IMPACT OF INORGANIC, ORGANIC AND BIOLOGICAL SOURCES OF NUTRIENTS ON RICE PRODUCTIVITY AND SOIL FERTILITY IN AN INCEPTISOL SOIL OF TAMIL NADU

THESIS SUBMITTED FOR THE AWARD OF THE DEGREE OF

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DECLARATION

I, hereby declared that the presented work in the thesis entitled **“IMPACT OF INORGANIC, ORGANIC AND BIOLOGICAL SOURCES OF NUTRIENTS ON RICE PRODUCTIVITY AND SOIL FERTILITY IN AN INCEPTISOL SOIL OF TAMIL NADU”** in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision Name of supervisor: Dr. Kamini Kumar, Professor, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, India and Name of co-supervisor: Dr. K. Arivazhagan, Professor, Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Tamil Nadu, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

S. Ah

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled **“IMPACT OF INORGANIC, ORGANIC AND BIOLOGICAL SOURCES OF NUTRIENTS ON RICE PRODUCTIVITY AND SOIL FERTILITY IN AN INCEPTISOL SOIL OF TAMIL NADU”** submitted in fulfillment of the requirement for the reward of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Soil Science and Agriculture Chemistry, School of Agriculture is a research work carried out by **Arun Kumar S**, Registration No.12008598, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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ABSTRACT

The present research was completed in 2022 & 2023 in Tamil Nadu at the latitude of 11.395224° N and longitude of 79.720181° E that is a tropical climate. Soil texture is clay loam with pH-8.1, EC-0.7 dSm^{-1} and the available NPK status of 186.3, 23.2 and 192.25 kg ha^{-1} respectively during 2022; pH-8.0, EC-0.7 dSm^{-1} & available NPK 198.6, 24.3 and 201.2 kg ha^{-1} respectively during 2023. Nine treatments in the field experiment *viz.*, T_1 – Control, T_2 - 100% RDF Alone, T_3 - 125% RDF Alone, T_4 - 100% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_5 – 100% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria, T_6 – 100% RDF + Coirpith Compost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_7 – 125% RDF + Press mud @ 10 t ha^{-1} +2% Zinc Solubilizing Bacteria, T_8 – 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria, T_9 – 125% RDF + Coirpith Compost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria. The experiment conducted in RBD i.e., Randomized Block Design and three replications. ADT 37 was the test variety of the rice crop.

The growth and yield characteristics like leaf area index, plant height, dry matter production, number of productive tillers $hill^{-1}$, number of panicles m^{-2}, chlorophyll content, straw yield, number of grains $plant^{-1}$ and the yield of grain in rice were significantly affected by treatments 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria, followed by 125% RDF + Press mud @ 10 t ha^{-1} +2% Zinc Solubilizing Bacteria.

Yields in grain and straw were much higher in crop raised along application of different sources of nutrients over control. Among the nine treatments, the treatment of 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria recorded maximum yield of straw and grains. The control yields for grain and straw were the lowest.

The dry matter production was also higher with 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria. Less Dry matter yield was recorded under absolute control.

Higher values in quality of rice was also registered in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria (T_8) and in it is comparable with 125% RDF + Press mud @ 10 t ha^{-1} +2% Zinc Solubilizing Bacteria (T_7). The less values were recorded in control plot.

Among the treatments, 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria treatment registered significantly higher nutrient uptake over other treatments and the control.

The post-harvest soil status of NPK, Zn and organic carbon and B:C ratio was higher in 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria (T_8). The least values recorded in control (T_1).

Based on present experimental results, cultivation of rice in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} +2% Zinc Solubilizing Bacteria (T_8) was found to be agronomically viable, practice for augmenting higher productivity, B:C ratio and sustainable yield.

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I dedicate this thesis to my lovable ***Parents****,* ***Supervisor*** *&* ***Co-Supervisor.***

S. Arun Kumar

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LIST OF ABBREVIATION USED

%	**-**	Per cent
@	-	At the rate of
°C	-	Degree Celsius
ADT	-	Aduthurai
C:N	-	Carbon:Nitrogen
CD	-	Critical Difference
cm	-	Centimeter
CPC	-	Coir Pith Compost
DAS	-	Days after sowing
DMP	-	Dry matter production
dSm^{-1}	-	Deci siemen per metre
EC	-	Electrical conductivity
et al.	-	Co workers
Fig.	-	Figure
g	-	Gram
ha	-	Hectare
i.e	-	That is
K	-	Potassium
K/K_2O	-	Potassium
$kg\ ha^{-1}$	-	Kilogram per hectare
$km\ hr^{-1}$	-	Kilometre per hour

LAI	-	Leaf area index
m ha^{-1}	-	Million hectare
mm	-	millimetre
MMT	-	Million metric tonnes
N	-	Nitrogen
N	-	Nitrogen
P/P_2O_5	-	Phosphorus
PM	-	Press mud
ppm	-	Parts per million
RBD	-	Randomized Block Design
RDF	-	Recommended Dose of Fertilizer
RH	-	Relative humidity
SEd	-	Standard error of deviation
t ha^{-1}	-	Tonnes per hectare
T	-	Tonnes
VC	-	Vermicompost
Viz.,	-	Namely
Zn	-	Zinc
ZSB	-	Zinc Solubilizing Bacteria

