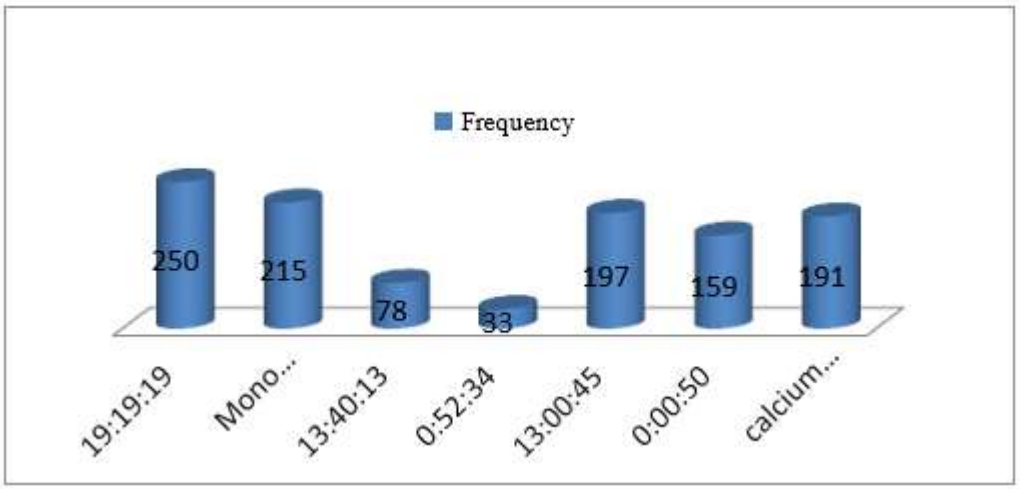
GRAPH 4.6: WSF Fertilizer

From the above Graph 4.6, 84% of farmers from the sample size are using WSF and 16% are not use WSF yet. From this we can conclude that due to enough irrigation facility Most of thefarmers Using WSF. So from this graph we have great market Potential for WSF in future.

TABLE 7
WSF FERTILIZER

Particulars	Frequency	Percentage
Yes	252	84
No	49	16

4.7 Which type of WSF grade do you use?



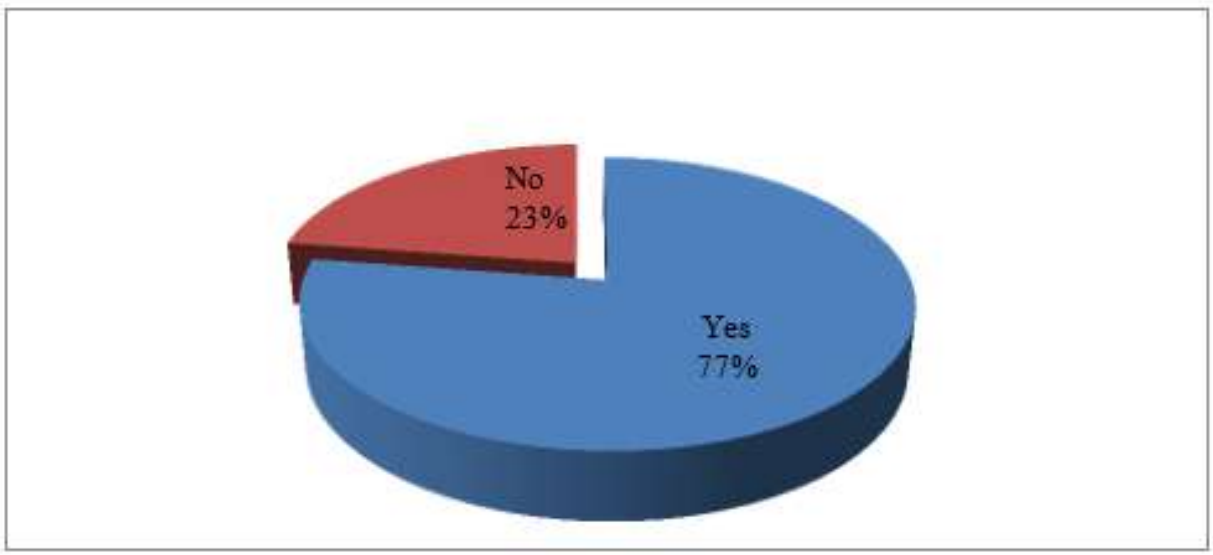
GRAPH 4.7: WSF Grade

From above graph 4.7, the WSF Grade is 19:19:19 is 22%,12:61:00 is19% of farmers are used,13:40:13 is 7% of farmers use, 00:52:34 is 3%,13:40:45 is 18%, 00:00:50 is 14%,Calcium nitrate is 17% of farmers are used.

TABLE 8
WSF GRADE

Particulars	Frequency	Percentage
19:19:19	250	22
Mono-ammonium phosphate	215	19
13:40:13	78	7
0:52:34	33	3
13:00:45	197	18
0:00:50	159	14
calcium Nitrate	191	17

4.8 Do you change WSF brand regularly?



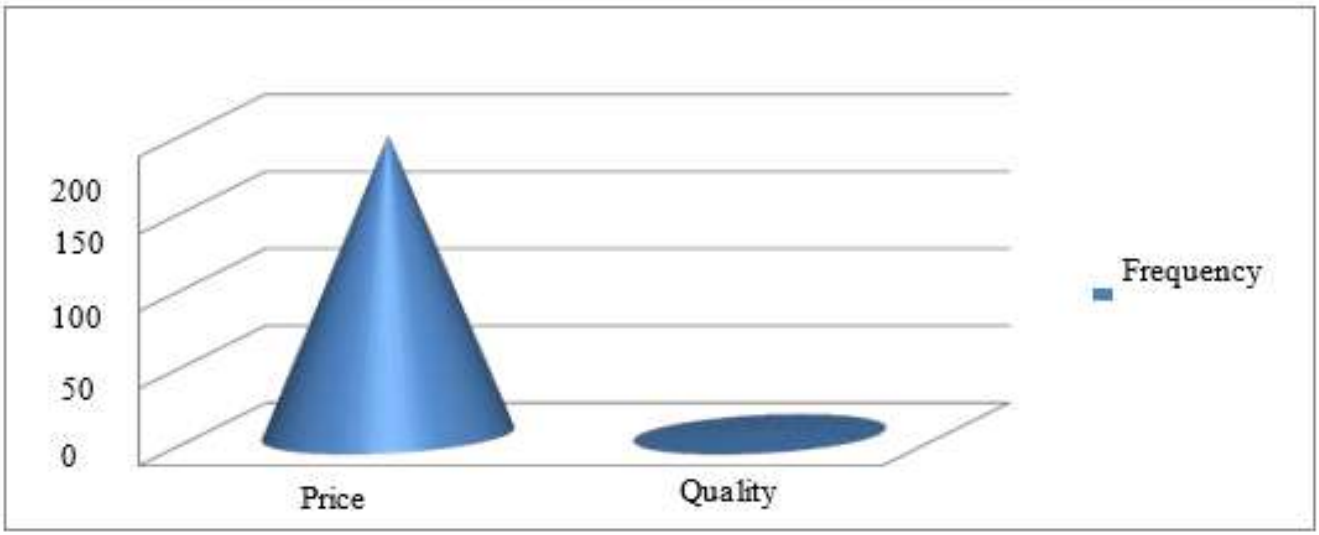
GRAPH 4.8: WSF brand regularly

From above graph 4.8, from the given sample size 77% of farmers regularly change theWSF farmers and 23% of farmers not change WSF brand.

TABLE 9
WSF BRAND REGULARLY

Particulars	Frequency	Percentage
Yes	195	77
No	57	23

4.9 Why do you change WSF brand?



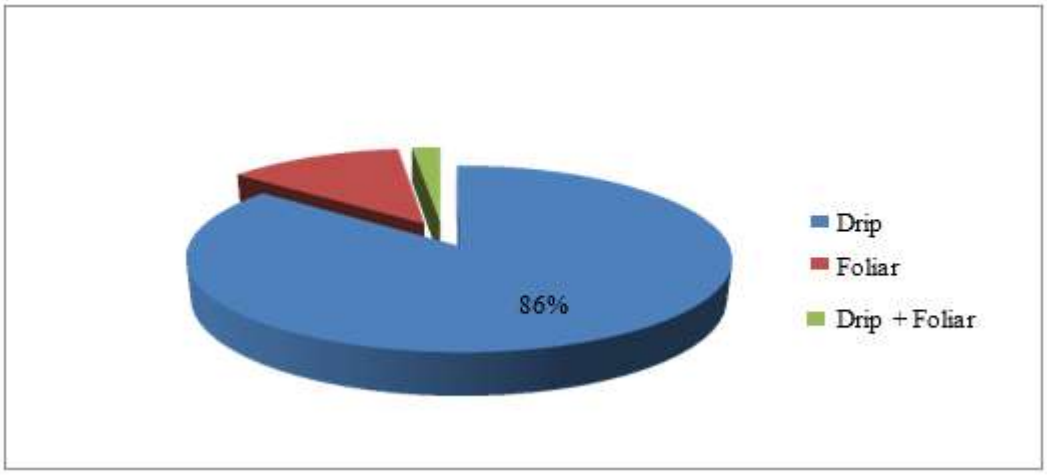
GRAPH 4.9: Factor influencing change in WSF brand

From the above graph 4.9, it clearly shows that 98% of farmers change WSF brand due to the price, price is the most important factor to change in WSF brand and only 2% of farmers change WSF brand due to quality while availability and others factors are not affect to change in WSF brand.

TABLE 10
FACTOR INFLUENCING CHANGE IN WSF BRAND

Particulars	Frequency	Percentage
Price	194	98
Quality	3	2

4.10 How do you apply WSF in your crop?



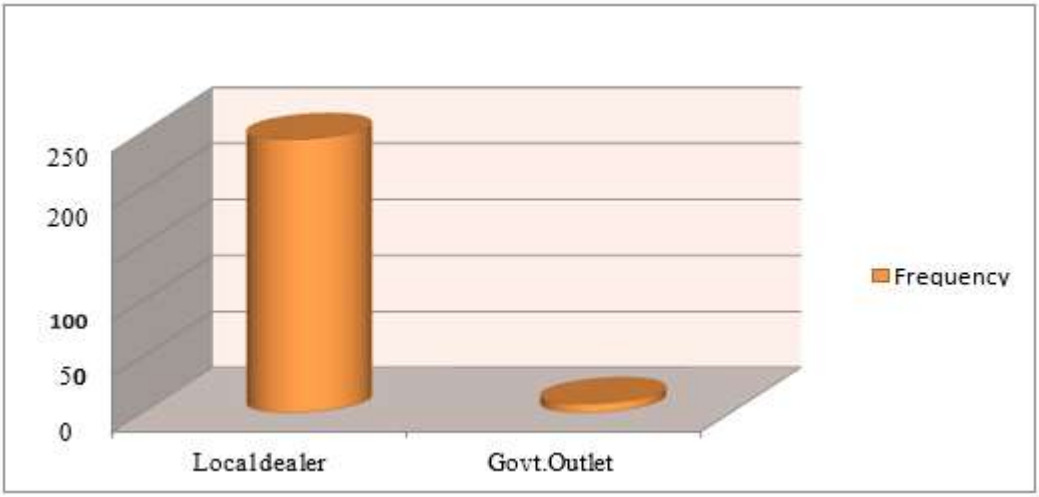
GRAPH 4.10: Application of WSF

From the above graph 4.10, 86% farmers used drip irrigation for the application of WSF,12% of farmers use foliar irrigation for the application of WSF and only 2% of farmers use drip + foliar for application WSF. Here in Gujarat highly drip irrigation followed by farmers so itis good for application of WSF and health of the plants.

TABLE 11
APPLICATION OF WSF

Particulars	Frequency	Percentage
Drip	216	86
Foliar	31	12
Drip + Foliar	5	2

4.11 Where you purchase WSF?



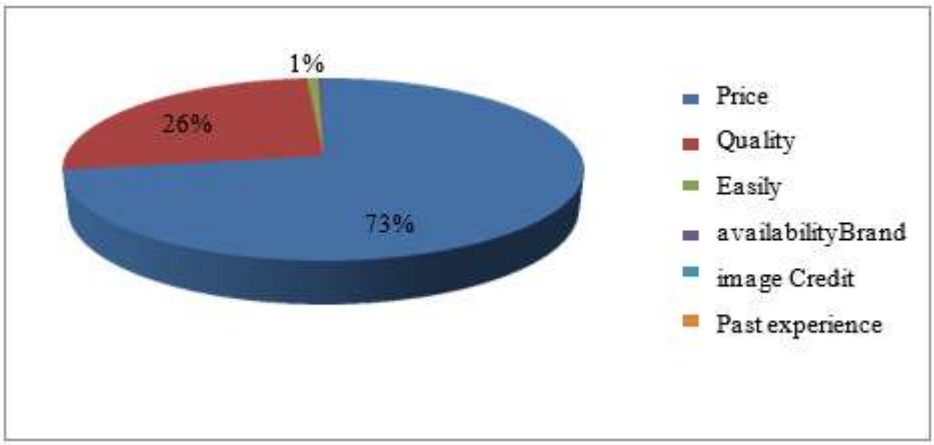
GRAPH 4.11: WSF Purchase

From above graph 4.11, 97% of farmers purchase WSF brand from local dealers and only 3% of farmers purchase WSF brand from Govt. outlets.

TABLE 12
WSF PURCHASE

Particulars	Frequency	Percentage
Local dealer	244	97
Govt. Outlet	8	3

4.12 Which factor do you consider during buying WSF?



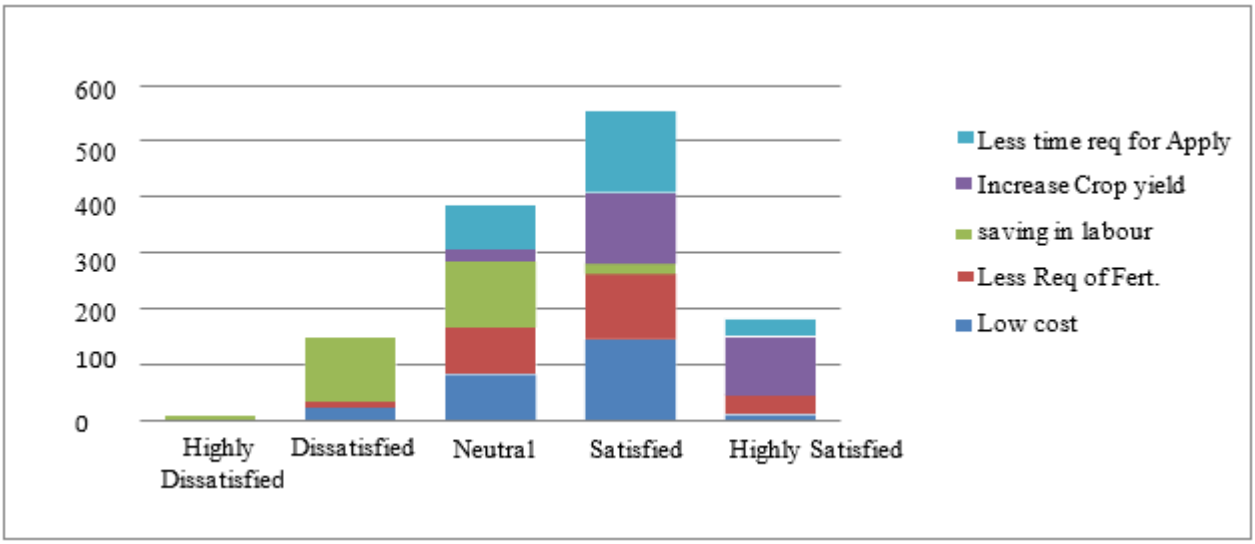
GRAPH 4.12: Factor influencing buying WSF

From the above graph 4.12, it shows the 73% of farmers from the sample size is mainly influence by the price during the buying of WSFs while 26% of farmers influence by quality and very few farmers influence by other factor. Most of the farmers are as per price change their buying behavior of WSFs.

TABLE 13
FACTOR INFLUENCING BUYING WSF

Factors	Price	Quality	Easily availability	Brand image	Credit	Past experience
Rank 1	183	66	2	1	0	0
Rank 2	64	156	23	9	0	0
Rank 3	2	26	49	172	1	3
Rank 4	3	4	174	60	5	5
Rank 5	0	0	3	9	89	151
Rank 6	0	0	1	1	157	93

4.13 How satisfied are you with the following aspects of WSFs:



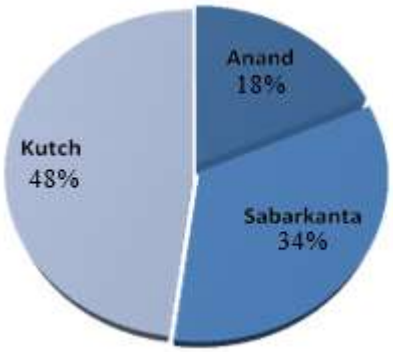
GRAPH 4.13: Satisfied aspects of WSF

From above graph 4.13, most of the farmers are satisfied with low cost ,some are neutral about less requirement of fertilizers, most of farmers are dissatisfied about saving in labour that is labour cost and labour are not related to using WSF. Labour requirement varies as per the crops and farmers. Most of the farmers satisfied with increase in crop yield by using WSF and also satisfied with relation WSF application and less time required for application. But in this type of question the major limitation is the decision varies as per the farmers views so it cannot be predicted completely.

TABLE 14
SATISFIED ASPECTS OF WSF

Parameters	Highly Dissatisfied	Dissatisfied	Neutral	Satisfied	Highly Satisfied
Low Cost	2	22	80	142	8
Less req. of fertilizers	0	11	86	119	36
Saving in labour	4	112	117	19	0
Increase Crop yield	0	0	22	126	104
Less time required for apply	0	0	77	146	29

V. DEALERS AND RETAILERS SURVEY:

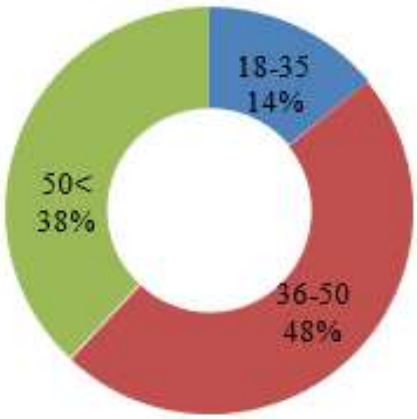


GRAPH 5: Region

TABLE 15
AGE OF FARMER

Region	Percentage
Anand	18%
Sabarkantha	34%
Kutch	48%

5.1 Age of Respondent:



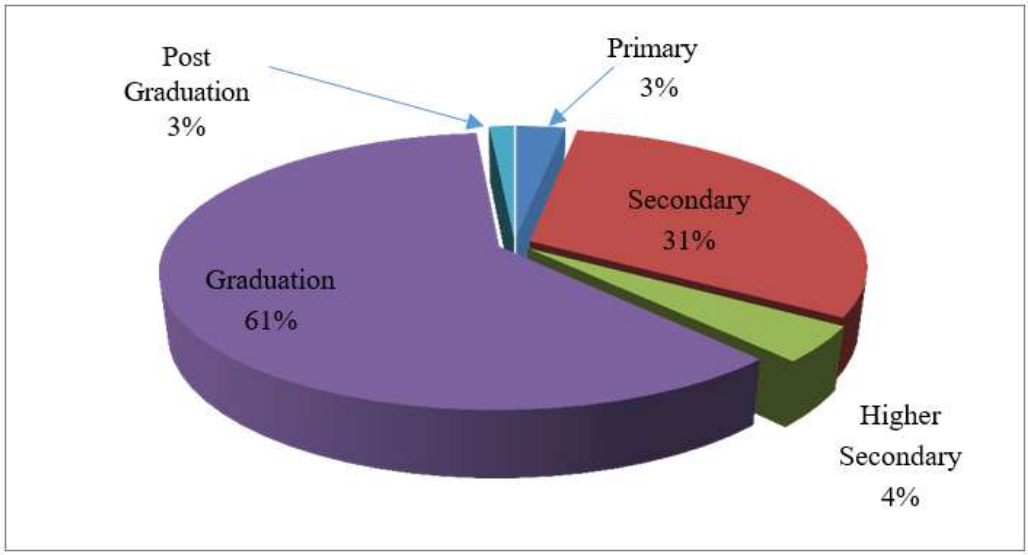
GRAPH 5.1: Age of dealers

From the above graph 5.1, 38% of dealers are above age of 50 years, 48% of dealers are between 36-50 years old and 14% dealers are youngsters, it makes agriculture better and new innovations new products are easily convey to the farmers.

TABLE 16
AGE OF FARMER

Particulars	Frequency	Percentage
18-35	10	14
36-50	34	48
50<	27	38

5.2 Education:



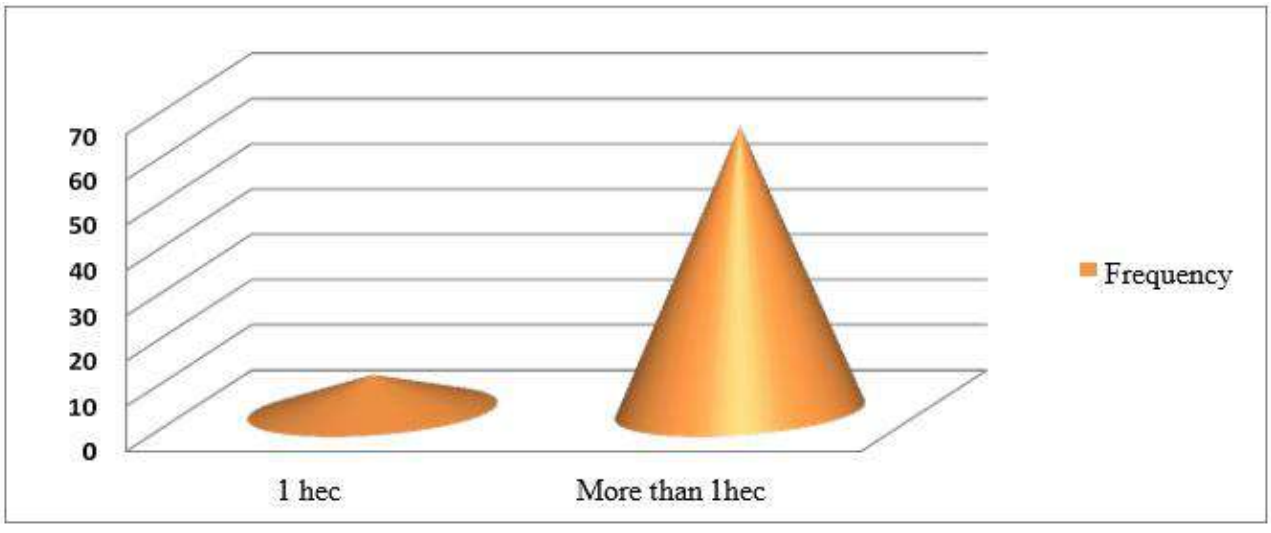
GRAPH 5.2: Education

From the above graph 5.2, 61% of dealers are graduate 1% are post graduate,3% of dealers are did primary education,31% of dealers did secondary education and 4% did higher secondary education.

TABLE 17
EDUCATION

Particulars	Frequency	Percentage
Primary	2	3
Secondary	22	31
Higher secondary	3	4
Graduation	43	61
Post-graduation	1	1

5.3 Land holdings:



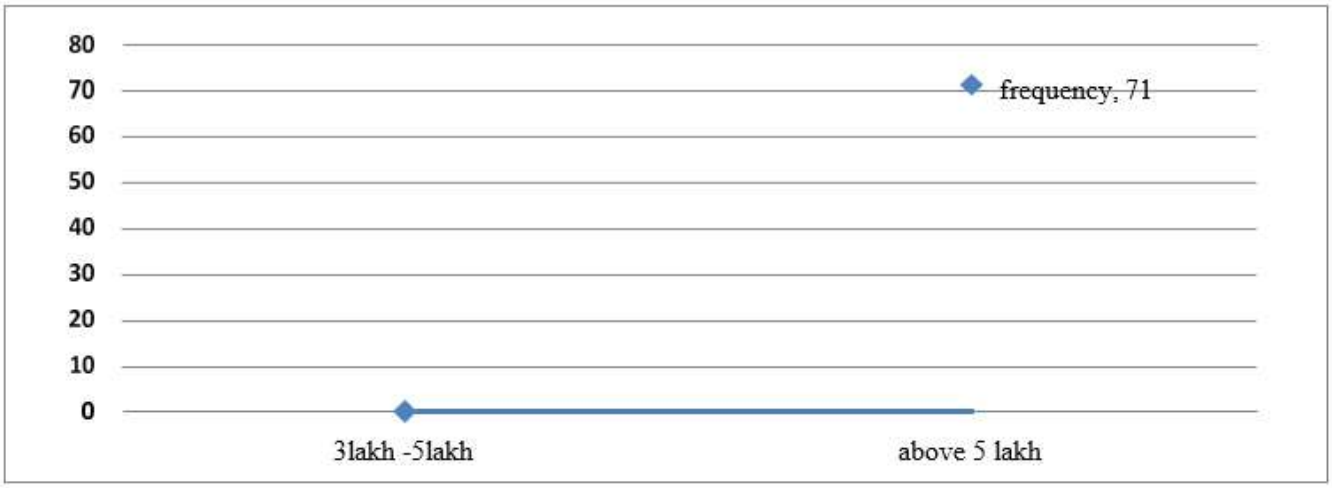
GRAPH 5.3: Land holding

From the above graph 5.3, 11% of dealers have upto 1hector land and 89% of dealershave more than 1hector of land.

TABLE 18
LAND HOLDING

Particulars	Frequency	Percentage
1 hec	8	11
more than 1hec	63	89

5.4 Annual Income:



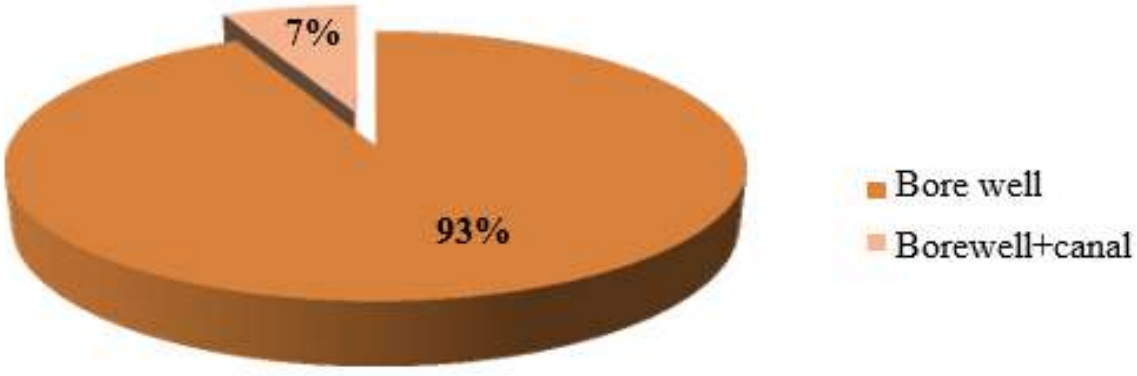
GRAPH 5.4: Annual Income

From the above graph 5.4, according to given sample size in that 100% of dealers haveabove 5 lakh of yearly in income.

TABLE 19
ANNUAL INCOME

Particulars	Frequency	Percentage
3lakh -5lakh	0	0
above 5 lakh	71	100

5.5 Source of irrigation:



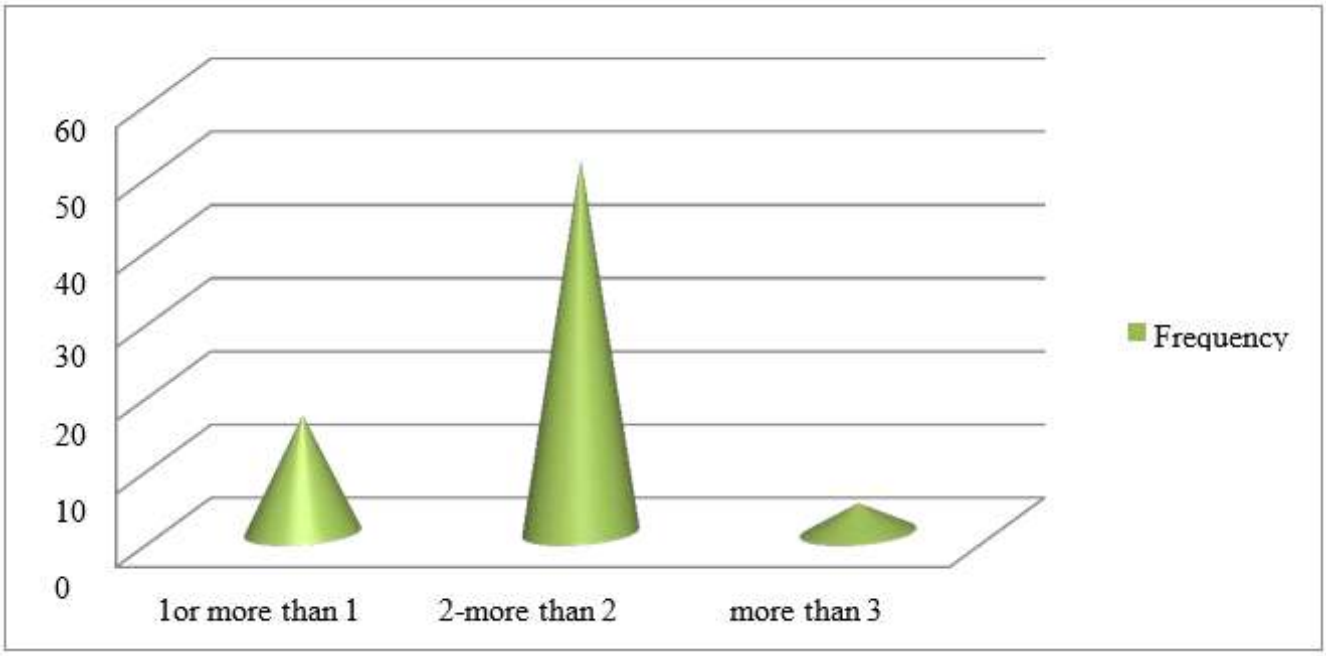
GRAPH 5.5: Source of Irrigation

From the above graph 5.5, 93% of dealers use bore well as source of irrigation and7% of dealers use bore well +canal use for irrigation.

TABLE 20
SOURCE OF IRRIGATION

Particulars	Frequency	Percentage
Bore well	66	93
Bore well +canal	5	7

5.6 How many crops grow in a year?



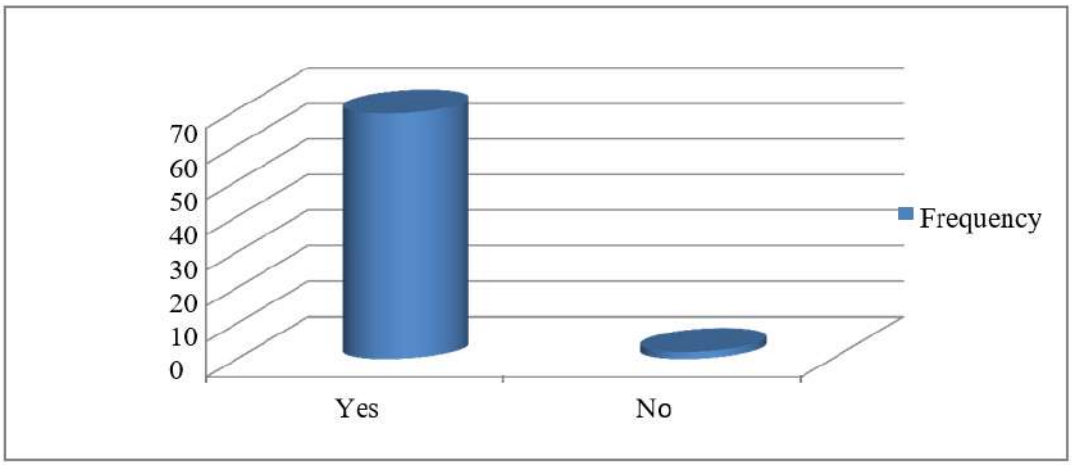
GRAPH 5.6: Crops in a year

From the above graph 5.6, according to the sample size 22% dealers cultivate 1 ormore than crop, 72% have 2 or more than 2 crops and 6% have more than 3 crops in a year.

TABLE 21
CROPS IN A YEAR

Particulars	Frequency	Percentage
1or more than 1	16	22
2-more than 2	51	72
more than 3	4	6

5.7 Do you use WSF?



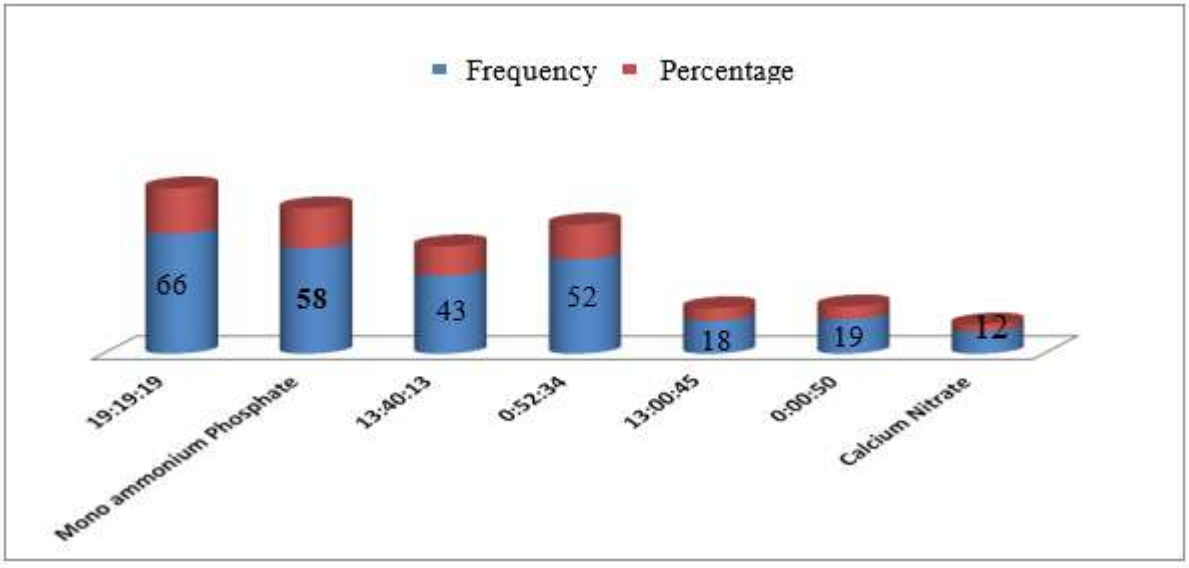
GRAPH 5.7: WSF use

From the above graph 5.7, 97% of dealers use WSF and 3% are not use WSF brand. So that here we can state that most of dealers can increase the WSF Sale in future.

