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Growth and Yield Response of Indica Paddy Cultivars Cultivated Through Organic Agriculture System of Paddy Intensification and Conventional Technique under Wetland Conditions in East Uttar Pradesh, India

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Abstract:

Organic agriculture remains in its embryonic stage in most developing countries. Currently, organic produce turnout in addition to organic paddy is in huge demand because of its potential to induce prime value within the world market. Developing crop varieties that are less dependent on the heavy application of artificial fertilizers is important for the sustainability of agriculture. Four Indica paddy cultivars Saket-4, Panth-12, IR-50, and Sarju-52 were planted in the experiment field with and without organic inputs. The experiment was conducted as a factorial randomized block design. The results indicated that the uses of organic manures and biofertilizers such as soil organic supplement (SOS), arbuscular mycorrhizal fungi (AM fungi), plant growth-promoting rhizobacteria (PGPR), biostimulants have inflated the nitrogen (N), organic carbon (OC) contents within the soil and increase growth and productivity of all paddy cultivars. Panth-12 cultivars produced a higher grain yield (6. 61 t ha^{-1}) followed by Saket (4.62 t ha^{-1}), IR-50 (5.51 t ha^{-1}), and Sarju-52 (6.28 t ha^{-1}) as compared to conventional nonorganic control (CNOC) Panth-12 (6 t ha^{-1}), Saket-4 (4.00 t ha^{-1}), IR-50 (4.50 t ha^{-1}) and Sarju-52 (5.00 t ha^{-1}). The extremely mycorrhiza root colonization (MRC) percentage, plant height, number of the tillers, and panicles/hill were noticed in organic inputs (OI) treatments paddy cultivars and minimum in CNOC. Overall, findings clearly show that AM fungal root colonization in the initial stage influenced insect pest resistance, plant growth as well as paddy grain yield (PGY). Organic carbon and N increase in OI treatment paddy cultivars as compared to CNOC and initial soil analysis. These findings indicate that the acceptable nutrient and insect/pest management combined with paddy cultivars can improve the resilience of soil health (SH) and paddy productivity.

Keywords: *Organic manures, mycorrhiza, PGPR, Biostimulants, Biocontrol Agent, Productivity.*

1. Introduction

In India, paddy is cultivated over 44.6 million hectares with a production of 90.0 million tones and stands second in the world's ranking after China. India has tremendous potential to become a significant exporter of organic rice within the international market. The demand for organically produced food is increasing day by day worldwide. As per the report of IFOAM (2020), the marketing research company Ecovia Intelligence evaluations that the global market for organically produced food surpassed a hundred billion US dollars in the year 2018 (more than 97 billion euros) as compared to 89.7 billion US dollars in the year 2016 and it was estimated to grow at a higher rate in the coming years. In general, countries with higher incomes have a higher demand for organic food (OF). The United States is the leading market with 40.6 billion euros, followed by Germany (10.9 billion euros) and France (9.1 billion euros).

The developing countries in the main South Asian countries have also observed a rapid growth in OF production. The increasing fear regarding the tough effects of intensive use of chemicals in agriculture has covered the way to embrace organic farming worldwide (Prasad, 2005; Prasad, 2021b; Prasad, 2022a, b). Organic agriculture (OA) remains in its embryonic stage in most developing countries.

OA systems aim at resilience and buffering capability within the farm ecosystem, by stimulating internal self-regulation through purposeful agrobiodiversity in and above the soil, rather than external regulation through chemical protectors (Bueren et al., 2002). OA would like specific varieties that are adapted to their lower input farming system (LIPS) and might perform higher yield stability than conventional varieties (Bueren et al., 2002). Several breeding programs took yield potential because of the primary target. However, with the increasing living standards and therefore the enhancements in cooking, the eating and appearance quality of the rice grain has become a priority (Zhang, 2007.) For additional improvement of organic product quality and yield stability, new varieties are needed that are adapted to OA systems (Bueren et al., 2002). The emphasis on small-scale integrated farming systems has the potential to revitalize rural areas and their economies. Currently, India ranks seventh in terms of total land (approximately 2.8 million ha) beneath organic cultivation and first in the number of organics produced within the world.

Paddy (*Oryza sativa* L.) is a most important member of the family Graminae. It is a plant of Asian origin and therefore the second most significant crop in India, next to wheat. It forms the staple food of over 75% of the population. Virtually 90% of the world's total paddy production comes from Asia. Among the Asian countries, China and India remain the world's top two producers of paddy. Cultivated paddy belongs to two species: *Oryza sativa* which originated in Asia and *Oryza glaberrima* which originated in West Africa. *O. sativa* is wide cultivated species worldwide. Asian cultivated paddy has evolved into three eco-geographic races–indica, japonica, and javanica. Over 600 improved cultivars of indica paddy have been released for cultivation since 1965. The key paddy-growing states in India are Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal, Odisha, Andhra Pradesh, Assam, Punjab, Tamil Nadu, Karnataka, Maharashtra, and Haryana. In India, paddy is cultivated over 44.6 million hectares with a production of 90.0 million tones and stands second in the world's ranking after China. India has tremendous potential to become a significant exporter of organic rice within the international market.

OA has an objective to encourage and enhance the health, biodiversity, and soil biological activities of the agro-ecosystem (Singh et al. 2005; Badgley et al. 2006; Chouichom and Yamao, 2010; Prasad, 2013; Prasad, 2015; Prasad, 2017; Prasad, 2020; Prasad, 2021a, b, c, d; Prasad, 2022a, b). Adoption of OA would facilitate mitigating the issues connected with input-intensive conventional agriculture (Wheeler, 2008; Prasad et al., 2021). Conventional agriculture (CA) has resulted in a negative impact on the environment, the presence of toxic residues in food, and an overall reduction in the quality of food that has increased numerous diseases (Prasad and Yadav, 2022). The organic production system (OPS) has the potency to solve these difficulties. This study focuses on promoting climate-resilient agriculture technologies by appropriately investigating the cultivars of appropriate paddy and OI applications that may enhance the expansion and quality of paddy productivity sustainably.

2. Materials and Methods

2.1. Experimental Field Location

A field experiment was conducted at Bahadurpur, District- Basti, East Uttar Pradesh, India during the Kharif season. The district lies between the parallels of 26° 23' and 27° 30' North and Latitude and 82° 17' and 83° 20' East longitude (Figure 1). It is the maximum length from north to south is about 75 km. and breadth from east to west about 70 km. The district lies between the newly created district Sant Kabir Nagar on the east and Gonda on the west. The area has a moderate and tropical climate. Humidity is fairly high throughout the year. The temperature throughout summer touches 35-45.0°C and during winter its 8.0°C. The average annual rainfall is 1166 mm and also the average annual temperature is 26.5°C. Field trial soil is alluvial, with a light to medium texture having an almost neutral pH.