CHAPTER I

INTRODUCTION

The staple food of billions of people worldwide is rice. Since rice cultivation occupies 9% of the planet's arable land and maybe the ancient cultivated grain i.e., of (10,000 years), this is the source of main nutrition for billions, of the world's people and the greatest crop that used the land for food production. 21% of the calories and 15% of the protein consumed by humans worldwide each year comes from rice. In Asia, where it makes up between 50 and 80 percent of daily caloric intake for the impoverished, rice is a particularly significant source of calories. China, India, and Indonesia together account for 90% of global rice production contributing most in the world. Around 6 to 7 percent of rice’s production in the world is sold on the international level market. The biggest exporters worldwide are Thailand, Vietnam, China, and the United States. United States, with 80% of that harvest coming from Arkansas, California, and Louisiana. About 85% of the rice grown worldwide is consumed directly by people. Other rice applications include cereals, snacks, brewed drinks, oil, syrup, flour & rituals of the religions. Rice provides 66 to 70% of the body calorie intake of consumers (Barah and Pandey, 2005; Awal and Siddique, 2011).

There are two domesticated and 22 wild rice species, all of the genus *Oryza*. *Oryza sativa* and *Oryza glaberrima* are the two domesticated spp. Worldwide, *Oryza sativa* is farmed, although *Oryza glaberrima* has just recently (around 3500 years) been domesticated in West Africa. While there are many other environments and methods for growing rice, the process of submerging rice in water is the one that is most frequently employed globally. Only rice can grow in standing water for extended periods. About 57% of rice is farmed in irrigated lands, 25% of rice grown in lowland receives rainwater, 10% on the uplands, 6% in deep water & 2% in marshes. An aquatic biodiversity field exists in the flooded rice that is a living place for a variety of animals and plants, including plants, fish, frogs, crustaceans, reptiles, and mollusks, many of which may be utilized as a source of protein for the underprivileged and malnourished populations of low- and middle-income nations that grow rice. On a global basis, rice provides 21% of the energy and 15% of the protein requirement of the human population (Maclean *et al.*, 2002; Depar *et al.*, 2011).

Because rice has many varied properties and can be cultivated in various conditions, certain varieties are more well-liked in specific parts of the world than others. Short, medium, and long grain sizes of rice are all possible. Additionally, it may or may not be waxy (sticky). Some types of rice are thought to be fragrant. Globally no food grain is more important than rice from a nutritional food security or economic perspective (Smith and Dilday, 2003).

According to the Ministry of Agriculture & Farmers Welfare, India is expected to produce a record-breaking 102.36 million tonnes of paddy in the *kharif* season of the 2020–21 crop year due to favorable monsoon rainfall and acreage. The 2019–20 crop year's *kharif* season had a production high of 101.98 million tonnes of rice. The first early projections of significant *kharif* crop output were made public by the Union Agriculture Ministry.

In Tamil Nadu during the years 2018–19, 61.32 lakh metric tonnes of rice are produced across an area of 17.21 lakh hectares. In the year 2019-2020, Paddy is cultivated 63.08 million metric tonnes of output are produced across 18.04 million hectares, and during 2020-2021, it is programme to cover area about 18.75 m ha^{-1} producing 75 million metric tonnes.

By having a positive impact on the chemical, biological & physical characteristics of the soil, organic manures—valuable byproducts of agriculture and related industries—help plants thrive. The availability of nutrients is significantly impacted by organic manures as well. There is much evidence supporting the many advantages of organic manures. Organic manure has a profound influence on enhancing soil's biological, chemical, and physical qualities enhancing the productivity of field crops. As organic matter determines the fertility and nutrient status of soil, the maintenance of soil organic matter around 2.5 to 3.0 percent is desirable for satisfactory crop growth (Debnath *et al.*, 2014).

The vermicomposting is made up of earthworm excretions, which can help the soil's health and nutritional condition. Through the process of vermiculture, various kinds of biodegradable wastes, including those from farms, markets, agro-based companies, and animals, are transformed into full of nutrients vermicompost as they travel through the worms' guts. The earthworms (*Eisenia foetida*) are utilised in this context to function as biological agents that ingest those wastes and deposit excrement in the vermicomposting process. Vermicompost typically comprises 1.5 – 2.2 % N, 1.8 – 2.2 % P and 1 – 1.5 % K and micronutrients are present, between 9.15 and 17.98 % of the total carbon is organic. Due to its high concentration of humus, micronutrients, nitrogen-fixing and phosphate-solubilizing bacteria, actinomycetes, and the growth hormones "auxins," "gibberlins," and "cytokinins," earthworm excrement is a highly nutritious organic fertiliser. In comparison to ordinary compost and artificial fertilisers, vermicompost promotes growth by 50–100% and 30–40%, respectively (Sinha *et al.,* 2010).