TABLE 22
WSF USE

Particulars	Frequency	Percentage
Yes	69	97
No	2	3

5.8 Which type of WSF grade do you use?



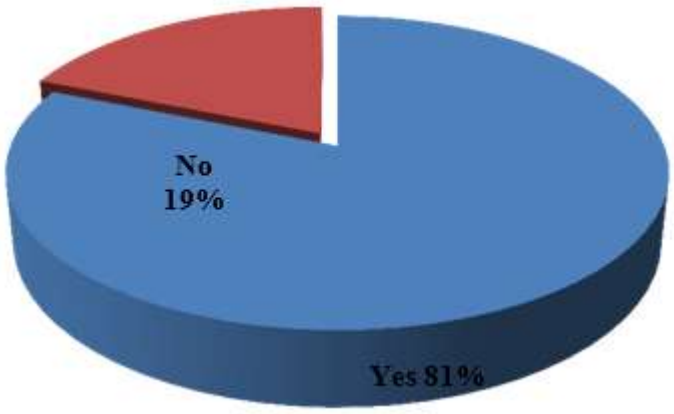
GRAPH 5.8: WSF Grade

From the above graph 5.8, according to sample size,25% use of 19:19:19, 22% use of monoammonium phosphate,16% of use 13:40:13,19% of use 0:52:34, 7% of use 13:00:45, 7% of use of 00:00:50, 4% of use calcium nitrate.

TABLE 23
WSF GRADE

Parameters	Frequency	Percentage
19:19:19	66	25
Mono-ammonium Phosphate	58	22
13:40:13	43	16
0:52:34	52	19
13:00:45	18	7
0:00:50	19	7
Calcium Nitrate	12	4

5.9 Do you change WSF brand regularly?



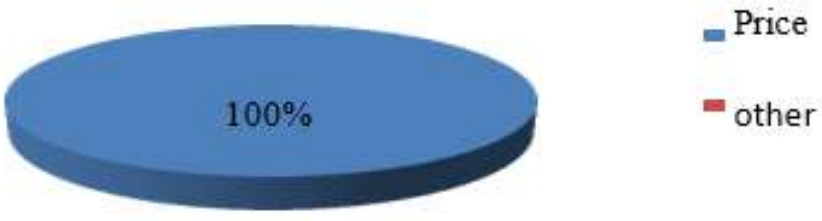
GRAPH 5.9: Change WSF brand

From above graph 5.9, 81% dealers are change WSF brand while 19% dealers notchange the WSF brand they use.

TABLE 24
WSF BRAND

Parameter	Frequency	Percentage
Yes	56	81
No	13	19

5.10 Why do you change WSF brand?



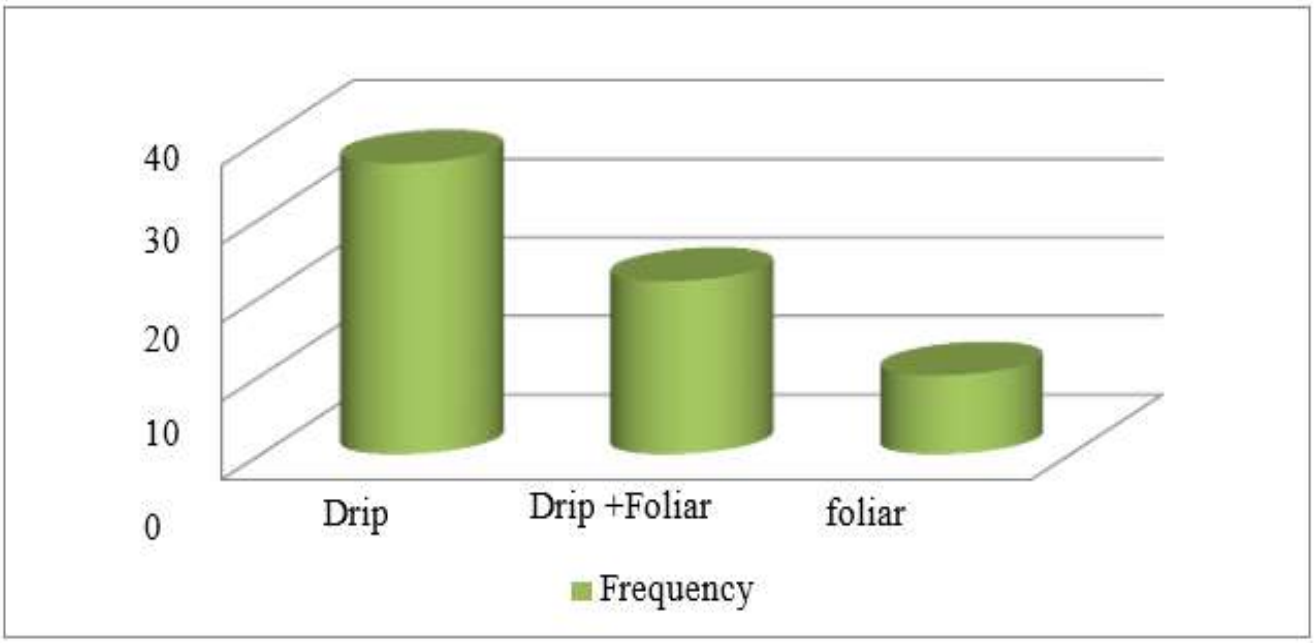
GRAPH 5.10: Factor affecting change brand

From the above graph 5.10, according sample size we can easily analyze 100% are change the WSF brand due price factor only other factors like quality and availability are not affecting towards changing the WSF brand.

TABLE 25
FACTOR AFFECTING CHANGE BRAND

Parameters	Frequency	Percentage
Price	56	100
other factors	0	0

5.11 How do you apply WSF in your crop?



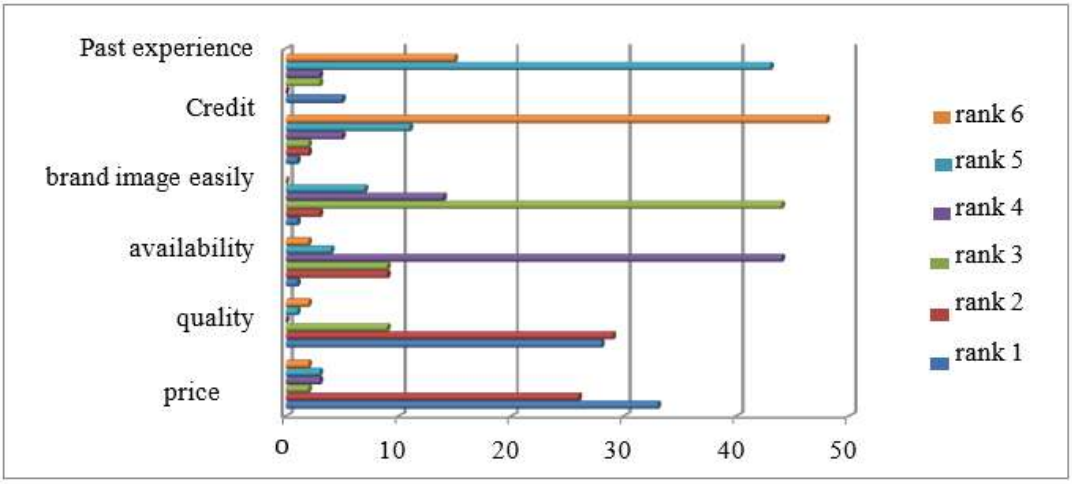
GRAPH 5.11: Application of WSF

From above graph 5.11, From the sample size 54% dealers use drip irrigation for the application of WSF, 22% are using drip + foliar irrigation for the application of WSF while 14% are using foliar irrigation for the application of WSF. From this we can analyze the land under dripirrigation increasing and we have great demand in future of WSF, most of farmers used WSF dueto irrigation facilities.

TABLE 26
APPLICATION OF WSF

Particulars	Frequency	Percentage
Drip	37	54
Drip +Foliar	22	32
foliar	10	14

5.12 Which factor do you consider during buying WSF?



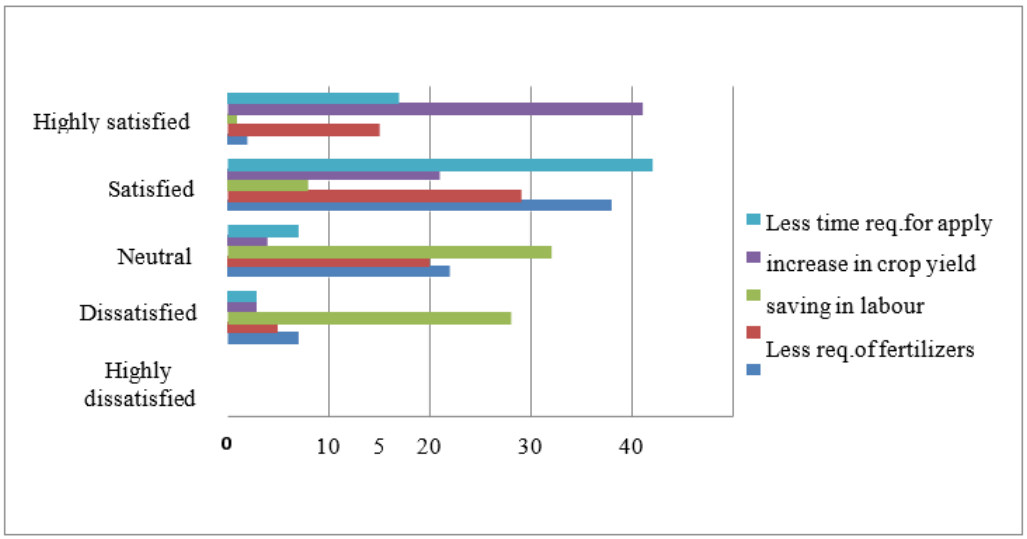
GRAPH 5.12: Factor influencing buying WSF

From the above graph 5.12, it shows that 48% of dealers change their buying behavior of WSFs due price while 41% dealers change due to quality of WSFs brand and very few dealers changes due to other factors. The main factor is price of WSFs brand that influencing the buying behavior of dealers.

TABLE 27
FACTOR INFLUENCING BUYING WSF

Factor	Price	Quality	Easily availability	brand image	Credit	past experience
Rank 1	33	28	1	1	1	5
Rank 2	26	29	9	3	2	0
Rank 3	2	9	9	44	2	3
Rank 4	3	0	44	14	5	3
Rank 5	3	1	4	7	11	43
Rank 6	2	2	2	0	48	15
Percentage	48%	41%	2%	1%	1%	7%

5.13 How you satisfied with the following aspects of WSFs?



GRAPH 5.13: Aspects of WSFs

From above graph 5.13, according respondent all has different views 38 dealers satisfied with the costing among sample size, 29 dealers satisfied with less requirement of fertilizers, 32 dealers neutral about labour saving with relation with WSF use, 41 dealers highly satisfied with increase in crop yield with the relation with WSF use and 42 satisfied with less time required for application with relation with WSFs.

TABLE 28
ASPECTS OF WSFS

Parameters	Highly dissatisfied	Dissatisfied	Neutral	satisfied	Highly satisfied
Low cost	0	7	22	38	2
Less req.of fertilizers	0	5	20	29	15
saving in labour	0	28	32	8	1
increase in crop yield	0	3	4	21	41
Less time require for apply	0	3	7	42	17

VI. FINDINGS AND RECOMMENDATIONS

6.1 Findings from farmer's survey:

Through the detail survey of farmers and dealers relates with Consumption trends ofWSF and its future prospects, I got some findings which are mention below:

1) More than 80% of farmers in Gujarat are aware about WSF.
2) 37% of farmer's age is in between 36-50 and now youngsters are also involving in agriculture.
3) No. of farmers are educated so they are easily adapting new techniques of farming.
4) 71% of farmers have more than 1 hector Maximum of land. Where they cultivate vegetables, horticultural crops cash crops and field crops.
5) More than 80% of farmers have drip irrigation, so we have great market potential towards WSF.
6) Most of the farmers have quite high annual income from vegetable and horticultural crops, so they prefer to cultivate it regularly.
7) Presently 84% of farmers, from the sample use WSF and in future the consumption and demand of WSF will be increase.
8) Most of the farmers are use all WSF grade according crops requirement.
9) More than 90% farmers purchase WSF from the local dealers.
10) Most of the farmers are highly satisfied with the increase in crop yield due to application of WSF in crops.
11) Over all farmers are well satisfied with WSFs results, they use WSF in a great manner and they also suggest to other farmers to use WSF specially in Kutch region farmers are very active and they follows all new practices on their field, so in future consumption will definitely increases.

6.2 Findings from dealer's survey:

1) Above 50% of dealers are youngsters and 60% are graduates and agri. Diploma respectively.
2) Most of them started their firm before 10-15 years, so the farmers believe them what they suggested to the farmers.
3) Most of the dealers suggested farmers use WSF which increases crop yield and farmers follow their suggestions.
4) 97% of dealers themselves use WSF on their crops.
5) Most of the dealers says more advertising is required and field demonstration from that farmers are ready to learn more about application WSF as per the stages of crop.

6.3 Recommendation:

Recommendations are always considered to be the most important part of any project report because for every pros there is a cons associated with and to reduce the effect later.

From the detail survey of farmers and dealers relates with consumption trends of WSF, followingrecommendations must be taken into consideration.

- It is suggested that WSF Company should conduct awareness campaign programmes about WSF grades for the farmers so that they can understand its benefits.
- To strengthening the market of WSFs, company should pay attention towards promotional activities in the form of field demonstrations, farmers meeting at village level to make the farmers familiar with the products.
- It is suggested that company should provide field advisor at many possible villages through that farmers are following their suggestions and familiar with WSFs and learn how to apply the WSFs at every stage of crop. From this they can mouth publicity to products to the other farmers. Mouth publicity is the best way to communicate one farmer to other.
- Company should have to improve packaging of some product. Dealers says polythene packaging product leaked sometimes, especially in micro-nutrient that is Agromin max and Boron packaging.
- Dealers and retailers are also working as like wheels of vehicle for company, so company should not neglect them. Sales indirectly depend on them because most of the farmers prefers dealers and retailers recommendations that time he use push strategy for sale of the product, so company should provide tours, refreshment gifts and yearly diaries, calendars to them.

VII. CONCLUSION

From the above whole study it can be conclude that, in Gujarat i.e. from the survey region Sabarkanta, Anand, Kutch region it shows that here all vegetables, horticultural crops, cash afield crops are cultivated in large amount.

The productivity and fertility of the land is well. The irrigation is very good most of the farmers have drip irrigation facility. And most of the farmers new techniques of farming. Most of the farmers use WSF in wide range.

Hence, there is very wide scope for WSF in Gujarat to enhance the market potential its function area, to there is no any doubt that here lots of scope to capture for WSF market. There are many companies which are putting their efforts to prove how their WSF than the others. They mainly focus on price of WSF. As per the farmers expectations companies should maintain the little bit less price of WSF and more accessible in local or village level stores. There is need of advertisements with the help of Wall paintings, shop paintings, trolley paintings etc.

From the all above detail study the present consumption of WSF is at good amount and in future the consumption trends of WSF is increase very fast at very wide area.

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Enhancing Germination and Growth in Fruit Crops: A Comprehensive Review of Pre-Sowing Treatments

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Abstract— *Pre-sowing treatments are pivotal interventions in optimizing nursery practices for fruit crop production, addressing the demand for increased planting material, especially grafts. This review paper comprehensively analyzes the efficacy and mechanisms of pre-sowing treatments, encompassing hormonal priming, osmopriming, and halo-priming techniques. Molecular and physiological mechanisms underlying seed germination and seedling growth are elucidated, emphasizing their influence on gene expression patterns, hormonal signaling pathways, and physiological processes within seeds. Interactions with plant hormone signaling pathways, particularly the modulation of gibberellin (GA) and abscisic acid (ABA) levels, are explored in detail, highlighting their role in regulating seed dormancy and germination. Moreover, the review discusses the impact of pre-sowing treatments on gene expression related to germination and growth, shedding light on the molecular basis of their effects. Challenges in fruit crop production, such as the need for accelerated seed germination and seedling growth, are addressed, with pre-sowing treatments identified as key solutions. The paper concludes by outlining future prospects and emphasizing the indispensable role of pre-sowing treatments in modern fruit crop production systems. In summary, this review provides a comprehensive understanding of pre-sowing treatments, their mechanisms of action, and their implications for nursery management and sustainable fruit crop production.*

Keywords— Pre-sowing treatment, seedling emergence, mango.

I. INTRODUCTION

Seed germination in horticultural crops, such as mango Kagzi lime, Karonda, Jamun, Papaya, and Phalsa, relies heavily on environmental factors like water potential, temperature, humidity, and light. Successful propagation of these crops from seeds necessitates a comprehensive understanding of seed viability, storage conditions, optimal sowing times, and the factors influencing germination and seedling care. However, poor seed germination is still a significant challenge in fruit crops, often which can be due to the presence of germination inhibitors in the seed coat, including benzoic acid, cinnamic acid, coumarin, naringenin, jasmonic acid, and abscisic acid (ABA). The low germination rates and extended germination periods, along with slow seedling growth rates, hinder the use of these crops as rootstocks, essential for budding and grafting processes. Dormancy or hard seed coats are common reasons for seed germination failure, prompting the exploration of pre-sowing treatments to enhance germination and subsequent seedling growth. Methods such as scarification or soaking in solutions like KNO_3, Urea, hot or cold water, thiourea, cow urine, cow dung slurry, or GA_3 aim to increase seed coat permeability and improve germination rates as displayed in Fig 1. These pre-sowing treatments enhance embryo growth potential, reduce germination time, weaken seed coats, and promote maximum germination percentages. Additionally, the application of plant growth regulators like GA_3, IBA, and IAA, in appropriate concentrations alongside scarification, can regulate growth behavior and enhance seed germination and seedling growth. Extensive experimentation has been conducted to identify optimal treatments tailored to

different fruit crops, emphasizing the importance of uniform germination for effective planting or rootstock use. This paper addresses gaps in understanding the molecular and physiological mechanisms of pre-sowing treatments, particularly focusing on hormonal priming. It aims to explore specific genes and signaling pathways influenced by these treatments across different fruit crop species. Additionally, the review highlights the need for long-term studies on the effects of pre-sowing treatments on plant growth and yield. Furthermore, it emphasizes the lack of comparative studies under varying environmental conditions and suggests avenues for future research, including novel treatment exploration and integration into sustainable nursery management practices. Through these efforts, the paper aims to enhance our understanding of pre-sowing treatments and their potential applications in fruit crop production.

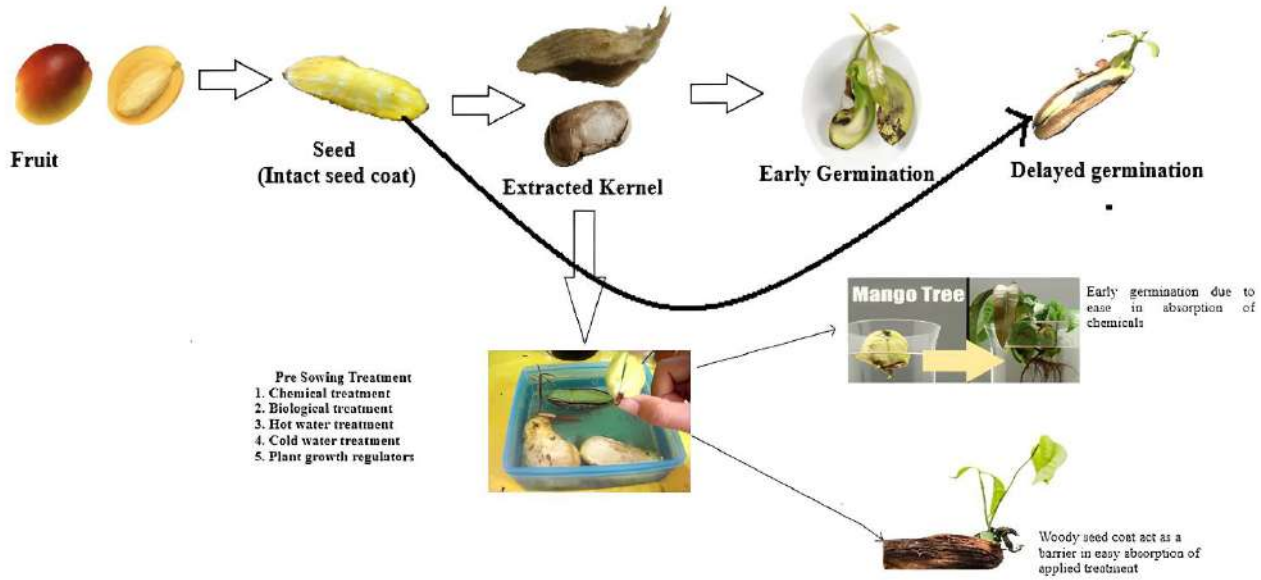

FIGURE 1: Schematic representation of difference on using pre-sowing treatments

FIGURE 2: Pre-sowing treatment impacting fruit industry

Seed priming: Seed priming is a widely adopted physiological technique involving seed hydration and drying to enhance metabolic processes prior to germination, thereby accelerating germination, seedling growth, and overall crop yield under normal as well as diverse biotic and abiotic stress conditions. It serves as a cost-effective and efficient method to stimulate seed germination (Dawood, 2018). Seed priming promotes synchronized seed germination and increased emergence (Ghassemi-Golezani *et al.*, 2012; Dalil, 2014), offering multiple benefits such as reduced fertilizer usage, enhanced crop yield through synchronized germination, and induction of systemic resistance in plants, all in a cost-effective and environmentally friendly manner.

TABLE 1
SEED PRIMING

Priming Method	Description	Advantages
Hydro-priming	Soaking of seeds with water.	Established and cost-effective method.
Halo-priming	Treatment of seeds with inorganic solutions (e.g., NaCl, KNO_3, $CaCl_2$, $CaSO_4$).	Enhances germination.
Osmo-priming	Soaking seeds in osmotic solutions with varying concentrations of solutes.	Creates an osmotic gradient, facilitates water movement into or out of seeds.
Hormonal-priming	Seed priming with hormone solutions.	Enhances seed germination and vigor.
Solid-based Matrix	Immersing seeds in a solid matrix for gradual water absorption.	Enhances efficacy of fungicides and insecticides, controls soil-borne insects and diseases.
Bio-priming	Integrates biological elements (e.g., seed inoculation with beneficial organisms) and physiological aspects (e.g., seed hydration).	Safeguards seeds, manages diseases, promotes seed vigor.

II. COMPARATIVE ANALYSIS OF DIFFERENT PRE-SOWING TREATMENT

The comparative analysis of various pre-sowing treatments, as observed by different researchers across different plant species, highlights the diverse effects of chemical treatments, growth regulators, and biological inoculants on seed germination and seedling growth. Among all the chemical treatments (50%HCl, 5%H_2SO_4, 1% thiourea, 1% KNO_3, 2% sucrose, 2% urea, 2% bleaching powder) and growth regulator (100 ppm GA_3), seeds treated with 2 percent bleaching powder in 24 hrs treatment emerged as the best regarding germination, growth of the seedlings of Passion fruit followed by seeds treated with 100 ppm GA_3 for 30 min (Mehta *et al*., 2016). Similarly, Patel *et al.,* (2016) found that seed priming with GA_3 150 mg litre^{-1} resulted in germination percentage (84.33 %). Al-Absi, K.M. (2010) recorded the highest germination percentage (65.0%) in mahaleb cherries (*Prunus mahaleb* L.) seeds stratified for 90 days treated with gibberellic acid at 1000 ppm. Whereas, Heidari *et al.,* (2008) found immersion of *P. scoparia* seeds in sulfuric acid for 30 minutes + 30 days of stratification increased the percentage of germination by 74.5%. Sayan *et al.,* (2019) in wood apple (*Feronia limonia*) found that amongst the different concentrations of used chemicals, the maximum germination percentage (81.67 %) was found in treatment with GA_3 100 ppm. Patil *et al.,* (2012) recorded higher germination of rangpur lime (98.66%) under GA_3 150 ppm under Akola conditions. In Aonla, Bhadauria *et al.,* (2000) reported that seed treatment with Azospirillum biofertilizer slurry for 24 hrs increased germination percentage (79%). While, Kumar *et al.,* (2008) observed that the mango stones pre-treated with 3% Panchagavya took a lesser number of days for the initiation of germination and recorded maximum germination (75.22%). Additionally, in Khirni seeds, Shirol *et al.,* (2005) found that pre-soaking of seeds in cow dung slurry for 24 hours resulted in higher (66.83%) seed germination whereas, khirni seeds treated with GA_3 50 ppm resulted in the highest germination percentage (92.31%) followed by GA_3 75 ppm (92.31%) and GA_3 75 ppm (89.76%) (Wankhede *et al.,* 2008). Furthermore, Venudevan and Srimathi (2013) in bael observed higher germination (84%, 80%, and 76%) when seeds were soaked in water for (6 hrs, 9 hrs and 12 hours) respectively under Coimbatore conditions. Overall, the findings suggest that the efficacy of pre-sowing treatments varies depending on the plant species and the specific treatment method used. However, treatments involving Gibberellic acid and biological inoculants consistently showed positive effects on seed germination across different plant species.

2.1 Effect of pre-sowing treatments on different parameters:

2.1.1 Impact of pre-sowing treatments on number of days for germination:

Germination in certain fruit crops encounters barriers known as dormancy, stemming from internal or external factors. External dormancy can arise from tough seed coats, exemplified by mangoes, walnuts, and almonds, or from a slimy covering like sarco-testa found on papaya seeds. Internally, inhibitors within seeds can hinder germination until removed. Several methods exist to overcome dormancy, including seed coat removal, which promotes early germination by mitigating mechanical constraints on embryo growth. Banyal *et al.,* (2021) reported earlier germination of the extracted kernel in comparison to those that were sown along with seedcoat as the kernel can directly absorb the water while the kernels with seed coat delayed germination as the seed coat was woody which hindered the absorption of water by the seed. Once the seed coat was softened, the entry of water into the seed coat resulting in the initiation of germination. Also, soaking the seed in GA_3 @ 100 ppm resulted in earlier

germination. Similarly, Muralidhara *et al.,* (2016) found that seed coat removal reduced germination time compared to intact seed coats, with initiation and completion of 50% germination occurring in 16.5 and 25.9 days, respectively, compared to 20.2 and 30.5 days by the control. Late germination with intact seed coats may be attributed to the stony endocarp acting as a barrier against inhibitor escape, as observed by Padma and Reddy (1997). Abbas *et al.,* (2015) also observed delayed germination with unhusked seeds compared to husked seeds. Sinnadurai (1975) reported earlier germination in mango seeds with removed seed coats, with initiation on the 6th day for some cultivars, compared to the 10th day for controls. Chemical treatments like GA_3 have also been effective in promoting early germination by increasing amylase activity, as shown by Muralidhara *et al.,* (2015) and Patel *et al.,* (2016). GA_3 @200 ppm induced early germination in 12 days and completion of 50% germination in 28 days, compared to 18 and 32 days for the control, respectively. Patel *et al.,* (2016) found GA_3 @100 ppm reduced germination time in mango seeds compared to beejaaumrit 2%. These findings emphasize the importance of tailored treatments to overcome dormancy and optimize germination in fruit crops.

Reddy and Reddy (2017) found that KNO_3 @2% required 21 days for germination initiation and 29 days for 50% germination completion, while control seeds took 27 days for initiation and 37 days for 50% germination. Reshma and Simi (2019) observed that sowing mango stones with the stalk end up (22.95 days) reduced germination time compared to flat sowing (21.95 days), with 50% germination completing in 31.75 days for stalk end up and 40.91 days for flat sowing. Similarly, GA_3 @ 200ppm exhibited minimum initiation time (22.62 days) and 50% germination completion (31.78 days), while control seeds took longer (31.01 days for initiation, 42.94 days for 50% germination). Vidya *et al.,* (2018) reported that GA_3 @ 250 ppm-initiated germination in 12.07 days, with earliest completion in GA_3 @ 500 ppm and cow urine @ 50% (50.91 days). Dawale *et al.,* (2012) found earliest germination initiation after 10.67 days with panchgavya @ 3%, 50% germination completion in 20.33 days with neem seed kernel extract @ 5%, and quickest complete germination in 36.67 days with neem seed kernel extract @ 5%. Kumar *et al.,* (2008) observed earliest germination initiation (12.25 days) and complete germination (46.18 days) with Panchgavya 3%, while control seeds took longer (17.31 days for initiation, 50.49 days for complete germination). Kolekar *et al.,* (2017) reported minimum initiation time (12.57 days) and completion time (44.34 days) with GA_3 @ 100ppm, similar to water soaking. Chaudhary (2016) found that seeds treated with Cow dung slurry for 24 hours-initiated germination in 10.87 days, while control seeds-initiated germination after 21.30 days. Parmar *et al.,* (2018) provided similar findings in jackfruit, where chemicals were found to initiate quick germination. The first germination was observed in cow dung slurry within 13.73 days. Singh *et al.,* (2015) reported rapid germination in 8.50 days in seeds treated with GA_3 @200ppm, while seeds under control took the maximum number of days (13.50 days). Tandon *et al.,* (2019) studied the effect of organic substances and plant growth regulators on seed germination and survival of tamarind seedlings. They observed germination initiation within 5.27 days in seeds treated with GA_3 @ 200 ppm. 50% germination was observed after 16.00 days, with the maximum time required for germination observed in the control treatment (12.71 days), and 50% germination occurring after 26.67 days. Pavithra *et al.,* (2018) provided reports on the time taken by Surinam Cherry (*Eugenia uniflora* L.) for germination. Water-soaked seeds, initiated germination in 18.33 days, with 50% germination recorded in 25.00 days. Seeds treated with HCl 25% required the maximum number of days (24.33 days) for germination, while 50% germination was completed in 27.67 days with thiourea 1% and KNO_3 1%. Palepad *et al.,* (2017) recorded the minimum number of days (10.27) required for germination of custard apple seedlings by treating seeds with GA_3 @ 1000 ppm for 24 hours. Babu *et al.,* (2008) found the minimum number of days (29.73 days) required for germination of papaya seeds treated with GA_3 @ 100 ppm. Kalyani *et al.,* (2014) noted that the minimum number of days required for germination was 19.20 days in guava seeds treated with GA_3 @ 1000 ppm. Seed coat removal and chemical treatments, such as GA3 application, significantly reduce germination time in various fruit crops. External barriers like tough seed coats delay germination by hindering water absorption, while internal inhibitors also contribute to dormancy. Tailored treatments, including seed coat removal and GA3 application, optimize germination by promoting early water uptake and enhancing enzymatic activity.

2.1.2 Impact of pre sowing treatment on Germination percentage:

Sumaila *et* al., (2019) found removing seed coat before germination resulted in early germination then sowing along with seed coat in mango under Ghana conditions. Ghosh *et al*., (2003) found that most seed treatments, except for a six-hour soak and treatment with 200 ppm sodium thiosulfate, did not enhance germination in fresh seeds. However, germination rates improved with GA_3 treatment, particularly with 50 ppm GA_3 (75%) and 100 ppm GA_3 (44.00%) (Stenzel *et al.,* 2003). Further, Ratan and Reddy (2004) observed that soaking seeds in 400 ppm GA_3 resulted in the highest germination percentage (69.00%), with seeds soaked in 600 ppm GA_3 initiating germination the earliest (16.00 days). Similarly, Banful *et al*., (2011) noted a total germination of 29.80% after 42 days when *Annona squamosa* seeds were sown in Ghana. However, maximum germination was achieved by soaking seeds in 400 ppm GA_3 for 12 hours, yielding both the highest germination percentage and seedling

height (Gharge *et al.,* 2011). Jadhav *et al.,* (2015) found that treating custard apple seeds with GA_3 at 50 ppm for 48 hours resulted in higher germination rates. Additionally, Parmar *et al.,* (2016) reported that soaking seeds in GA_3 at a concentration of 200 mgL^{-1} for 12 hours led to the shortest germination time (24.00 days) and the highest germination percentage (63.99%). While in citrus Khan *et al*., (2002) investigated pre-sowing seed treatment effects on grapefruit, Kinnow mandarin, and rough lemon seeds. While GA_3 treatment did not significantly affect final germination percentages, Kalalbandi *et al.,* (2003) found high germination rates in Kagzi lime seeds soaked in GA_3 and NAA, particularly with GA_3 at 80 ppm. Similarly, Shinde *et al.,* (2008) observed higher seed germination rates in Rangpur lime with GA_3 at 80 ppm, while Dhaka and Pal (2009) demonstrated better germination, growth, and survival in lime seeds with GA_3 at 500 ppm. Additionally, Patil *et al.,* (2012) reported higher germination rates in Rangpur lime under GA_3 treatment at 150 ppm compared to the control group.