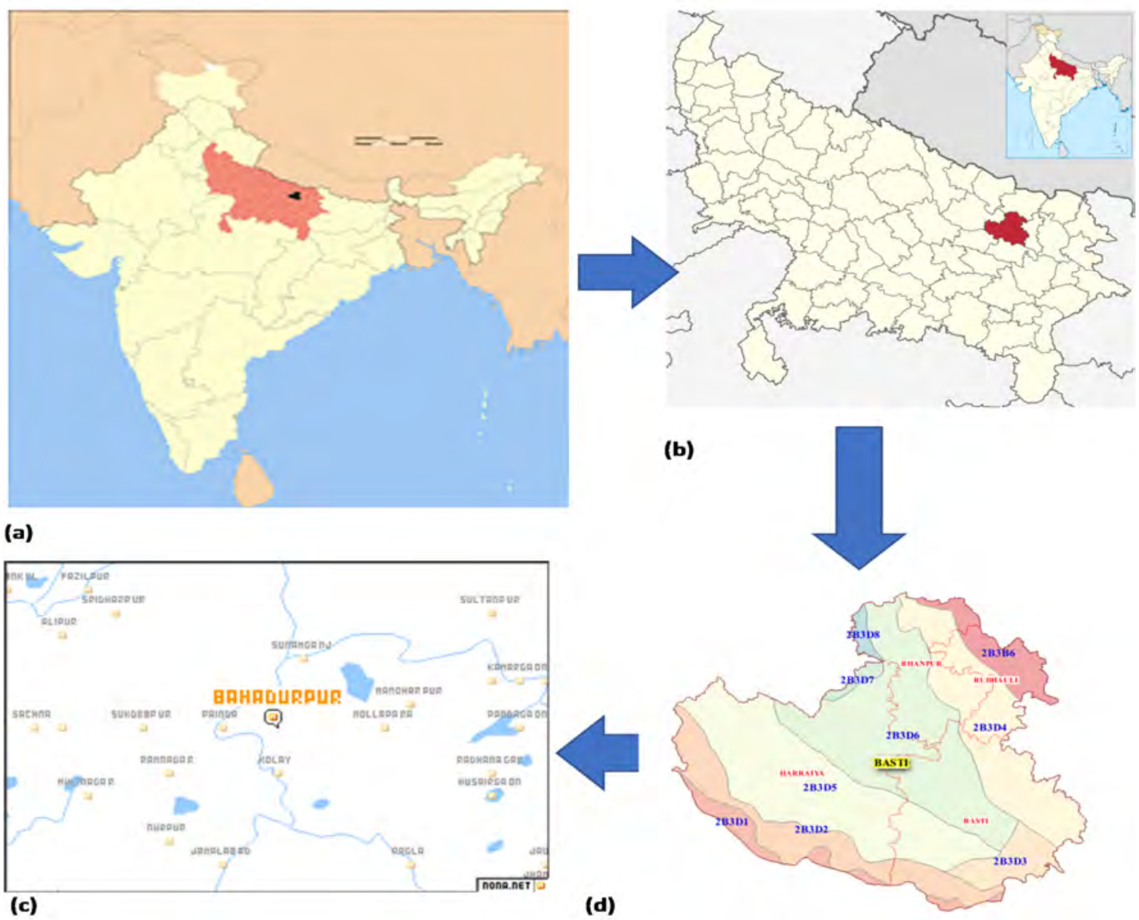


Figure 1: Graphical map **(a)** India, **(b)** Uttar Pradesh (State), **(c)** Basti (District) and **(d)** Bahadurpur (City).

2.2. Procurements of Conventional Inorganic Fertilizers and Organic Inputs

Conventional chemical fertilizers and paddy cultivars were purchased from the native market and organic inputs (OI) such as soil organic supplement (SOS), vermicompost, neem cake, Absolute Biologicals microbial cultures such as Arbuscular mycorrhizal fungal biofertilizer, *Pseudomonas fluorescens, Fraturia aurantia, Azotobacter chroococcum,* ($1x10^{11}$ CFU ml^{-1}) PGPR; *Trichoderma harzianum* ($2x10^{8}$ spores ml^{-1}), *Bacillus subtilis*, ($2x10^{9}$ CFU g^{-1}), *Metarhizium anisopliae*, ($2x10^{8}$ spores ml^{-1}), *Beauveria bassiana* ($2x10^{8}$ spores/ml) and Absolute Biologicals biostimulants was prepared our labs for the experiments.

2.3. Paddy Field Experiment (PFE)

The Indica paddy experiments were conducted within the Kharif season for the development of organic vs. conventional cultivation and their comparative assessment through new concepts and strategies of potential crop improvement. Organic and inorganic inputs were obligatory as basal and split doses into completely different paddy cultivars and their different growth stages.

2.4. Preparation of Paddy Nursery Bed (PNB)

Indica paddy cultivar seedlings were prepared at the experiment site. 500 m^2 nursery bed sizes were raising India paddy seedlings for one hectare of land transplantation (50 kg ha^{-1} seeds) for every Indica paddy cultivar. At the time of ultimate preparation of nursery bed, entire water was drained out and also the field was leave water for 48 hrs. Once ploughing the nursery bed (four times), 10 kg neem cake mixed with 25 kg of vermicompost was spread on conventional non-organic control (CNOC) nursery bed soils whereas in organic nursery bed (ONB), 10 kg neem cake, 1 kg SOS was properly mixed with 25 kg of vermicompost and spread on ONB soil during the last ploughing. Later, the soil ought to be properly levelled. The next day Indica paddy (Saket-4, Panth-12, IR-50, and Sarju-52) cultivars were seeded on CNOC and ONB on an individual basis (Figure 2).

2.5. AM fungi Inoculant

The density of AM fungi that were mixed with triple sterile talc powder was adjusted with 3000 infected propagules (IP) per gram of inoculants containing growing to subtract, infected roots bits, hyphae, and mycelial mass. Absolute Biologicals AM fungi inoculum containing one million infected propagules (IP) per hector were treated with seeds at the time of seeds sowing in the nursery for samplings.

2.6. Seed Treatment

In ONB, Indica paddy cultivars (Saket-4, Panth-12, IR-50, and Sarju-52) were treated with Absolute Biological PGPR cultures such as *P. fluorescens, F. aurantia, A. chroococcum* ($1x10^{11}$ CFU ml^{-1}) and biocontrol agent (BA) *T. harzianum* ($2x10^{8}$ spores ml^{-1}) along with AM fungi before sowing within the nursery beds.

2.7. Nursery Precaution for Healthy Sapling

After ten days of sowing, applied Chlorpyriphos 20 EC (2.5 L ha^{-1}) on CNOC nursery beds and Absolute Biologicals Biostimulant (500 g ha^{-1}) and *B. subtilis* (250 g ha^{-1}) on ONB as a foliar spray.

2.8. Preparation of Main Experimental Field

The main field was irrigated and ploughed fourfold. The bunds were trimmed and plastered to prevent water outflow. Rat holes found within the field were sealed. FYM (12.5 t ha^{-1} and neem cake (250 kg ha^{-1}) were applied as basal manure doses during the final ploughing altogether plots. The land was levelled before the transplantation of saplings.