A highly significant based-agro industry India in is the production of sugar, which has a significant positive impact on the nation's economic growth. Cane crushing with a daily capacity that ranges from 800-10,000 tons day^{-1}, of the nation's 579 companies in sugar, generates 19.0 million tonnes of white sugar. These sugar factories also release a significant number of byproducts in addition to the sugar. Press mud, molasses, and bagasse total 7 million tonnes, 7.5 MT, and 45 MT, respectively, in terms of a yearly byproducts production in these sectors (Murthy and Chaudhari, 2009)

Press mud, a byproduct of the sugar industry, is another source of nutrients that may be used in composting. In sugar distillery complexes, the practice of composting sugarcane press mud is prevalent, and more than 100 units have used this strategy in India. As an organic fertilizer, the item is packed and offered for sale. A pressmud bio compost has 1.07% of N, 2.02% P, 1.05% K, and 0.39% S as major nutrients and micronutrients. Press mud added not only increases the nutrient ‘P’ but also increases the availability of fertilizer P. It is generally known that adding organic matter to soil may improve soil fertility and hence increase crop output. Thus, applying press mud biocompost to the soil might restore nutrients, improve soil fertility, and reduce the cost of fertilizer while also assuring safe waste disposal. The inclusion of organic material such as press mud has been advocated to improve soil organic matter, structure, water infiltration, and decrease pH (Ibrahim *et al.,* 2012).

Worldwide production of coconuts is projected to be 5.74 MMT. Coconuts (*Cocos nucifera*) are produced in India in quantities of 0.77 MMT, or around husk fibrous in an amount of 0.35 million metric tonnes. Pith from the coir industry makes up around half of the husk. With a C: N ratio of 112:1, coir pith has a very low nitrogen concentration. Any organic waste should not have a C: N ratio this high since it will harm the crops when used as organic manure in agricultural operations. There isn't an economically practical way to get rid of coir pith. The cost-effectiveness of coir pith compost for use in landscaping has been established. Microbial degradation of coir pith is considered to be a safe, effective, and environmentally friendly process which may reduce the time for lignin degradation (Ganesh and Suresh Kumar, 2016).

High costs and a lack of readily available big volumes of organic manure are two issues with organic farming. Composted coir pith is one of the many organic agricultural wastes that have a great deal of potential for supplying crops with additional nutrients. To in order enhance a physical state and moisture soil as a status, composted coir pith plays a crucial role. As a result, it may be utilised as a useful mulch and boost crop yield (Savithri and Khan, 1994).

As a result of their interaction with plant roots and the exudates those roots produce that attract chemotherapy, ZSBs are renowned for their ability to solubilize zinc effectively (Shakeel *et al.*, 2015). Even while ZSB contains a variety of advantageous traits that support plant development, this also entails competition with other bacteria. This may lead to consistent bacterial colonization of plant roots. When ZSB is applied to rice seedlings, information on its root colonization on rice at various zinc rates may be obtained.

Hypothesis of research

Most of the previous research work carried out in rice with inorganic nutrients alone or organic nutrients alone or inorganic with organic nutrients or organic with biological nutrients or inorganic with biological nutrients. This research work examine the performance of rice by the combined effect of inorganic, organic and biological sources of nutrients. Thus it increase the growth, yield, quality, nutrient uptake of rice, post harvest fertility status of soil and B:C ratio.

OBJECTIVES

- To study the effect of inorganic fertilizers and organic manures along with zinc solubilizing bacteria on the growth and yield of rice
- To assess the effect of inorganic fertilizers and organic manures along with zinc solubilizing bacteria on the quality of rice
- To evaluate the effect of different combinations of the inorganic fertilizers and organic manures along with zinc solubilizing bacteria on the nutrient content and uptake by rice
- To study the effect of inorganic fertilizers and organic manures along with zinc solubilizing bacteria on the post-harvest fertility status of the soil

CHAPTER II

REVIEW OF LITERATURE

2.1 NPK in rice

2.1.1. Impact of NPK to yield & growth of rice

Alam *et al.,* (2010) the research was undertaken to examine how rice responded to nitrogen applications to the soil and the leaves, and it was found that these applications had a major impact on the crop's growth and production. The yield of grain maximum produced was by using 262 kg of urea per ha^{-1} of soil (5.34 t ha^{-1}).

Bhamanyar and Soodaee Mashaee (2010) stated that fertilizing with N and K significantly improved, biological yield, number of tillers, percentage of hollow grains, number of grains panicle^{-1}, plant height, panicle length, grain yield, percentage of hollow grains, and panicle length. The potassium was applied at a different rate such as 0, 30, and 60 kg ha^{-1} by the form of potassium chloride (60 percent K_2O).

Islam *et al.,* (2010) carried out a field study using four genotypes and P levels of 0, 5, 10, 20 and 30 kg ha^{-1} of P. The results revealed that P rates did not differ among genotypes in are T Aman season and significant differences existed by the Boro season. As grain production was considerably boosted as that usage of 10 kg ha^{-1} as P, but differences in grain yield across genotypes were not present at 20 and 30 kg ha^{-1} as P.