In anola, various treatments have been studied to enhance aonla seed germination. Soaking seeds in 250 ppm GA_3 or distilled water with alternating soaking and drying for 72 hours resulted in the highest germination percentages (Dhankhar and Kumar, 1996). Similarly, soaking seeds in 500 ppm GA_3 led to quicker germination (Sharma, 1996). Treatment with 250 ppm GA_3 resulted in the earliest and highest germination percentages (Dhankhar and Singh, 1996). Treating seeds with 400 ppm GA_3 resulted in a higher percentage of germination (Wagh *et al.,* 1998). Seed treatment with Azospirillum biofertilizer slurry increased germination percentage compared to the control (Bhadauria *et al.,* 2000). Early germination and a high germination percentage were observed with treatment using 200 ppm GA_3 (Gholap *et al.,* 2000). Treatment with Azospirillum + Phosphobacteria + 0.5% KNO_3 resulted in high germination percentages (Rajamanickam and Anbu, 2001). Additionally, treatments using 1% KNO_3 or 200 ppm GA_3 resulted in the highest germination percentages (Rajamanickam and Balakrishnan, 2004). Maximum germination percentages were achieved with treatment using 1% KNO_3 or GA_3 500 ppm (Purbey and Meghwal, 2005; Kumari *et al.,* 2007). The highest germination percentage was observed with treatment using GA_3 750 ppm + Azospirillum (Supe *et al.,* 2012). Scarification and treatment with 1% gibberellin overturned seed dormancy, resulting in a 43% germination percentage (Perera *et al.,* 2014).

In sapota Several studies have investigated methods to enhance the germination of sapota and khirni seeds. Pampanna *et al*. (1995) found that soaking sapota seeds with cracked seed coats in GA_3 300ppm for 24 hours resulted in 53% germination. In contrast, Pampanna and Sulikeri (2001) discovered that treating sapota seeds with GA_3 400 ppm + ethrel led to significantly higher germination rates of 90% within 11.50 days. Similarly, Shirol *et al*. (2005) observed that pre-soaking khirni seeds in cowdung slurry for 24 hours resulted in 66.83% germination. Additionally, Wankhede et al. (2008) reported that in khirni seeds, GA_3 treatments of 50 ppm recorded the highest germination percentage of 92.31%, followed by GA_3 treatments of 75 ppm, both at 92.31%, and GA_3 treatment of 75 ppm at 89.76%. In other fruit crops several studies have explored diverse methods to enhance seed germination in various plant species. Ghyare (2005) observed that tamarind seeds treated with 400 ppm GA_3 exhibited a remarkable 100% germination rate. Abuduca *et al*. (2006) found that wild pistachio seeds treated with GA_3 showed increased germination rates, with the highest rate recorded at a concentration of 200 mg/L. Cetinbas and Koyuncu (2006) reported increased germination in prunus avium seeds soaked in 7500 ppm KNO_3. Ahmad (2010) discovered that 2000 ppm GA_3 resulted in the maximum germination of kiwi fruit seeds. Singh *et al.* (2011) achieved maximum germination in Manila tamarind seeds treated with 50 ppm IBA and GA_3. Yatoo *et al.* (2012) observed that kinetin pre-treatment enhanced apple seed germination. Shabaq (2013) demonstrated that GA_3 treatment at 250 ppm improved germination in loquat seeds. Shah *et al.* (2013) reported significant improvement in peach, plum, and apricot germination with GA_3 treatment combined with water soaking. Venudevan and Srimathi (2013) found increased bael seed germination with prolonged water soaking. Gurung *et al.* (2014) achieved maximum passion fruit seed germination with thiourea treatment. Vasantha *et al*. (2014) noted higher tamarind seed germination with GA_3 treatment. Lastly, Parvin *et al.* (2015) observed improved black walnut seed germination with chilling and GA_3 treatment, while Thakur (2015) found that mechanical rupturing of the seed coat enhanced peach rootstock flordaguard seed germination. These studies collectively highlight diverse strategies for optimizing seed germination across different plant species.

2.2 Effect of pre-sowing treatment on growth parameters:

2.2.1 Seedling height:

Muralidhara *et al*. (2016) found that the mean height of husked seeds was 19.5 cm, while it was only 17.6 cm for un-husked seeds. The highest seedling length was observed for husked seeds, which was 69.02 cm, compared to non-husked seeds without any treatment, where the height was only 28.67 cm in the given time. Among the chemical treatments, the maximum height of 48.76 cm was achieved by using GA_3 @ 1000ppm for 48 hours, as observed by Abbas *et al*. (2015). Shaban (2010) conducted an experiment that resulted in higher seedling length (58.7 cm) for husked seeds and 49.1 cm for unhusked seeds. In the case

of non-husked seeds, GA_3 @200ppm resulted in the highest seedling length (52.50 cm), while in the case of husked seeds, GA_3 @ 200 ppm resulted in the highest seedling length (58.7 cm) according to the study by Muralidhara *et al*. (2015). Thakriya *et al*. (2017) reported the highest seedling height (22.26 cm) for vermiwash 1% treatment, while the lowest height (17.20 cm) was found in custard apple leaf extract 10%. The highest shoot length was found in treatment with thiourea @ 1%, which was 42.77 cm, while the lowest was found to be in the case of beejaaumrit @ 2% which turned out to be 34.42 cm according to Patel *et al*. (2016). Reshma and Simi (2019) reported the highest seedling height in the case of stalk end up position (21.84 cm), while in flat sowing position, it was recorded only 18.34 cm. GA_3 @ 200 ppm resulted in the highest seedling height (22.69 cm), and the least height was observed in the case of control (16.45 cm). Aalta and Srihari (2013) reported that GA_3 @ 500 was best for producing the highest seedling in treated stone and extracted kernel, which was recorded as 23.43 cm and 24.13 cm, respectively. Meanwhile, the least height was recorded in control in Whole nut (18.70 cm) and Extracted kernel (20.12 cm). Dawale *et al*. (2012) recorded maximum height after 90 days after sowing in Panachgavya @ 3%, which was found to be 27.30 cm, while the minimum recorded height was recorded in control, which was found to be 19.87 cm. As per reports provided by Reddy and Reddy (2017), the maximum height recorded by using KNO_3 @2% was 26.3 cm, while the height recorded in control was found to be 15.4 cm, which was considerably less. Kumar *et al*. (2008) reported results after 30 days of sowing, in which GA_3 @100 ppm was found to be effective in producing the tallest seedlings with a height of 24.74 cm, whereas treating seeds with cow urine for 12 hours produced only a height of 18.4 cm. Thakriya *et al*. (2017) reported the maximum seedling height of 22.26 cm in seedlings from vermiwash @ 1% treated seedlings, whereas vermiwash @ 2% and basil leaf extract were found at par with this treatment, and the least height (17.20 cm) was recorded in seeds treated with custard apple leaf extract @10%. Vidya *et al*. (2018) recorded the maximum height after 90 days of sowing in the seeds treated with GA_3 @ 500 ppm, which was 44.26 cm, while the least height was recorded in the case of seeds treated with vermiwash @ 50% (25.43 cm). Kolekar *et al*. (2017) recorded the maximum height in seedlings treated with GA_3@100 ppm for 4 hours, and the minimum height was recorded in seeds treated with cow dung slurry for 4 hours. Chaudhary (2016) observed the height after 8 months of sowing and recorded the maximum height of 65.99 cm in seeds treated with cow dung slurry for 24 hours, while the recorded minimum height in seeds under control was 51.94 cm only. Parmar *et al*. (2018) recorded the maximum plant height of 51.67 cm after 120 days of sowing, whereas seedlings from seeds treated with 3% panchgavya recorded the maximum height of 48.12 cm. Singh *et al*. (2015) reported the highest seedling height in the seeds treated with GA_3 @ 200ppm, where the height was found to be 27.25 cm, whereas the minimum recorded height was found in control, which was found to be 22.62 cm. Harshavardhan and Rajasekhar (2012) reported that the maximum height attained by jackfruit seedling was found to be 70.6 cm with KNO_3 @ 0.50% for 24 hours, and the minimum recorded height was found in control, which was 57.4 cm. Gurung *et al*. (2013) after 90 days of sowing recorded the maximum seedling height of 20.91cm in the seeds treated with GA_3 @ 500 ppm, while the lowest recorded height 13.48 cm was found in the seedlings under control. Dilip *et al*. (2017) reported the effect of different concentrations and time intervals of soaking of GA_3 on the germination and growth of Rangpur lime, where the maximum height of 11.97 cm was recorded with GA_3 @ 80ppm for 12 hours, and seeds without any treatment resulted in plants with the least height of 7.92 cm after 120 days of sowing. Pavithra *et al*. (2018) after 120 days of transplanting recorded the maximum height of 13.67 cm with GA_3 @ 500 ppm, and the lowest recorded height was found to be 8.87 cm in the seeds under control. Archana *et al*. (2015) recorded the maximum height of 12.70 cm on treating seeds with GA_3 50 ppm, and the minimum height of 8.52 cm was found in the control treatment after 70 days of sowing. Sharaf (2016) conducted an experiment for 2 years and observed the maximum seedling height.

2.2.2 Seedling diameter:

Muralidhara *et al.,* (2016) recorded mean diameter of unhusked seeds to be 0.56 cm whereas in case of the seed lacking in the seed coat were found to be 0.62cm. Similar results were also reported by Abbas *et al.,* (2015) where maximum seedling diameter was found 0.91 cm in case of husked seeds when compared to non-husked seeds the diameter of non-husked seeds was only found to be 0.47 cm. In case of chemical treatment, the maximum diameter (0.56 cm) in non-husked seeds was found in GA_3 @500ppm for 48 hours. Same results were reported by Shaban (2010) where seedlings from husked seeds were found to have the diameter of 0.55cm in comparison to the non-husked seeds which were found to have the only 0.51c m of diameter. The results of chemical soaking were also reported were GA_3 @ 200ppm was found superior having diameter of 0.56 cm and 0.59cm in non-husked and husked seeds respectively. Muralidhara *et al.,* (2015) reported the diameter 0.59 cm which was recorded highest among all other treatments as result of KNO_3 @ 1% and lowest stem diameter was found to be in control of 0.40cm. Almost similar result were obtained by Thakriya *et al.,* (2017) in which reports regarding diameter 0.59 cm as the highest obtained by vermiwash 1% and lowest of 0.53 cm with custard apple leaf extract @10%. Maximum collar girth was found to be 9.02 cm in case of GA_3 @ 100 ppm and the lowest collar girth was recorded in beejaumrit @ 2% (8.13 cm) Patel *et al* (2016). Aalta and Srihari (2013) reported KNO_3 @0.5% to best for production of maximum seedling diameter in treated

stone and extracted kernel which was recorded 6.90 mm and 7.10 mm respectively and least diameter was recorded in control in whole nut (5.00 mm) and extracted kernel (6.00 mm). Dawale *et al.,* (2012) concluded panchgavya @ 3% was having highest seeding diameter of 6.40 mm and minimum recoded diameter was recorded in control (5.38 mm). Similar results were reported by Reddy and Reddy (2017) where maximum diameter was achieved by the use of KNO_3 @2% (0.70 cm) and in control it was only obtained as 0.46vcm. Kumar *et al.,* (2008) after 30 days of sowing and GA_3@100 ppm was found having 5.55mm diameter and water soaking (5.34 mm), panchgavya 3% (5.44 mm) was found at par with GA_3 @ 100 ppm. Thakriya *et al.,* (2017) provided reports about increase in diameter which was found highest (0.59 cm) in vermiwash @1%and vermiwash @ 2% and Basil leaf extract @10% were found at par with vermiwash@1% and minimum diameter was recorded in custard apple leaf extract @10%. Vidya *et al.,* (2018) after 90 days after sowing recorded maximum seedling diameter in the seeds treated with GA_3 @ 500 ppm which was 7.93 mm, least diameter was recorded in case of seeds treated with Salicylic acid@2ml/l (5.94 mm). Kolekar *et al.,* (2017) recorded maximum stem diameter (0.67 cm) in the seedling treated with GA_3 @ 100 ppm for 4 hours and minimum diameter was recorded in seeds soaked in cow urine 12 hours which was 0.61cm. Chaudhary (2016) recorded maximum collar girth (13.08 mm) in seeds treated with cow dung slurry for 24 hours after 8 months of sowing and minimum girth was recorded in control (9.24 mm). Parmar *et al.,* (2018) recorded girth in jackfruit seeds where 9.06 mm was found maximum with seeds treated with cow dung slurry after 120 days after sowing and minimum girth was recorded in seeds under control. Reports about seedling diameter in cashew as provided by Singh *et al.,* (2015) where maximum diameter of 1.15 cm which was found in seeds treated with GA_3 @200 ppm and minimum seedling diameter was recorded in control where diameter was recorded as 0.82 cm Harshavardhan and Rajasekhar (2012) in jackfruit recorded maximum diameter (0.78 cm) was found in GA_3 200 ppm for 24 hours and minimum diameter was recorded in control (0.63cm). Pavithra *et al.,* (2018) recorded maximum diameter of 2.17mm with GA_3 @ 500 ppm and least diameter was recorded in seeds under control which was 1.27mm after 120 days. Archana *et al.,* (2015) provided reports about maximum seedling diameter after 70 days of sowing which was found maximum (0.94cm) in seeds treated with GA_3 @50 ppm and least diameter (0.64 cm) was found in seeds under control. The maximum diameter of papaya seedling recorded by Mali *et al.,* (2015) was found to be 0.253 cm and 0.323 cm at 20 and 30 days after sowing respectively in variety Taiwan on treating seeds with GA_3 @ 500. Maximum diameter was recorded in the seedling under treatment of GA_3 @ 1000 ppm which was found to be 0.926 cm as per reported Palepad *et al.,* (2017). Rahangdale *et al.,* (2019) represented the effect of GA_3 and maximum diameter was recorded 4.68 mm with concentration of GA_3 @ 500 ppm after 120 days after sowing. Ramteke *et al.,* (2015) recorded maximum collar diameter of 5.78 mm in seedling arising from the seeds under treatment of GA_3 @ 200 ppm in papaya seedlings. Manthri and Bharad (2017) recorded stem diameter at 30 days after sowing and was found maximum (0.133 cm) when seeds were treated with GA_3 @1000 ppm

2.3 Number of leaves

In various studies, the number of leaves per plant has been observed in both husked and unhusked seeds. Muralidhara *et al.* (2016) found a higher number of leaves in husked seeds (8.70) compared to unhusked seeds (7.60). Abbas *et al.* (2015) reported that husked seeds had more leaves per plant (28.08) compared to unhusked seeds (11.67). Similarly, GA_3 @ 500 ppm led to 21.00 leaves. Shaban (2010) found that husked seeds had fewer leaves (25.2) compared to unhusked seeds (31.2). In the case of GA_3 200ppm, husked seeds (34.2) had more leaves than unhusked seeds (27.6). The highest number of leaves (9.73) was observed with GA_3 @200 ppm, whereas the control had the lowest number of leaves (5.77) (Muralidhara *et al*., 2015). Patel *et al.* (2016) found that GA_3 100ppm had the highest number of leaves per plant (17.90), while beejaumrit @2% had the least (13.17). Aalta and Srihari (2013) reported that KNO_3 @ 0.5% had the highest number of leaves (10.10) in whole nut and extracted kernel, and the least was found in whole nut (8.50) and extracted kernel (9.00). Dawale *et al.* (2012) observed that the number of leaves per seedling was highest (14.37) after 90 days of sowing, and the control had the least number of leaves per plant (9.47) after 90 days of sowing. Reddy and Reddy (2017) reported that KNO_3 @2% had the maximum number of leaves (10.9), while the control had 7.6. Kumar *et al.* (2008) found that leaf area after 30 days of sowing was highest in Amritpani 3% for 3 hours, and other treatments were at par with seeds treated with GA_3 @100 ppm (6.59) and water soaking (5.66). Vidya *et al.* (2018) observed that the number of leaves recorded after 90 days of sowing was maximum in GA_3 @ 250 ppm (11.28), and GA_3 @ 500ppm and Salicylic acid@4ml/l were found to be at par with this treatment. The lowest number of leaves was found in seeds under control (9.07). Kolekar *et al.* (2017) reported that GA_3 @ 100 ppm for 4 hours had the highest number of leaves (15.63), while seedlings under control had the lowest number of leaves (12.0). After 8 months of sowing, the maximum number of leaves per plant (29.97) was observed in cow dung slurry for 24 hours, and the least number of leaves were found in the control treatment (20.08) (Chaudhary, 2016). Parmar *et al.* (2018) found that cow dung slurry resulted in the maximum number of leaves per plant (16.95) after 120 days of sowing. In cashew, Singh *et al.* (2015) found that GA_3@ 200 ppm had the highest number of leaves per plant (13.91), while the control had the lowest number of leaves per plant (22.62).

Gurung *et al*. (2013) observed that the maximum number of leaves per plant (14.25) was recorded in GA_3 @ 500 ppm, and the least number of leaves per plant was found in the control treatment (9.45) after 90 days of sowing. Dilip *et al*. (2017) noted that after 120 days of sowing, the maximum number of leaves (18.89) was found in seedlings treated with GA_3 @ 80ppm for 12 hours, while the control had the lowest number of leaves (11.27). Pavithra *et al*. (2018) recorded that GA_3 @ 500 ppm resulted in the maximum number of leaves per plant (24.00), and the lowest number of leaves was recorded in seedlings treated with HCl @ 25% (13.60) after 120 days. Archana *et al*. (2015) found that the maximum number of leaves per seeding (8.66) was observed in the seeds treated with GA_3@ 50 ppm, while the lowest number of leaves (6.00) was found in the control treatment after 70 days of sowing. Palepad *et al*. (2017) reported that the number of leaves was highest in seeds treated with GA_3 @ 1000 ppm (32.64). Rahangdale *et al*. (2019) found that the maximum number of leaves per plant (13.86) was observed after 120 days of sowing in the seedlings emerged from seeds treated with GA_3 500 ppm. Ramteke *et al*. (2015) reported that the maximum number of leaves per plant (9.22) was found in seedlings treated with GA_3@ 200 ppm. Manthri and Bharad (2017) found that the significantly maximum number of leaves per seedling (3.77) was observed GA_3 @ 1000 ppm (24 hours).

2.4 Leaf area:

Muralidhara *et al*. (2016) found that the mean leaf area in different mango cultivars was higher (219.2 cm^2) for husked seeds, whereas the maximum mean leaf area was found to be 158.5 cm^2 for unhusked seeds. The maximum leaf area (101.56 cm^2) was recorded in the case of husked seeds, while the area recorded in the case of non-husked seeds (53.56 cm^2) treated with 0.3% KNO_3 was found to be lower, as reported by Abbas *et al*. (2015). Shaban (2010) reported higher leaf area in plants that originated from husked seeds (61.9 cm^2) than in those that originated from non-husked seeds (55.1 cm^2). Seeds treated with GA_3 without seed coat (68.6 cm^2) were found to have more leaf area than those treated with GA_3 @ 200 + seed coat (60.4 cm^2), as reported by Abbas *et al*. (2015). Muralidhara *et al*. (2015) recorded the maximum leaf area (226.8 cm^2) in the case of GA_3 @ 200 ppm, which was considerably higher than the control treatment, which had an area of only 61.3 cm^2. Similar results were obtained by Patel *et al*. (2016), where the highest leaf area (69.85 cm^2) was found in the seedlings that were treated with thiourea @ 1%, and the least leaf area was recorded in the seedlings that were treated with beejaaumrit @ 2% (60.50 cm^2). Kolekar *et al*. (2017) recorded the maximum leaf area (37.89 cm^2) in GA_3 @ 100 ppm, and the minimum leaf area was found in cow dung slurry 12 hours, which was 32.35 cm^2. Chaudhary (2016) reported the maximum leaf area (176.2 cm^2) in cow dung slurry for 24 hours, and the minimum leaf area was observed in the control (154.9 cm^2). According to Parmar *et al*. (2018), the significantly maximum leaf area in the plant (69.58 cm^2) was recorded after 120 days of sowing in the seeds treated with cow dung slurry. Singh *et al*. (2015) reported that the maximum leaf area in cashew (37.75 cm^2) was obtained with GA_3 @200 ppm, and the smallest leaf area was recorded in the control (28.28 cm^2). Harshavardhan and Rajasekhar (2012) found that the maximum leaf area per seedling was 2526 cm^2, whereas the minimum recorded leaf area per seedling was found in the control (1290 cm^2). The maximum leaf area of papaya seedling, as recorded by Mali *et al*. (2015), was found to be 6.67 cm and 9.78 cm at 20 and 30 days after sowing, respectively, in the Taiwan variety on treating seeds with GA_3 @ 500. The maximum leaf area of 76.42 cm^2 was recorded in the seedling that had germinated from seeds under treatment of GA_3 1000 ppm. Ramteke *et al*. (2015) recorded leaf area of 44.89 cm^2 in seedlings arising from papaya seeds under treatment with GA_3 @200 ppm. Manthri and Bharad (2017) recorded the maximum leaf area (3.13 cm^2) at 60 days after sowing when seeds were treated with GA_3 @1000.

III. CROP VIGOUR (SEEDING VIGOUR INDEX, FRESH WEIGHT)

3.1 Assessment Seedling vigor index growth basis following pre-sowing treatments

Different pre sowing treatments have resulted in improved seeding vigor index which is an indication of improved plants growth and development. Various workers have provided favorable results of applying pre-sowing treatments. Muralidhara *et al*. (2016) found that the husked seed had a seedling vigor of 1599 cm, while the unhusked seed had a vigor of 1123.4 cm. GA_3 100ppm produced the highest seedling vigor index of 1248.8 cm, and the lowest was recorded in the control treatment at 612.2 cm (Muralidhara *et al*., 2015). Patel *et al*. (2016) reported that Thiourea 1% resulted in the highest seedling vigor at 5286.17 cm, while the lowest was found in the beejaumrit @2% treatment at 3337.16 cm. Reshma and Simi (2019) discovered that the stalk end up position had the highest seedling index at 1324.23 cm, while the flat position only had 746.93 cm. GA_3 @100 ppm produced the highest seedling vigor index at 1322.78 cm, and the lowest was recorded in the control treatment at 613.06 cm. Aalta and Srihari (2013) found that KNO_3 @0.5% resulted in the highest vigor index in the whole nut at 1227.80 cm and in the extracted kernel at 1517.30 cm. The lowest vigor index was found in the whole nut at 928.73 cm and in the extracted kernel at 1026.1 cm. Chaudhary (2016) discovered that the highest vigor was found in seedlings treated with cow dung slurry at 1739.60 cm, while the lowest vigor was recorded in the control treatment at 982.16 cm. Gurung *et al*. (2013) reported that the highest

seedling vigor index was 1547.34 cm in seeds treated with GA_3 @ 500 ppm, while the lowest was found in the control treatment at 404.4 cm. Palepad *et al*. (2017) found that the highest seedling vigor index was 2385.7 in seedlings treated with GA_3 @ 100 ppm for 24 hours. Ramteke *et al*. (2015) recorded a seed vigor index of 2430.50 in papaya seedlings using GA_3 @ 100 ppm, which was the highest among all other treatments.

3.2 Fresh weight:

Muralidhara *et al*. (2016) found that the husked seed had a seedling vigor of 1599 cm, while the unhusked seed had a vigor of 1123.4 cm. The application of GA_3 at a concentration of 100 ppm produced the highest seedling vigor index of 1248.8 cm. The lowest vigor was recorded in the control treatment at 612.2 cm (Muralidhara *et al*., 2015). Patel *et al*. (2016) reported that Thiourea at a concentration of 1% resulted in the highest seedling vigor of 5286.17 cm. Meanwhile, the lowest vigor was found in the beejaumrit treatment at 2%, which recorded only 3337.16 cm. Reshma and Simi (2019) discovered that the best position for seedling growth was with the stalk end up, which had a seedling index of 1324.23 cm. In contrast, the flat position only had 746.93 cm. GA_3 at a concentration of 100 ppm produced the highest seedling vigor index at 1322.78 cm, whereas the control treatment had the lowest vigor at 613.06 cm. Aalta and Srihari (2013) found that KNO_3 @0.5 % resulted in the highest vigor index in the whole nut at 1227.80 cm and in the extracted kernel at 1517.30 cm. The lowest vigor index was found in the whole nut at 928.73 cm and in the extracted kernel at 1026.1 cm. Chaudhary (2016) discovered that the highest vigor was found in seedlings treated with cow dung slurry, which had a seedling vigor index of 1739.60 cm. In contrast, the control treatment only recorded 982.16 cm of vigor. Gurung *et al*. (2013) reported that the best vigor index was 1547.34 cm in seeds treated with GA_3 at a concentration of 500 ppm. Meanwhile, the control treatment had the lowest vigor index of 404.4 cm. Palepad *et al*. (2017) found that the highest seedling vigor was recorded at 2385.7 in seedlings treated with GA_3 at a concentration of 100 ppm for 24 hours. Ramteke *et al*. (2015) recorded the highest seed vigor index of 2430.50 in papaya seedlings, which was the highest among all other treatments.

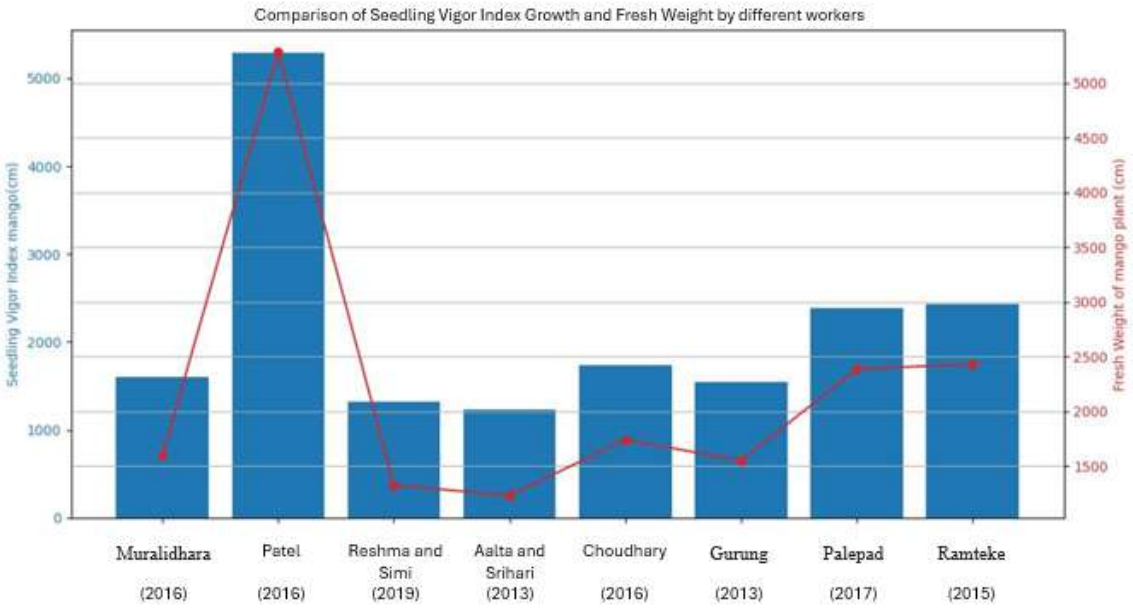

FIGURE 3: Year wise finding of seed vigor

3.3 Mode of action:

3.3.1 Molecular and physiological mechanism under lying pre sowing treatment:

Pre-sowing treatments exert their effects on seeds through intricate molecular and physiological mechanisms that underlie seed germination and subsequent seedling growth. These mechanisms vary depending on the type of treatment applied and its specific mode of action. At the molecular level, pre-sowing treatments can influence gene expression patterns within seeds. For example, hormonal priming treatments, such as gibberellic acid (GA_3) application, can activate specific genes involved in breaking seed dormancy and promoting germination. This activation triggers a cascade of molecular events that lead to the production of hydrolytic enzymes responsible for breaking down stored reserves in the seed, making them available for germination and early seedling growth. Physiologically, pre-sowing treatments can affect processes such as water uptake, metabolic activity, and nutrient mobilization within the seed. Osmopriming treatments, which involve soaking seeds in osmotic

solutions, facilitate water uptake by seeds, leading to increased hydration levels and activation of metabolic pathways necessary for germination. Similarly, halo-priming treatments, which utilize inorganic solutions like potassium nitrate (KNO_3) or calcium chloride ($CaCl_2$), can enhance nutrient uptake and ion balance within seeds, optimizing conditions for germination and early growth. Furthermore, pre-sowing treatments can modulate hormonal signaling pathways within seeds. Hormonal priming treatments alter the balance between different plant hormones, such as gibberellins (GA) and abscisic acid (ABA), which play crucial roles in regulating seed dormancy and germination. By influencing hormone levels, pre-sowing treatments can orchestrate physiological responses that promote germination and seedling vigor.

3.3.2 Interaction with plant hormone and signaling pathway:

Pre-sowing treatments can significantly impact the interaction with plant hormone signaling pathways, thereby influencing seed germination and subsequent plant growth. For instance, hormonal-priming treatments involve the application of hormone solutions to seeds, which can modulate hormone levels within the seed and interact with various signaling pathways.

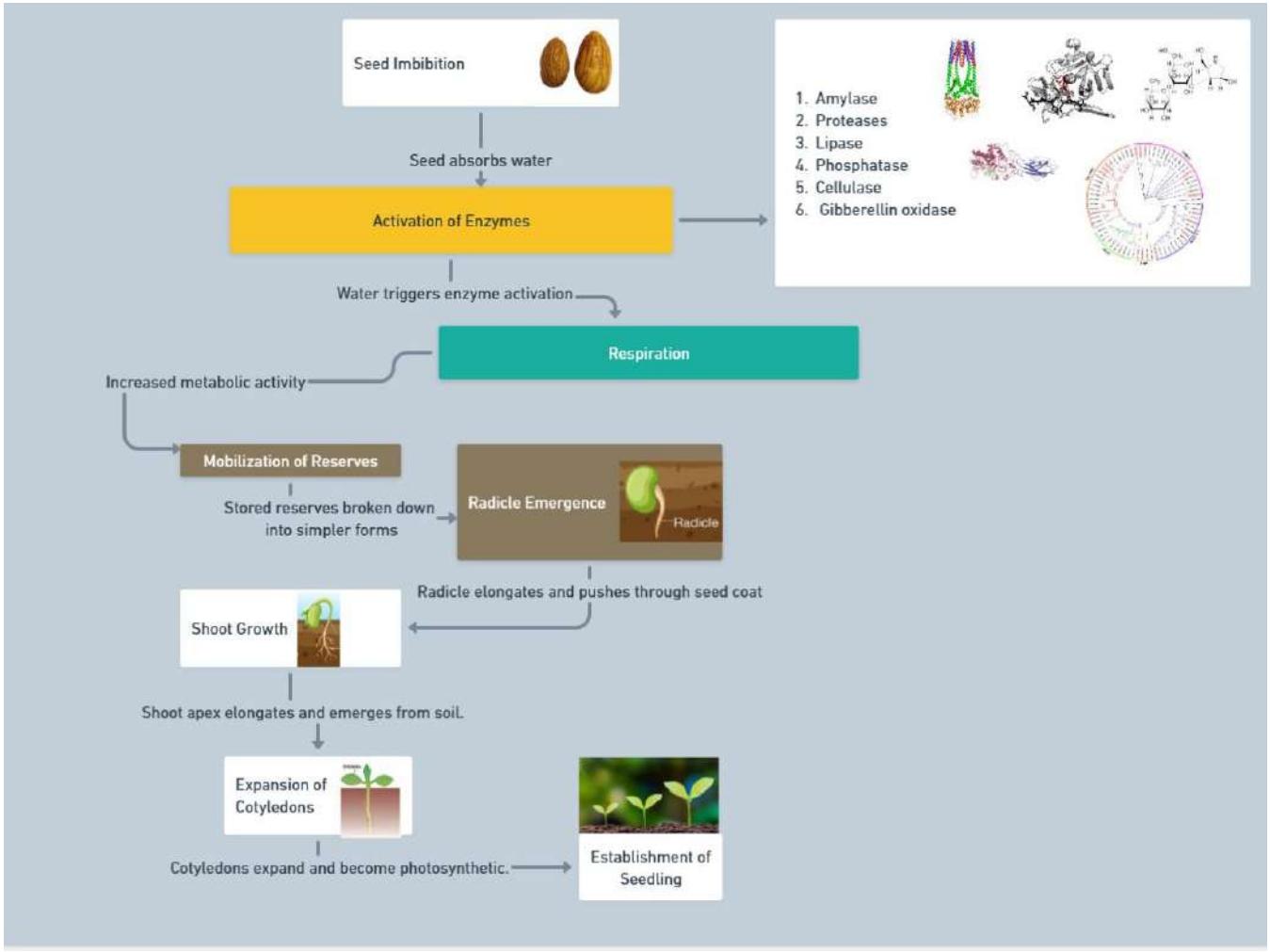

FIGURE 4: Mechanism of seed germination

Seed priming with IAAs enhances cell division, photosynthetic activities, and translocation of carbohydrates, which results in lateral root initiation, flowering, and good stand establishment Seed priming with IAAs enhances cell division, photosynthetic activities, and translocation of carbohydrates, which results in lateral root initiation, flowering, and good stand establishment.(MacDonal 1997; Naeem *et al.*,,2004) Gibberellic acid (GA_3), a commonly used hormone in seed priming, can stimulate the expression of genes involved in germination by promoting cell elongation and breaking seed dormancy (Ge *et al.*,, 2023; Rao *et al.*,, 2019; Zahang *et al.*,, 2024). Additionally, hormone treatments may interact with abscisic acid (ABA), another crucial hormone involved in seed dormancy regulation. By modulating the balance between GA_3 and ABA levels, pre-sowing treatments can regulate downstream signaling pathways, such as those involved in reactive oxygen species (ROS) production, Ca^{2+} signaling, and gene expression. These interactions ultimately influence processes like seed imbibition, embryo growth, and radicle emergence, contributing to improved seed germination and seedling vigor.