2.9. Soil Sampling and Analysis

Soil (0-15 cm) from every replicate was sampled in initial soil and each plot treatment at harvest and pooled together, air-dried ground, and through a 2 mm sieve for chemical analysis. Observations were created in chemical properties of initial soil and once treatments with differing kinds of organic and inorganic fertilizers. Soil organic carbon was measured by the dichromate digestion technique. Total N was measured by the Kjeldahl steam distillation technique (Subbiah and Asija, 1956).

2.10. Experimental Design and Sapling Transplantation

20 days of nursery-raised Indica paddy saplings were transplanted in the main experimental field three uniform sizes of Indica paddy saplings per hill at the depth of 3 cm deep in the first week of July and 15 cm x 20 cm (between plant x row) spacing was maintained. The size of the experimental plot was set to 1000 m^2 with a 0.5 m buffer in between three replicates. To compare the treatments, a randomized complete block design (RCBD) was used before transplantation, clipping off the tips of the saplings. This facilitates uniform growth and helps to remove egg mass and insect pests if present on the leaf tips.

2.11. Nutrient Management in Main Paddy Field (MPF)

2.11.1. Basal Dose

Various level of conventional chemical fertilizers (CCF) was applied in the CNOC paddy field in the form of nitrogen (N) 0.6 q ha^{-1}, P_2O_5 (P) 0.6 q $ha^{-1,}$ and K_2O (K) 0.6 q ha^{-1} as 100 % recommended rate of fertilizers (RRF) such as Farmer's practiced. 0.25 q ha^{-1} of SOS was applied as a basal dose in the organic field before sapling transplanting. 0.125 q ha^{-1} of blue-green algae (BGA) was applied after 25 days of transplanting altogether fields.

2.11.2. Split Dose

After twenty-five days of transplantation, urea was applied as a top dressing in three equal splits doses (1.2 q ha^{-1}) in the CNOC plot whereas, in the organic plot (OP), Absolute Biologicals Biostimulant (500 g ha^{-1}) and *B. subtilis* (2.5 kg ha^{-1}) were applied as a foliar spray in thrice between twenty days interval.

2.12. Weeding Management

Weeding was finished manual weeder with hand, doubly once thirty days interval of transplantation. Recommended cultural operations (RCO) were carried out throughout the complete cropping period to ensure a healthy crop.

2.13. Water Management

The saturated condition was maintained for up to one week for the establishment of saplings' growth. 3-5 cm water level was maintained throughout the complete growth period. Water is needed particularly throughout the critical stages of tillering, flowering, and milk formation. Once 15 days of milk formation water was drained out for superior grain formation.

2.14. Management of Insects and Disease in CNOC Paddy

Foliar spray of Chlorpyriphos 10 G (0.1 q ha^{-1}) was applied 30 days after transplanting (DAT) of saplings. Pheromone (63 ha^{-1}) traps and Yellow GlueePad (63 ha^{-1}) was installed in control plots for stable gear for insect pest. Foliar spray of Chlorpyriphos 20 EC (2 L ha^{-1}) at 60 DAT. Neem oil (5 ml L^{-1}) was accustomed to CNOC plots for the management of insects and pests' infection.

2.15. Management of Insects and Disease in Organic Paddy

Organic paddy saplings' roots were dipped for 15 min in the Absolute Biologicals seed treatment kit containing *P. fluorescens, F. aurantia, A. chroococcum*) before transplantation (Prasad, 2021e). *B. bassiana* (2.5 L ml ha^{-1}), *M. anisopliae* (2. 5 L ha^{-1}), and *P. lilacinus* (2.5 L ha^{-1}) were properly mixed in water and sprayed once thirty days of transplantation. Foliar application of neem oil (5 ml L^{-1}) was also used to manage the insects and pests. Pheromone traps (63 ha^{-1}) and Yellow GlueePad (63 ha^{-1}) was installed in organic plots conjointly with the trap of insect.

2.16. Assessment of mycorrhizal root colonization (MRC) percentage in root system

Approximately 1-2 g of fresh roots were collected from every treatment and all cultivars before transplant of paddy sapling in the main field. All CNOC and OI nursery bed roots were used for staining and therefore the assessment of MRC percentage. Root fragments were washed in fresh and clean water, cleared with 10% KOH, acidified with 1N HCl, and stained with 0.05% Trypan blue (Phillips and Hayman, 1970). Quantification of root colonization for AM fungi was conducted using the gridline intersection technique (Giovanetti and Mosse, 1980) and one hundred segments of every sample were observed below a compound microscope (Leica DM750). The presence or absence of AM fungal structure in root segments such as vesicles, arbuscules, and hyphae at specific fixed points was recorded, and therefore the results were expressed as a percentage MRC of observations.

2.17. Morphological and Yield Attributes of Trials

The plant observations were created in generative and post-harvest phases. The observed characteristics were the plant height, the number of tillers and panicles carried out at eight weeks once planting as standard world agriculture production systems (SWAPS), grain yield carried out once harvest of the crops (12 weeks, SWAPS).

2.18. Harvesting, Threshing, Drying, and Milling of Paddy

All paddy cultivars were harvested once 80% of grains within the panicles were ripened (12 weeks SWAPS). Separate threshing was done immediately after harvesting every cultivar and treatment of paddy. Paddy was dried beneath the shade and 12% moisture content was maintained in grains for storage purposes besides 14 % of milling (SWAPS).

2.19. Statistical Analysis

Observations on growth, productivity, and alternation in chemical properties in soil were analyzed using SPSS (SPSS INC. version 17.0). Results were subjected to a one-way analysis of variance and also the significant difference was determined according to Duncan's Multiple Range Test at the significant level of ($p<0.05$).

3. Results and Discussion

3.1. Chemical Soil Properties (CSP)

The OI improved the organic C, nitrogen (N), and C/N magnitude relation of the soil compared to the preliminary soil analysis (Table 1). The organic C of soil exaggerated from 0.82% to more than 2% at Saket-4, Panth-12, IR-50, and Sarju-52 cultivars. Maximum organic carbon was noticed in OI treated plots [(Panth-12 (2.35%), Sarju-52 (2.34%), IR-50 (2.19%), Saket-4 (2.14)] and minimum in CNOC (100% RRF) [(Sarju-52 1.62%, Panth-12 1.58%), IR-50 (1.56%), Saket (1.45%)] that indicates an increase in soil health. The appliance of 100% RRF had a lower increase in organic C, which did not reach 2%. However, an organic matter content of 2-3% is required to nurture the long-term soil quality (Sabarmati et al., 2018). Table 1 exemplifies that the total N exaggerated from 0.10% to 0.2% in all OI applied cultivars. Utmost organic C, N, and C/N ratios were noticed in OI applied paddy cultivars compared to CNOC. Nitrogen is one of the foremost needed mineral nutrients for plant growth and productivity, as a result, it not solely enhances the yield but conjointly improves the food quality (Ullah et al. 2010; Leghari et al. 2016, Prasad et al., 2022).