Mannan *et al*., (2010) used numerous Basmati cultivars in conducted research at Bangladesh Rice Research Institute (BRRI), and discovered that adding nitrogen of 75 kg N ha^{-1} improved straw production, spikelet sterility, length of panicles, tiller number, number of panicles, and plant height.

Zhao *et al.*, (2010) conducted field experiments to determine the impacts of varying nitrogen doses on rice yield and nitrogen utilization and concluded that SRI (System of Rice Intensification) increased rice yield & nitrogen uptake as compared to TF (Traditional flooding).

Chaudhary *et al.,* (2011) a study found that the maximum grain production (4.12 t ha^{-1}) to be attained with 75% of the recommended nitrogen dosage (RDN) and 25% N from Dhaincha.

Islam *et al.,* (2011) found that urea super granules and prilled urea did not provide higher values in grain yield (7.47 t ha^{-1}) compared to NPK briquettes.

Dastan *et al.,* (2012) noticed that the effect of nitrogen on the morphological characteristics of rice in north India and noticed that the growth and yield of rice increased linearly as N rates increased from 0 (4350 kg ha^{-1}) to 150 kg ha^{-1} of N (6063 kg ha^{-1}).

Diana Samira *et al.,* (2012) noticed that use of NPK had a significant impact on 1000 grain weight, total number of grains panicle^{-1}, plant height, percentage of filled grain panicle^{-1}, number of panicles clump^{-1}, percentage of unfilled grain, number of tillers 35 and 45 DAP and grain yield per hectare.

Dinesh Sharma *et al.,* (2012) studied in relationship between nitrogen and phosphorus rates and basmati cultivar yields noticed to have higher the growth of all crops was considerably enhanced by NP levels in growth characteristics and yield attributes. Pusa Basmati-1121 provided a grain yield maximum at (4870 kg ha^{-1}), and using 92 kg N and 45 kg P2O5 was determined to be ideal.

El-Refaee (2012) noted that usage at 100% NPK combined in straw compost of rice at 2 t ha^{-1} were comparable to 100% NPK application and 75% NPK combined to the straw of compost in rice at 2 t ha^{-1} and improved effectively LAI, grain dry matter output, plant height & other characteristics.

Hasamuzzaman *et al.,* (2012) research was done on how hybrid rice will react to various amounts of N and P. The findings demonstrated that the effects of nitrogen and phosphorus caused a considerable variance in yield contributing traits and yield. Phosphorus application at 50 kg P_2O_5 ha^{-1} got the highest grain yield (7.85 t ha^{-1}).

Mahyar Germai and Ramesh (2012) researchers examined the impact of nitrogen and silicon rates on rice yield components and concluded that rice growth and yield rise with Si and N rates, with the best yield of 33.66 g hill^{-1} being attained with 100 ppm of N and Si.

Sarwar (2012) reported that when nitrogen and phosphorus were added to K fertilisation, rice yield tended to be particularly responsive to plant K levels. This treatment combination was the most effective for generating greater yields of all treatments.

Yusef Tabar (2012) reported that results on conduct of experiment to research the impact of N & P to yield and growth to the rice which showed application at 90 kg P_2O_5 ha^{-1} & 130 kg N ha^{-1} registered the highest value in growth and yield of rice.

Zhang *et al.,* (2012) investigated response of rice to P application under two cultivation methods and noticed that as P level increased grain yields of both upland and paddy under dry condition (DC) over control.

Amod Kumar Thakur *et al.,* (2013) observed that grain yield with System of Rice Intensification (SRI) is more at the rate of 49% compared with transplanted flooded rice (TFR), increased yield with each dosage of N applied.

Diana Samira *et al.,* (2013) reported increased total N by 22.22%, available P by 12.18%, available K by 17.50%, and organic C by 56.69% compared to initial planting when NPK fertilizer and charcoal residue were used.

Lungumuana *et al.,* (2013) noticed that effect of organic manures & P fertilizer to rice yield cv. IR 36 in Alfisols. They concluded that grain and straw yield because of several treaments that varied from 2.25 - 4.65 t ha^{-1} & 2.05 - 4.33 t ha^{-1}. Adding P fertilizer and vermicompost produced the highest rice yield.

Morteza Siavoshi *et al.,* (2013) found that plants fed with a mix of chemical fertilizer and 1.5 tonnes ha^{-1} organic fertilizer had the highest grain production in 2009 (4662.71 kg ha^{-1}).

Pramanik and Bera (2013) investigated how hybrid rice responded to fertilizer nitrogen addition & that observed are 200 kg N ha^{-1} treatment higher result rice growth & production than other levels as N. The percentage improve is grain yield was 72.5, 44.4, 23.8 and 5.1% over N_0, N_{50}, N_{100} and N_{200} kg ha^{-1} respectively.