3.3.3 Influence on gene expression related to germination and growth:

Pre-sowing treatments exert a significant influence on gene expression related to germination and growth processes in seeds. These treatments can modulate the expression of specific genes involved in various physiological pathways essential for seed germination and subsequent seedling growth. For instance, hormonal priming treatments, such as gibberellic acid (GA_3) application, can trigger the upregulation of genes associated with cell elongation, cell division, and nutrient mobilization within the seed. GA_3 activates specific transcription factors that regulate the expression of genes involved in breaking seed dormancy and promoting germination. This includes genes encoding hydrolytic enzymes responsible for breaking down stored reserves such as starch and proteins into forms that can be readily utilized by the growing embryo. Similarly, other pre-sowing treatments like osmopriming and halo-priming can also influence gene expression patterns. Osmopriming treatments involve soaking seeds in osmotic solutions, which can induce the expression of genes involved in stress tolerance and osmotic regulation. These genes help seeds cope with environmental stresses such as drought or salinity during germination and early seedling establishment.

IV. CHALLENGE AND FUTURE PROSPECTS

Pre-sowing treatments play a vital role in optimizing nursery practices for fruit crop production, especially in addressing the pressing need for increased planting material, such as grafts. With the demand for fruit crops steadily rising, nursery managers face the challenge of producing sufficient rootstocks with graftable sizes within shorter timeframes. To expedite this process, accelerating seed germination and seedling growth becomes imperative, making pre-sowing treatments a cornerstone of efficient nursery management. These treatments are not only crucial for meeting the immediate demands of nursery production but also contribute significantly to broader agricultural objectives. They play essential roles in various aspects of fruit crop cultivation, including propagation techniques, breeding programs, and germplasm evaluation. By enhancing germination rates and promoting robust seedling growth, pre-sowing treatments facilitate the timely development of healthy and vigorous planting material, which is essential for achieving optimal yields and maintaining orchard productivity. The effectiveness of pre-sowing treatments transcends individual fruit species, encompassing a wide array of crops in the fruit production sector. Whether it's accelerating the germination of mango, papaya, citrus, or aonla seeds, these treatments have consistently demonstrated their efficacy in fostering rapid and uniform seedling establishment. Consequently, their integration into nursery management practices has become increasingly prevalent, reflecting their indispensable role in modern fruit crop production systems. In a nut shell, pre-sowing treatments represent a cornerstone of nursery management in fruit crop production, offering a pragmatic solution to the challenges posed by increasing demand and time constraints. By expediting seed germination and enhancing seedling growth, these treatments not only optimize nursery operations but also contribute to broader agricultural goals, ensuring the sustainable supply of high-quality planting material for fruit growers worldwide.

V. CONCLUSION

Pre-sowing treatments have proven to be valuable tools for enhancing seed germination and seedling growth in fruit crop production. By overcoming challenges like dormancy and germination inhibitors, these treatments significantly improve nursery practices and ultimately lead to increased yields. Various techniques, including chemical treatments, growth regulators, and biological inoculants, have demonstrated effectiveness in promoting seed germination and seedling vigor. Hormonal priming, particularly with gibberellic acid, has been particularly effective in reducing germination time and increasing germination percentages. Additionally, pre-sowing treatments have been shown to positively impact seedling height, diameter, and the number of leaves, resulting in healthier and more robust seedlings. However, the effectiveness of these treatments can vary depending on the specific fruit crop species, emphasizing the need for tailored approaches. Future research should focus on understanding the underlying mechanisms, long-term effects, and the development of innovative treatment methods. Overall, pre-sowing treatments offer promising avenues for improving fruit crop production and ensuring sustainable agricultural practices.

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Standardization of Suitable Concentration and duration of Seed Biopriming with Liquid Biofertilizers for Seedling Vigour Improvement in Rice

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Abstract— *An investigation was carried out with PMK (R) 4 riceseed in order to standardize suitable concentration and duration of seed biopriming with liquid biofertilizers (Azospirillum, Phosphobacteria and Silicate Solubilizing Bacteria) and liquid biocontrol agent (Pseudomonas fluorescens) a laboratory experiment was conducted in Department of Seed Science and Technology, Madurai, Tamil Nadu Agricultural University, in Completely Randomized Design with four replicates along with control. The results of theexperiments revealed that seeds bioprimed with20% concentration Pseudomonas fluorescens and 20% Azospirillum for 18h duration germinated earlier and expressed its vigour in terms of increased speed ofgermination, germination percentage, shoot and root length and vigour index compared to other treatments.*

Keywords— Biopriming, Germination, Pseudomonas fluorescens and Vigour.

I. INTRODUCTION

Rice (Oryza saiva L.) is the world's most important staple food-grain grown in over 100 countries, consumed regularly by over two billion people and the primary source of protein for millions. India is the leading rice producing country in terms of area and is the second largest producer next to China. Rice plays an important role in food as well as livelihood security for almost every household, more so in India. To feed this estimated 1.6 billion population of India by 2050 calls for stepping up the current production of 106 mt of milled rice to 140 mt. Higher production and productivity of crop is possible only through use of good quality seeds and proper management practices (Punithavathi et al.,2020). Good quality seeds imply vigour, uniformity and structural soundness besides its genetic and physical purity. Seed priming with living bacterial inoculum is termed as biopriming that involves the application of plant growth promoting rhizobacteria. This type of priming increases germination rate, seedling vigour and also protects seeds against various soil and seed borne pathogens. Bio priming also enhances the ability of plants to withstand against extreme environmental conditions. The bacteria used in biopriming are able to colonize the rhizosphere and help plant through direct or indirect mechanism. Biopriming has emerged as an effective approach for increasing seed vigour. The biofertilizers were found to have not only the ability to fix nitrogen but also the ability to release phytohormones similar to gibberellic acid and indole acetic acid, which could stimulate plant growth, absorption of nutrients, and photosynthesis (Kokila and Baskaran,2016). There is no standard procedure in biopriming as the treatment duration, concentration depends on species, cultivars and seed types. The optimum such variability is a major limitation of the priming method since numerous trials are required to identify the most appropriate strategy for each situation. There is no general rule concerning modalities of seed priming and there is no clear trend of priming response according to the taxonomic position of the species. This undoubtedly limits the commercial implementation of priming treatments. At present, the carrier based biofertilizers are replaced by liquid formulations which are easy to use as it spreads well, mixed uniformly and does not require sticker agent (Nethery, 1991). Rice and Olsen, 1992 suggested that liquid formulations were an effective method for seed inoculation of biofertilizer than carrier based inoculants application. Many studies are available on the beneficial effects of inoculating biofertilizers on crop productivity.

Research information on the use of liquid biofertilizers as seed treatment is very scanty and the concentrations or duration of soaking are to be in different crops. With this background, the present investigation was carried out to standardize the appropriate concentration and priming duration for rice var. PMK(R) 4.

II. MATERIALS AND METHODS

Genetically pure, fresh seeds of PMK(R) 4 rice formed the base seeds for this study. Standardization and evaluation of priming treatments were carried out at the Department of Seed Science and Technology, Agricultural Collage & Research Institute, Tamil Nadu Agricultural University, Madurai. In order to standardize the optimum concentration of biopriming agents and duration of priming, fresh seeds of PMK-4 rice having 92% germination were imposed with water and liquid biopriming agents *viz*., *Azospirillum, Phosphobacteria, Silicate Solubilizing Bacteria* and *Pseudomonas fluorescens*. Priming solutions were prepared in three different concentrations viz., 10, 15 and 20 per cent and the seeds were soaked in double the volume of solutions for three different durations viz., 6, 12 and 18 hours. After priming, the seeds were removed from the solutions, shade dried for 12hrs at room temperature and subjected to germination test (ISTA, 1999). The duration of hydropriming was also standardized by priming the seeds in water with nonprimed seed serving as control.

The number of seeds germinated on each day was recorded daily up to fourteen days. After fourteen days of germination their performance were evaluated for germination (ISTA, 1999), shoot length (cm), root length (cm) dry matter production per 10 seedlings (g), speed of germination (Maguire, 1962) and vigour index values (Abdul-Baki and Anderson, 1973). The experiment was carried out with four replications in Factorial Completely Randomized Block Design. The data obtained were analysed by the 'F' test of significance following the methods described by Rangaswamy (2002). The per cent values were transformed to arc-sine values and used for analysis. The critical differences (CD) were calculated at 1 and 5 per cent probability level. The data were tested for statistical significance by two way ANOVA.

III. RESULTS AND DISCUSSION

Statistically significant variations were observed for all the parameters tested including speed of germination and germination due to priming treatments and its concentration, duration of biopriming and its interaction effect. Among the biopriming agents the performance of *Pseudomonas fluorescens* was better compared to others at all concentrations. This might be due to the plant growth hormones and secondary metabolites produced by *Pseudomonas fluorescens* in alleviating the effect of disease causing organism. The vigour of the seeds registered as germination, root and shoot length and vigour index values were all the highest with the seeds primed with 20% concentration with a soaking duration of 18h irrespective of the priming agents. The effect of priming was much pronounced when concentration of the priming solution was increased with advancement in soaking duration.

3.1 Standardization Biopriming of *Azospirillum:*

Biopriming with *Azospirillum* at 10, 15 and 20% concentrations, the duration of 6, 12 and 18h revealed that seed biopriming at 20% for 18h was the best which recorded the highest speed of germination of 6.1. Early germination was observed in seeds bioprimed at 20% concentration (5.8) against nonprimed seeds (2.8). Among the priming durations, 18h priming recorded the maximum values (5.5). An increase in speed of germination was noticed with an increase in the soaking duration and increase was from 4.2 (12h) to 4.5 (18h) duration. Similar trend was noticed with germination percentage also where maximum germination (97%) was observed at 20% concentration with a priming duration of 18h against 85 per cent in nonprimed seed (Figure.1). Vigour parameters expressed as root and shoot length (19.7 and 10.2cm), drymatter production (0.121g 10seedlings^{-1}). Among the biopriming treatments, *Azospirillum* 20% recorded the greatest vigour index values (2959) and lowest was with nonprimed seeds (1590). Regarding the durations of biopriming, 18h had the greatest vigour index value of 2424 and the least was recorded with 6h (2142). The interaction effect indicated that vigour index values (3130) were also maximum with same combination of azospirillum 20% with 18h soaking duration. Punithavathi *et al*.,2020 reported that that it enhanced seedling vigour encompassing speed of germination, seedling length and dry weight of high vigour as well as low vigour seedlots. Similar results were demonstrated in rice seeds where *Azospirillum liporferum* registered increased germination rate (Kavitha, 2011), tomato and snackgouard (Gowthamy *et al*,2017).

In this study, the colonization of *Azospirillum* was the highest in 20% concentration ($11.0x10^6$CFU ml^{-1}) than 15% ($9.0x10^6$CFU ml^{-1}) and 10% ($9.3x10^5$CFU ml^{-1}) concentrations and adequate population might be the reason for the best performance of the seedlings at 20% concentration.

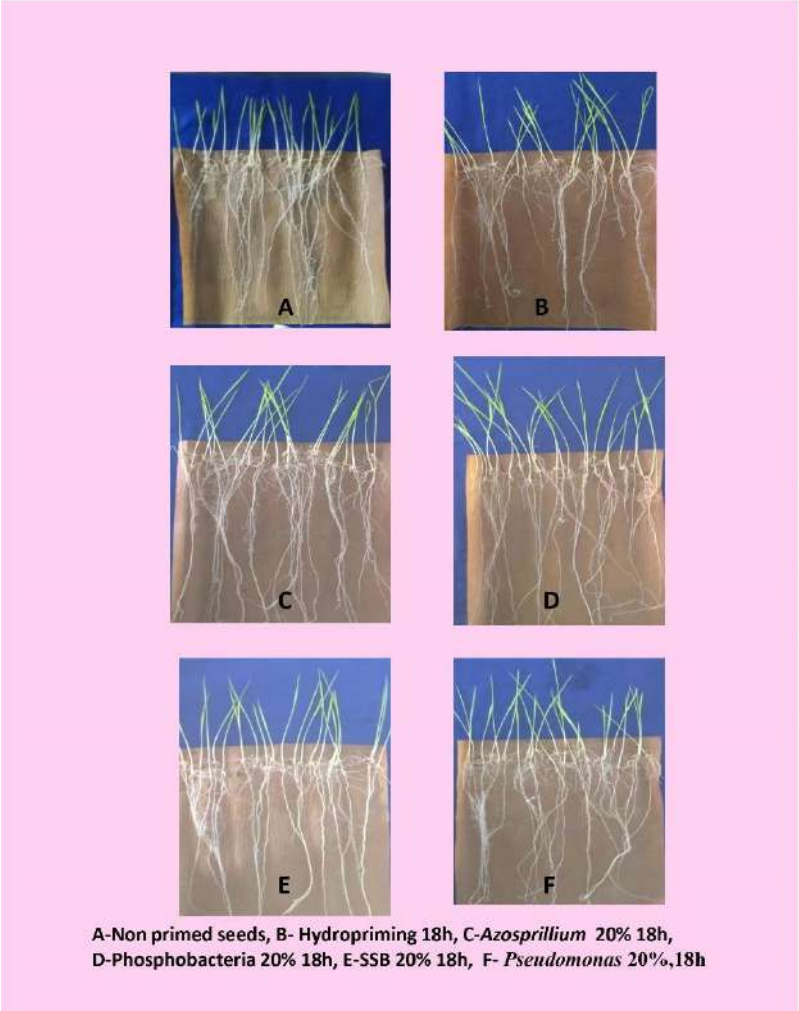

FIGURE 1: Influence of Seedling vigour on 14th day of Germination of rice var. PMK(R) 4

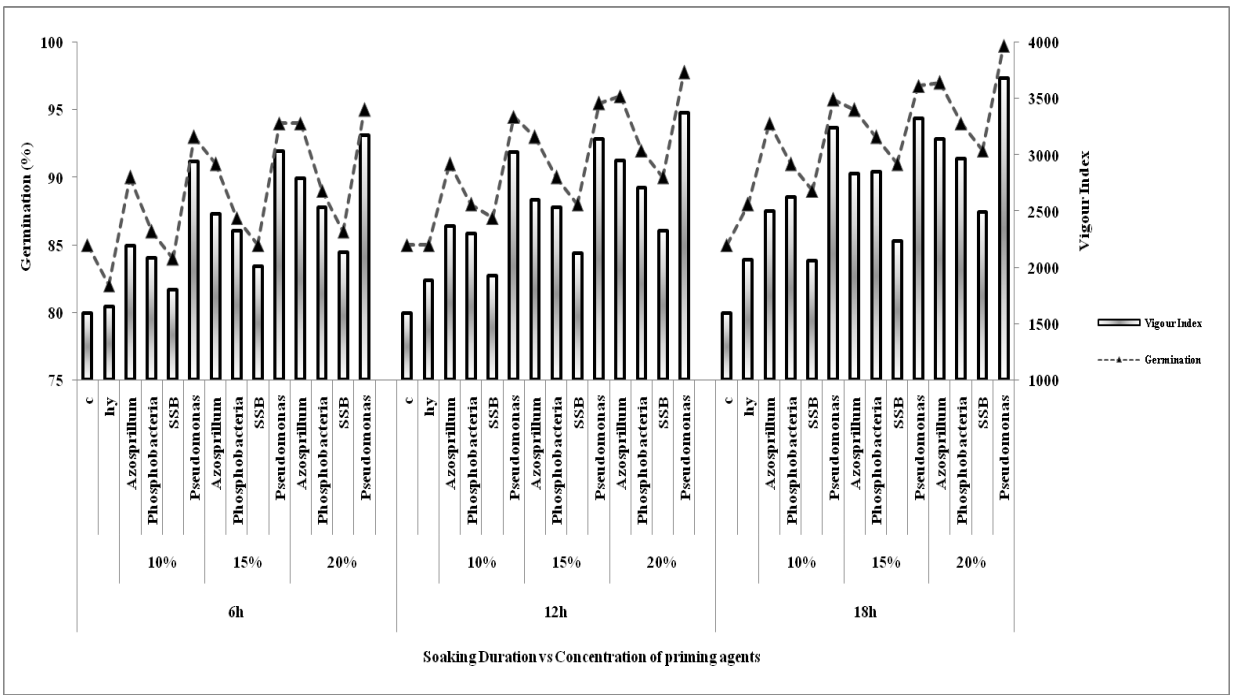

FIGURE 2: Effect of different biopriming agents and duration of priming on germination (%) and vigour index of rice var.PMK(R) 4

TABLE 1

EFFECT OF DIFFERENT BIOPRIMING AGENTS AND DURATION OF PRIMING ON SPEED OF GERMINATION, GERMINATION, SHOOT AND ROOT LENGTH AND DRY MATTER PRODUCTION OF RICE VAR.PMK(R) 4

Biopriming T+A1:Q24reatments / Biopriming agents	Speed of Germination				Shoot Length(cm)				Root Length(cm)				Dry Matter Production(g/10seedlings)			
	6	12	18	Mean	6	12	18	Mean	6	12	18	Mean	6	12	18	Mean
Azosprillium sp 10%	4.5	4.6	4.7	4.6	9.5	9.9	10.1	9.8	14.8	17.4	20.2	17.5	0.106	0.108	0.114	0.109
Azosprillium sp 15%	5.3	5.4	5.6	5.4	9.7	10	10.3	10	16	18	21	18.3	0.111	0.113	0.117	0.114
Azosprillium sp 20%	5.6	5.7	6.1	5.8	9.8	10.2	10.6	10.2	17	20	22	19.7	0.115	0.116	0.121	0.117
Mean	5.1	5.2	5.5	5.3	9.7	10	10.3	10	15.9	18.5	21.1	18.5	0.111	0.112	0.117	0.113
Phosphobacteria 10%	4.8	4.9	5.1	4.9	9.4	9.8	10.2	9.8	15	16.8	17.8	16.5	0.104	0.106	0.107	0.106
Phosphobacteria 15%	5.1	5.2	5.5	5.3	9.6	10	10.3	10	17	18.3	19	18.1	0.105	0.109	0.11	0.108
Phosphobacteria 20%	5	5.4	5.7	5.4	9.7	10.1	10.4	10.1	18	18	20.6	18.9	0.108	0.111	0.115	0.111
Mean	5	5.2	5.4	5.2	9.6	10	10.3	9.9	16.7	17.7	19.1	17.8	0.106	0.109	0.111	0.108
SSB 10%	4	4.2	4.3	4.2	9.2	9.6	9.8	9.5	12.3	13.6	14.3	13.4	0.102	0.106	0.108	0.105
SSB 15%	4.6	4.7	5.1	4.8	9.4	10	10.1	9.7	13.4	14.6	15.6	14.5	0.104	0.107	0.11	0.107
SSB 20%	4.6	4.8	4.8	4.7	9.5	9.9	10.2	9.9	14.5	15	17	15.5	0.105	0.109	0.111	0.108
Mean	4.4	4.6	4.7	4.6	9.4	9.7	10	9.7	13.4	14.4	15.6	14.5	0.104	0.107	0.11	0.107
Pseudomonas 10%	5.4	5.6	6	5.7	11	11.4	11.6	11.3	20.6	20.6	21.8	21	0.113	0.115	0.116	0.115
Pseudomonas 15%	6.6	7.3	7.5	7.1	11.1	11.5	11.8	11.5	21	21.3	23	21.8	0.116	0.116	0.118	0.117
Pseudomonas 20%	7.2	7.4	7.7	7.4	11.3	11.7	12.3	11.8	22.4	22.6	24.5	23.2	0.118	0.12	0.122	0.12
Mean	6.4	6.8	7.1	6.7	11.1	11.5	11.9	11.5	21.3	21.5	23.1	22	0.116	0.117	0.119	0.117
Hydro priming	2.8	3	3.4	3.1	9	9.2	9.3	9.2	11.2	13	14.2	12.8	0.099	0.1	0.105	0.101
Control	2.8				7.5				11.2				0.086			
Grand Mean	3.4	3.5	3.6	3.5	7.5	7.7	7.9	7.7	10.8	12.5	13.5	12.5	0.084	0.086	0.088	0.086
T		**D**	**TXD**		**T**	**D**		**TXD**	**T**	**D**		**TXD**	**T**	**D**		**TXD**
SE(D)	0.06	0.02	0.11		0.13	0.06		0.23	0.24	0.11		0.41	0.001	0.0004		0.001
CD (P=0.05%)	0.12**	0.05**	0.21**		0.27**	0.12**		0.46**	0.47**	0.22**		0.82**	0.002**	0.0009**		0.003**

3.2 Standization of Phosphobacteria Biopriming:

In the present study, with reference to seed priming with phosphobacteria among the different concentrations seeds bioprimed with 20% registered maximum speed of germination (5.4). interaction (Table 1). Among the treatments, maximum germination was observed (92%) in the seeds bioprimed with Phosphobacteria at 20% concentration and minimum was with nonprimed seed (85%). Among the durations, the highest germination was observed in the seeds bioprimed for 18h (90%) and lowest (86 %) was in 6h treated seeds. The interaction effect indicated that seeds bioprimed with Phosphobacteria at 20% for 18h registered the highest germination of 94 per cent and lowest was with nonprimed seed (85 %). Similar trend was observed with reference to longest root and shoot length (18.9 and 10.1cm) and dry matter production than other concentrations. The seed germination and vigour status of primed seeds was in the increasing trend when the concentration and soaking duration was increased. The relative enhancement of germination and seedling vigour might be attributed to the role of phosphorus solubilising bacteria known as phosphobacteria in enhancing the solubilisation of insoluble phosphorus and making it available to the germinating seed with consequent enhancement in the metabolic activity which resulted in higher germination (Cooper, 1979). Phosphobacteria biopriming at 20% for 18h was the best recording the highest vigour index value (2963) and nonprimed seed registered the lowest value (1590). Karthika and Vanangamudi,2013 reported that, seed biopriming with phosphobacteria 20% for 12 h was found to be the best biopriming treatment for improving the seed germination and seedling vigour of COH(M)5 maize hybrid. In this present investigation also, the colonization of Phosphobacteria at 20, 15 and 10% concentrations were 9.7 x 10^6, 8 x 10^6 and 9 x 10^5 $CFUml^{-1}$. This heavy colonization may be the reason for increase in germination and seedling vigour.

3.3 Standardization Biopriming of *Silicate Solubilizing Bacteria:*

The maximum speed of germination was recorded @ 20% concentrations (5.4). With reference to soaking duration, 12h was found to be the best (4.7) than 6h duration. The interaction effect of soaking duration and concentration of biopriming agent, seeds bioprimed with 20% silicate

soluble bacteria for 12hrs recorded maximum values (4.8). Same trend was followed in germination (92%), root and shoot length (17cm and 10.2cm), Dry matter production (0.111g $10seedlings^{-1}$) and vigour index (2492) values. Vijayapriya and Muthukkaruppan, 2010, reported that presents of silicon (Si) in the silicate solubilizing bacteria inoculated seeds might have reduce the incidence of fungal diseases and also induced the plant growth in rice. The colonization of Silicate Solubilizing Bacteria was highest in 20% concentration at 18h (9 x 10^6 $CFUml^{-1}$) than 10% (8.6 x 10^5 $CFUml^{-1}$) concentrations at 18h.

3.4 Standardization Biopriming of *Pseudomonas fluorescens:*

The result of seed priming with *Pseudomonas fluorescens* revealed that among the priming durations, 18h priming recorded the maximum speed of germination (5.5), germination (94%), longest root and shoot (23.1 and 11.9cm), seedling dry matter of 0.119 g 10 $seedlings^{-1}$ and highest vigour index value of 3416 irrespective of soaking durations. With respect to the interaction among the concentrations and priming durations 20% *Pseudomonas fluorescens* for 18hrs recorded maximum speed of germination (7.7). Pradhan *et al.,* (2022) found similar type findings in cowpea while Sharma *et al.,* (2018) reported similar in soybean seeds. Seeds primed with *Pseudomonas fluorescens* (20%) for 18h registered cent per cent germination against hydropriming (88%) and unprimed seed (85%) (Fig.1). The results are in confirmation with the findings of Kokila and Bhaskaran (2016) who reported that rice seeds bioprimed with *Pseudomonas fluorescens* for 12h expressed highest germination percentage and seedling vigour. Punithavathi et al.,2020, revealed that seed biopriming with Pseudomonas fluorescens produced desirable results, both promoting the 91% germination as well as increased the seedling growth and vigour of rice (2972). Similarly root and shoot length of the primed seeds were better than control. Advancement in metabolic activation during germination has registered 118 and 64% increased over control. But the increase was 72 and 32% over hydroprimining. Increased seedling length revealed more drymatter production (0.122 g $10seedlings^{-1}$) and vigour index (3680) which accounted for 41 and 131 per cent increased over the nonprimed seeds (Table 1). Nandakumar *et al*., 2001 found that bio-priming of rice seed with *Pseudomonas fluorescens* induce the production of plant growth regulators such as gibberellins, cytokinins and indole acetic acid, increased availability of minerals and other ions, extensive rooting which facilitates water and nutrient uptake thereby increased seed germination and seedling vigour over the unprimed seeds. Biopriming of sunflower seeds with *Pseudomonas fluorescens* UTPf76 and UTPf86 enhanced the ability of seeds to invigorate and seedlings to grow uniformly (Moeinzadeh *et al*. 2010). Mohan Raj and Sundareswaran (2016) reported that seed biopriming with liquid *Pseudomonas fluorescens* Pf 1 @ 8% concentration for 9 h was found to be the best biopriming treatment for improving the seed germination and production of vigourous diseases free seedling vigour of tomato. As that of other microorganisms, the number of $CFUml^{-1}$ of *Pseudomonas fluorescens* was significantly more (16 x 10^7 $CFUml^{-1}$) at 20% than 15% (13 x 10^7 $CFUml^{-1}$) and 10% (15 x 10^6 $CFUml^{-1}$).

Higher germination and enhanced seedling establishment was also obtained through seed priming with PGPR (Anitha *et al*., 2013) and PGPR inoculation increased the stress resistance and production of the crops; including wheat (Chakraborty *et al.,* 2013; Kumar *et al*. 2014), rice (Bal *et al.,* 2013; Lavakush *et al.,* 2014), soybean (Masciarelli *et al.,* 2014), groundnut (Paulucci *et al.,* 2015) and tomato (Mohan raj and Sundareswaran,2020).

IV. CONCLUSION

Overall it could be concluded that the increase in speed of germination, germination, shoot length, root length and dry matter production could be made seeds bioprimed with liquid *Pseudomonas fluorescens@* 20% for 18hrs for rice PMK(R) 4. Seed treatment with *Azospirillum* and *Phosphobacteria* can be done at the concentration of 20% for 18hrs to have better establishment in rice. Seed coating or priming techniques to be developed and standardized for all type of field, plantation and horticultural crops, which should be cost-effective, time-saving and affordable to all the level of farmers.

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Land Conversion and Industrialization and its Impact on Crop Production

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Abstract— *Agriculture, specifically crop production, is a crucial driver of prosperity in the Philippines, contributing to economic growth, employing 36% of the workforce, and ensuring food security. Palay is Central Luzon's most widely grown crop, making it the country's largest producer. Crops like palay do not grow on their own; a variety of factors, such as arable land availability, urbanization, and agricultural mechanization influences them. Therefore, this study examines the effect of selected agricultural input on palay production in Central Luzon from 1970 to 2019, with CobbDouglas production function as its basis. The adopted methodology is the unit root test by the Augmented Dickey-Fuller (ADF) approach, a test for long-run relationship (Johansen cointegration), and the Ordinary Least Squares (OLS) multiple regression method. The study would like to know how the chosen input will affect the output of palay production in the area. The study indicates that the variables are stationary. Land use conversion and Agricultural mechanization show that it significantly affects palay production in the region. Considering that the area is well suited for crop production, the governing bodies should urgently establish and impose policies that cultivate agricultural development to support the country's food security and economic prosperity*.

Keywords— Agricultural Mechanization, Agriculture, Central Luzon, Crop Production, Land Use Conversion, Urbanization.

I. INTRODUCTION

Crop production is one of the main activities classified as agricultural output. It is the process of cultivating crops for both domestic and commercial consumption. Nemethova et al. (2022) further defined it as a branch of agriculture that focuses on growing crops on the land. Factors such as the availability of arable land, agricultural technology, yields, macroeconomic uncertainty, consumption patterns, and crop genetic potential play a significant role (Organisation for Economic Co-operation and Development, 2017). It is critical to understand how to manage these factors in agricultural practices as they play an essential role in ensuring the nation's food security (Kumar et al., 2023). As a developing country, land is a scarce variable that plays a vital role in the nation's advancement. According to De Maria (2019), it is a commodity for almost every output known to humanity. Given the country's soil, tropical climate, and prosperous farming culture, it is best positioned for agricultural activities. Agriculture is the Philippine economy's backbone, contributing significantly to the country's economic output. The crop productivity in the country was 3% in 1970, but has declined to 2.3% in 2020 (Evenson & Sardido, 1986; Philippine Statistics Authority, 2020). In the period 1960s to 1969 it is seen that the agricultural sector contributes most in the Gross Domestic Product (GDP) in the country, with a contribution of 4.2% in the GDP of 4.7% (Briones, 2021). However, as time progresses it placed at the third spot in contributing most in the GDP from 2012 to 2022 (Statista, 2024). The country's population is rapidly increasing, inextricably linked to social and economic services such as housing, health care, educational institutions, recreational facilities, and office buildings (Liu, 2018). As a result, conflict among different industries regarding land use may arise, such as unplanned land use, which impedes the nation's growth.

Azadi et al. (2018) defined land use conversion as the transformation of agricultural land for urban development. It is the process of changing the current physical use of a piece of agricultural land into a non-soil cultivation use. Currently, neoliberalism, a political-economic practice, has spread throughout the country due to structural adjustment programs. It accelerated capital accumulation and dispossession and reshaped land and agrarian relations, promoting economic growth by protecting private property rights, free markets, and free trade (Imbong, 2021). Such ideology frequently serves the interests of foreign and large corporations (Dizon, 2020). Ariola and Park (2014) stated that many agricultural lands in Metro Manila's neighboring regions have been converted to promote economic development and improve infrastructures, adapting to global competition. However, land conversion poses significant challenges because it comes after the loss of agricultural land, threatening the Philippines' palay production and food security.

Central Luzon, the Philippines' rice granary and the major rice producer, is a prime example of rapid land conversion for urbanization and slow land distribution for agricultural farming (German et al., 2022). According to Kajisa et al. (2022), the region's farm size of 2.54 hectares in 1970 has decreased to 1.79 hectares in 2020. With its ideal conditions for maximum development and growth of crops, it contributes 18.7% of the country's rice basket; however, it is the region that has the largest area of converted lands (Navarro, 2023). Also, the region's farmlands are declining by 5% due to land conversion according to Fair Finance Asia, (2021). Currently, the country's largest producer of palay has been regarded as the "next frontiers" of Philippine urbanization, becoming the center of the ongoing development of the roadworks of the Alviera and Clark Green City (CGC) projects despite being ideal for agricultural production (Campos, 2016). Hence, there is an observed misalignment between the supposed land use of Central Luzon and the region's current development trajectory.

In addition, Central Luzon is experiencing rapid urbanization due to Metro Manila's northward urban expansion. According to Harini et al. (2012), such economic activity is increasing in tandem with growth in population, making it difficult to avoid competition for land utilization between farming and other industries. People now require housing as a consequence of these developments. As a result, several real estate developers have been eyeing the region to expand their projects, and they are now taking over Central Luzon. Thus, the conversion of land from agricultural to non-agricultural land use is becoming increasingly prevalent. Such occurrence may result in countless investors looking to profit from non-agricultural development in the region (Cabildo et al., 2017). Moreover, it has improved the economic corridors stretching through Central Luzon's provinces, creating a strategic market access system and boosting regional growth leading to flourishing of business and financial activities (Rosete & Eleria, 2020). However, every economic activity involves a trade-off. For instance, rapid urbanization caused by the desire for economic advancement aggravates the country's limited resources. Land use conversion might be a major factor in reducing agricultural lands in Central Luzon, hampering palay production in the region and potentially contributing to the Philippines' shrinking rice basket and compromising the nation's food security. Similar to the study of Long et al. (2018), Farmland loss poses a threat to food availability because it is the primary resource for ensuring food security.

In the agricultural context, industrialization is defined as the shift to traditional agriculture to modernization through technological progress (Yang & Zhu, 2013). According to Peng et al. (2022), agricultural machinery and tractors utilized as capital assist in transforming ways of farming. Mechanization saves time and effort in farming operations, increasing agricultural efficiency and productivity (Rodriguez and Piadozo, 2016). As a result, farmers carry out their tasks more efficiently and accurately, resulting in lower labor intensity, increased safety and comfort for agricultural workers, and less crop waste. Moreover, utilizing machinery in agricultural activity not only boosts productivity but also alleviates the burdens of manual labor, primarily when fewer people work in agriculture, caused by rural-urban migration and the aging farming population (Dela Cruz & Bobier, 2016).

In Asian middle-income countries, the structure of the agricultural sector is changing rapidly alongside mechanization (Dawe, 2015). Over the past 50 years, Asia has shown substantial progress in agricultural machinery; over the last three decades, a significant correlation between farm power availability and productivity in countries like China, Pakistan, India, and Bangladesh has been observed (Rehman & Khan, 2019). However, mechanization is not happening uniformly across all countries. For instance, the Philippines falls behind since the utilization of machinery is not seen as urgent due to rural landlessness, keeping labor productivity and income for rural workers low (Mataia et al., 2016). It suggests that mechanized farming in the Philippines is emphasized when there is only land to cultivate crops. Thus, it is observed that most machines available in the Philippines were utilized to cultivate rice and corn, the predominant grain crop grown in the country (Dela Cruz & Bobier, 2016).

Although several studies have been conducted on the relationship between land use conversion and agricultural industrialization on crop production, most of these studies have concentrated solely at the national level, with a few focusing on Central Luzon specifically. In addition, only a few studies have considered Central Luzon's (Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, Zambales) accelerated urbanization due to Metro Manila's northward development and the existence of the Philippines' largest homebuilder in studying the region's crop production index.