Table 1: Chemical properties of initial soil and fertilized plot with different types of organic inputs plots

Parameter*	Initial soil analysis	Saket- 4		Panth- 12		IR- 50		Sarju- 52	
		CNOC	OI	CNOC	OI	CNOC	OI	CNOC	OI
Organic Carbon (%)	0.82	1.45	2.14	1.58	2.35	1.56	2.19	1.62	2.34
Nitrogen (%)	0.09	0.13	0.19	0.16	0.23	0.18	0.21	0.17	0.23
C/N ratio	7.6	11.2	10.3	9.9	10.2	8.7	8.6	9.5	10.2

*Mean of three replicates, CNOC- Conventional non-organic control: OI- Organic Inputs

3.2. Crop Morphological Characters (CMC)

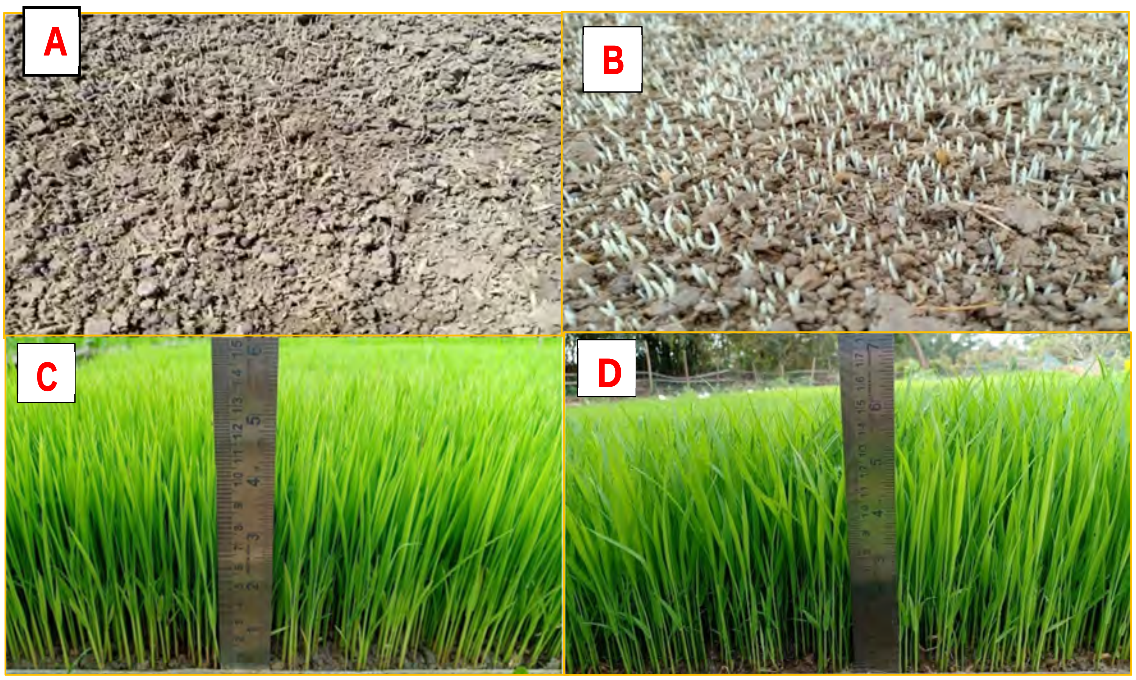
The periodic observation was noticed, and details were mentioned within the individual figures. The paddy growth was vigors and satisfactory throughout the cropping season as a result of higher grains and long panicle formation (Figure 2- 5). Mortality of plants in all paddy cultivars was terribly low (3%) in OI treated paddy as compared to CNOC (7%) (100% RRF i.e., Farmer's practiced).

3.3. Plant Height (cm)

Significant variations (SV) were recorded in paddy height between the cultivars and treatments. Organic inputs applied to paddy cultivars were noticed on average the greatest plant height

compared to CNOC. The maximum height was detected in OI treated Panth-12 cultivars shows a figure 3 (141.92 cm) followed by Sarju-52 (134.75 cm), IR-50 (131.82 cm) and Saket-4 (127.46 cm) and minimum in CNOC [Panth-12 (119.74 cm), Sarju-52 (117.8 cm), IR-50 (115.68 cm) and Saket-4 (113.92 cm)] (Figure 2 and 4). It absolutely was ascertained that 18.29%, 14.20%, 13.41%, and 11.47% accrued height in OI treated paddy cultivars Panth-12, Sarju-52, IR-50, and Saket-4 severally over the CNOC. The paddy height is one of the parameters that indicate the impact of the environment to plant growth. It's a central part of the ecological strategy of a plant. It is a powerful correlation with life span, seed mass, and time to maturity, and may be a major determinant of a species' ability to compete for light (Moles et al., 2009). The distinction in paddy height between cultivars was due to genetic distinction. Variations in genetic response to the environment affect the expansion patterns between treatment and cultivars (Sitaresmi, 2016; Prasad, 1993; Prasad, 2021f).

Figure 2: Morphology of Paddy seedlings cv. Panth- 12 nursery control vs. Organic Inputs A-



Conventional non-organic control (CNOC) (100% RRF); B- Organic Inputs (OI) at 20 DAS; C-CNOC; D-OI

Figure 3: Spikelet development stage of Paddy cv. Panth-12 at 80 DAT in control (100% RDF i.e. Farmer's practiced) vs. OI (Long and healthy spikelet)