Sirisena *et al.,* (2013) noticed response in rice to use as phosphorus in Plonnaruwa district low to country dry area in Sri Lanka by adding P fertilizer every year or alternate year. The findings demonstrated that using P fertilizer @ 48 kg ha^{-1} one season per year is sufficient to maintain the present yield level.

Thakur *et al.,* (2013) investigated that with different doses of nitrogen in System of Rice Investigation (SRI) grain yield was 49% higher as compared to Traditional Flooding Rice (TFR).

Alemayehu Balcha (2014) performed an experiment in Ethiopia to look at the impact of phosphorus delivery on yield and phosphorus efficiency across rice cultivars. The results showed that if too much phosphorus was supplied, it might end as least grain yield growth & less phosphorus restore.

Bi *et al.,* (2014) reported that the order of fertilizers effects at grain yields were N<NK<NP<NPK<2NPK, with the administration in P fertilizer increasing rice production while also enhancing yield stability.

Deshrath Sing and Anil Kumar (2014) examined how N sources affected rice's growth and output in the kharif seasons of 2010 and 2011 in Uttar Pradesh. The findings indicated that using 100% N as (Neem coated urea) gave significantly higher tiller hill^{-1} (13.6, 13.9), grain yield (50.49, 49.85 q ha^{-1}) & straw yield (83.75, 81.0 q ha^{-1}) in 1st & 2nd year.

Dileep Kumar *et al.,* (2014) it was shown that adding 10 mg kg^{-1} potassium humate, combined in 100% NPK fertilizers and 12.5 mg kg^{-1} zinc sulphate, considerably elevated height of plant, number of tillers, height and length of panicles, test weight, yield of straw, and yield of rice.

Husan *et al.,* (2014) noticed as use of Urea Super Granules (USG), Prilled Urea (PU) individually with mixing a manure of poultry or dung of cow considerably boosted a growth and production of rice and Nutrient Use Efficiency (NUE) above control. This was according to research on nitrogen usage yield of rice & accuracy as impacted to Urea Super Granules and Prilled Urea (PU) along with absence of manure. Urea Super Granules (USG) with poultry manure powdered the highest grain and straw yield. Further Urea Super Granules (USG) along with poultry manure also is proved Nutrient Use Efficiency (NUE).

Iqbal *et al.,* (2014) studied how various rice varieties react to N rate in rice-rice sequence and reported that all varieties responded to N rates significantly in both seasons. Among the rice varieties BRRI dhan 49 showed maximum growth and yield (5.42 t ha^{-1}). At two seasons, maximum grain yield was noticed (8.28 t ha^{-1}) by using 110 kg N ha^{-1}.

Mandana Tayefe *et al.,* (2014) at Gulian Province, Iran, researchers examined the impact of nitrogen on yield components and rice yield between 2008 and 2009. A proven result as yield both components & rice yield increased linearly with N levels, with 90 kg N ha^{-1} producing total grains panicle^{-1} (103.8), panicles m^{-2} (235.89), tiller m^{-2} (250.20), grain yield (3662 kg ha^{-1}), highest biomass (8366 kg ha^{-1}) & plant height (127.98 cm) values.

Maryam Jalali Moridani and Ebrahim Amiri (2014) did research to look at how rice yield characteristics will be affected by nitrogen and potassium fertilizer. Nitrogen (0, 30, 60, and 90 kg ha^{-1}) and Potassium (0, 75, 150 kg ha^{-1}) and made up the experimental variables. The findings showed that the interaction between nitrogen and K was substantial and influenced the paddy yield as measured at the rate of tillers and filled grains panicle^{-1}.

Rao *et al.,* (2014) in the Kharif seasons of 2005–10, 2010–11, and 2011–12, researchers in Andhra Pradesh evaluated the impact of N dosages on the yields of promising rice cultivars in high-altitude areas. The results revealed that among the rice varieties, RGL 2257 recorded the highest growth and yield compared to RGL 2332 and MTU 7029. The highest growth and yield were noticed at 120 kg N ha^{-1}.

Rithesh Sharma *et al.,* (2014) notice a response a basmati rice cultivars to graded nitrogen levels under transplanted conditions and observed that basmati rice varieties responded significantly to N addition in both years (2012 and 2013). A more yield of rice was noticed by 120 kg N ha^{-1}.

Sanjivkumar and Malarvizhi (2014) researchers who used the tracer technique to study the differential response of phosphorus utilization efficiency in rice found that certain genotypes of rice have the capacity to use both the available and non-available by releasing various organic acids in the root region, plants can solubilize phosphorus in its insoluble state and thereby increase phosphorus utilization efficiency.

Sekhar *et al.,* (2014) in Andhra Pradesh, researchers looked at how planting practices and nitrogen sources affected rice output during the 2011 *kharif* season. According to their findings, the combination of 100% N through fertilizer and 25% N through FYM resulted in the maximum growth and yield of rice on various management practices of nitrogen.

Zacharie Segda *et al.,* (2014) studied nitrogen use efficiency by NERICA varieties in Burking FeSo and noticed that without N application, NERICA ensured a good yield when correlated with control. It was effective difference yield among varieties due to N application. Based on NUE, NERICA-L-41, NERICA-L-20 and NERICA-L-19 were efficient varieties.