The study will be beneficial as it can provide essential information and raise awareness on the current status of the country's agricultural production in light of rapid urbanization in Central Luzon, whether positive or negative. Since Central Luzon is the country's largest rice producer, it is imperative to comprehend the factors that affect it to maintain consistent food security. The study's findings can contribute to future studies, such as the economic and environmental implications of land use conversion among agricultural lands. Moreover, it can provide additional information in the field of academics, which may extend to developing policies that will balance urban expansion and agricultural sustainability. It can also provide the researchers an extensive knowledge about the crop production situation in the region that could be useful in their future studies in the agricultural industry in the Philippines.

The research explores whether the production theory is evident in Central Luzon's agricultural industry. According to Cobb and Douglas (1928), the production theory implies that a change in input results in a change in output units. Hence, the development of the factors of production plays a significant role in the crop production of the region. In addition, using time series data, it investigates the effects of the (IV1) land use conversion to the (DV) crop production of the Central Luzon region, the (IV2) Urbanization Level on Central Luzon region (DV) crop production, and the (IV3) quantity of agricultural machinery and tractors available for the (DV) crop production of the region of Central Luzon with 50 observations. This data analysis will be carried out regionwide to ensure a thorough analysis and conclusion. Specifically, the current undertaking seeks: to investigate the effect of land use conversion on crop production (palay) in Central Luzon; to investigate the effect of the rise of the urbanization level on crop production (palay) in Central Luzon; to investigate the effect of agricultural mechanization and industrialization on crop production (palay) in Central Luzon.

The study will concentrate on the effects of land conversion, urbanization level, and industrialization of agricultural machineries on crop production, specifically in Central Luzon. The study's data will come from secondary sources and publicly available statistics. It will only validate the impact or relationship between the three independent variables, land use, conversion and industrialization, on the crop production index, and will not address the effects or consequences of such independent variables. The survey's focus on palay production in general limits its ability to narrow down to specific crops. Moreover, the data covered in this study spans 50 time periods, commencing from 1970 to 2019.

II. REVIEW OF RELATED LITERATURE

Crop production is heavily reliant on production factors; hence, understanding the factors influencing it is critical for improving and strengthening its role in the country. One theory that addresses this issue is the theory of production. Cobb and Douglas (1928) stated that the theory of production investigates the interdependence of production factors such as land, labor, capital, entrepreneurship, and the yield of goods and services. Increasing an input (factors of production) will result in a corresponding change in output units. As such, this study will focus on two agricultural production factors: land and capital, specifically land use conversion, the expansion of housing projects, and agricultural machinery.

2.1 Crop Production:

The agricultural sector dominates the Philippines' economy, with food crops accounting for two-thirds of total output. According to Nemethova et al. (2022), crop production is the branch of agriculture that deals with crop cultivation on land. It is primarily a farming activity that generates crops for food and fiber. Some of the most popular crops in the country are rice, corn, and sweet potatoes (Cagasan & Dogello, 2021). In the Philippines, fruit and vegetable production has increased significantly; double cropping of rice, corn, and some vegetables is standard in many areas but not universally (Cagasan & Dogello, 2021). As such, it is a staple activity in the Philippine economy, supporting exports and household consumption while also significantly contributing to the country's overall economic growth (Cagasan & Dogello, 2021; Velza et al., 2023). Moreover, crop production is the country's primary source of employment, employing 36% of the total working population (Asian Development Bank, 2016). As a result, it serves as the foundation for the country's economic growth and food security, emphasizing its importance to the country's prosperity (Parreno, 2023).

Palay is the most widely grown crop in Central Luzon, making the region the largest producer in the country (Fair Finance

Asia, 2021). Crops, such as palay, do not grow by themselves; they are influenced by a variety of factors, including arable land availability, macroeconomic uncertainty, and consumption patterns (OECD, 2017). Agricultural inputs such as planting materials, fertilizers, pesticides, and labor availability can also limit harvest volume. Furthermore, the presence of agricultural technology, machinery, equipment, and facilities impacts crop production (Velza et al., 2023). For instance, fuel, fertilizer, land rent, planting season, and land area all impact rice production and technical efficiency in region three (Koirala et al., 2014). With this, ensuring the quality and effective utilization of these factors is critical for successful crop productivity.

2.2 Land Use Conversion:

As the human population continues to grow, the competition for scarce resources such as land has become cutthroat. Calura et al. (2023) reported that Increasing population has caused agricultural lands to significantly shrink due to rapid urban expansion and growing demand for goods and services. Furthermore, this loss in agricultural land is especially severe in developing countries with an estimated reduction of 2.2 hectares in land per person every 12 years. Thus, land conversion in the Philippines is becoming increasingly prevalent to keep up with human growth. Harewan et al. (2023) defined land use conversion as the process of shifting a land's function to another. For instance, agricultural land such as the rice fields in Pampanga has been converted into residential areas. As a result, farm sizes in Central Luzon have decreased from 2.54 hectares in 1970 to 1.79 hectares in 2020 (Kajisa et al., 2022). The primary drivers of land conversion are rapid urbanization, increased population, economic growth, and infrastructure development; however, urban expansion remains one of the most significant contributors to the conversion of agricultural lands, with countless investors eyeing the area for earnings from this non-agricultural development (Mishra et al., 2021; Cabildo et al., 2017). Such urban expansion or rural urbanization is driven mostly by infrastructure developments such as highway construction (Song et al., 2016) and the movement of rural areas into large urban centers such as Metro Manila (Estacio et al., 2021).

While such activities aim to achieve industrial expansion goals and meet the needs of residential communities (Mishra et al., 2021), they come at a significant cost. Converting agricultural lands into residential, commercial, and industrial developments has resulted in a substantial loss of agricultural lands, serious food security concerns, environmental consequences, and social displacement. Furthermore, despite rice being a staple food of three-fourths of the country's population, there is still an inability to meet the Filiino's rice demands. As such, the country has become the world's second-largest rice importer, and nearly 51 million suffer from food insecurity (Food and Fertilizer Technology Center for the Asian and Pacific Region, 2019). Furthermore, the conversion of agricultural lands has resulted in environmental degradation, such as erosion, landslides, climate change, pollution, and social displacement, putting Filipinos' livelihoods at risk (Mishra et al., 2021).

2.2.1 Land Use Conversion on Crop Production:

Crop production heavily depends on production factors such as land, which was established in the early centuries to serve an essential purpose in agricultural activities (Belous, 2022). According to Mf O. et al. (2022), the relationship between production and land size suggests that expanding farm size is another way to boost output. Land is recognized as a critical fixed factor in production and used as a commodity in almost every product known to humanity (De Maria, 2019). However, since areas on the outskirts of Manila are experiencing rapid urbanization and a growing economy, agricultural land has been converted for residential, business, and industrial development purposes, which may impede rural development. This phenomenon is called land use conversion, which is the transfer of land from one use to another, as well as the transformation from its natural state to human use (Phuc et al., 2014; Liu, 2018). Moreover, it is the legal process that changes a land's original use into a completely different purpose (Fulgar, 2023). For instance, the beneficiaries of comprehensive agrarian reform law in the country who acquired land for farming deemed to have a greater economic value if used for other purposes can convert their land into their desired purpose after five years that it is awarded to them (Department of Agrarian Reform, 1998).

Land supply scarcity and finite nature foster fierce land-use competition between agricultural and non-agricultural sectors, resulting in agricultural land conversion (Rondhi et al., 2018). The competition for land for other purposes, leads to a very limited potential for expansion of agricultural land (Eitelberg et al., 2014). Rapid urbanization and population growth are the primary driving forces for land use conversion, as well as environmental, geographical, and socioeconomic factors and the shifting from a rural to an urban society (Hassan, 2016; Van Vliet et al., 2015). For instance, the National Irrigation Authority (NIA) reported that Central Luzon had the most converted lands, with 111,079.46 hectares of formerly irrigated land converting to other purposes between 2012 and 2022. Worse, aside from the expansion of large urban centers and metropolitan areas, peri-urbanization and the spread of villages that consume more land per person has added as the culprit for larger amount of agricultural land loss which further constraints the capacity of the growing population to produce food (Van Vliet et al., 2017).

Converting agricultural land for development leads to forcing farmers to abandon farming, losing stable livelihoods and income (Zhang, 2014; Taer, 2024). In addition, conversion of farmlands to other uses has substantially depleted agricultural land and decreased crop production. The conversion of lands used for agricultural activities to urban use due to economic growth has resulted in a drastic decrease in crop production and a change in the agricultural landscape of the Metropolitan Manila area and urban fringes (Bravo, 2017). Since most cities are distributed on the neighboring agricultural lands, converting agricultural land into urban centers may cause land use and food conflicts in the future (Magsi et al., 2017). Moreover, these land use changes reduce arable land productivity by reducing the size of farms and decreasing the efficiency of the country's agricultural sector, resulting in a slow improvement in food security. (Ye et al., 2022; Lagare 2021). In addition, the loss of cultivable land due to land use conversion will pose a significant threat to crop production and food security (Dela Cruz & Bobier, 2016). Especially if the region is densely populated and there is less land available for farming, it would lead to food insecurity (Giller et al., 2021). Furthermore, it demonstrates that having less available land impedes agriculture and crop production (Nilsson, 2018). These losses of agricultural land due to conversion had also resulted in loss in crop production as a continued decline in crop production is seen because of the transitions that occurred (Skog & Steinnes, 2016; Ge et al., 2018). The selling of crops is the bread and butter of the farmers so when farmlands are shrinking so is the produced crops, resulting in a declining agricultural income (Noack & Larsen, 2019). Similar to the study of Giller et al., (2021), where it is discussed that shrinking arable land constrain agricultural production and income. Increased arable land availability has significantly improved grain yields, demonstrating that arable land availability influences agricultural productivity, specifically crop yields (Su, 2022; Dait, 2023).

In contrast to these studies, the spatial transition of farmlands can gradually create a spatial pattern that optimizes grain production and might also have some positive effects on conserving nearby farmland as new residents create new business opportunities for local producers (Ge et al., 2018; Qiu et al., 2015). Land use conversion having a positive or no effect on the crop production in the area might be because land is not the only factor involved in crop production. For instance, a more significant quantity of farm size is not the only factor influencing yields; factors such as irrigation and pesticides are also necessary in achieving crop productivity (German et al., 2022). Furthermore, not only does land size affect production, but so do highly industrialized methods that now have more extensive tracts of land to raise a narrow range of crops (Spangler, 2020). Moreover, the spatial transition of farmlands can gradually create a spatial pattern that optimizes grain production and might also have some positive effects on conserving nearby farmland as new residents create new business opportunities for local producers (Ge et al., 2018; Qiu et al., 2015).

2.3 Urbanization:

Urbanization has resulted in the depletion of arable land (Wang et al., 2019). As cities grow, competition for land between urbanization and food production (agriculture) increases (Van Vliet et al., 2017). Urbanization reduces the availability of land, which has a negative impact on staple crop production and yields. This urbanization is expected to continue, claiming millions of hectares of cropland (Andrade et al., 2022). Worse, rural areas are gradually urbanizing due to population growth and industrialization demands, causing farming activities to stagnate and agricultural output to decline (Yamagishi et al., 2021).

This is evident in the Philippines, which has undergone rapid urbanization, transitioning from an agrarian to an urban-centered society in just fifty years, and the effects of urbanization in the country have not produced the expected positive results compared to neighboring countries (Rob & Talukder, 2013). Furthermore, in the Philippines, urbanization is defined as expanding existing urban areas by transforming or converting neighboring agricultural lands into non-agricultural uses (Chaves et al., 2020). The ongoing urbanization and industrialization of the Philippines' provinces surrounding Metro Manila has resulted in a persistent decrease in productive agricultural land due to extensive conversion for industrial, commercial, and residential development (Estacio et al., 2021). Additionally, it increases commercial centers, residential subdivisions, and industrial and technological facilities, creating job opportunities and income sources for residents. However, it also puts pressure on agricultural lands, challenging locals to balance their basic needs while adapting to land use conversion and population growth (Bragais, 2022).

In Central Luzon, prime lands for agricultural activities must be sacrificed to satisfy the thirst for urban development (Tinio, 2013). According to Quimba and Estudillo (2021), the spread of urbanization forces in the region has significantly benefited its constituents by creating more employment opportunities outside the farming sector. However, since non-farm activities are now more appealing farming now becomes a non-primary source of income putting agricultural production in danger.

2.3.1 Urbanization on Crop Production:

Urban development is an antecedent to agricultural land conversion since it requires accommodating population growth and expanding cities. It is also driven by housing, infrastructure, and commercial space demand (Juarez et al., 2022). This is similar to the study of Dadi et al. (2016), where they indicated that agricultural land conversion mostly takes place to cater to infrastructure development and residential expansion. Liu (2018) stated that the rapid expansion of urban regions represents more than just a significant shift in land usage globally but also has significant impacts on rural areas that must be observed as it exacerbates issues associated with rural diseases that contribute to the depletion of agricultural land and occasionally has irreversible consequences. Thus, by 2030, it is projected to cause a decrease in global croplands, wherein Asia will encounter the most significant absolute decline in cropland (d'Amour et al., 2017). According to Yamagishi et al. (2021), rural areas gradually urbanize as development demands rise.

For the past two decades, urbanization in the Philippines has plateaued, with a slow pace indicating a higher rate of growth in the rural population than in the urban population (Bravo, 2017). Hence, urbanization in rural areas has resulted in a significant loss of arable land and depletion of high-quality farmland (Li & Song, 2019). It also coincides with rural settlements, which have a negative impact on cropland productivity because they frequently result in the construction of houses (Song & Liu, 2014). Similar to the study of Wang et al. (2018), in which the total amount of land used for rural settlements increased as demand for improved housing conditions increased. This results in the fact that urban development planning and execution in the Philippines have excessively prioritized housing (Navarro, 2016). Thus, intense urbanization, specifically residential expansion, directly impacts the capability to produce food (Gardi et al., 2014).

The urban expansion around Metro Manila will impact nearby regions like Central Luzon (Valerio, 2020). Central Luzon, located on the outskirts of Manila, has become a haven for real estate, commercial, and infrastructure development, but at the expense of farms and rice lands (Arceo-Dumlao et al., 2021). This owes to urbanization expanding to fertile areas that are great for farming; hence, direct competition for land arises between crop production and urbanization (d'Amour, 2017; Thebo et al., 2014; van Vliet et al., 2017). Urbanization causes cities to expand, leading to a need for enough housing to accommodate the growing urban population. As economic development increases, so does the demand for housing (Lall, 2015). This is observed with Central Luzon. During the year 2010, the region ranked third highest in population at 10,137,737 among the other regions, and in connection with this, the region ranked fourth highest in urbanization due to population at 51.6% (Navarro, 2016). Worse, residential expansion, such as housing areas, often has a negative impact on agricultural areas (Ahmed & Jackson-Smith, 2019). Residential expansion and infrastructure development are the main reasons for converting agricultural land, which reduces the size of cultivated land and crop production (Dadi et al., 2016). Existing residential zones frequently attract new housing developments, often surrounded by agricultural areas (van Vliet et al., 2013). Farmland conversion has reduced income sources due to farmers who till the land have been displaced for residential developments (Tufa & Megento, 2022). It also caused significant changes during the farmland requisition process, such as a transition from farmhouses to urban apartments, a shift in identity from peasants to urban residents, a shift in occupation from farming to non-farming jobs, and a change in resident structure from a single village to several. Such socio-spatial changes have gradually faded in urban areas as people move from rural villages to urban housing districts (Tufa & Megento, 2022).

In addition, these developments for both residential and commercial use have harmed farming and food production, resulting in a decline in agricultural activity (Osumanu & Ayamdoo, 2022). Furthermore, access to urban and rural farmlands is critical for food security, as prices are low when agricultural lands are plentiful (Tacoli., 2019). According to Waseem et al. (2019), crop production has been reduced due to the loss of agricultural land due to housing development. This may result in increased food prices due to reduced crop production. Less availability of agricultural land can further limit the food and crop production capacity (van Vliet et al., 2017). Crop production has decreased significantly as agricultural lands have been converted to residential areas (Cai et al., 2023). Similar to this, Wang et al. (2021) found that converting farmlands into residential areas reduced total crop production, leading to food insecurity and potential social unrest.

On the other hand, urbanization negatively affects agriculture as it takes over farmlands reducing food security and the expansion of the market allows cheaper options that hurt local farmers' produce and profits. Wang et al. (2021) indicated in their study that crop production increases with urbanization because urbanization has the potential to release rural land areas that were once occupied for residential use or housing. Moreover, a study by Omotoso et al. (2022) revealed that crop yields are higher in rural areas with developed infrastructure than those with less developed infrastructure. Additionally, such an occurrence may also result in economic benefits, such as many investors looking to profit from the region's non-agricultural development (Cabildo et al., 2017). Furthermore, the development of transportation infrastructure is not solely due to

investments made by individual states/provinces. Furthermore, (Qiu et al., 2015) found that new residents create new business opportunities for local producers, which benefits the conservation of nearby farmland. Other research, however, has revealed a variety of perspectives on the impact of urbanization on crop production. According to Li and Li (2019), urbanization has both a positive and negative impact on agriculture. It was explained that urbanization positively impacts crop production because it brings scientific and technological advancements that help improve seeds, increase crop yields, and enable efficiency. These enable the movement of agricultural products from rural to urban markets and provide farmers with more opportunities to increase their income.

2.4 Agricultural Mechanization and Industrialization:

Agricultural mechanization is a critical component for running farm operations efficiently and productively. According to Zou and Qui (2017), introducing automated agricultural machinery in agricultural powerhouse countries such as China represents societal progress in meeting growing agricultural demands. Incorporating agricultural automation is an effective way to increase productivity, lower costs, and improve product quality in agricultural production. Furthermore, mechanization positively impacts the cost, output values, income, and return rate of all crops, as seen in Chinese agriculture (Peng et al., 2022). However, it's important to note that using agricultural mechanization is a complex process. While it is expected to increase agricultural output, it also leads to a decrease in other agricultural inputs, such as employment, as machines outperform humans in tasks (Rodriguez & Piadozo, 2016). Moreover, application of mechanization differs between developing and developed countries, wherein developing countries apply mechanized farming in order to alleviate challenges they face in their economy such as food security for a growing population (Emami et al., 2018).

Considering the Philippines' agricultural nature, adopting mechanization holds significant potential for reaping numerous benefits. However, the country's current mechanization levels are classified as low (Suministrado, 2013). Recognizing the importance of a mechanized agricultural sector, the Philippine government has started promoting its development by enacting the Agricultural and Fisheries Mechanization (AFMech) Law (Bautista et al., 2017). This shift towards mechanization has improved labor productivity, efficiency, cropping intensity, and global market competitiveness, lowering labor requirements and production costs through timely operations (Mataia et al., 2016).

Despite being referred to as the 'Rice Granary of the Philippines,' Central Luzon is falling behind in farm mechanization compared to other regions. By 2022, the region is expected to have a farm mechanization rate of 2.62 horsepower per hectare (hp/ha), mirroring the national trend of declining farm mechanization (Lagare, 2023). The primary reason for this is the lack of access to such machinery, which most farmers are hesitant to acquire due to the high costs of purchase and maintenance, as well as the need for more knowledge and training.

2.4.1 Agricultural Mechanization on Crop Production:

Mechanization is not just a tool but a key driver of global competitiveness in the agricultural sector. The deficiency in mechanization or technical support leads to decreased cultivated land and delayed agricultural production, creating a substantial loss in agricultural products (Mashkov et al., 2019). For instance, Ukraine’s economy observed a decrease or loss of agricultural machinery, leading to a significant loss in their agricultural sector (Navrotskyi & Petrov, 2023). This underscores the crucial role of mechanization in the extension services offered to farmers or agricultural workers, directly impacting agricultural yield (Rodriguez & Piadozo, 2016).

Tractors, as one of the primary examples of agricultural mechanization, demonstrate the practical benefits of this technology. It is at the forefront of farm machinery and stands out arguably as the most crucial agricultural instrument employed in farming as it is versatile in performing various tasks which makes it the best implement in modern agriculture (Munar et al., 2021). With their positive impact on agriculture, the farming industry is recommended to preserve the existence of this agricultural machinery and increase its number of units (Peng et al., 2022). Specifically, tractors revolutionize labor efficiency, reduce dependency on human labor, and streamline agricultural operations such as plowing, cultivating, and smoothing, resulting in increased harvesting efficiency and the abolition of archaic farming methods (Turky et al., 2023).

The utilization of agricultural machinery such as tractors positively affects crop production in general agricultural production as observed in improved crop yields in Uganda (Epule et al., 2018). However, its effects may differ depending on the crop, as only rice crops benefit from mechanization (Takeshima et al., 2020). Singh (2015) similarly stated that the degree of mechanization to be utilized varies depending on which crop type is to be grown. With agricultural technology development playing a critical role in enhancing crop yields in agriculture, its vital application is necessary among agricultural countries such as the Philippines.

Despite being an agricultural country, the Philippines faces significant challenges, such as low productivity, which strains and hinders agricultural production (Cagasan & Dogello, 2021). Thus, the Philippine government has been dedicated to modernizing the country's agriculture, specifically the rural sector, where most originates (Calibuso et al., 2021). As part of the Philippine government's efforts to modernize its agricultural sector was to implement Republic Act 10601 or the Agricultural and Fisheries Mechanization Law of 2013 (AFMech Law), which aims to promote the adoption and utilization of agricultural mechanization technologies in order for the country's agricultural sector to be in line with its Association of Southeast Asian Nations (ASEAN) neighbors (Amongo & Larona, 2015). Enactments such as this presented an opportunity for technological innovation and paved the way for a transformative shift in the country's agricultural sector. Machineries as one of these technical innovations generated benefits such as increased crop yields (Cagasan & Dogello, 2021).

In 2011, 77% of the farm power utilized for rice production was supplied by mechanical power, playing a crucial role in the advancement of the country's rice industry (Dela Cruz & Bobier, 2016; Bautista et al., 2023). This is due to the fact that rice is a significant crop in the Philippines and that enhancement done on the productive and post-production systems is achieved through agricultural mechanization technologies (Amongo et al., 2018). Thus, farm machinery was found to be one of the incorporated inputs that increase the possibility of higher rice yield potential (Bautista & Minowa, 2010). It was reported that the two-wheel single tractor axle (2WT) is commonly produced and utilized in the Philippines (Singh, 2015). However, despite the mechanization in the Philippines, much is still to be improved. Although the Philippines produces 2WT tractors, as mentioned, the country still imports tractors from other countries (Singh, 2015). Despite the supposed positive effect of mechanized farming, the opposite or no effect may manifest as it may not be compatible with the farming conditions. Mendoza (2016) mentioned that the country imports numerous machinery that is not usually compatible with the country's local farming conditions as most farms are small and are usually situated on slopes that require smaller machines, yet the imported machines are large, which makes it unsuitable and may need necessary adjustments on its tires.

However, some studies disagree with the positive effects of machinery or mechanization on crop production. Such agricultural machinery has no significant effect on agricultural productivity, but rather farm size, pesticide application, and irrigation influence rice productivity (Ojiya et al., 2017; German et al., 2022). Moreover, similar to what was mentioned earlier, tractors are also a double-edged sword. Tractors influence environmental pollution by emitting exhaust gasses, which release harmful substances (Lovarelli & Bacenetti, 2019). Thus, implying that as tractors instigate the deterioration of the environment, it may create various challenges that may hinder optimal crop production.

Moreover, it's claimed that highly mechanized farms make greater profits than conventional farms because their output and income per hectare increase with mechanization degree (Rodriguez, 2016). Despite increased yield and thus a greater demand for harvesting and threshing these machines pose a danger to human capital because they decrease the amount of manual labor input, leading to comparatively steady person-days in this activity (Rodulfo Jr. et al., 2021). People may be more reluctant to enter the farming industry, and if farming is not thoroughly studied before employment, it could impede crop output.

Furthermore, the study by Parvin et al. (2022) shed light on another perspective of mechanization's impact, revealing that agricultural machinery can adversely affect soil quality specifically, how exertion of loads, pressure, and vibrations during machinery operations may lead to soil degradation, thus posing a significant concern for the productivity of growing crops. Similarly, Khafizov et al. (2021) mentioned in their study that the propeller of tractors causes soil compaction and, as a result, reduces crop yield. Additionally, a study by Ojiya et al. (2017) indicates that agricultural machinery yields no substantial impact on agricultural productivity. This finding from the study implies that adopting machinery may not lead to the expected increases in crop yields or overall agricultural output, as mentioned in other studies.

Crop production is a farming activity heavily dependent on labor, capital, entrepreneurship, and land. Several studies and scholarly articles confirm that certain factors influence crop production and that if the necessary conditions are met, crop production may be slow. For example, studies have shown that as the human population rapidly increases, so does the intense competition for finite resources such as land between urbanization and food production (Van Vliet et al., 2017). As a result, agricultural land for development purposes such as urbanization and residential expansion has become common throughout the country. This phenomenon is defined as land use conversion or the process of shifting a land's function to another. For instance, agricultural land such as rice fields in Pampanga had been converted into residential areas leading to the depletion of arable land (Wang et al., 2019; Harewan et al., 2020).

Land use conversion may be conducive to economic growth, but it can also reduce agricultural productivity, making the country's economy unsustainable. According to Mishra et al. (2019), agricultural land conversion has a cost, including significant land loss, serious food security concerns, environmental consequences, and social displacement. However, some

studies show that land use conversion has little to no effect on crop production in the area, possibly because land is not the only factor in crop production. For example, larger farm sizes are not the only factor influencing yields; irrigation and pesticides are also required for crop productivity (Germna et al., 2022).

In addition, capital, such as agricultural mechanization, is required for farms to run efficiently and effectively. It is primarily found in leading agricultural nations, such as China, where the adaptation of agricultural machinery represents societal progress toward meeting agriculture's growing demand (Zou & Qui, 2017). This is because agricultural machinery has been shown to improve crop yields (Epule et al., 2018). Given the Philippines' agricultural nature, mechanization has the potential to provide numerous benefits. Moving toward mechanization increases productivity, efficiency, crop frequency, and competitiveness (Mataia et al., 2016). Notably, given that Central Luzon is the Philippines' rice granary, mechanization in farming is essential. Bautista and Minowa (2010) noted that incorporating farm machinery can help increase rice yields. As a result, this emphasizes the significance of studying land use conversion and agricultural mechanization in Central Luzon.

2.5 Theoretical Framework:

The theoretical framework in this study will be constructed on the CobbDouglas Production Function to illustrate how changes in the inputs affect the quantity of output produced.This production function illustrates the relationship between input and output, in which the input determines the output.According to Sinha (2023), CobbDouglas production in the sense of agricultural production encompasses crop production being dependent on variables such as the quantity and quality of land and agricultural technologies. In this study, the quantity of farmlands left due to land use conversion and urbanization and the quantity of available agricultural machinery are considered for the palay production of the region.

Based from the studies by Sinha (2023) and Singh et al. (2017), the Cobb-Douglas Production Function is as follows:

$$Q = AL^{\alpha}K^{\beta} \text{ or } Y = A_0 f(K^{\alpha}, L^{\beta}, N^{\gamma}) \quad (1)$$

Where Q or Y is the output, which in this case is the palay production. On the other hand, the inputs such as farm size, urbanization level, and agricultural mechanization are represented by $L, K,$ and N. Its elasticity is then represented by $\alpha, \beta, and\ \gamma$, which when summarized equates to 1 (Singh et al., 2017).The constant value of A or A_0 is for the total factor production. Taking into account that this may be a level of technology which is known as the "Total Factor Productivity" or the "Solow Residual" (Singh et al., 2017).

Kamanga et al. (2000) stated that choosing a function and deciding which factors to utilize involves some judgment, such as choosing the inputs that affect the output for a production function. Therefore, the production function needs to be simplified depending on the study. Thus, the Cobb-Douglas Production Function in this study will be transformed to a general form:

$$Y = AX_1^{a1}\, X_2^{a2}, X_3^{a3}, \ldots X_n^{bn} \quad (2)$$

Where Y is the quantity of output, which in this case is the palay production in Central Luzon. On the other hand, X_i are the inputs or the vector of variable resources with $i = 1,2,3,\ldots,n$. It is the levels of inputs (land conversion, urbanization level, and mechanization in the form of tractors) that affect the level of corresponding output or crop production. Moreover, the estimation of elasticity of the input X_i is estimated with A and a_i with i = 1,2,3,...,n.

Moreover, Kamanga et al. (2000) wrote in their study that in order to figure out the values for the constants (coefficients) to further understand the extent of how one influences the other involves transforming the general Cobb-Douglas production model into a linear equation will result to a logarithmic linear function as follows:

$$log\ Y = log\ A + a_1 log X_1 + a_2 log X_2 + a_3 log X_3 + \ldots + b_n log X_n$$

Or

$$log\ Y = B_0 + B_1 log X_1 + B_2 log X_2 + B_3 log X_3 + \ldots + B_n log X_n \quad (3)$$

The above general linear Cobb-Douglas production function will be tested for a multiple linear regression analysis to estimate the coefficients from the equation. Moreover, it will also be utilized since it is similar to the Double Logarithmic multiple linear regression.

As for the elasticities, in reference to the study by Singh et al. (2017), it can be done from the logarithmic form where the data set are converted to the natural logarithmic (base e = 2.71828…) or base 10. With this the value of A is $A = e^{B0}$. Similar to this, the values of a_1, a_2, a_3 are as follows: $a_1 = e^{B1}, a_2 = e^{B2}, a_3 = e^{B3}$.

Values of B_1 B_2 B_3 can be measured by getting the output elasticity of each inputs where $B_1 = (dY/dX_1) * (X_1/Y)$, $B_2 = (dY/dX_2) * (X_2/Y)$, $B_3 = (dY/dX_3) * (X_3/Y)$.

III. METHOD

Cobb and Douglas' (1928) production theory states that there is a relationship between the units of factor production and the units of output of goods and services. It is also demonstrated that if the number of inputs used changes, the units of output produced will undoubtedly change. The positive sign on the variable Agricultural Tractors (IV3) signifies a positive relationship between it and the dependent variable (Crop production). The negative sign on the Land Conversion (IV1) and Urbanization Level (IV2) denotes a negative relationship with the dependent variable (Crop production).

With the production theory as a foundation, the proposed research framework investigates the relationship between land conversion, agricultural tractors, urbanization level, and crop production. It would use the production function to investigate how independent and dummy variables influence crop production in the Philippines, specifically in Central Luzon.

3.1 Data:

The data used from 1970-2019. Data for the IV1 or the Land Conversion measured through Farm Size (Hectares) and the IV3 or the Industrialization/Mechanization measured through Adoption of New Technologies (%) were collected from the Central Luzon Loop Survey by the International Rice Research Institute (IRRI) Emerging-Economy State and International Policy Studies. Data for the IV2 of the Urbanization measured through Urbanization Level (%) were collected from the Urban Transition, Poverty, and Development in the Philippines journal by the Ateneo de Manila University, the Urban Population in the Philippines report by Philippine Statistics Authority (PSA), and Central Luzon Quickstat by PSA. The DV or the Crop Production measured through Palay Production (Metric Tons) was collected from the PhilRice website by the Department of Agriculture wherein data sources are from Philippine Rice Information System, PSA, PalayStat, World Bank, and DOST-FNRI.

3.2 Research Design:

This study utilized quantitative methods and time-series analysis to examine the impact of land use conversion for non-agricultural purposes and residential development on crop production in Central Luzon. It will also look into the impact of urbanization in the region and agricultural mechanization on crop production.

3.3 Research Method:

This study examined the relationship between palay production and land use conversion, urbanization, agricultural mechanization, and industrialization in Central Luzon. Therefore, the researchers used the following econometric model:

$$CP = \beta 0 - \beta 1LC - \beta 3U + \beta 2AM + e \quad (4)$$

where *CP* refers to Crop Production, *LC* refers to land conversion, *U* refers to urbanization and *AM* refers to agricultural mechanization. Land conversion and urbanization are expected to negatively impact crop production, while agricultural mechanization is expected to positively affect crop production.

With this, the researchers will use quantitative method analysis and time-series analysis to assess the long-term impact of variable land use conversion, the urbanization level, and agricultural mechanization and industrialization. Moreover, analysis on these variables will also serve to allow understanding of the complex interactions between them.

3.3.1 Unit Root Tests:

The study by Ojiya et al. (2017), which investigated the effect of agricultural input on agricultural productivity and is similar to the current study, will serve as a reference for the tests that will be conducted. This study will employ a time series test, specifically the Augmented Dickey-Fuller Test, which can detect and correct for nonstationarity in a time series. It will determine whether crop production is constant or varies over time. This test will examine the relationship between the independent and dependent variables during the period. Furthermore, since it yields consistently good results for time series with a higher number of observations, it will be employed for this investigation as a trustworthy unit root testing technique (Arltova & Fedorova, 2016).

Johansen Cointegration will also be used to determine whether the variables in the dataset have a long-term relationship with one another as stated in the study by Ojiya et al. (2017). Johansen's methodology takes its starting point in the vector

autoregression (VAR) of order p given by:

$$y_t = \mu + A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + \beta \chi_t + \varepsilon_t, \quad (5)$$

where A stands for the autoregressive matrices and Y_t is a vector of endogenous variables. The parameter matrices are represented by B, and the deterministic vector is X_t.

3.3.2 Ordinary Least Square Model:

After doing the augmented dickey fuller test, this study will now use an ordinary least squares model, specifically a multiple linear regression. According to Muraya (2017), establishing a production function is required to determine the individual or combined contribution of inputs to outputs. The general neoclassical production function: Y = F (X1, X2, X3,….Xn) or Y = F (LC, U, AM) for this study where Y is the output level, Xs are the inputs; in this study it is the land conversion, urbanization, and agricultural mechanization, respectively.