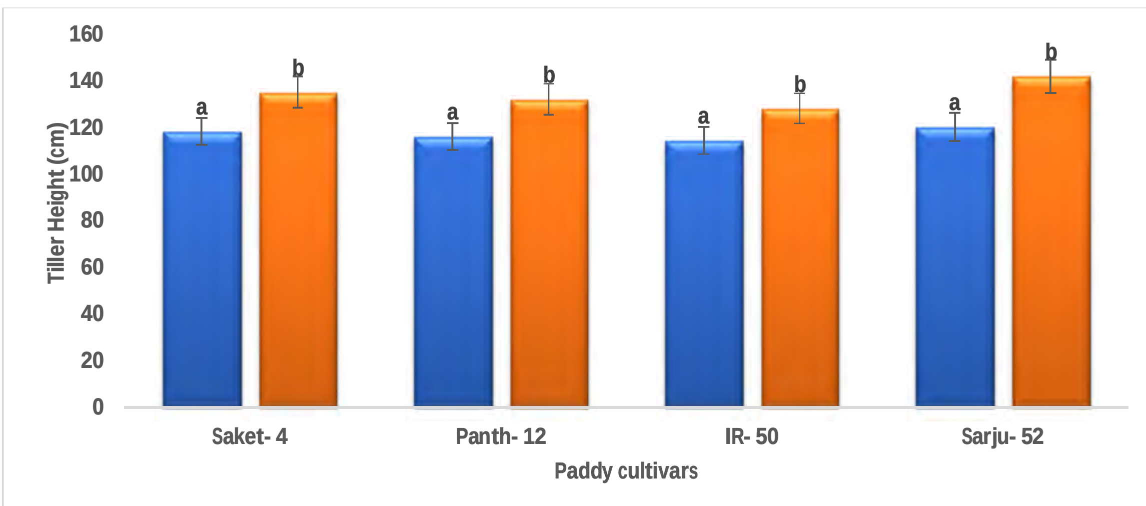
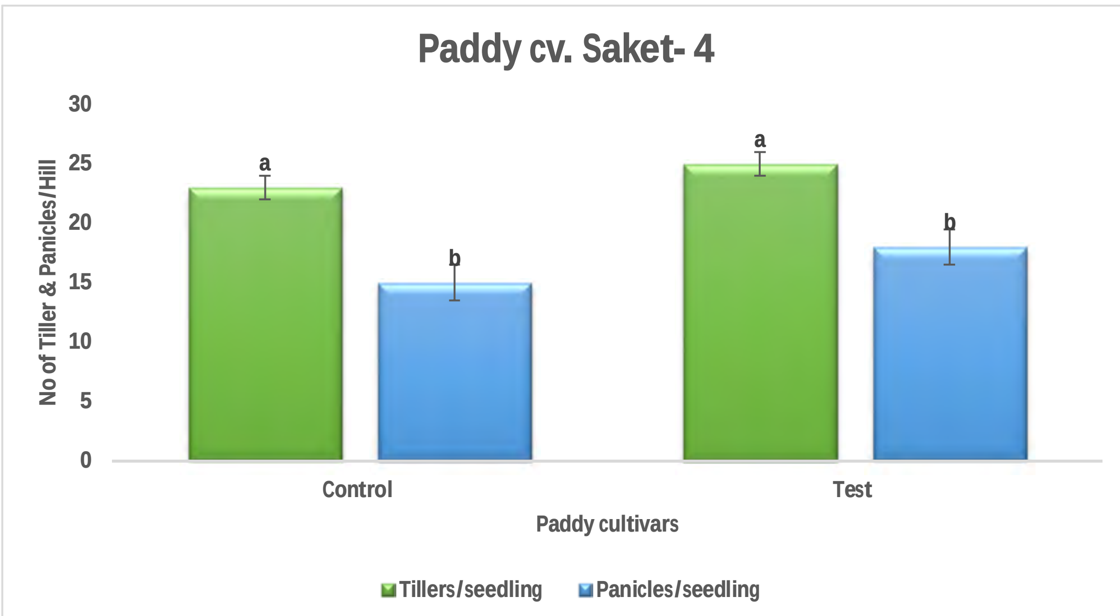


Figure 4: Plant height differences between in control (100% RRF) and Organic Inputs (Test) treated Test Paddy cultivars; Mean 25 replications per treatment (n = 25); a, b. letters at the column head indicate a significant difference at ($p < 0.05$) according to DMRT

3.4. Number of tiller and Panicles

Paddy treated with OI showed a higher number of tillers and panicles as compared to the CNOC (100% RRF). OI influenced several tiller and panicles in paddy cultivars (Figure 5-8). However, the maximum number of tillers was found in OI treated Panth-12 (30 tillers hill^{-1}) followed by Sarju-52 (25 tillers hill^{-1}), IR-50 (24 tillers hill^{-1}), and Saket-4 (23 tillers hill^{-1}) whereas the same trend was noticed in CNOC paddy cultivars however value was lower (Figure 8). The greatest numbers of panicles per hill were revealed altogether organic paddy cultivars receiving within the OI; this finding was substantial when compared to the CNOC (100% RRF). It had been noticed that an 11.47%, 13.41%, 14.2%, 18.29% increase in tillers hill^{-1} in OI applied paddy cultivars IR-50, Panth-12, Saket-4, and Sarju-52 respectively over the CNOC. It had been noticed that OI treated paddy, panicles hill^{-1} increased 19% in Sarju-4, 14.60% in Saket-4, 14.80% in IR-50, and 34.40% in Panth-12 over the CNOC (100%



RRF). **Figure 5:** Number of tiller and panicles differences in control (100% RRF) and Test (Organic inputs) Paddy cv. Saket-4; Mean 25 replications per treatments (n =25); a, b. letters at the column head indicate a significant difference at ($p < 0.05$) according to DMRT

The current finding was supported by Paddy Standard Evaluation System (PSES), the number of tillers is high (more than 25 tillers plant^{-1}), Good (20 -25 tillers plant^{-1}), medium (10 –19 tillers plant^{-1}), low (5 – 9 tillers plant^{-1}), and very low (less than 5 tillers plant^{-1}) (IRRI, 2002).

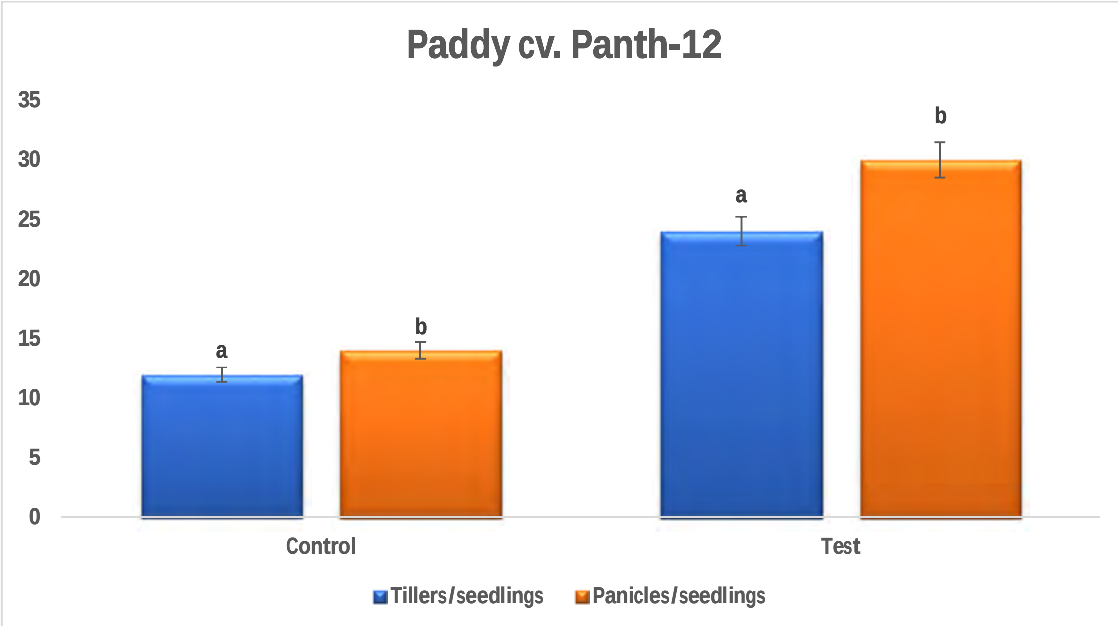


Figure 6: Number of tiller and panicles differences in control (100% RDF) and Test (Organic inputs) Paddy cv. Panth-12; Mean 25 replications per treatments (n =25); a, b. letters at the column head indicate a significantly different at ($p < 0.05$) according to DMRT