Alhassan *et al.,* (2015) reported irrigation of effect deficit and N fertilization by the grain of yield rice in Nigeria. The results showed that grain yield and straw yield were higher in 4-day irrigation intervals & 150 kg N ha^{-1}. Higher agronomic nitrogen use was noticed on the above treatment.

Chhay Ros *et al.,* (2015) studied that found using N+P fertilizer in the nursery resulted in more nutrient-dense seedlings that had more vigor and survived submersion. These seedlings also grew better after transplanting whether or not they were under drought or nutritional stress, increasing rice yields.

Dawood Barari Tari and Ebrahim Amir (2015) noticed an impact by N rates to yield and Nutrient Use Efficiency (NUE) in irrigated rice in Iran. A result confirmed that Nutrient Use Efficiency (NUE) and grain yield was effectively affected by different N-splitting applications. Applying 120 kg N ha^{-1} at 25% basal + 37.5% at panicle initiation stage recorded the highest grain yield and Nutrient Use Efficiency (NUE).

Fabio Luiz Checchio Mingotte *et al.,* (2015) examined the relationship between nitrogen topdressing and upland rice varieties' agronomic effectiveness and grain quality. The results revealed that there existed differential grain yield and agronomic efficiency among upland rice N of function as variety application & Campo cultivars followed by BRS, Monarca, and BRSMC Curinga were better cultivars.

Faisal Nadeem *et al.,* (2015) found that the impact of Basmati rice on time of P usage with a combination of zinc under anaerobic conditions. They reported that maximum growth, yield components, and rice yield by application of P and Zn during the last ploughing and minimum were noticed when P was applied at 20 DAT.

Hoang Mai Thao *et al.,* (2015) reported when the level of nitrogen, phosphorus and potassium was increased, the grain yield also increased. It was also found that the N3P3K3 compound produced the highest grain yield of rice.

Hun *et al.,* (2015) investigated how changing nitrogen rates and precipitation patterns affected the yields of rice that was directly sown and watered. The study observed 120 kg N ha^{-1} generated a maximum grain production during the main season when the rice crop normally receives more rainwater and more nitrogen fertilizer. However, the best N rate is needed during the off-season, which is 200 kg N ha^{-1}.

Hossain *et al.,* (2015) studied how distinct phosphorus-solubilizing microorganisms and minerals affected rice yield and its yield components. They concluded that yield components and rice yield were maximum (699.9 g m^{-1} and 51.8% over control) in plots that received PSP and 83 kg P ha^{-1}.

Imdad Ali Mahmood and Arshad Ali (2015) studied the reaction of rice that was directly planted, P application & crop residue incorporated in saline-sodic soil and noticed that the incorporation of crop residue along with 80 kg P_2O_5 ha^{-1} caused a 22% increase in yield over control in both years.

Merkebu Getachew and Techale Birhan (2015) investigated the effects of time and N application ratio on rice development and yield in Jimma, South West Ethiopia. According to the findings, the maximum biomass production (3333 kg ha^{-1}) and grain yield (1079 kg ha^{-1}) were seen when N was applied at 25% at sowing + 50% at the active tillering stage and 25% at the panicle initiation stage.

Ochwoh *et al.,* (2015) showed an impact on phosphorus and nitrogen on grain yield in upland rice in Eastern Uganda & showed a combined usage like 150 kg N ha^{-1} & 25 kg P_2O_5 ha^{-1} got a maximum yield of grain.

Sarker *et al.,* (2015) placement deep the that found of the NPK briquette (2 2.4 g) boosted yield by around 10% while saving 37% N, 30% P, and 44% K compared to the recommended amount of fertilizer in the Boro season. For the T Aus and T Aman seasons, respectively, NPK briquette (1 3.4 g) increased rice output by 28% and 18% over the BRRI recommended rate of fertilizer while simultaneously conserving 26-39% N.

Sarmin Sultana *et al.,* (2015) field an out carried in the season of Aman to optimize dose growth on the nitrogen of ad of yield BRRI dhan 49 differed significantly to N rates. The optimized dose was found to be 90 kg N ha^{-1} which recorded the highest yield of grain (6.17 t ha^{-1}) & yield of straw (7.50 t ha^{-1}).

Bandaogo Almata *et al.,* (2016) studied the effect the Urea Super Granules (USG) and P application by rice in efficiency use and yield in Burkina Faso and observed that the use of Urea Super Granules (USG) 1.8 g in both seasons increased the yield. Similarly, P application significantly increased the grain yield. The highest rice yield was recorded in the Urea Super Granules (USG) (1.8 g) and P usage as 30 kg P ha^{-1}.

Bekele Anbessa Fayisa & Getahun Dereje Welbira (2016) Ethiopian researchers examined the N & P effect fertilizer rates by rice rain output in the Kamashi Zone of the

Benshal-Jul-Gumuz area. With higher doses of N & P, they saw that yield and growth dramatically increased. When 46 kg N and 10 kg P were applied per hectare of land, the amount of grain production that increased over control was 16.2% and 32.5%, respectively.