Furthermore, according to Muraya (2017), in order to eliminate the bias in the Cobb-Douglas production function, the formula can be converted by taking the logarithm of both sides. The transcendental logarithmic function (trans-log) is more flexible than the Cobb-Douglas production function. Thus, it is more suitable when estimating a complex production relationship. The ordinary least squares (OLS) technique can estimate this transformed function. The model can now be estimated using ordinary least squares (OLS) because its parameters are linear. With all of the variables in logs, this becomes a double log model which is as stated in the theoretical framework.

Furthermore, based on the theoretical framework, a double logarithmic regression will be utilized. By means of this, it will verify the percentage increase and decrease of the output or DV for every given 1% increase in the input or IV. Thus, the double logarithmic regression will be as follows:

$$\text{Log Crop Production} = \beta 0 - \beta 1 \log LC - \beta 2 \log U + \beta 3 \log AM + e \quad (6)$$

where log *CP* refers to log Crop Production, log *LC* refers to log land conversion, log *U* refers to the log urbanization and log *AM* refers to log agricultural mechanization. The log land conversion and log urbanization are expected to negatively impact the lpg crop production, while the log agricultural mechanization is expected to positively affect the log crop production.

3.3.3 Post Diagnostic Test:

Suphannachart and War (2011), who investigated the effects or impact of inputs on agricultural production or productivity, similar to the current study, used the autocorrelation test to validate the regression analysis. Autocorrelation will be determined by assuming that the model has no serial autocorrelation and that the alternative hypothesis is that the model has serial autocorrelation. If the value exceeds the p-value, then the null hypothesis is accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted. Autocorrelation will be tested to verify that the errors in the model are unrelated or that the error for one observation does not influence the error of another observation (Burton, 2021). Durbin-Watson is the most commonly used test for autocorrelation. However, the Breusch-Godfrey test has been shown to be superior to other autocorrelation tests for models with lagged dependent variables (Uyanto, 2020).

Uyanto (2020) presented the Durbin-Watson equation as follows:

$$d = \frac{\Sigma_{t=2}^{n} (\hat{u}_t - \hat{u}_{t-1})^2}{\Sigma_{t=1}^{n} \hat{u}_t^2} \quad (7)$$

Here the $\hat{u}_t^2$ represents the errors from the model in different times and the Durbin-Watson compares how these errors vary from one time to another. The squared difference compares the overall size of the errors. The value of d will always fall between 0 and 4. Values close to 2 means no autocorrelation in the model or errors are independent. Values close to 0 means positive autocorrelation or that the errors are related. Values close to 4 means negative autocorrelation or that the errors move in opposite directions.

Uyanto (2020) also presented the Breusch-Godfrey equation as follows:

$$Y_t = \beta_1 + \beta_2 X_t + u_t \quad (8)$$

The test figures out if the errors in the regression model are related to each other over time by running a secondary regression through this auxiliary regression:

$$u_t = a_1 + a_2 X_t + \hat{p}_2 \hat{u}_{t-2} + \ldots + \hat{p}_p - \hat{u}_{t-p} + \varepsilon_t \quad (9)$$

The above auxiliary regression will be done to obtain R^2 or the squared regression which is similar to calculating in any standard OLS regression wherein R^2 = 1 - (RSS/TSS). RSS is the residual sum of squares and TSS is the total sum of squares (Erickson, 2014). Asymptotically, once the R^2 is obtained, it can demonstrate the following equation below:

$$(n-p)R^2 \sim X_p^2 \tag{10}$$

The normality test adopted the Jarque-Bera statistics using the skewness and kurtosis of the derived ordinary least squares model.

The equation will be as follows:

$$JB = \frac{n}{6}(S^2 + \frac{(K-3)^2}{4}) \tag{11}$$

It will determine whether the dataset in the regression model follows a normal distribution. The normality will be determined by assuming the null hypothesis has normal residuals and the alternative hypothesis has non-normal residuals. If the value exceeds the p-value, then the null hypothesis is accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted.

Also, to ensure that the regression analysis was valid and reliable. Heteroskedasticity will be determined by whether the null hypothesis states that the model is homoscedastic or not, and the alternative hypothesis states that the model is heteroskedastic. If the value exceeds the p-value, the null hypothesis will be accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted. This test is applied to the study as heteroskedasticity determines the spread or variability of error, which can cause an error on the OLS done. Hence, there is a need to validate whether the model has heteroskedasticity or homoscedasticity to ensure reliability and efficiency in estimating the relationship of the variables (Mills, 2014).

Mills (2014) presented the heteroskedasticity equation as follows:

$$V(u_i) = E(u_1^u)\sigma^2 \tag{12}$$

Classical linear regression assumes that the spread of errors should be the same for all data points. This is what is known as homoscedasticity. If this is false and the spread of errors varies, then it is what is known as heteroskedasticity.

Furthermore, Sanaullah et al. (2020), utilized the Variance Inflation Factor (VIF) in testing multicollinearity in their study. The equation are what follows:

$$VIF = \frac{1}{1-R_j{}^2}; \tag{13}$$

$$VIF = \frac{1}{1-0.235642} \tag{14}$$

The R_j is the coefficient of multiple correlation between j and other regressors. When the variable is not correlated with other variables, the minimum value will be at 1.0. According to Neter, Wasserman, and Kutner (1990), a number larger than 10 is often interpreted as a value that suggests a significant degree of collinearity. Thus, it is recommended to check the biggest VIF as a diagnostic value for collinearity.

Suphannachart and War (2011) also used the Ramsey test for functional form misspecification (RESET) in their study. Thus, this test will also be used in the current study. The null hypothesis has no specification error, while the alternative hypothesis has one. If the value exceeds the p-value, then the null hypothesis is accepted. If the value is less than the p-value, the null hypothesis is rejected, while the alternative hypothesis is accepted. This test will be utilized to verify if the model being tested is indeed linear as nonlinearity may occur caused by various factors such as nonlinear relationship between variables or presence of outliers (Prabowo et al., 2020).

Prabowo et al. (2020) presented the Ramsey RESET equation as follows:

$$Y_i = \lambda_1 + \lambda_2 X_i + u_i \tag{15}$$

Starting with the original regression model, there's a pattern and there's suspicion the model needs improvement. To improve the model, new forms of the predicted values are added, such as squaring or cubing $\hat{Y}$ in order to validate if it explains the data better:

$$Y_i = \beta_1 + \beta_2 X_i + \beta_3 \hat{Y}_i^2 + \beta_4 \hat{Y}_i^3 + u_i \quad (16)$$

After, comparison of performance of the original model with the improved model is done using Ftest. If the new model is significantly better, reject the idea that the original model was enough, meaning that the model might be nonlinear.

$$F_{hit} = \frac{(R^2_{model2} - R^2_{model1})/k}{(1-R^2_{model2})/(n-p_2)} \quad (17)$$

IV. RESULTS AND DISCUSSION

TABLE 1
JOHANSEN COINTEGRATION (LINEAR AND DOUBLE-LOG) TEST RESULTS

Rank	EigenValue	Trace Test	p-value	Lmax test	p-value
0	24858	29.037	0.7667	14.004	0.8175
1	0.17132	15.033	0.7811	9.208	0.8131
2	0.10485	5.8252	0.7183	5.4276	0.6902
3	0.008083	0.39768	0.5283	0.39768	0.5283

The conducted Johansen Cointegration test for the linear and double-logarithmic model acquired the same results. Both models revealed that the alternative hypothesis is accepted at all ranks, wherein cointegration exists. It implies that the variables in the model exhibit a long-run relationship. Moreover, this implies that even if shocks were to occur in the short run and may affect movement individually, the variables would converge in time.

TABLE 2
ADF (LINEAR AND DOUBLE-LOG) TEST RESULTS

Variable	t-statistics	Prob.*
(First-Difference) Land Conversion	-6.80372	1.11E-09
(First-Difference) Agricultural Mechanization	-6.82516	9.73E-10
(First-Difference) Urbanization	-7.0336	2.69E-10
(First Difference) Crop Production	-9.48524	1.45E-17

To begin the long-run regression analysis, the study begins with unit root tests for stationarity of each model variable using Augmented Dickey-Fuller (ADF). The unit root test, conducted using the Augmented Dickey-Fuller (ADF) test, revealed that both models acquired the same results. The test revealed that there were no variables that were non-stationary across levels, and therefore the null hypothesis of non-stationarity across levels could not be rejected. Therefore, variables do not change when it encounters a shift in time and space.

TABLE 3
MULTIPLE OLS ON CROP PRODUCTION, LAND CONVERSION, URBANIZATION, AND AGRICULTURAL MECHANIZATION (1975-2019)

Variable	Coefficient	Std. Error	t-ratio	p-value
Const	0.0419833	0.019499	2.153	0.0374**
Land Conversion	0.559446	0.295141	1.896	0.0653*
Agricultural Mechanization	0.234659	0.137793	1.703	0.0963*
Urbanization	0.0097553	0.245462	0.03974	0.9685
Crop Production	-0.338355	0.138537	-2.442	0.0191**
● R-squared: 0.235642				
● Adjusted R-squared: 0.159207				
● F-statistics: 0.026472				

Log Crop Production = β0 - β1 log LC - β2 log U + β3 log AM + e (18)

The result of the regression analysis is shown in Table 3, illustrates the effect of land use conversion, urbanization level, and agricultural mechanization on palay production in Central Luzon between 1970 and 2019. The p-value of 0.0374 of the model, which is less than the alpha of 0.05, shows that the model is significant. Moreover, variables land conversion, agricultural mechanization, and crop production have resulted in 0.0653, 0.0963, and 0.0191 respectively, indicating that the variables are significant to the model. On the other hand, the variable urbanization level acquired a result of 0.9685, which tells us that it does not have significance to the model. In a nutshell, land conversion and agricultural mechanization can bring significant changes on palay production in Central Luzon, unlike the variable of urbanization level Specifically, land conversion decreases the palay production in Central Luzon which supports the studies by Bravo (2017), Dela Cruz and Bobier (2016), Nilsson (2018), Skog and Steinnes (2016), and Ge et al. (2018) that the conversion of agricultural land significantly reduced land available which impedes agriculture and results to decreased crop production. Because of this land use and food conflicts will rise (Magsi et al., 2017) and risk of food insecurity will grow (Ye et al., 2022; Lagare 2021, Dela Cruz & Bobier, 2016; Giller et al., 2021). However, mechanization has shown to increase the palay production in Central Luzon which supports the study by Epule et al. (2018) that the use of agricultural machinery, such as tractors, generally boosts crop production and leads to improved crop yields. As for the urbanization level, it shows that it is insignificant or that it has no strong effect on the palay production in Central Luzon.

This model also reveals that for every hectare of land being converted for non-agricultural activities, the palay production will experience a decrease of 0.05594 metric tons. Every one-percent increase in agricultural mechanization will correspond to a 0.2347 metric ton increase in palay production in the region. The OLS results revealed that the hypotheses that the increase in land conversion and the increase in agricultural mechanization will increase crop production have been proven correct. Hence, the hypotheses of both variables of the study were accepted.

TABLE 4
DIAGNOSTIC TEST ON CROP PRODUCTION, LAND CONVERSION, URBANIZATION, AND AGRICULTURAL MECHANIZATION (1975-2019)

	Normality Test	Breusch-Godfrey Test	Durbin Watson Test	White's Test	Breusch Pagan	RESET Test
Test Statistic: Chi-square (2)	6.67032	0.857489	2.12876	6.49452	3.97946	0.52118
p-value	0.0356089	0.360137	positive: 0.6877777 negative: 0.312223	0.889134	0.4008793	0.598003

Diagnostic tests serve as crucial to assessing the model involved to yield unbiased and non-misleading outcomes. The model was then tested for normality, serial correlation, heteroscedasticity, and stability (Table 4). In terms of the econometrics test, the p-value of the normality of residuals observed at the table is less than the alpha of 0.01, thus there is non-normality of residuals. Also, the p-value of the Breusch - Godfrey Serial Correlation LM test is greater than the alpha of 0.05, indicating that there is no significant first-order autocorrelation detected in the regression output. Moreover, the p-values of the Durbin Watson Test are both greater than the alpha of 0.05 showing that there is no significant autocorrelation, either positive or negative, detected in the regression output. This entails that the errors or residuals in the model are independent of each other (Burton, 2021). The p-value of the White's test is greater than alpha of 0.05, indicating that the model in the study is homoscedastic or there is no heteroskedasticity. Similar results were observed with the Breusch Pagan Heteroskedasticity test as the p-value is greater than the alpha of 0.05 which indicates that the model in the study is homoscedastic or there is no heteroskedasticity. This entails that the variance of error or residuals in the model is constant among all levels of the independent variables (Mills, 2014). Lastly, since the p-values of the RESET test are greater than alpha of 0.05, then there is no misspecification error in the regression output. This entails that the results of the model is more likely valid and likely that there are no nonlinear relationships between the variables (Prabowo et al., 2020).

TABLE 5
MULTICOLLINEARITY TEST (LINEAR AND DOUBLE-LOG MODEL)

Crop Production	1.011
Land Conversion	1.001
Urbanization	1.006
Agricultural Mechanization	1.005

The conducted multicollinearity test on the linear and double-logarithmic model accepts the null hypothesis that the model has no multicollinearity. Specifically, the model has low multicollinearity or is moderately correlated since VIF values are more significant than one but less than five.

V. CONCLUSION

Despite the Philippines slowly shifting its main contributor to Gross Domestic Product (GDP) from agrarian to service sector, the agricultural sector still plays a vital role in the country's economic position. Crop production has an integral role in the Philippines' economy. Agriculture has been the country's backbone for centuries, with Central Luzon as its leading contributor, earning the title "Rice Granary of the Philippines." It is responsible for employing 36% of the Filipino workforce, providing a continuous income stream, and allowing individuals access to their needs. Furthermore, the country is experiencing a growing population, which entails growing demands. Hence, the agricultural sector is vital to securing food security for this concern.

The main objective of this study is to investigate the effect of variables such as land use conversion, urbanization level, and agricultural mechanization on palay production in Central Luzon. Specifically to validate that the persistent land use conversion and urbanization in the Philippines negatively affect the crop production in Central Luzon. Moreover, it also aims to validate that the addition and utilization of mechanized farming positively affects crop production in Central Luzon. Furthermore, the study employs the Cobb-Douglas production function in another approach, wherein the production inputs to be utilized will substitute the traditional inputs on the function and instead have input factors such as land conversion, urbanization, and agricultural machinery.

The variables estimated through multiple regression analysis demonstrated that the decreasing farm size input, which results from land use conversion and the amount of available agricultural machinery, significantly impacts the growth of palay production in the region. The continuous land use conversion has negatively affected the palay production. On the other hand, the increasing availability of agricultural machinery has positively influenced the production of palay in the area. However, results showed that despite the region experiencing rapid urbanization, it does not significantly affect palay production.

Since Central Luzon is the country's major rice producer, the governing body should boost agricultural development in the region. Through establishing and enforcing land-use policies and zoning regulations that prioritize the protection of agricultural lands, as well as fostering collaboration among urban planners regarding sustainable urban development to prioritize the preservation of existing farmlands and reduction, or better, the avoidance of negative impacts on agricultural lands. It is also noted that adopting more mechanized farming positively affects the palay production. Hence, the adoption of agricultural machinery should be supported through subsidies or incentives among farmers to increase their productivity and efficiency to boost the production of crops and secure food for the growing population. These measures hold the promise of a more sustainable and productive agricultural future for Central Luzon. Moreover, the study provides future researchers knowledge to find strategies to balance the preservation of agriculture and the growing urbanization in rural areas. It may also create more nuanced knowledge and examine land conversion's effects on crops and geological areas. This could also extend to future researchers assessing how well different land management techniques preserve agricultural land and productivity in the face of increasing urbanization.

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Seasonal Incidence of Major Pests of Ash Gourd, *Benincasa hispida* Thunb. in Relation to Weather Parameters

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Abstract— *Studies on seasonal occurrence of major pests of ash gourd, Benincasa hispida Thunb. revealed that the incidence of Liriomyza trifolii Burgess and aphid, Myzus persicae Sulzer were highest during first week of October 2018 (SW 40) and first week of February 2019 (SW 05) respectively. Red pumpkin beetle, Aulacophora foveicollis Lucas and Pumpkin caterpillar, Diaphania indica Saunders were highest during second week of October 2018 (SW 41). The correlation and regression analyses showed that weather parameters significantly influenced the incidence of M. persicae, L. trifolli, A. foveicollis and D. indica as 38.34, 23.50, 19.88 and 31.23 per cent of total variation, respectively.*

Keywords— Ash Gourd, Correlation, Insect Pests, Seasonal Incidence, Weather Parameters.

I. INTRODUCTION

Ash gourd, *Benincasa hispida* Thunb is one of the most important vegetable crops, being cultivated throughout the humid tropical and sub tropical regions. It is also known as tallow gourd, Chinese preserving melon, Chinese water melon, white gourd and wax gourd which is originated in the Asian subtropics. Ash gourd is mainly grown in India, China, Malaysia, Bangladesh, Indonesia, Philippines, Taiwan and the Caribbean Islands for vegetable and medicinal purposes. The immature fruits are used as vegetable and mature fruits are used for preparing candy, sweets and also some ayurvedic medicines (Tindall, 1986).

Ash gourd is attacked by wide range of insect pests *viz.*, aphids, *Aphis gossypii* Glover and *Myzus persicae* Sulzer (Aphididae: Hemiptera), whitefly, *Bemisia tabaci* Gennadius (Aleyrodidae: Hemiptera), leafhopper, *Amrasca devastans* Distant (Cicadellidae: Hemiptera), thrips, *Scirtothrips dorsalis* Hood (Thripidae: Thysanoptera), Serpentine leaf miner, *Liriomyzat rifolii* Burgess (Agromyzidae: Diptera), Pumpkin caterpillar, *Diaphania indica* Saunders (Crambidae: Lepidoptera), Red pumpkin beetle, *Aulacophora foveicollis* Lucas (Chrysomelidae: Coleoptera) and Melon fruit fly, *Bactrocera cucurbitae* Coquillett (Tephritidae: Diptera) (Atwal, 1993; Dhillon *et al.* 2005; Tamilnayagan *et al.* 2017a and Tamilnayagan *et al.* 2017b).

Incidence of insects can change over time due to varied reasons including macroclimatic and microclimatic changes and variation in the availability of food resources (Wolda, 1988). The present study is undertaken to study the seasonal incidence of major pests of ash gourd, *B. hispida* which in turns helps in developing timely management practices.

II. MATERIALS AND METHODS

Studies on the seasonal incidence of major pests of ash gourd were carried out under field conditions at Department of Agricultural Entomology, Agricultural College and Research Institute, Killikulam, Thoothukudi district, Tamil Nadu, India during August 2018 to August 2019. Ash gourd seeds (F_1 hybrid MAH 1) were sown at 10 days interval in micro plots. The incidence of major pests *viz.*, aphid (*M. persicae*), serpentine leaf miner (*L. trifolii*), red pumpkin beetle (*A. foveicollis*) and pumpkin caterpillar (*D. indica*) was recorded at weekly intervals during August 2018 to August 2019 on five randomly selected plants and correlated with weather parameters. The data on weather parameters *viz*., maximum and minimum temperature (°C),

relative humidity (%), sunshine hours, total rainfall (mm) and wind velocity (km per hour) during the study period was obtained from the Meteorological Observatory of Agricultural College and Research Institute, Killikulam.

III. RESULTS

3.1 Incidence of major pests of ash gourd:

3.1.1 Aphids, *M. persicae:*

The incidence of *M. persicae* ranged from 0.00 to 8.20 aphids per plant during the entire study period. During the standard weeks (SW) 35, 37, 40, 42, 43, 44 of 2018 and 16, 29, 30, 31, 32, 33, 34 of 2019 there was no incidence of *M. persicae* and the highest incidence (8.20 aphids per plant) was recorded during first week of February 2019 (SW 05) (Fig. 1).

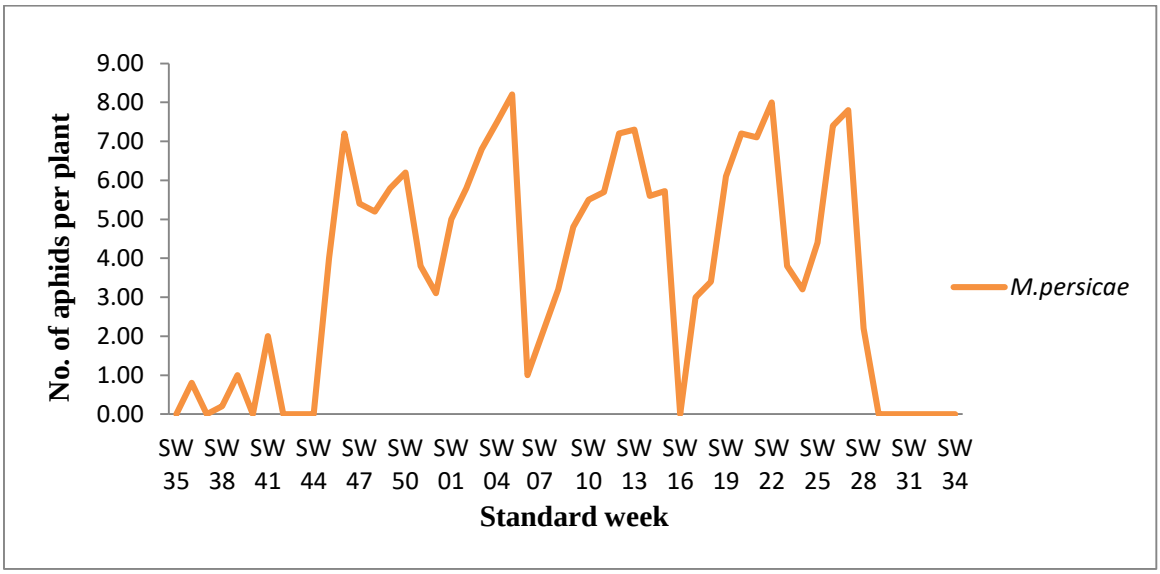

FIGURE 1: Seasonal incidence of *M. persicae* during August 2018 - August 2019

3.1.2 Serpentine leaf miner, *L. trifolii*

The per cent leaf damage of serpentine leaf miner, *L. trifolii* ranged from 3.08 to 24.30 per cent per plant during the entire study period. The incidence of *L. trifolii* was highest (24.30 per cent leaf damage) during first week of October 2018 (SW 40) and minimum (3.08 per cent) during first week of November 2018 (SW 44) (Fig. 2).

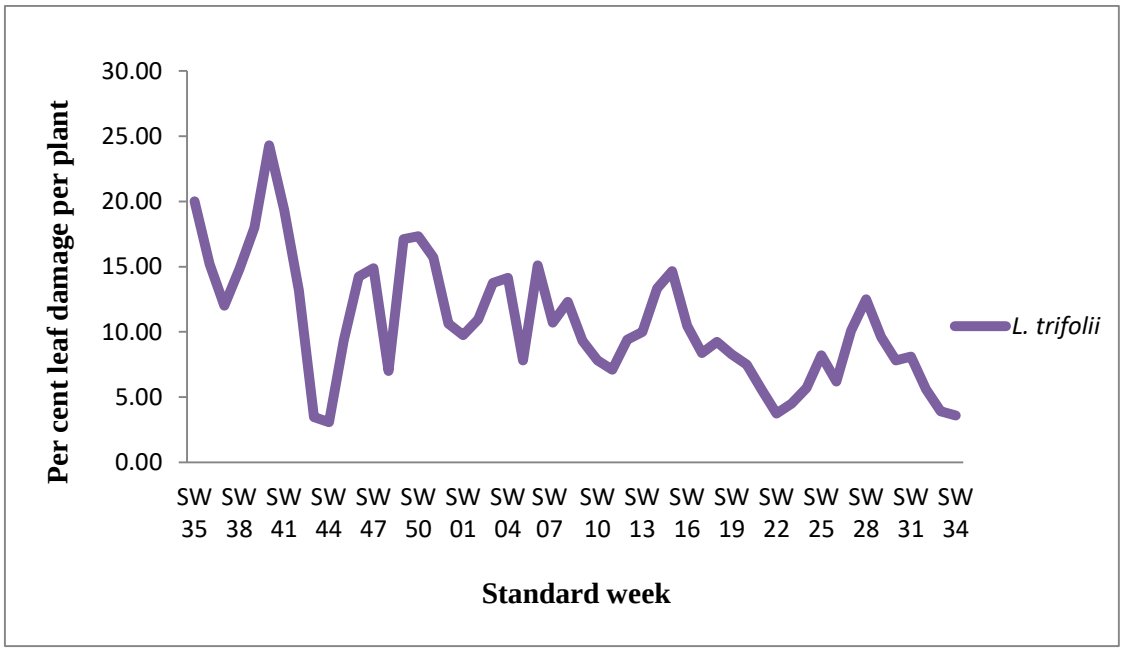

FIGURE 2: Seasonal incidence of *L. trifolii* during August 2018 - August 2019

3.1.3 Red Pumpkin beetle, *A. foveicollis:*

The incidence of *A. foveicollis* ranged from 0.00 to 1.40 beetles per plant during the entire study period and the highest incidence (1.40 beetles per plant) was recorded during second week of October 2018 (SW 41). There was no incidence of *A. foveicollis* during the standard weeks 37, 38, 42, 43, 44, 45, 46 of 2018 and 10 to 25 and 28, 31 of 2019 (Fig. 3).

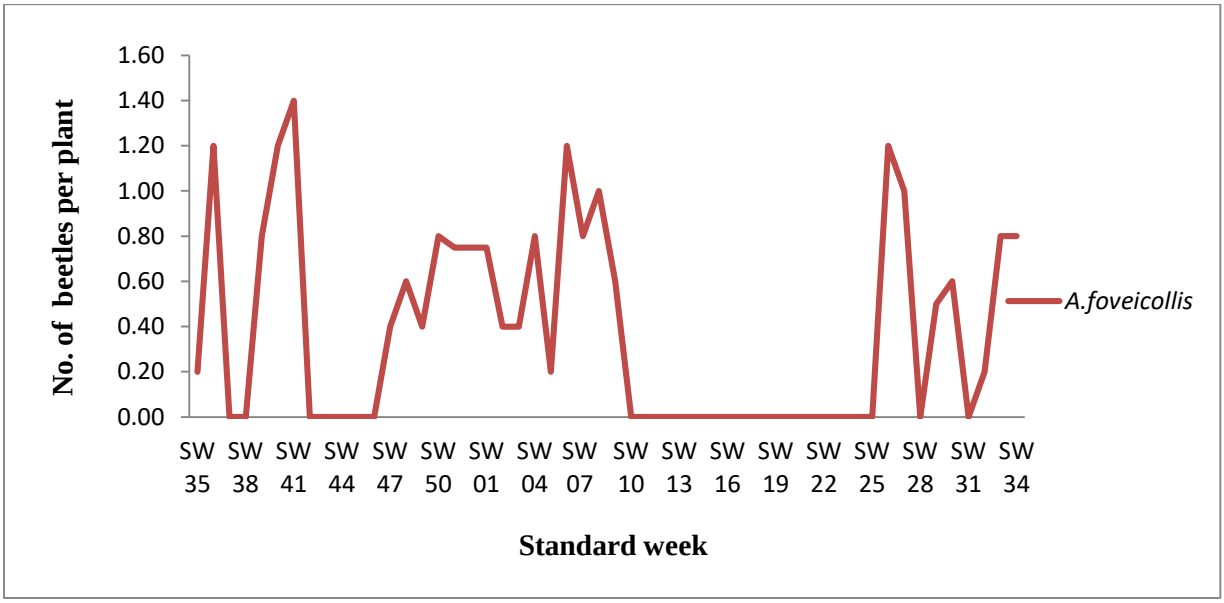

FIGURE 3: Seasonal incidence of *A. foveicollis* during August 2018 - August 2019

3.1.4 Pumpkin caterpillar, *D. indica*:

The incidence of *D. indica* ranged from 0.00 to 1.80 larvae per plant during the entire study period. The highest population of *D. indica* (1.80 larvae per plant) was recorded during second week of October 2018 (SW 41) and no incidence was recorded in the standard weeks 35, 36, 39, 40, 44, 46, 47 of 2018 and 05, 06 and 10 to 31 of 2019 (Fig 4).

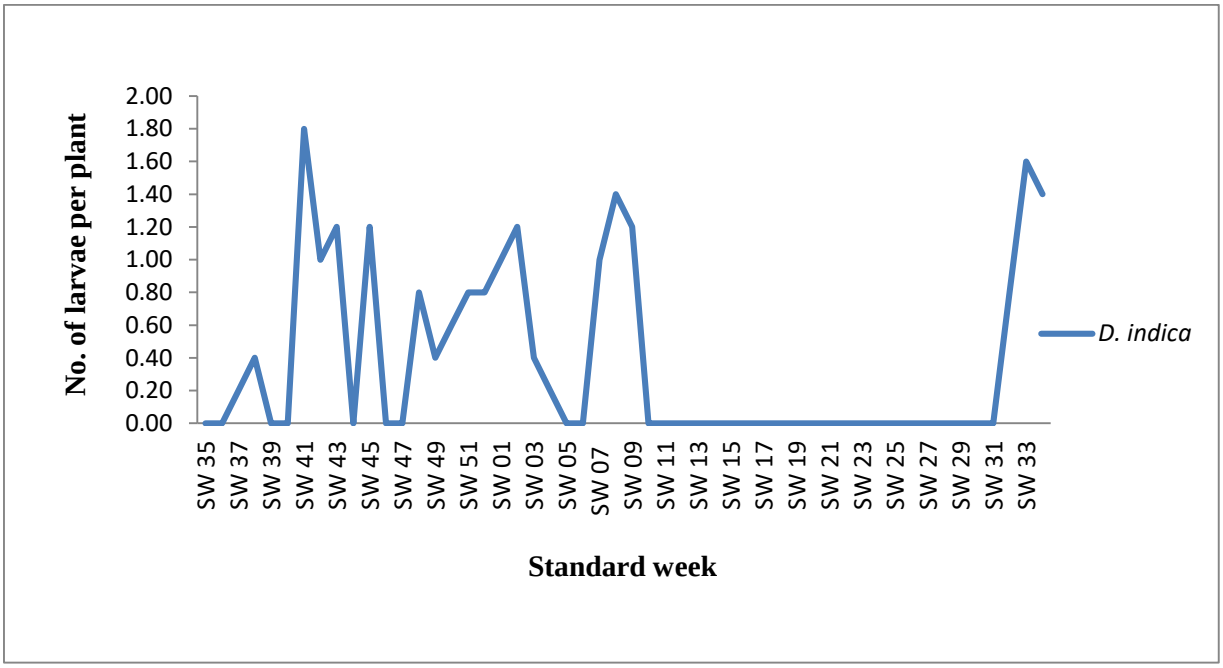

FIGURE 4: Seasonal incidence of *D. indica* during August 2018 - August 2019

3.2 Correlation and regression between incidence of major pests of ash gourd and weather parameters:

Seasonal incidence of major pests of ash gourd during August 2018 - August 2019 was correlated with the weather parameters through simple correlation, simple and multiple regression analyses.

3.2.1 Simple correlation studies on major pests of ash gourd:

3.2.1.1 Aphids, *M. persicae:*

The incidence of *M. persicae* was significantly and positively correlated with the sunshine (r= 0.447**) whereas, rainfall (r= -0.437**) had significant negative correlation. However, the correlation of maximum temperature (r= 0.130), minimum temperature (r= -0.115), relative humidity (r= -0.110) and wind velocity (r= -0.009) was non-significant with the incidence of *M. persicae* (Table 1).

3.2.1.2 Serpentine leaf miner, *L. trifolii:*

The relative humidity (r= 0.408**) had significant positive correlation with the incidence of *L. trifolii* whereas, maximum temperature (r= -0.355**) and minimum temperature (r= -0.422**) had significant negative correlation. However, rainfall (r= 0.099), sun shine (r= -0.179) and wind velocity (r= -0.271) had non-significant correlation with the incidence of *L. trifolii* (Table 1).

TABLE 1
CORRELATION ANALYSIS BETWEEN WEATHER PARAMETERS ON SEASONAL INCIDENCE OF MAJOR PESTS OF ASH GOURD DURING 2018-2019

Variables	*Myzus persicae*	*Liriomyza trifolii*	*Aulacophora foveicollis*	*Diaphania indica*
Maximum temperature (T_{max}) (^{o}C)	0.13	-0.355**	-0.335*	-0.509**
Minimum temperature (T_{min}) (^{o}C)	-0.115	-0.422**	-0.227	-0.393**
Relative humidity (%)	-0.11	0.408**	0.159	0.157
Rainfall (mm)	-0.437**	0.099	0.011	0.16
Sun shine (hours)	0.447**	-0.179	-0.131	-0.249
Wind velocity (km/hr)	-0.009	-0.271	0.17	-0.007

**** Correlation coefficient significant at 1% level***
*****Correlation coefficient significant at 5% level***

3.2.1.3 Red Pumpkin beetle, *A. foveicollis*:

The maximum temperature (r= -0.335*) had significant negative correlation with the incidence of *A. foveicollis* whereas, minimum temperature (r= -0.227), relative humidity (r= 0.159), rainfall (r= 0.011), sun shine (r= -0.131) and wind velocity (r= 0.170) had non-significant correlation (Table 1).

3.2.1.4 Pumpkin caterpillar, *D. indica:*

The incidence of *D. indica* had significant negative correlation with the maximum temperature (r= -0.509**) and minimum temperature (r= -0.393**) whereas, the correlation with relative humidity (r= 0.157), rainfall (r= 0.160), sun shine (r= -0.249) and wind velocity (r= -0.007) were non-significant (Table 1).

3.2.2 Simple linear regression studies on major pests of ash gourd:

3.2.2.1 Aphids, *M. persicae*:

The influence of different weather parameters on the incidence of *M. persicae* has been worked out with simple linear regression analysis (Table 2) and the equations are presented below:

Y_1= -0.670+0.122 X_1 which indicate that for every unit increase in maximum temperature *M. persicae* incidence increased by 0.122.

Y_1= 6.048-0.104 X_2 which indicate that for every unit increase in minimum temperature *M. persicae* incidence decreased by 0.104.