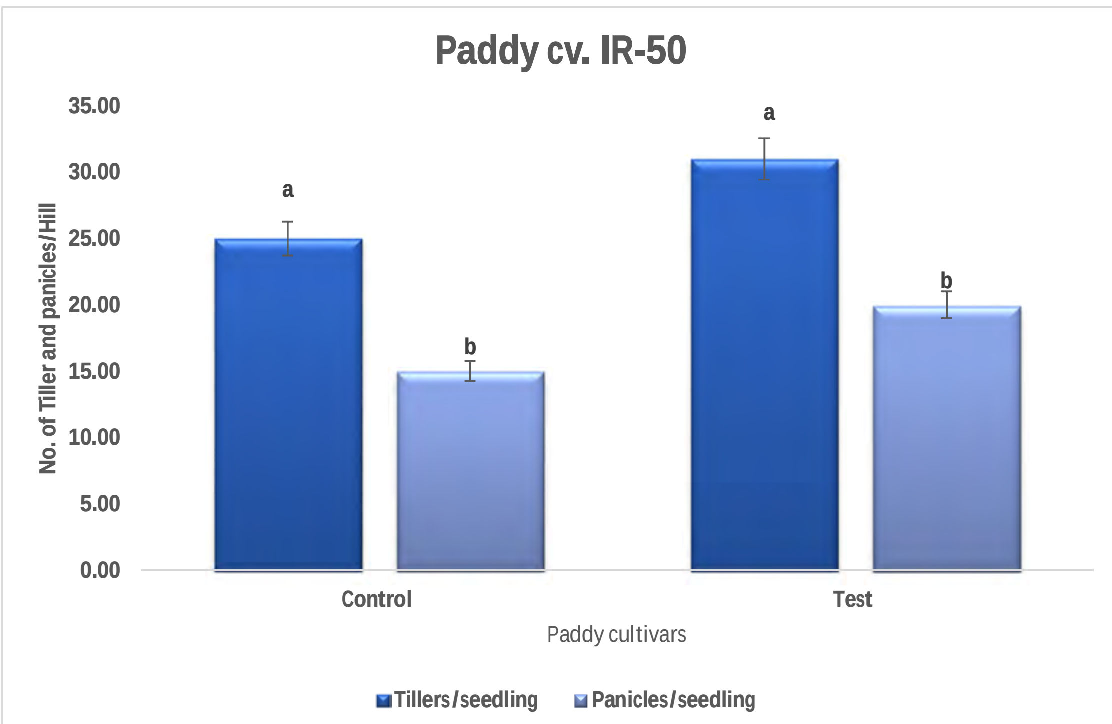


Figure 7: Number of tiller and panicles differences in Control (100% RRF) and Test (organic inputs) Paddy cv. IR-50; Mean 25 replications per treatments (n =25); a, b. letters at the column head indicate a significant difference at ($p < 0.05$) according to DMRT

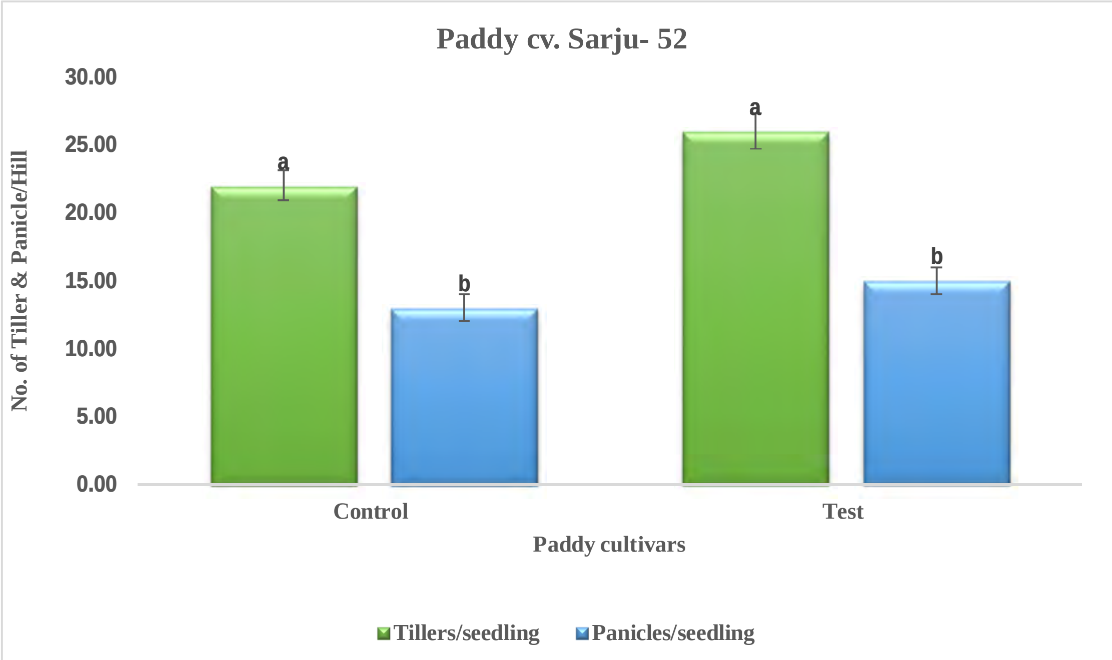


Figure 8: Number of tiller and panicles differences in control (100% RDF) and Test (Organic inputs) Paddy cv. Sarju-52; Mean 25 replications per treatments (n = 25); a, b... letters at the column head indicate significant different at ($p < 0.05$) according to DMRT

3.5. Paddy Yield Characters

Paddy field experiment grain yield information conferred in figure 9 showed that maximum paddy grain yield (PGY) was detected in OI applied paddy cultivars as compared to CNOC (100% RRF). In OI applied paddy, maximum PGY yield was recorded in cultivars Panth-12 (6.61 t ha^{-1}) followed by Sarju-52 (6.28 t ha^{-1}), IR-50 (5.51 t ha^{-1}), and Saket-4 (4.62 t ha^{-1}), whereas in CNOC, most PGY was noticed in Panth-12 (6.61 t $ha^{-1)}$ and minimum in Saket-4 (4.62 t ha^{-1}). It additionally decreases the soilborne pathogens due to microorganisms being suppressed by the disease's frequencies. Biocontrol agent application manages the insect/pest as well as soilborne pathogens attack on organic agriculture treatments. Organic manure, Absolute Biologicals biostimulants, and biofertilizers had a significant effect on increasing soil fertility and improving total yield wherever decrease the pathogens in paddy cultivars. Our results suggested that Absolute Biologicals PGPR (*P. fluorescens, F. aurantia, A. chroococcum*) application could be used to decrease accumulation and promote paddy growth and productivity. Absolute Biologicals *P. fluorescence* is capable of converting insoluble inorganic phosphorous into a soluble form by manufacturing organic acids and acids phosphates furthermore as management of pathogens. Absolute Biologicals *F. aurantia* produces organic acids and enzymes that facilitate solubilizing the fastened potassium into exchangeable form and building it assumable by paddy. Absolute Biologicals *A. chroococcum* is synthesizing biologically active substances such as auxins, cytokinins, and GA-like substances thereby stimulating plant growth. This stimulates rhizospheric microbes and protects the plants from phytopathogens, improves nutrient uptake, and ultimately boosts biological nitrogen fixation (BNF) (Vessey, 2003; Prasad, 2021 a, b, c, d; Prasad et al., 2021; Prasad, 2022b).