Mahbubul Haque Imrul *et al.,* (2016) studying the effects of nitrogen and phosphorus on the development and yield of BRRI dhan 57 led researchers to the conclusion that 120 kg as N and 35 kg as P per hectare resulted in the greatest growth, yield components, and grain yields of 4.95 t ha^{-1}, 5.39 t ha^{-1}, & 10.34 t ha^{-1}, respectively.

Kalala *et al.,* (2016) studied that depending on nutrient essential levels in the soil, the response of rice to fertilization with phosphorus and potassium Kilombera valley and observed that grain yield increased significantly for ric grown in 8 out of 10 soils tested due to application to K and P. An optimum in 40 mg P & 400 mg K kg^{-1} as optimum rates of P and K fertilization.

Koffi Djaman *et al.,* (2016) observed that at Ndiaye, rice production ranged from 3.3 to 8.6 Mg ha^{-1} following the application of fertilizer, N-P, and from 3.5 to 8.8 Mg ha^{-1} when applying fertilizer, make sure to N-P-K. When N-P fertilizer was used in Fanaye, rice output ranged from 3.7 to 8.6 Mg ha^{-1} and from 3 to 10.3 Mg ha^{-1} when N-P-K fertilizer was used.

Muhammad Asif Kamal *et al.,* (2016) demonstrated that the two rice hybrids (PHB-71 and Leader-555) produced more yield and associated parameters, including 1000 grain weight, harvest index, straw yield, number of spikelets $spike^{-1}$, grain yield & productive tillers m^{-2} when 162-120-72 kg NPK ha^{-1} was applied.

Ashiana Javeed *et al.,* (2017) demonstrated that at applied was N when a graded dose to 60 kg ha^{-1}, it greatly elevated a growth parameters (dry matter accumulation & plant height) well to the production of grain and straw.

Djomo Sime Herve *et al.,* (2017) reported that fertilizer N-P-K (20-10-10) offered a greater yield than fertilizer N-P-K (23-10-05) in the same variety while fertilizer N-P-K (20-10-10) gave a superior growth with the right dosages compared to all the varieties tested in this study. Utilizing fertilizers in the right amounts will greatly increase rice output and promote excellent development.

Muhammad Yousaf *et al.,* (2017) revealed that throughout the research sites, crop yields improved by 19–41% (for rice) and by 61–76% (for rapeseed) rice–rapeseed sequence over a 2 years of NPK fertilization as opposed to PK fertilization. According to an order of response of yield, fertilization, N insufficiency is more at a restrictive factor rice-rapeseed sequence in a, continued by K & P shortage.

Vinod Kumar *et al.,* (2017) according to reports of higher grain and straw yields (45.04 and 72.0 q ha^{-1}, respectively) was got when 75% RDF was used as inorganic fertilizers combined with green manuring of dhaincha.

Anjana J. Atapattu *et al.,* (2018) direct seeded rice output and grain quality were seen to increase when K fertilizer was applied at a rate 50% higher (18.75 kg K ha^{-1}) than the advised rate at the time of heading and harvested at optimal maturity, which is 5 days later than the advised period.

Gill and Aulakh (2018) found that when FYM and 1% recommended nitrogen (RN) were applied together, the maximum grain production (34.90.54 q ha^{-1}) was attained.

Singh *et al.,* (2018) observed that by applying N @ 150 kg ha^{-1} & 120 kg ha^{-1} than rate higher a control, growth plant's (including a number of tillers m^{-2} & plant height) & yield (including straw & yield) both rise noticeably.

Abdul-Basit Iddrisu Abdul-Rahman (2019) found that data gathered at 7 and 9 weeks following planting indicated that plant height was positively influenced by fertilizer levels and variety. At nine weeks following planting, fertilizer amount and variety also had a good impact on the leaf chlorophyll.

Betty Natalie Fitriatin *et al.,* (2019) conducted a pot culture experiment and observed that 100% NPK fertilizers recorded higher values in productive tillers (37.17), panicle length (2.15 cm), and weight (45.38 g pot^{-1}).

Budiono *et al.,* (2019) a novel NPK fertilizer with the composition 15-15-15 and 300 kg ha^{-1} urea has been observed to respond well to the vegetative and generative development of rice plants, with 250 kg ha^{-1}.

Masni and Wasli (2019) noticed that the red rice variety (MRM 16) had the highest yields in (35 kg ha^{-1} P, 40 kg ha^{-1} K & 60 kg ha^{-1} N).

Oyange *et al.,* (2019) a considerable increase in plant height, tiller number, grain weight, and spikelets $panicle^{-1}$ was seen of application the of result as inorganic N. Spikelets panicle^{-1} & grain weight effectively was affected the between interaction the by treatment as *Azolla* and inorganic N.

Oyange *et al.,* (2019) has demonstrated that the application of nitrogen as inorganic effectively increases grain yield, panicle length, number of panicle m^{-2}, neck node, plant height, and tiller counts.