Y_1= 6.966-0.046 X_3 which indicate that for every unit increase in relative humidity *M. persicae* incidence decreased by 0.046.

Y_1= 4.176-0.074 X_4 which indicate that for every unit increase in rainfall *M. persicae* incidence decreased by 0.074.

Y_1= -0.922+0.666 X_5 which indicate that for every unit increase in sun shine *M. persicae* incidence increased by 0.666.

Y_1= 3.736-0.014 X_6 which indicate that for every unit increase in wind velocity *M. persicae* incidence decreased by 0.014.

TABLE 2

SIMPLE REGRESSION ANALYSIS ON THE INCIDENCE OF MAJOR PESTS OF ASH GOURD DURING 2018-2019

Variables	*Myzus persicae* (Y_1)		*Liriomyza trifolii* (Y_2)		*Aulacophora foveicollis* (Y_3)		*Diaphania indica* (Y_4)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Maximum temperature (T_{max}) (^oC) (X_1)	-0.67	0.122	30.05	-0.549	2.081	-0.048	3.535	-0.089
Minimum temperature (T_{min}) (^oC) (X_2)	6.048	-0.104	25.094	-0.626	1.099	-0.031	1.9	-0.066
Relative humidity (%) (X_3)	6.966	-0.046	-9.545	0.285	-0.349	-0.01	-0.514	0.012
Rainfall (mm) (X_4)	4.176	-0.074	10.47	0.027	0.377	0	0.333	0.005
Sun shine (hours) (X_5)	-0.922	0.666	13.679	-0.439	0.585	-0.029	0.85	-0.069
Wind velocity (km/hr) (X_6)	3.736	-0.014	14.663	-0.679	0.147	0.039	0.384	-0.002

a = Intercept and b = Slope

3.2.2.2 Serpentine leaf miner, *L. trifolii*:

The influence of different weather parameters on the incidence of *L. trifolii* has been worked out with simple linear regression analysis and the equations are presented below.

Y_2= 30.050-0.549 X_1 which indicate that for every unit increase in maximum temperature *L. trifolii* incidence decreased by 0.549.

Y_2= 25.094-0.626 X_2 which indicate that for every unit increase in minimum temperature *L. trifolii* incidence decreased by 0.626.

Y_2= -9.545+0.285 X_3 which indicate that for every unit increase in relative humidity *L. trifolii* incidence increased by 0.285.

Y_2= 10.470+0.027 X_4 which indicate that for every unit increase in rainfall *L. trifolii*incidence increased by 0.027.

Y_2= 13.679-0.439 X_5 which indicate that for every unit increase in sun shine *L. trifolii* incidence decreased by 0.439.

Y_2= 14.663-0.679 X_6 which indicate that for every unit increase in wind velocity *L. trifolii* incidence decreased by 0.679.

3.2.2.3 Red Pumpkin beetle, *A. foveicollis*:

The influence of different weather parameters on the incidence of *A. foveicollis* has been worked out with simple linear regression analysis and the equations are presented below.

Y_3= 2.081-0.048 X_1 which indicate that for every unit increase in maximum temperature *A. foveicollis* incidence decreased by 0.048.

Y_3= 1.099 -0.031 X_2 which indicate that for every unit increase in minimum temperature *A. foveicollis* incidence decreased by 0.031.

Y_3= -0.349-0.010 X_3 which indicate that for every unit increase in relative humidity *A. foveicollis* incidence decreased by 0.010.

Y_3= 0.377+0.000 X_4 which indicate that for every unit increase in rainfall *A. foveicollis* incidence increased by 0.000.

Y_3= 0.585-0.029 X_5 which indicate that for every unit increase in sun shine *A. foveicollis* incidence decreased by 0.029.

Y_3= 0.147+0.039 X_6 which indicate that for every unit increase in wind velocity *A. foveicollis* incidence decreased by 0.039.

3.2.2.4 Pumpkin caterpillar, *D. indica*:

The influence of different weather parameters on the incidence of *D. indica* has been worked out with simple linear regression analysis and the equations are presented below.

Y_4= 3.535-0.089 X_1 which indicate that for every unit increase in maximum temperature *D. indica* incidence decreased by 0.089.

Y_4= 1.900-0.066 X_2 which indicate that for every unit increase in minimum temperature *D. indica* incidence decreased by 0.066.

Y_4= -0.514+0.012 X_3 which indicate that for every unit increase in relative humidity *D. indica* incidence increased by 0.012.

Y_4= 0.333+0.005 X_4 which indicate that for every unit increase in rainfall *D. indica* incidence increased by 0.005.

Y_4= 0.850-0.069 X_5 which indicate that for every unit increase in sun shine *D. indica* incidence decreased by 0.069.

Y_4= 0.384-0.002 X_6 which indicate that for every unit increase in wind velocity *D. indica* incidence decreased by 0.002.

3.2.3 Multiple regression studies on major pests of ash gourd:

The multiple regression coefficients for different weather parameters and incidence of *M. persicae*, *L. trifolii*, *A. foveicollis* and *D. indica* were worked out and presented in Table 3. The results showed that the incidence of *M. persicae*, *L. trifolii*, *A. foveicollis* and *D. indica* on ash gourd was significantly influenced by the weather during the study period.

TABLE 3

MULTIPLE REGRESSION ANALYSIS ON THE INCIDENCE OF MAJOR PESTS OF ASH GOURD DURING 2018-2019

Variables	*Myzus persicae*	*Liriomyza trifolii*	*Aulacophora foveicollis*	*Diaphania indica*
	(Y_1)	(Y_2)	(Y_3)	(Y_4)
Maximum temperature (T_{max}) (^oC) (X_1)	-0.098	-0.026	-0.084	-0.123*
Minimum temperature (T_{min}) (^oC) (X_2)	-0.121	-0.396	0.034	-0.001
Relative humidity (%)(X_3)	0.027	0.165	0.012	-0.024
Rainfall (mm) (X_4)	-0.067**	-0.031	-0.001	0.002
Sun shine (hours) (X_5)	0.714**	0.074	0.003	0.012
Wind velocity (km/hr) (X_6)	-0.392	-0.333	0.063	-0.001
Coefficient of determination (R^2)	0.383	0.235	0.198	0.312

***Regression coefficient significant at 5% level*

**Regression coefficient significant at 1% level*

3.2.3.1 Aphids, *M. persicae:*

The multiple regression equation fitted with weather parameters in order to predict *M. persicae* incidence on ash gourd is furnished below.

Y_1= 5.829 – 0.098 $\mathbf{X_1}$ – 0.121 $\mathbf{X_2}$+ 0.027 $\mathbf{X_3}$ – 0.067 $\mathbf{X_4}$ + 0.714 $\mathbf{X_5}$ – 0.392 $\mathbf{X_6}$ with coefficient of determination (R^2 = 0.383).

The present investigations showed that the weather parameters contributed for 38.34 per cent of total variation in the incidence of *M. persicae* on ash gourd during August 2018 - August 2019.

3.2.3.2 Serpentine leaf miner, *L. trifolii*:

The multiple regression equation fitted with weather parameters in order to predict *L. trifolii* incidence on ash gourd is furnished below.

$Y_2 = 10.717 - 0.026\ \mathbf{X_1} - 0.396\ \mathbf{X_2} + 0.165\ \mathbf{X_3} - 0.031\ \mathbf{X_4} + 0.074\ \mathbf{X_5} - 0.333\ \mathbf{X_6}$ with coefficient of determination ($R^2 = 0.235$).

The present investigations showed that the weather parameters contributed for 23.50 per cent of total variation in the incidence of *L. trifolii* on ash gourd during August 2018 - August 2019.

3.2.3.3 Red Pumpkin beetle, *A. foveicollis*:

The multiple regression equation fitted with weather parameters in order to predict *A. foveicollis* incidence on ash gourd is furnished below.

$Y_3 = 1.100 - 0.084\ \mathbf{X_1} + 0.034\ \mathbf{X_2} + 0.012\ \mathbf{X_3} - 0.001\ \mathbf{X_4} + 0.031\ \mathbf{X_5} + 0.063\ \mathbf{X_6}$ with coefficient of determination ($R^2 = 0.198$).

The present investigations showed that the weather parameters contributed for 19.88 percent of total variation in the incidence of *A. foveicollis* on ash gourd during August 2018 - August 2019.

3.2.3.4 Pumpkin caterpillar, *D. indica*:

The multiple regression equation fitted with weather parameters in order to predict *D. indica* incidence on ash gourd is furnished below.

$Y_4 = 6.398 - 0.123\ \mathbf{X_1} - 0.001\ \mathbf{X_2} - 0.024\ \mathbf{X_3} + 0.002\ \mathbf{X_4} + 0.012\ \mathbf{X_5} - 0.000\ \mathbf{X_6}$ with coefficient of determination ($R^2 = 0.312$).

The present investigations showed that the weather parameters contributed for 31.23 per cent of total variation in the incidence of *D. indica* on ash gourd during August 2018 - August 2019.

Where:

Y_1 = *M. persicae* incidence	X_1 = Maximum temperature
Y_2 = *L. trifolii*incidence	X_2 = Minimum temperature
Y_3 = *A. foveicollis*incidence	X_3 = Relative humidity
Y_4 = *D. indica*incidence	X_4 = Rainfall
R^2 = Coefficient of determination	X_5 = Sun shine
	X_6 = Wind velocity

IV. DISCUSSION

The incidence of *M. persicae* was highest during the first week of February 2019 in the Standard Week 05 and it had significant positive correlation with the sunshine and significant negative correlation with the rainfall. These results are in line with the Tamilnayagan *et al.* (2017a) who also stated that sunshine had a positive correlation with the incidence of *M. persicae.*

The highest per cent leaf damage of *L. trifolii* was recorded during first week of October 2018 (SW 40) and it was positively correlated with the relative humidity and negatively correlated with the maximum and minimum temperature. Chaudhari and Senapati (2004) also reported that relative humidity had positive correlation with the *L. trifolii.*

The population of *A. foveicollis* was higher (1.40 beetles per plant) during second week of October 2018 (SW 41) and it had significant negative correlation with the maximum temperature in accordance with Boopathi *et al.* (2017) and Kumar and Saini (2018) who also recorded the highest population of *A. foveicollis* during October 2012, 2013 and 2014.

The incidence of *D. indica* was also higher (1.80 larvae per plant) during second week of October 2018 (SW 41) and it was negatively correlated with the maximum and minimum temperature in accordance with the Barma and Jha (2014) who reported that maximum and minimum temperature had significant negative correlation with the population of *D. indica*.

V. CONCLUSION

The results of the study indicate that the incidence of *L. trifolii* and *M. persicae* were highest during SW 40 and SW 05, respectively and the incidence of *A. foveicollis* and *D. indica* were highest during SW 41. The correlation and regression analyses showed that the weather parameters significantly influenced the incidence of insect pests. The findings of the study can be helpful for the timely management of insect pests of ash gourd.

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Use Sentinel Satellite Data for Estimation of Soil Properties: A Review

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Abstract**—** *Soils are an important component of the critical zone and a finite resource. Mapping and monitoring these resources in the field, regional, and global stages is crucial for better management and prevention of degradation. Remote sensing (RS) techniques provide several advantages over conventional approaches for evaluating soil parameters, including large-scale coverage, non-destructive nature, temporal monitoring, multispectral capabilities, and rapid data collecting. Aside from laboratory circumstances, Sentinel satellite data has been used to estimate various soil parameters in a variety of applications. This review highlights research on soil properties estimation using sentinel data, including methodology and outcomes for each study. Various soil properties like Soil Texture, Soil Salinity, Soil Texture, Soil Organic Carbon estimated using sentinel data.*

Keywords**— Soil, Sentinel, Satellite, Properties.**

I. INTRODUCTION

Accurate information, needed to managing the variability in soil properties, is an important aspect in the implementation of site-specific farming also known as precision agriculture (PA) (Jarosalv et al., 2018). In agricultural fields, soil properties often show relevant spatial variations (Yuzugullu et al., 2020) due to several factors, e.g., parent material, geomorphology, previous use, and management. The primary method for the characterization of soil involves manually collecting soil samples, drying them, and subsequently performing chemical analyses in a laboratory setting (Toth et al., 2013). However, the manual collection of soil samples, along with their corresponding physicochemical characterization, is a time-consuming process that lacks scalability for extensive areas (Wang et al., 2014). Different soil properties interact with electromagnetic radiation in diverse ways. As electromagnetic waves strike the Earth's surface, they can be absorbed, transmitted, or reflected. The reflection and absorption patterns at different wavelengths provide insights into the composition, structure, and properties of the observed materials (Barnes et al., 2000). More recently, hyperspectral, and multispectral soil characterization has emerged as a highly valuable tool for the estimation of soil properties without the need for chemical analyses of the soil samples (Lagacherie et al., 2008 and Helfer et al., 2021). Another approach is given by multispectral satellite sensors. Since 1972, Landsat satellites gather images that can be useful in environmental studies. For example, sensor thematic mapper (TM) on-board Landsat 5 was used to detect bare soil (Dematte et al. 2009). In 2015, the European Space Agency (ESA) begin to deliver free of cost, good spatial resolution (10 m) Earth images. Sensors on-board optical Sentinel-2 satellites are equipped with 12 spectral bands, which can be useful for soil properties mapping. The usefulness of the acquired image data largely depends on the way it is processed and analysed. Many statistical methods are used to obtain reliable soil information from multispectral images, such as multiple linear regression (MLR) analysis, principal component regression (PCR) and partial least squares (PLS) regression. Application of the latter method to hyperspectral data allows to determine several soil parameters with high values of correlation coefficient and low errors, including grain size composition, pH, cation exchange capacity (CEC) or some chemical elements (Mammadov et al. 2020, Vestergaard et al. 2021). Recently, machine learning algorithms based on random

forests and Cubist development models have been used to study the relationship between spectral data and soil characteristics. The Cubist model is often used to estimate SOC; in such cases, it is also advisable to use spectral indices as variables in addition to raw reflectance (Peng et al. 2015). More precisely, which soil parameters, with what method of data analysis and with what accuracy, can be estimated based on satellite data.

II. A REVIEW ON VARIOUS SOIL PROPERTIES ESTIMATION USING SENTINEL SATELLITE IMAGES

2.1 Soil Moisture:

Qi et al used use of Sentinel-1 and Sentinel-2 data for soil moisture mapping at 100 m resolution. This paper presents two methodologies for the retrieval of soil moisture from remotely-sensed SAR images, with a spatial resolution of 100 m. These algorithms are based on the interpretation of Sentinel-1 data recorded in the VV polarization, which is combined with Sentinel-2 optical data for the analysis of vegetation effects over a site in Urgell (Catalunya, Spain). The first algorithm has already been applied to observations in West Africa by Zribi et al., 2008, using low spatial resolution ERS scatterometer data, and is based on change detection approach. In the present study, this approach is applied to Sentinel-1 data and optimizes the inversion process by taking advantage of the high repeat frequency of the Sentinel observations. The second algorithm relies on a new method, based on the difference between backscattered Sentinel-1 radar signals observed on two consecutive days, expressed as a function of NDVI optical index. Both methods are applied to almost 1.5 years of satellite data (July 2015–November 2016), and are validated using field data acquired at a study site. This leads to an RMS error in volumetric moisture of approximately 0.087 m^3/m^3 and 0.059 m^3/m^3 for the first and second methods, respectively. No site calibrations are needed with these techniques, and they can be applied to any vegetation-covered area for which time series of SAR data have been recorded.

Paloscia et al studied soil moisture mapping using Sentinel-1 images. The main objective of this research is to develop, test and validate a soil moisture content (SMC) algorithm for GMES Sentinel-1 characteristics. The SMC product, which is to be generated from Sentinel-1 data, requires an algorithm capable of processing operationally in near-real-time and delivering the product to the GMES services within 3 h from observation. An approach based on an Artificial Neural Network (ANN) has been proposed that represents a good compromise between retrieval accuracy and processing time, thus enabling compliance with the timeliness requirements. The algorithm has been tested and subsequently validated in several test areas in Italy, Australia, and Spain. In all cases the validation results were very much in line with GMES requirements (with RMSE generally 4%SMC – between 1.67% SMC and 6.68% SMC – and very low bias), except for the case of the test area in Spain, where the validation results were penalized by the availability of only VV polarized SAR images and MODIS low-resolution NDVI. Nonetheless, the obtained RMSE was slightly higher than 4%SMC.

Figure 1 Histogram of the comparison between the ANN-estimated and the ground measured SMC over the Cordevole area. SMC was subdivided into 4 classes between 25% and 45%. Two ANNs were considered: one used only VV polarized data, and the other one also used the NDVI information.

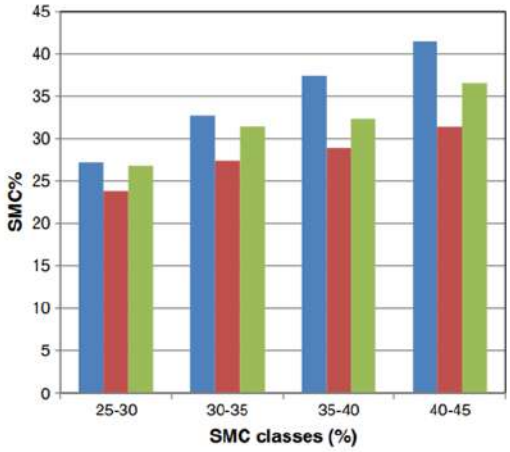

FIGURE 1: Histogram of SMC Comparison Between ANN-Estimated and Ground Measured Values

Table 1 Validation results, obtained over the test site in Spain, by considering (a) or disregarding (b) NDVI information. In grey, the couples of values SMC estimated/SMC measured, for which the NDVI information worsened the results, have been singled out.

TABLE 1
VALIDATION RESULTS FOR ANN-ESTIMATED SMC WITH AND WITHOUT NDVI INFORMATION

Part A				
Acquisition date	**SMC ANN (%)**	**SMC ground (%)**	**RMSE (%)**	**St. Dev. (%)**
10 May, 2010	16.11	24.05	5.34	3.45
14 June, 2010	12.66	14.35	3.52	2.66
23 August, 2010	10.18	7.86	3.41	2.19
27 September, 2010	17.19	14.99	6.38	4.76
25 February, 2011	13.74	21.41	4.58	0.69
22 June, 2011	11.58	10.85	4.35	3.44
Mean			4.6	2.87
Part B				
10 May, 2010	20.06	24.05	2.72	0.97
14 June, 2010	16.37	14.34	4.01	2.69
23 August, 2010	16.65	7.85	8.5	2.9
27 September, 2010	17.92	14.99	5.12	3.23
25 February, 2011	20.31	21.4	2.31	0.58
22 June, 2011	16.39	10.85	5.21	1.71
Mean			4.64	2.01

Natalia et conducted study on soil moisture estimation using Sentinel-1/-2 Imagery coupled with cycleGAN for Time-series Gap Filing This study aimed to explore the possibility of taking advantage of freely available Sentinel-1 (S1) and Sentinel-2 (S2) EO data for the simultaneous prediction of SMC with cycle-consistent adversarial network (cycleGAN) for time-series gap filling. The proposed methodology, first, learns latent low-dimensional representation of the satellite images, then learns a simple machine learning model on top of these representations. To evaluate the methodology, a series of vineyards, located in South Australia's Eden valley are chosen. Specifically, we presented an efficient framework for extracting latent features from S1 and S2 imagery. They showed how one could use S1 to S2 feature translation based on Cycle-GAN using S1and S2 time series when there are missing images acquired over an area of interest. The resulting data in our study is then used to fill gaps in time series data. We used the resulting latent representations to predict SMC with various ML tools. In the experiments, cycleGAN and the autoencoders were trained with data randomly chosen around the site of interest, so we could augment the existing dataset. The best performance was demonstrated with random forest algorithm, whereas linear regression model demonstrated significant overfitting. The experiments demonstrate that the proposed methodology outperforms the compared state-of-the-art methods if there are missing optical and synthetic-aperture radar (SAR) images.

Figure 2 Proposed architecture relies on building a latent representation of each domain (S1 and S2) based on autoencoders and then predicting Soil Moisture (through an additional prediction model) based on these representations. A cycleGAN is also trained to recover missing data from S1 to S2 and vice-versa.

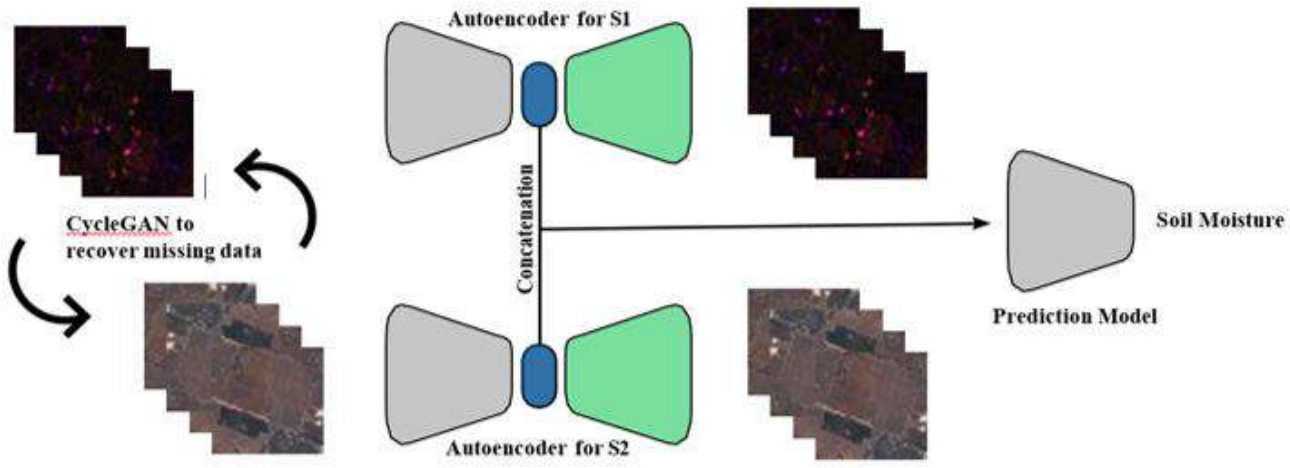

FIGURE 2: Proposed Architecture for Cross-Domain Soil Moisture Prediction

Sutariya et al presents the potential for soil moisture (SM) retrieval using Sentinel-1 C-band Synthetic Aperture Radar (SAR) data acquired in Interferometric Wide Swath (IW) mode along with Land Surface Temperature (LST) estimated from analysis of LANDSAT-8 digital thermal data. In this study Sentinel-1 data acquired on 27 February 2020 was downloaded from Copernicus website and LANDSAT-8 OLI data acquired on 24 February 2020 from the website https://earthexplorer.usgs.gov/.The soil samples were collected from 70 test fields in different villages of three talukas for estimating soil moisture content using the gravimetric method. The Sentinel-1 SAR microwave data was analysed using open-source tools of Sentinel Application Platform (SNAP) software for estimation of backscattering coefficient. Land surface temperature estimated using Landsat-8 thermal data. The Landsat8, Thermal infrared sensor Band-10 data and operational land imager Band-4 and Band-5 data were used in estimating LST. The Soil Moisture Index (SMI) for all field test sites was computed using the LST values. The regression analysis using σ0VV and σ0VH polarization with soil moisture indicated that σ0VV polarization was more sensitive to soil moisture content as compared to σ0VH polarization. The multiple regression analysis using field measured soil moisture (MS %) as dependent variable, and σ0VV and SMI as independent variable was carried which resulted in the coefficient of determination (R^2) of 0.788, 0.777 and 0.778 for Godhra, Gogh amba and Kalol talukas, respectively. These linear regression equations were used to compute the predicted soil moisture in three talukas.

Esmaeili et al estimated of soil moisture using sentinel-1 and sentinel-2 images. For this study, soil moisture was sampled at 24 points in the common area of the two images in the south of Malard city, Tehran province (Iran) was obtained by survey. After pre-processing the images, the values of bands 1 to 7, 11, and 12 of the Sentinel-2 and applying filters (Gaussian, Laplacian, Majority, Morphology, and rank) to the Sentinel-1 soil moisture were calculated. Moreover, R, R^2, and RMSE were calculated using soil moisture obtained from sample points. Furthermore, Maps of data used by sentinel-1 and sentinel-2 images were obtained. Using maps of data shows the potential of applied filters to sentinel-1 and bands used for sentinel-2 in the estimation of soil moisture. According to the results, the highest coefficient of determination (R^2) for the Sentinel-2 is related to band 6 with 84%. The result of Sentinel-1 demonstrated that the highest coefficient of determination was related to the Rank filter (54%). The highest correlation of the Sentinel-2 and the Sentinel-1 is related to band 6 with 74% and the Rank filter with 46%, respectively. The lowest RMSE in Sentinel-2 and Sentinel-1 is related to band three (1.64 %) and rank filter (1.03 %), respectively. According to the obtained results, band 6 in the Sentinel-2 and filter in Sentinel-1 have better performance among the data and methods used. However, it is emphasized that using more samples can be tested for improving results.

TABLE 2

CORRELATION AND RMSE RESULTS BETWEEN INPUT DATA AND SOIL MOISTURE

Data	RMSE	R	Soil Moisture Values (%)
B1	11.42	0.13	8.7
B2	3.68	0.2	8.09
B3	1.64	0.306	7.93
B4	6.16	0.315	8.29
B5	4.5	0.67	8.16
B6	3.68	0.74	8.097
B7	3.67	0.369	8.096
B8	2.26	0.415	7.98
B11	4.4	0.16	8.15
B12	4.88	0.19	8.19
Sentinel-1	4.92	0.18	8.19
Gaussian	11.34	0.15	8.69
Laplacian	14.29	0.068	8.92
Major	2.36	0.069	7.99
Rank	1.03	0.46	7.89
Morphology	6.67	0.13	8.33

2.2 Soil Organic Carbon and Soil Organic Matter:

Castaldi et al assessed the capability of Sentinel-2 time-series to estimate soil organic carbon and clay content at local scale in croplands. This work is focused on the feasibility of Sentinel-2 based approaches for the high-resolution mapping of topsoil clay and organic carbon (SOC) contents at the within-farm or within-field scales, for cropland sites of contrasted climates and soil types across the Northern hemisphere. Four pixelwise temporal mosaicking methods, using a two years-Sentinel-2 time series and several spectral indices (NDVI, NBR2, BSI, S2WI), were developed and compared for i) pure bare soil condition (maxBSI), ii) driest soil condition (minS2WI), iii) average bare soil condition (Median) and iv) dry soil conditions excluding extreme reflectance values (R90). Three spectral modelling approaches, using the Sentinel-2 bands of the output temporal mosaics as covariates, were tested, and compared: (i) Quantile Regression Forest (QRF) algorithm; (ii) QRF adding longitude and latitude as covariates (QRFxy); (iii) a hybrid approach, Linear Mixed Effect Model (LMEM), that includes spatial autocorrelation of the soil properties. We tested pairs of mosaic and spectral approaches on ten sites in Türkiye, Italy, Lithuania, and USA where soil samples were collected and SOC and clay content were measured in the lab. The average RPIQ of the best performances among the test sites was 2.50 both for SOC (RMSE = 0.15%) and clay (RMSE = 3.3%). Both accuracy level and uncertainty were mainly influenced by site characteristics of cloud frequency, soil types and management. Generally, the models including a spatial component (QRFxy and LMEM) were the best performing, while the best spatial mosaicking approaches mostly were Median and R90. The most frequent optimal combination of mosaicking and model type was Median or R90 and QRFxy for SOC, and R90 and LMEM for clay estimation.

TABLE 3
FREQUENCY OF ACCURACY VALUES HIGHER THAN 90% FOR SOC ESTIMATION AMONG THE TEN TEST SITES ACCORDING TO SYNTHETIC BARE SOIL IMAGES METHOD (SBSI) AND PREDICTION MODELS.

	maxBSI	minS2WI	Median	R90	Mean frequency
QRF	10%	50%	40%	50%	37.50%
QRFxy	40%	50%	60%	60%	52.50%
LMM	30%	40%	30%	50%	37.50%
Mean frequency	26.70%	46.70%	43.30%	53.30%	

Castaldi et al investigated soil organic carbon mapping using LUCAS Topsoil database and Sentinel-2 Data: An approach to reduce soil moisture and crop residue effects. In this regard, the high temporal, spatial, and spectral resolution of the Sentinel-2 data can be exploited for monitoring SOC contents in the topsoil of croplands. In this study, we aim to test the effect of the threshold for a spectral index linked to soil moisture and crop residues on the performance of SOC prediction models using the Multi-Spectral Instrument (MSI) Sentinel-2 and the European Land Use/cover Area frame Statistical survey (LUCAS) topsoil database. The LUCAS spectral data resampled according to MSI/Sentinel-2 bands, which were used to build SOC prediction models combining pairs of the bands. The SOC models were applied to a Sentinel-2 image acquired in North-Eastern Germany after removing the pixels characterized by clouds and green vegetation. Then, we tested different thresholds of the Normalized Burn Ratio 2 (NBR2) index in order to mask moist soil pixels and those with dry vegetation and crop residues. The model accuracy was tested on an independent validation database and the best ratio of performance to deviation (RPD) was obtained using the average between bands B6 and B5 (Red-Edge Carbon Index: RE-CI) (RPD: 4.4) and between B4 and B5 (Red-Red-Edge Carbon Index: RRE-CI) (RPD: 2.9) for a very low NBR2 threshold (0.05). Employing a higher NBR2 tolerance (higher NBR2 values), the mapped area increases to the detriment of the validation accuracy. The proposed approach allowed us to accurately map SOC over a large area exploiting the LUCAS spectral library and, thus, avoid a new ad hoc field campaign. Moreover, the threshold for selecting the bare soil pixels can be tuned, according to the goal of the survey. The quality of the SOC map for each tolerance level can be judged based on the figures of merit of the model.

Madugundu et al studied estimation soil organic carbon in agricultural fields: A remote sensing approach. Landsat-8 (L8) and Sentinel-2 (S2A) satellite images were used for the characterization of SOC stocks in the topsoil layer (0-10 cm) of the experimental fields. Soil samples were randomly collected from six (50 ha each) agricultural fields and analysed in the laboratory for SOC (SOC) following Walkley and Black A method. While, vegetation indices (VI), such as the Normalized Difference Vegetation Index (NDVI), NDVIRedEdge, Enhanced Vegetation Index (EVI), Bare Soil Index (BSI), and Reduced Simple Ratio (RSR) were computed and subsequently used for the development of SOC prediction models. Univariate linear regression technique was employed for the recognition of a suitable band/VI for SOC (SOC) mapping. The SWIR-1 P2 band of both L8 (R^2 = 0.86) and S2A (R=0.77) data was promising for predicting SOC with 16% (S2A) and 18% (L8) of BIAS.

Xinxin et al estimated soil organic matter content using sentinel-2 imagery by machine learning in Shanghai. This article aimed to evaluate the capacity of Sentinel-2 for SOM prediction in an urban area (i.e., Shanghai). 103 bare soil samples filtrated from 398 soil samples at a depth of 20 cm were selected. Three methods, partial least square regression (PLSR), artificial neural network (ANN), and support vector machine (SVM), were applied. The root mean square error (RMSE) of modelling (mRMSE) and the coefficient of determination (R^2) of modelling (mR^2) were used to reflect the accuracy of the model. The results show that PLSR has the poorest performance. ANN has the highest modelling accuracy (mRMSE = 7.387 g kg^{-1}, mR^2 = 0.446). The ANN prediction accuracy of RMSE (pRMSE) is 4.713 g kg^{-1} and the prediction accuracy of R^2 (pR^2) is 0.723. For SVR, the pRMSE is 4.638 g kg^{-1}, and the pR^2 is 0.732. The prediction accuracy of SVR is slightly higher than that of ANN. The spatial distribution of SOM demonstrates that the value obtained by ANN is the closest to the range of the bare soil samples, and ANN performs better in vegetation-covered areas. Therefore, Sentinel-2 can be used to estimate SOM content in urban areas, and ANN is a promising method for SOM estimation.

TABLE 4
ACCURACY EVALUATION OF MODEL AND PREDICTION ACCURACY

Method	Modelling Accuracy		Prediction Accuracy	
	mR^2	mRMSE	pR^2	pRMSE
ANN	0.446	7.387	0.723	4.713
SVR	0.256	8.556	0.732	4.638
PLSR	0.155	9.12	0.349	7.224

Klara et al presented study on have collected 303 photos of soil surfaces in the Belgian loam belt where five main classes of surface conditions were distinguished: smooth seeded soils, soil crusts, partial cover by a growing crop, moist soils, and crop residue cover. Reflectance spectra were then extracted from the Sentinel–2 images coinciding with the date of the photos. After the growing crop was removed by an NDVI < 0.25, the Normalized Burn Ratio (NBR^2) was calculated to characterize the soil surface, and a threshold of NBR^2 < 0.05 was found to be able to separate dry bare soils from soils in unfavourable conditions i.e. wet soils and soils covered by crop residues. Additionally, we found that normalizing the spectra (i.e. dividing the reflectance of each band by the mean reflectance of all spectral bands) allows for cancelling the albedo shift between soil crusts and smooth soils in seed–bed conditions. They then built the exposed soil composite from Sentinel–2 imagery for southern Belgium and part of Noord Holland and Flevoland in the Netherlands (covering the spring periods of 2016–2021). They used the mean spectra per pixel to predict SOC content by means of a Partial Least Squares Regression Model (PLSR) with 10–fold cross–validation. The uncertainty of the models was assessed via the prediction interval ratio (PIR). The cross validation of the model gave satisfactory results (mean of 100 bootstraps: model efficiency coefficient (MEC) = 0.48 ± 0.07, RMSE = 3.5 ± 0.3 g C kg^{-1}, RPD = 1.4 ± 0.1 and RPIQ = 1.9 ± 0.3). The resulting SOC prediction maps show that the uncertainty of prediction decreases when the number of scenes per pixel increases, and reaches a minimum when at least six scenes per pixel are used. The results of a validation against an independent data set showed a median difference between the measured (average SOC content 13.5 g C kg^{-1}) and predicted SOC contents at field scale. Overall, this compositing method shows both realistic within field and regional SOC patterns.