The organic compound of the soil improves the biological, physical, and chemical properties of the soil (Espe et al., 2015; Prasad, 2022a, b; Prasad et al., 2022). Besides its performance as a source of nutrients such as N, P, S, and soil organic matter additionally can increase the power of the soil to carry nutrients (Liu et al., 2014). In the present study, the OI treatments showed the highest performance in paddy cultivars as compared to control (RRF) although the variations were significant.

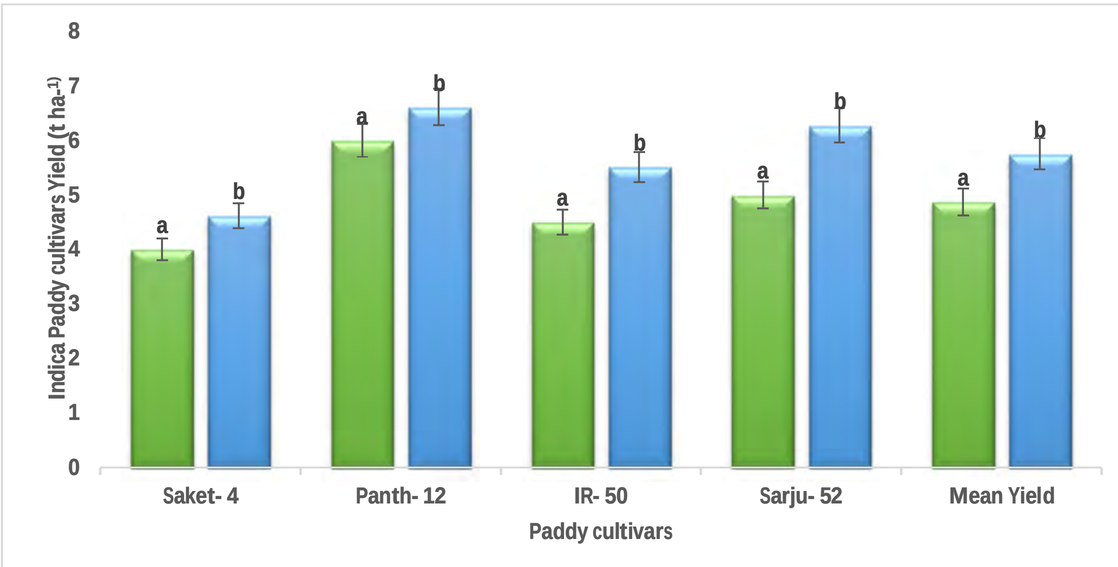
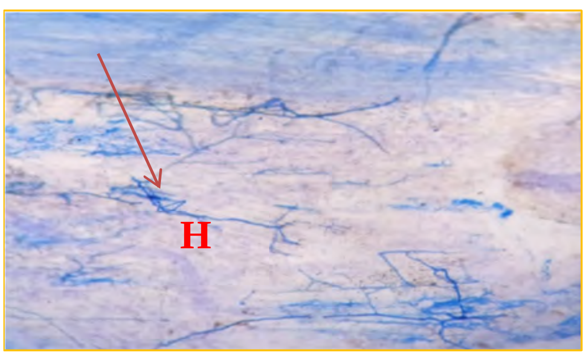


Figure 9: Grain Yield of different cultivars of paddy cultivated in Control (100% RRF) and Test (Organic Inputs) plots; Mean 3 replications per treatment (n = 3); a, b. letters at the column head indicate a significantly different at ($p < 0.05$) according to DMR

Paddy cultivars can have completely different effects on nutrient uptake, inflicting variations in accumulating nutrients in plants and increasing productivity. The paddy grain yield could be a quantitative character influenced by several genes and powerfully by the environment (Assange et al., 2017). The character of PGY is employed to calculate nutrient uptake potency. Consequently, it is seen that the type of paddy cultivars makes a transparent distinction within the PGY. Panth-12 cultivar includes a higher ability to absorb nutrients than alternative beneath a similar environmental condition. This is often one of the explanations that Panth- 12 produces higher yields. In line with Singh et al. (2015), higher grain yield beneath organic inputs treatment seems to be associated with each bigger and a lot of balanced nutrients uptake. This study discovered that Panth-12 had a higher ability of nutrient uptake. The higher nutrients uptake potency, the greater the cultivars have the flexibility to utilize nutrients. The manure combined with Absolute Biologicals biofertilizers and biostimulants resulted in higher environmental conditions for paddy plants by providing the nutrients that are needed by the paddy plants. Moreover, the appliance of OI with the improved cultivars Panth-12 produced the highest PGY; however, not considerably completely different from alternative treatments associated with soil health, and the appliance of varied forms of Absolute Biologicals organic inputs was able to improve the soil health and nutrient availability to support the paddy growth and productivity. Management of insect/pests of paddy, Absolute Biologicals insecticides *M. anisopliae*, *B. bassiana*, and *P. lilacinus* were applied. *M. anisopliae*, *B. bassiana*, and *P. lilacinus* controlled the economic pests and helps to cut back the chemical load on paddy.

3.6. Mycorrhizal Root Colonization (MRC) Percentage

Mycorrhizal root colonization (MRC) proportion in paddy saplings root was discovered in each treatment and cultivars (Figure 10-12). The maximum percentage of MRC was revealed in Sarju-52 (64.30%) followed by Saket-4 (60.20%), Panth-12 (57.48%) and IR-50 (56.4%), and minimum in CNOC [Sarju-52 root (19.2%), Panth-12 (18.6%), Saket-4 (17.5%) and IR-50 (16.4%)] at transplantation stage. Statistically significant ($p < 0.05$) variations were recorded between the treatments and cultivars. Root length in mycorrhizal treated paddy cultivars was longer than CNOC. AM fungal-treated paddy plants have been encouraged by higher water and mineral nutrients uptake from the soils as a result of the exaggerated entire root surface (Prasad, 2017; Prasad, 2021a, b, c; Prasad, 2022a, b). The colonization potential of AM fungi decreases in control (CNOC) treatment due to non-mycorrhiza treatment and rhizospheric mycorrhiza does not influence higher colonization. MRC percentage in paddy root was affected with an added in Absolute Biologicals mycorrhiza inoculum with OI and values were statistically totally different compared to CNOC developed saplings. Paddy seeds treated with Absolute Biologicals AM fungi recorded maximum height, tillers, panicle**s,** and grain yield are recommended as a sustainable approach to overcome the increase in crop yields due to altering the physiological and biochemical properties of the crop plant (Prasad, 2021c; Prasad, 2022b). Environmental factors influence the quantity, effectiveness, and nature of resource exchange among AM fungi and their hosts (Wardle et al. 2004; Johnson et al. 2010; Pineda et al. 2013; Bever, 2015; Prasad, 2013; Prasad, 2017; Prasad,2021a, b; Prasad, 2022b), and thus, the consequences of AM fungi on their hosts are variable. Positive effects of AM fungi on plant growth and nutrient concentrations (Solaiman and Hirata 1996, 1997, Prasad, 2021a, b, c), defense against pathogens (Prasad, 1998; Pozo et al. 2002; Liu et al. 2007; Prasad, 2011; Campos-Soriano et al. 2011), and photosynthetic rates (Black et al. 2000) have been shown in several studies. Within the current study, field knowledge quantifies the impact of vaccinating paddy seeds with Absolute Biologicals AM fungi on plant growth, nutritional status, resistance, and tolerance to insect pests and yield.



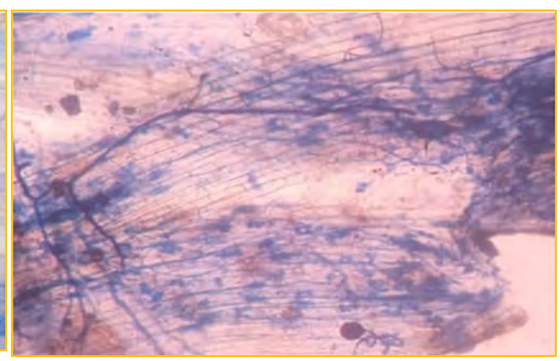


Figure 10: Root fragments stained with Trypan blue showing AM fungi structures in control paddy plants without being treated with AM fungi, Hyphae (H); Arbuscule (A)

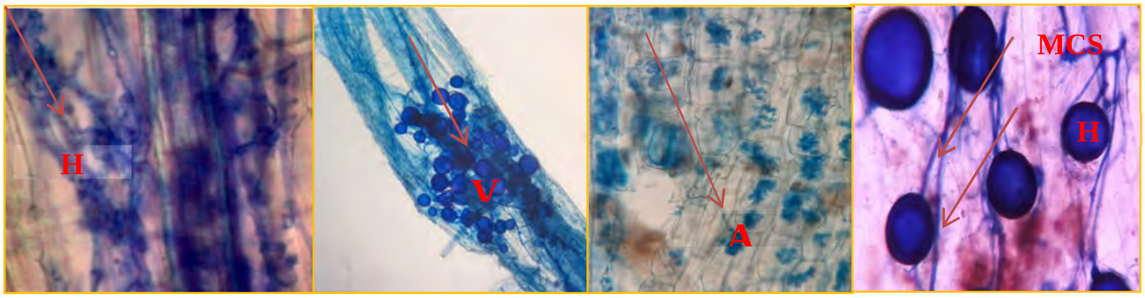


Figure 11: Root fragments stained with Trypan blue showing AM fungi colonization structures in paddy plants treated with AM fungi. Heavily mycorrhizal root colonization and its structure establish in mycorrhiza-treated paddy root fragments. Hyphae (H); Arbuscule (A); Bunches of Vesicle (V); Mature Chlamydospores (MCS).

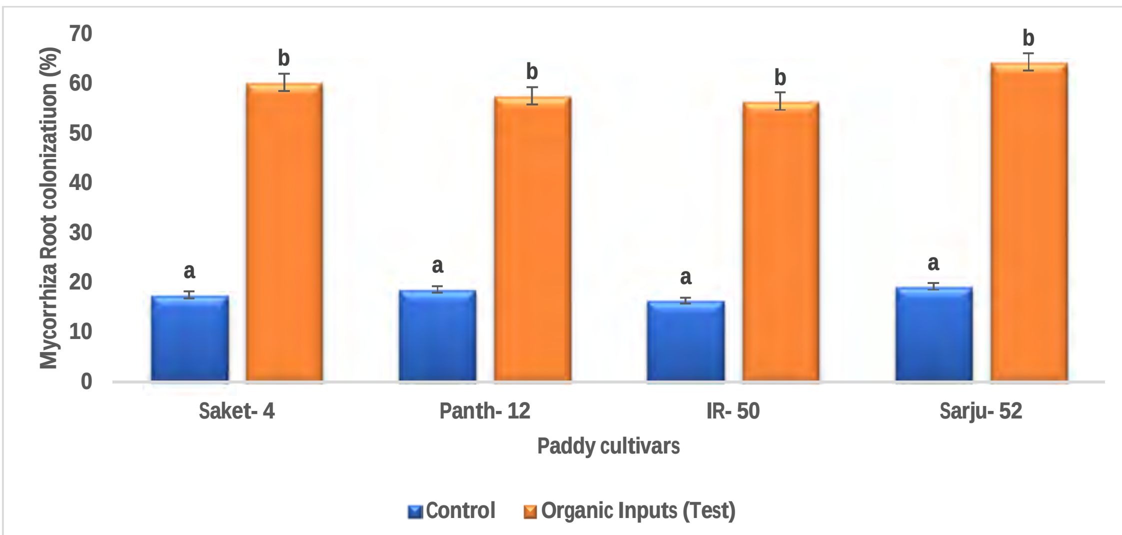


Figure 12: Arbuscular mycorrhiza fungal root colonization percentage of paddy cultivars cultivated in control (100% RRF) and Test (Organic Inputs) plots; AM fungi of 3 replications per treatment (n = 3); a, b. letters at the column head indicate a significant difference at ($p < 0.05$) according to DMRT

Overall, our findings clearly show that AM fungi root colonization in the initial stage influenced insect pest resistance, plant growth, and PGY. Colonization of roots with AM fungi can alter interactions with insects with positive, negative, or mixed effects (Prasad, 1993; Gange, 2001; Hartley and Gange 2009; Koricheva et al. 2009). Bernaola et al. (2018) showed that AM fungi inoculation with seeds increased the susceptibility of paddy to two other pests: a defoliating insect, and a fall armyworm (*Spodoptera frugiperda*), and soilborne pathogens, sheath blight of rice (*Rhizoctonia solani*). The ability of AM fungi to change the resistance of paddy plants opens new avenues for understanding mechanisms underlying susceptibility to insect pests and soilborne fungi. Consequently, mycorrhiza-induced susceptibility in paddy should be given greater consideration than in other crop systems (Miozzi et al., 2019; Simon et al., 2017).

Stimulation of plant growth and yields in response to AM fungi have additionally been reported (Prasad, 2021a; Prasad et al., 2005; Prasad et al., 2019). A global meta-analysis of field studies with major cereal crops as well as wheat, maize, rice, soybean, and sorghum demonstrated an overall 16% increase in yield because of inoculation with AM fungi (Prasad et al., 2005; Meghavanshi et al., 2008; Zhang et al. 2019; Prasad et al., 2019; Prasad, 2021a, c; Prasad, 2022a, b). Although the impact of AM fungi on yields can be variable, with the environmental and crop-specific effects, these meta-analyses still highlight the importance of integrating AM fungi in sustainable agriculture to increase the yield production of cereal crops (Pellegrino et al. 2015; Zhang et al., 2019).

4. Conclusions

Organic inputs treated paddy is chemical-free and farmers can sell organic produce paddy at a 10-25% higher price. Considering the current observations of the paddy performance in organic inputs treated conditions, it is concluded that this technology is cost-effective, a better substitute for chemical fertilizers, and provides higher quality PGY. This approach may be appropriate for marginal farmers and paddy growers with their low inputs farming practices. Further, the improvement towards soil health can be an extra advantage to the farmers.

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