TABLE 5
STATISTICS OF THE SOIL ORGANIC CARBON (SOC) CONTENT PREDICTION AND THE UNCERTAINTY (%) FOR THE PIXEL–BASED APPROACH AND FOR FIELD–BASED APPROACH. (SD = STANDARD DEVIATION)

Approach	N		Mean	Median	SD
Per-Pixel	11, 235, 492 pixels	SOC (g C kg^{-1})	14.1	13.3	4.7
		PIR (g C kg^{-1}) Per–field	12.4	11.8	1.6
Per-Field	92, 451 fields	SOC (g C kg^{-1})	13.6	12.7	3.2
	Validation (n=34 385	Residues (g C kg^{-1})	0.7	0.5	2.8

Chong et al mapped soil organic matter content using Sentinel-2 synthetic images at different time intervals in Northeast China. In this study, they processed all Sentinel-2 images covering the bare-soil period (March to June) in Northeast China from 2019 to 2022 and integrated the observation results into synthetic materials with four defined time intervals (10, 15, 20, and 30 d). Then, they used synthetic images corresponding to different time periods to conduct SOM mapping and determine the optimal time interval and time period before finally assessing the impacts of adding environmental covariates. The results showed the following: (1) in SOM mapping, the highest accuracy was obtained using day-of-year (DOY) 120 to 140 synthetic images with 20 d time intervals, as well as with different time intervals, ranked as follows: 20 d > 30 d > 15 d > 10 d; (2) when using synthetic images at different time intervals to predict SOM, the best time period for predicting SOM was always within May; and (3) adding environmental covariates effectively improved the SOM mapping performance, and the multiyear average temperature was the most important factor. In general, our results demonstrated the valuable potential of SOM mapping using multiyear synthetic imagery, thereby allowing detailed mapping of large areas of cultivated soil.

TABLE 6
SOC SAMPLE SET STATISTICS FOR EACH S2BSOIL USED FOR MODELLING

SOC g.kg−1										
S2Bsoil	**Sites**	**Minimum**	**Q1**	**Median**	**Mean**	**Q3**	**Maximum**	**SD**	**Skewness**	**Kurtosis**
S2Bsoil_0	353	3.46	11.4	13	13.4	15	27.8	3.3	0.86	4.83
S2Bsoil_1	304	3.46	11.41	13	13.4	15	27.8	3.3	0.93	5.18
S2Bsoil_2	350	3.46	11.39	13	13.4	15	27.8	3.3	0.85	4.82

Urbina-Salazar et al analysed Sentinel-2 and Sentinel-1 bare soil temporal mosaics of 6-year periods for soil organic carbon content mapping in Central France. To generate a reliable SOC map, this study addresses the use of Sentinel-2 (S2) temporal mosaics of bare soil (S2Bsoil) over 6 years jointly with soil moisture products (SMPs) derived from Sentinel 1 and 2 images, SOC measurement data and other environmental covariates derived from digital elevation models, lithology maps and airborne gamma-ray data. In this study, we explore (i) the dates and periods that are preferable to construct temporal mosaics of bare soils while accounting for soil moisture and soil management; (ii) which set of covariates is more relevant to explain the SOC variability. From four sets of covariates, the best contributing set was selected, and the median SOC content along with uncertainty at 90% prediction intervals were mapped at a 25-m resolution from quantile regression forest models. The accuracy of predictions was assessed by 10-fold cross-validation, repeated five times. The models using all the covariates had the best model performance. Airborne gamma-ray thorium, slope and S2 bands (e.g., bands 6, 7, 8, 8a) and indices (e.g., calcareous sedimentary rocks, "calcl") from the "late winter–spring" time series were the most important covariates in this model. Our results also indicated the important role of neighbouring topographic distances and oblique geographic coordinates between remote sensing data and parent material. These data contributed not only to optimizing SOC mapping performance but also provided information related to long-range gradients of SOC spatial variability, which makes sense from a pedological point of view.

2.3 Soil Salinity:

Meti et al carried-out sensitivity analysis for mapping of alkaline soil in Northern Dry Zone of Karnataka, India using Sentinel-1 and Landsat-8 bands. This paper focuses on exploring the possibility of using new generation medium resolution Landsat-8 and Sentinel-2 satellite data to map alkaline soils of Ramthal irrigation project area in north Karnataka. Surface soil salinity parameters of zone 20 were correlated with reflectance values of different band and band combination and traditional salinity indices and result has indicated that SWIR bands of both satellites showed significant negative correlation with soil pH, EC (r=-0.39 to - 0.45) whereas visible and NIR bands did not show significant relation. However, rationing of SWIR bands with visible blue band has significantly improved the correlation with soil pH and EC (r= +0.60 to +0.70). Traditional salinity index based on visible bands failed to show significant correlation with soil parameters. It is interesting to note that SWIR bands alone did not show significant correlation with soil sodicity parameters like exchangeable Na, SAR, RSC but band rationing with blue bands has significantly improved the correlation (r = 0.45). High resolution soil salinity map was prepared using simple linear regression model and using this map will serve as base map for the policy makers.

TABLE 7
LINEAR REGRESSION MODELS FOR PREDICTING SOIL SALINITY PARAMETERS FROM SATELLITE BANDS REFLECTANCE

Parameter	Satellite	Regression Model	R^2	RMSE
pH	Landsat 8	6.41+15.73(Aerosol/SWIR2) + 4.95(Green/NIR) -11.69 (Blue/SWIR1)	0.48	0.207
	Sentinel 2	7.17+8.72((Blue/SWIR2) +1.87(RedEdge2/RedEdge3)-5.44(SI7)-1.0(Blue/RedEdge1)	0.49	0.206
EC	Landsat 8	0.09+2.02(Aerosol/SWIR2) +0.67(Red/NIR)-7.35(Blue)-0.34(Blue/Green)	0.33	0.07
	Sentinel 2	0.17-0.94(SWIR2) +1.13(RedEdge1/SWIR1) +1.13(SI7)	0.3	0.07
Sodium	Landsat8	-17.04+144.29(Aerosol/SWIR2) +45.66(Green/NIR)-132.28(Blue/SWIR1)	0.49	1.51
	Sentinel 2	-1.59-51.1(SWIR2) +36.39((Blue/SWIR1) +17.28(Green/NIR)	0.45	1.58

Ghada investigated a PLSR model to predict soil salinity using Sentinel-2 MSI data. This study used spectral indices, including salinity and vegetation indices, Sentinel-2 MSI original bands, and DEM, to model soil salinity in the Great Hungarian Plain. Eighty-one soil samples in the upper 30 cm of the soil surface were collected from vegetated and non vegetated areas by the Research Institute for Soil Sciences and Agricultural Chemistry (RISSAC). The sampling campaign of salinity monitoring was performed in the dry season to enhance salt spectral characteristics during its accumulation in the subsoil. Hence, applying a partial least squares regression (PLSR) between salt content (g/kg) and remotely sensed data manifested a highly moderate correlation with a coefficient of determination R^2 of 0.68, a p-value of 0.000017, and a root mean square error of 0.22. The final model can be deployed to highlight soil salinity levels in the study area and assist in understanding the efficacy of land management strategies.

TABLE 8
MULTIPLE LINEAR REGRESSION ANALYSIS – ECp VERSUS LABORATORY ANALYSED SOIL ECe

		RMSE		MBE	
Model	R^2	(dS m^{-1})	(%)	(dS m^{-1})	(%)
1	0.44*	1.09	14.34	1.25	–17.29
2	0.54*	0.94	10.61	1.08	–14.22
3	0.62*	0.86	10.02	0.92	6.66

Khalid et al used Sentinel-2 images for effective mapping of soil salinity in agricultural fields. The present study was conducted to develop an effective soil salinity prediction model using Sentinel2A (S2) satellite data. Initially, the collected soil samples were analysed for soil salinity (ECe). Subsequently, multiple linear regression analysis was carried out between the obtained ECe values and S2 data, for the prediction of soil salinity models. The relationship between ECe and S2 data, including individual bands, band ratios and spectral indices showed moderate to highly significant correlations (R^2 = 0.43–0.83). A combination of SWIR-1 bands and the simplified brightness index was found to be the most appropriate (R^2 = 0.65; $P < 0.001$) for prediction of soil salinity. The results of this study demonstrate the ability to obtain reliable estimates of EC using S2 data.

Sameh studied Sentinel-2 based mapping of soil salinity of arid soils in southeastern regions of Tunisia. In this study, 80 samples were collected from the soil surface (the upper 10 cm). A predictive model was constructed based on the measured soil electrical conductivity (EC) and spectral indices developed from satellite image. The results revealed that salinity index SI1, SI2 and band 3 have the highest correlation with EC. Multiple regression analysis showed a moderate accuracy with R^2 = 0.42 and an RMSE = 18.3.

TABLE 9
MULTIPLE REGRESSION MODEL BETWEEN SPECTRAL INDICES AND MEASURED EC

Regression model	R^2	RMSE
EC= - 109.92-0.1b4 + 0.08b2-0.03b3-0.03SI2 + 0.07b8-0.05b6 + 0.03SI1	42%	18.3ds/m

Gogumalla et al detected soil pH from open-source remote sensing data: A case study of Angul and Balangir Districts, Odisha State. The objective of this research was to estimate soil pH from Sentinel-1, Sentinel-2, and Landsat-8 satellite-derived indices; data from Sentinel-1, Sentinel-2, and Landsat-8 satellite missions were used to generate indices and as proxies in a statistical model to estimate soil pH. Step-wise multiple regression (SWMR), artificial neural networks (ANN), and random forest (RF) regression were used to develop predictive models for soil pH, SWMR, ANN, and RF regression models. The SWMR greedy method of variable selection was used to select the appropriate independent variables that were highly correlated with soil pH. Variables that were retained in the SWMR are B2, B11, Brightness index, Salinity index-2, Salinity index-5 of Sentinel-2 data; VH/VV index of Sentinel 1 and TIR1 (thermal infrared band1) Landsat-8 with p-value 0.05. Among the four statistical models developed, the class-wise RF model performed better than other models with a cumulative correlation coefficient of 0.87 and RMSE of 0.35. The better performance of class-wise RF models can be attributed to different spectral characteristics of different soil pH groups.

Kaya et al studied predictive mapping of electrical conductivity and assessment of soil salinity in a Western Turkiye, Alluvial Plain. The current study area is located in the Isparta province (100 km^2), land cover is mainly irrigated, and the dominant soils are Inceptisols, Mollisols, and Vertisols. Digital soil mapping (DSM) methodology was used, referring to the increase in the digital representation of soil formation factors with today's technological advances. Plant and soil-based indices produced from the Sentinel 2A satellite image, topographic indices derived from the digital elevation model (DEM), and CORINE land cover classes were used as predictors. The support vector regression (SVR) algorithm revealed the best relationships in the study area. Considering the estimates of different algorithms, according to the FAO salinity classification, a minimum of 12.36% and a maximum of 20.19% of the study area can be classified as slightly saline. The low spatial dependence between model residuals limited the success of hybrid methods. The land irrigated cover played a significant role in predicting the current level of EC.

Nada et al obtained salinity properties retrieval from Sentinel-2 satellites data and machine learning algorithms. The objective of this study was to achieve the best estimation of electrical conductivity variables from salt-affected soils in a south Mediterranean region using Sentinel-2 multispectral imagery. In order to realize this goal, a test was carried out using electrical conductivity (EC) data collected in central Tunisia. Soil electrical conductivity and leaf electrical conductivity were measured in an olive orchard over two growing seasons and under three irrigation treatments. Firstly, selected spectral salinity, chlorophyll, water, and vegetation indices were tested over the experimental area to estimate both soil and leaf EC using Sentinel-2 imagery on the Google Earth Engine platform. Subsequently, estimation models of soil and leaf EC were calibrated by employing machine learning (ML) techniques using 12 spectral bands of Sentinel-2 images. The prediction accuracy of the EC estimation was assessed by using k-fold cross-validation and computing statistical metrics. The results of the study revealed that machine learning algorithms, together with multispectral data, could advance the mapping and monitoring of soil and leaf electrical conductivity.

2.4 Soil Texture:

Bousbih et al estimated soil texture using radar and optical data from Sentinel-1 and Sentinel-2. The study is based on Sentinel-1 (S-1) and Sentinel-2 (S-2) data acquired between July and early December 2017, on a semi-arid area about 3000 km^2 in central Tunisia. In addition to satellite acquisitions, texture measurement samples were taken in several agricultural fields, characterized by a large range of clay contents (between 13% and 60%). For the period between July and August, various optical indicators of clay content Short-Wave Infrared (SWIR) bands and soil indices) were tested over bare soils. Satellite moisture products, derived from combined S-1 and S-2 data, were also tested as an indicator of soil texture. Algorithms based on the support vector machine (SVM) and random forest (RF) methods are proposed for the classification and mapping of clay content and a three-fold cross-validation is used to evaluate both approaches. The classifications with the best performance are achieved using the soil moisture indicator derived from combined S-1 and S-2 data, with overall accuracy (OA) of 63% and 65% for the SVM and RF classifications, respectively.

Gomez et al used Sentinel-2 time-series images for classification and uncertainty analysis of inherent biophysical property: Case of soil texture mapping. Two sources of uncertainty were studied: uncertainties due to the Sentinel-2 acquisition date and uncertainties due to the soil sample selection in the training dataset. The first uncertainty analysis was achieved by analysing the diversity of classification results obtained from the time series of soil texture classifications, considering that the temporal resolution is akin to a repetition of spectral measurements. The second uncertainty analysis was achieved from each individual Sentinel-2 image, based on a bootstrapping procedure corresponding to 100 independent classifications obtained with different training data. The Simpson index was used to compute this diversity in the classification results. This work was carried out in an Indian cultivated region (84 km^2, part of Berambadi catchment, in the Karnataka state). It used a time-series of six Sentinel-2 images acquired from February to April 2017 and 130 soil surface samples, collected over the study area and characterized in terms of texture. The classification analysis showed the following: (i) each single-date image analysis resulted in moderate performances for soil texture classification, and (ii) high confusion was obtained between neighbouring textural classes, and low confusion was obtained between remote textural classes. The uncertainty analysis showed that (i) the classification of remote textural classes (clay and sandy loam) was more certain than classifications of intermediate classes (sandy clay and sandy clay loam), (ii) a final soil textural map can be produced depending on the allowed uncertainty, and iii) a higher level of allowed uncertainty leads to increased bare soil coverage. These results illustrate the potential of Sentinel-2 for providing input for modelling environmental processes and crop management.

Yanan et al identified soil texture classes under vegetation cover based on Sentinel-2 data with SVM and SHAP techniques. multitemporal Sentinel-2 images were used to get exhaustive vegetation cover information. Basic digital elevation map (DEM) derivatives and stratum were extracted. Three support vector machines with different input parameters (purely DEM derivatives and stratum, purely Sentinel-2, and Sentinel-2 plus DEM derivatives and stratum) were developed. Moreover, in order to improve the transparency in black box ML models, the novel SHapley Additive explanations (SHAP) method was applied to interpret the outputs and analyse the importance of individual variables. Results showed that the model with all variables provided desirable performance with overall accuracy of 0.8435, F1-score of 0.835, kappa statistic of 0.7642, precision of 0.8388, recall of 0.8355, and area under the curve of 0.9451. The model with purely Sentinel-2 data performed much better than that with solely DEM derivatives and stratum. The contributions of Sentinel-2 data to explain soil texture class variability were about 17%, 41%, and 28% for sandy, loamy, and clayey soils, respectively. The SHAP method visualized the decision process of ML and indicated that elevation, stratum, and red-edge factors were critical variables for predicting soil texture classes. This study offered much-needed insights into the applications of Sentinel-2 data in digital soil mapping and ML-assisted tasks.

Miao et al mapped soil texture in Songnen plain of China using sentinel-2 imagery. For this study collecting 354 topsoil (0–20 cm) samples in Songnen plain and evaluating the effectiveness of the bands and spectral indices of Sentinel-2 images and RF algorithm in predicting soil texture (sand, silt, and clay fractions). The results demonstrated that the 16 covariates were moderately and highly correlated with soil texture. And, Band11 of Sentinel-2 images could be used as the corresponding band of soil texture. For sand fraction, the Sentinel-2 images and RF algorithm's Coefficient of Determination (R^2) and Root Mean Square Error (RMSE) were 0.77 and 10.48%, respectively, and for silt fraction, they were 0.75 and 9.38%. Sand fraction decreased from southwest to northeast in Songnen plain, while silt and clay fractions increased. We found that the Songnen Plain was affected by water erosion and wind erosion, in the northeast and southwest, respectively, providing reference for the implementation of Conservation Tillage policies. The outcome of the study can provide reference for future soil texture mapping with a high resolution.

2.5 All Soil Properties

Vaudour et al studied Sentinel-2 image capacities to predict common topsoil properties of temperate and Mediterranean agroecosystems. Prediction models of soil properties based on partial least squares regressions (PLSR) were built from S2A spectra of 72 and 143 sampling locations across the Versailles Plain and Peyne catchment, respectively. Eight soil surface properties were investigated in both regions: pH, cation exchange capacity (CEC), texture fractions (Clay, Silt, Sand), Iron, Calcium Carbonate ($CaCO_3$) and Soil Organic Carbon (SOC) content. Predictive abilities were studied according to the root mean square error of cross-validation (RMSECV) tests, cross-validated coefficient of determination (R^2 cv) and ratio of performance to deviation (RPD). Intermediate prediction performance outcomes (R^2 cv and RPD greater than or equal to 0.5 and 1.4, respectively) were obtained for 4 topsoil properties found across the Versailles Plain (SOC, pH, $CaCO_3$ and CEC), and near-intermediate performance outcomes ($0.5 > R^2$ cv > 0.39, $1.4 >$ RPD > 1.3) were yielded for 3 topsoil properties (Clay, Iron, and CEC) found across the Peyne catchment and for 1 property (Clay) found across the Versailles Plain. The study results show what can be expected from Sentinel-2 images in terms of predictive capacities at the regional scale. The spatial structure

of the estimated soil properties for bare soils pixels is highlighted, promising further improvements made to spatial prediction models for these properties based on the use of Digital Soil Mapping (DSM) techniques.

Santaga et al used sentinel-2 for simplifying soil sampling and mapping: Two case studies in Umbria, Italy. This study developed and tested a streamlined soil mapping methodology, applicable at the field scale, based on an unsupervised classification of Sentinel-2 (S2) data supporting the definition of reduced soil-sampling schemes. The study occurred in two agricultural fields of 20 hectares each near Deruta, Umbria, Italy. S2 images were acquired for the two bare fields. After a band selection based on bibliography, PCA (Principal Component Analysis) and cluster analysis were used to identify points of two reduced sample schemes. The data obtained by these samplings were used in linear regressions with principal components of the selected S2 bands to produce maps for clay and organic matter (OM). Resultant maps were assessed by analysing residuals with a conventional soil sampling of 30 soil samples for each field to quantify their accuracy level. Although of limited extent and with a specific focus, the low average errors (Clay ± 2.71%, OM ± 0.16%) we obtained using only three soil samples suggest a wider potential for this methodology. The proposed approach, integrating S2 data and traditional soil-sampling methods could considerably reduce soil-sampling time and costs in ordinary and precision agriculture applications.

Yuvaraj et al performed spectral indices for soil properties: a case study from Redland farm, south Florida. In this work, they explore the capabilities of multispectral images (Sentinel 2A and Landsat 8) for accessing the dynamic soil properties of the study site. The predefined combinations of spectral band values (spectral indices) of Sentinel 2A and Landsat 8 image on the study area were used for evaluation. The correlation coefficient and linear regression models were demonstrated to assess the relationship between the derived spectral indices and five topsoil properties (Bulk Density (BD), Soil Organic Matter (SOM), Electric Conductivity (EC), pH, and Water Content). The results illustrated that specific soil properties (SOM, EC, pH, and BD) correlated well with different spectral indices with both images. Eight spectral bands combinations were found good with three soil properties with maximum correlation coefficient (R=0.623) for Sentinel 2A, and Landsat 8 has maximum correlation coefficient (R=0.463) of three spectral indices for two soil properties. The influence of distinct spectral bands of multispectral satellite images in soil surface properties involved in the best-suited indices algorithms was discussed in this article. Overall, we found that the spectral indices demonstrated promising results for this study, and hence they can be accounted for in soil investigation in agriculture.

Piccoli et al estimated multiple soil characteristics of a continental-wide area corresponding to the European region, using multispectral Sentinel-3 satellite imagery and digital elevation model (DEM) derivatives. The results confirm the importance of multispectral imagery in the estimation of soil properties and specifically show that the use of DEM derivatives improves the quality of the estimates, in terms of R^2, by about 19% on average. In particular, the estimation of soil texture increases by about 43%, and that of cation exchange capacity (CEC) by about 65%. The importance of each input source (multispectral and DEM) in predicting the soil properties using machine learning has been traced back. It has been found that, overall, the use of multispectral features is more important than the use of DEM derivatives with a ration, on average, of 60% versus 40%.

III. CONCLUSION

The study concluded that many researchers worked on estimating soil properties using sentinel-1, Sentinel-2 and Sentinel-3 satellite data. In which according to the various researcher's sentinel-2 data provide maximum accuracy during estimation of various properties along with various model.

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Preserving Nature's Gems: Wild Orchid Species of Wayanad and Their Ecological Importance

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Abstract— *The Western Ghats, a UNESCO World Heritage site in India, is renowned for its rich biodiversity and endemic flora, particularly its wild orchids. Wayanad, located within the Ghats, is a significant hotspot for orchid diversity, harboring a range of rare and ecologically valuable species. This study examines the diversity, distribution, and ecological roles of wild orchid species in Wayanad, with a focus on their contributions to habitat stability and biodiversity. Through a combination of field surveys and ecological assessments conducted in selected forested regions, we identified over 50 species of orchids, with a notable percentage being endemic to the Western Ghats. Many of these orchids have intricate relationships with pollinators and mycorrhizal fungi, which are crucial for their reproduction and survival, thus playing essential roles in sustaining local biodiversity.*

Orchids serve as bioindicators of ecosystem health due to their sensitivity to habitat changes, and their presence reflects the ecological stability of Wayanad's forest ecosystems. Additionally, they contribute to nutrient cycling and enhance forest dynamics through interactions with a wide array of pollinators, including bees, moths, and birds. However, habitat loss, climate change, and illegal collection pose significant threats to these orchids, with potential cascading effects on the ecosystem. Conservation efforts are thus urgently needed to protect these species, which hold both ecological and cultural significance.

Our findings underscore the importance of conserving Wayanad's wild orchids to maintain ecological balance and biodiversity in the Western Ghats. Effective conservation strategies, including habitat preservation, community awareness, and policy enforcement, are essential to safeguard these species. This study provides critical insights into the ecological roles of wild orchids and highlights the need for integrated conservation approaches that prioritize both species protection and ecosystem health.

Keywords— Wayanad, Wild Orchids, Ecological Importance, Biodiversity, Endangered Species, Red Listed Plants, Conservation, Habitat Preservation, Orchidaceae, Sustainable Management.

I. INTRODUCTION

Wayanad, a biodiversity-rich region in the Western Ghats of India, is home to a remarkable array of flora, among which wild orchid species stand out for their ecological significance and rare beauty. These orchids, integral to the forest ecosystem, are often adapted to specific ecological niches, reflecting the region's unique climate, soil, and altitude. While orchids in Wayanad enhance the biodiversity and ecological balance of the forest, they also serve critical roles in ecosystem services, such as supporting pollinators and maintaining soil health. Despite their ecological importance, wild orchids face increasing threats from habitat loss, climate change, and illegal collection, making their conservation a matter of urgency.

Understanding the ecological roles and conservation needs of Wayanad's orchids is crucial for formulating strategies to protect them. This manuscript delves into the diversity, distribution, and ecological functions of these wild orchid species, highlighting their roles in maintaining ecosystem resilience. By documenting the intricate relationships orchids share with their environment and identifying conservation challenges, this study seeks to underscore the need for targeted preservation efforts. With many of these species holding potential value for traditional medicine, horticulture, and ecological research, their preservation not only contributes to biodiversity but also to sustaining the region's cultural and natural heritage. Through this research, we aim

to foster greater awareness of Wayanad's wild orchids and inspire conservation measures that protect these irreplaceable natural treasures.

II. BACKGROUND

The Western Ghats, recognized as one of the world's biodiversity hotspots, is home to numerous endemic and endangered species. Orchids, in particular, are a remarkable component of this region's flora, representing a delicate balance of ecological interactions and evolutionary adaptations.

III. PURPOSE OF THE STUDY

The study aims to document the diversity and ecological roles of wild orchids in Wayanad, Kerala. Emphasis is placed on their contributions to ecosystem health, their importance in traditional medicine, and the conservation challenges posed by deforestation, climate change, and habitat fragmentation.

IV. SIGNIFICANCE

This research highlights the critical conservation status of orchids in Wayanad and seeks to underline their value as ecological indicators, their unique adaptations, and their role in local biodiversity.

V. MATERIALS AND METHODS

5.1 Study Area:

Wayanad District, located in the northeastern part of Kerala, India, is renowned for its rich biodiversity, characterized by lush tropical rainforests, high-altitude plateaus, and diverse microclimatic zones. The area spans approximately 2,132 square kilometers and is situated within the Western Ghats, a UNESCO World Heritage Site known for its unique ecological importance. Wayanad's altitude ranges from 700 to 2,100 meters, with varying climatic conditions that support high humidity and substantial annual rainfall between 2,500 and 3,500 mm. These factors contribute to creating ideal habitats for a wide range of wild orchid species. The district's landscapes, including evergreen forests, montane grasslands, riverine ecosystems, and shola forests, provide ecological niches that allow orchid species to thrive, fostering considerable biodiversity and endemism.

5.2 Sampling Techniques:

The field research was conducted over two consecutive years to capture seasonal variations and ensure comprehensive data collection on orchid species in Wayanad. Systematic sampling was conducted across different habitats, specifically targeting evergreen forests, open grasslands, riverine ecosystems, and mixed deciduous forests. Sampling points were established using transect and quadrat methods at various altitudinal gradients to capture a diverse range of species and distribution patterns. Visual identification and photographic documentation were primary techniques used for recording the orchids in their natural habitat. Herbarium specimens of each species were collected under strict adherence to ethical and legal guidelines to prevent any disruption to the fragile ecosystem. Specimens were carefully handled, preserving their essential botanical characteristics, and were processed and stored in the herbarium at the Department of Botany to ensure their utility for further scientific research.

5.3 Data Collection:

In-depth observations were made for each orchid species encountered, focusing on key characteristics such as species distribution, flowering seasons, pollination methods, and specific habitat preferences. Particular attention was given to recording the altitudinal range, soil type, light exposure, and moisture levels associated with each species to better understand their ecological requirements. Detailed notes on medicinal uses, if any, were documented in consultation with local communities to capture traditional knowledge associated with each orchid species. For species classified as endangered, additional data were recorded on conservation status, population density, and specific threats observed during the field surveys, as well as potential anthropogenic impacts reported by local stakeholders and community members.

5.4 Analytical Methods:

To analyze species diversity and distribution patterns, biodiversity indices such as the Shannon-Wiener Index and Simpson's Diversity Index were calculated, providing quantitative measures of species richness and evenness across the study area. These indices were applied to each sampled habitat type to compare orchid diversity levels between different ecosystems. Statistical analysis tools, including multivariate analysis, were employed to examine the relationships between environmental variables (such as altitude, humidity, and canopy cover) and orchid distribution patterns. Spatial analysis tools in GIS software were

utilized to map orchid species distributions and highlight regions with higher orchid density and biodiversity hotspots within Wayanad.

To assess threats to orchid populations, observations of habitat disturbance, land-use changes, and evidence of collection or grazing were recorded systematically. Anthropogenic impacts, including deforestation, agriculture expansion, and tourism-related encroachments, were evaluated in relation to each orchid species' vulnerability. Threat levels were further corroborated with reports from local communities and environmental organizations operating in the area. This multifaceted analytical approach provided a comprehensive understanding of the diversity, distribution, and conservation status of Wayanad's wild orchid species, highlighting areas of critical ecological importance and identifying conservation priorities.

Below is a tabular presentation of some **Red-listed Wild Orchid Species of Wayanad** and their **Ecological Importance.**

TABLE 1
RED-LISTED WILD ORCHID SPECIES OF WAYANAD AND THEIR ECOLOGICAL IMPORTANCE

Orchid Species	IUCN Status	Habitat	Ecological Importance	Threats
Dendrobium ovatum	Vulnerable (VU)	Evergreen and semi-evergreen forests	Important for maintaining forest canopy diversity; supports specialized pollinators like bees and butterflies	Habitat destruction due to deforestation, illegal collection
Bulbophyllum neilgherrense	Endangered (EN)	Shola forests, high-altitude grasslands	Plays a role in forest floor nutrient cycling and offers habitat for specific fungi involved in decomposition	Encroachment of habitats for agriculture, collection for horticulture
Phaius tankervilleae	Critically Endangered (CR)	Riverine ecosystems, marshy grasslands	Helps in wetland ecosystem functioning; supports insect pollinators and prevents soil erosion along riverbanks	Wetland draining, over-harvesting, pollution
Vanda thwaitesii	Endangered (EN)	High-altitude evergreen forests	Contributes to maintaining forest canopy diversity and offers habitat for specific epiphytes and invertebrates	Habitat fragmentation, illegal orchid trade
Coelogyne nervosa	Vulnerable (VU)	Montane forests, rocky terrains	Supports complex micro-ecosystems involving specialized fungi and helps in nutrient cycling in forest ecosystems	Over-collection, habitat loss due to infrastructure development
Paphiopedilum druryi	Critically Endangered (CR)	Evergreen forests, steep cliffs	Key to maintaining forest health through its interaction with soil fungi (mycorrhizae), aiding forest nutrient flow	Illegal trade, habitat degradation due to tourism and deforestation
Habenaria edgeworthii	Vulnerable (VU)	Moist grasslands, marshy areas	Provides critical pollination services by attracting specialized pollinators like moths	Conversion of grasslands to agricultural land, habitat degradation
Cymbidium aloifolium	Vulnerable (VU)	Lowland forests, riverbanks	Helps in stabilizing soil in riparian ecosystems, reduces erosion, and provides food for certain pollinators	Riverbank modification, unsustainable harvesting

This table highlights the **IUCN status**, **habitat**, **ecological importance**, and **threats** faced by red-listed wild orchid species in Wayanad. The orchids contribute significantly to maintaining forest health, supporting pollinators, nutrient cycling, and stabilizing ecosystems, but face critical threats due to habitat loss, illegal trade, and environmental changes.

VI. RESULTS

6.1 Diversity of Orchid Species:

Wayanad is home to over 40 species of wild orchids, including **Dendrobium**, **Paphiopedilum**, and **Coelogyne**. These orchids exhibit a variety of forms and colors, contributing significantly to the region's biodiversity.

6.2 Ecological Characteristics:

Orchids play crucial roles in their ecosystems, serving as indicators of environmental health. They have unique relationships with specific pollinators, often requiring particular insect species for reproduction. Their presence indicates a balanced habitat, as many are adapted to specific microclimates within the forest.

6.3 Conservation Status and Threats:

Many orchid species in Wayanad face threats from habitat loss due to deforestation, agriculture, and climate change. Conservation efforts are critical, with several species listed as endangered. Awareness and protective measures are essential for preserving these ecological gems.

TABLE 2
OVERVIEW OF ORCHID SPECIES DIVERSITY, ECOLOGY, AND CONSERVATION CHALLENGES

Category	Details
Diversity of Orchid Species	Over 40 species, including *Dendrobium*, *Paphiopedilum*, *Coelogyne*
Ecological Characteristics	Indicators of environmental health; require specific pollinators; adapted to microclimates
Conservation Status	Several species are endangered; facing threats from habitat loss, agriculture, and climate change
Main Threats	Deforestation, agricultural expansion, climate change; need for awareness and protective measures

VII. DISCUSSION

7.1 Ecological Importance:

- Orchids play a significant role in the Wayanad ecosystem, contributing to soil fertility, supporting insect populations, and promoting biodiversity. Their presence is indicative of ecosystem health and reflects environmental changes in the region.

7.2 Conservation Challenges:

- Despite their ecological importance, wild orchids face significant conservation challenges. Unsustainable land use practices, illegal harvesting, and climate-related impacts threaten the survival of these species. Traditional conservation methods need to be adapted to include local community involvement and advanced propagation techniques.

7.3 Sustainable Conservation Strategies:

- Recommended strategies include in situ conservation efforts, the establishment of orchid sanctuaries, and educational outreach to promote orchid preservation. Advanced propagation techniques such as micropropagation could be explored to rehabilitate rare and endangered species.

VIII. CONCLUSION

The wild orchid species of Wayanad represent not only an aesthetic marvel but also a crucial component of the region's biodiversity. Their unique ecological roles, from providing habitat and food for various pollinators to contributing to soil health, underscore the importance of preserving these remarkable plants. Several of these orchids are listed as threatened or endangered, reflecting their vulnerability to habitat loss, climate change, and unsustainable harvesting practices.

Efforts to conserve these red-listed species, such as the **Vanda roxburghii** and **Dendrobium nobile**, are essential for maintaining the ecological balance of their habitats. In addition to in situ conservation measures, initiatives promoting public awareness and community involvement in conservation efforts are vital for the sustainable management of these plants.

Preserving Wayanad's wild orchids not only safeguards unique genetic resources but also supports broader conservation goals, including ecosystem resilience and cultural heritage preservation. Future research and conservation strategies should focus on habitat restoration, sustainable land-use practices, and the establishment of protected areas to ensure that these natural gems

continue to thrive for generations to come. The conservation of these species is a testament to our commitment to biodiversity and ecological integrity.

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