Senthilvalavan and Ravichandran (2019) found that the use of NPK fertilizer in conjunction with 12.5 t ha^{-1} FYM and biofertilizers, namely Azospirillum and PSB, as a soil treatment demonstrated its advantages versus alternative treatments in relation to the physiological & growth characteristics of rice.

Novriani *et al.,* (2020) reported that applying NPK fertilizers and rice straw-derived trichocompost had an impact on growth & production of henic strain rice grown in upland arid areas. In comparison to other treatments, the use of NPK fertilizer at a dose of 400 kg ha^{-1} and trichocompost fertilizer made from the straw of rice at a dose of 30 t ha^{-1} tends to increase rice production by 4.6 kg plot.

Singh *et al.,* (2020) observed that 150% of the recommended dose of fertilizer (RDF) was found to be promising and also exhibited higher nutrient recovery efficiency and grain yield in the rice genotype IET 26692.

Umesh *et al.,* (2020) found that using the authorized amount of NPK coupled with green manuring resulted in the greatest improvement in rice grain and straw production.

Fitriatin *et al.,* (2021) found that applying biofertilizers @ amount 75 kg ha^{-1} + NPK @ amount 75% enhanced upland rice output by 164%.

Gharieb (2021) noticed that experiments have demonstrated that spraying NPK or N alone twice enhances a number of filled grains panicle^{-1}, panicle weight, panicle length, straw output, number of panicles hill^{-1}, grain weight, 1000-grain weight, and plant height.

Paiman *et al.,* (2021) study found that NPK Mutiara fertilizer might boost Ciherang rice's growth and production when planted in alluvial soil. According to the quadratic regression analysis, the highest grain dry weight per hectare was 4.26 t ha^{-1}, and the optimal dose of NPK Mutiata was reached at 656 kg ha^{-1}.

2.1.2. Impact of NPK in nutrient uptake, availability & quality of rice

Zhang *et al.,* (2009) noted that applying nitrogen fertilizer to the organic carbon (1.8%) over control.

Alam *et al.,* (2010) was found that which had the most total N absorption by T_2 (282 kg urea ha^{-1}) while the T_1 control had the lowest total N uptake.

Islam *et al.,* (2010) revealed that in a rice crop, the recommended fertilizer dose produced the maximum K absorption by grain and straw and the lowest by control.

Limei Zhao *et al.,* (2010) claimed that SRI allowed for greater agronomic N usage efficiency to be attained at a comparatively moderate N fertilizer rate (80 kg ha^{-1} N).

El-Refaee (2012) reported that the using a composted straw of rice & 100% NPK at a rate of two t ha^{-1} greatly advanced protein & N-uptake & was comparable to the applications of 100% NPK and 2 t ha^{-1} + 75% NPK straw rice compost.

Kumar *et al.,* (2012) revealed that, compared to controls, fertilizer N enhanced the soil's availability of P (17.7 kg ha^{-1}), K (318.3 kg ha^{-1}) & N (242.8 kg ha^{-1}).

Quddus *et al.*, (2012) found that the use of increased the total N content of 130 kg ha^{-1} in T. aman rice.

Amod Kumar Thakur *et al.,* (2013) observed that the system of rice intensification (SRI) had considerably greater N use-efficiency and N-uptake factor of partial production through used N than the transplanted flooded rice (TFR).

Sarker *et al.*, (2013) was noted that treatment T_3 had the greatest average P uptake of (14.11 kg ha^{-1}), K uptake (108.5 kg ha^{-1}), N uptake (97.4 kg ha^{-1}) and whereas treatment T_8 (control) had lowest average N uptake (36.62 kg ha^{-1}), P uptake as (4.94 kg ha^{-1}), & K uptake (42.2 kg ha^{-1}). The outcome shown that combined fertilizer treatment increased the amount of total N absorbed by rice.

Kaur and Singh (2014) revealed that using organic manures either exclusively or in combination to conjunction for fertilizers as inorganic increased total N and its components by a significant amount.

Singh and Sharma (2014) noticed improved in N, P, K, Ca & Zn uptake by grain due to addition of 40 kg P ha^{-1} over control & also observed as N, P, K, Ca & Zn uptake of additionally 80 kg ha^{-1} Zn more of control 25 kg Zn ha^{-1}.

Hoang Mai Thao *et al.,* (2015) observed that further application of potassium increased grain protein content. It was also found that N3P3K3 compound produced the highest quality of rice.

Srilatha *et al.,* (2015) according to their reports, uneven fertilization caused available phosphorus depletion to be greater (3–5% from the original condition) than under control (94–95%). When fertilizer was applied at a rate greater than the ideal amount, the accessible phosphorus buildup was at its maximum (123% increase).

Muhammad Yousaf *et al.,* (2017) noticed that NPK fertilization was shown to result in the largest accumulations a N, P, and K. According the to study's findings, a major management tactic for increasing rice-rapeseed production and environmental safety is the administration of balanced nutrients via NPK fertilization.

Ashiana Javeed *et al.,* (2017) noticed that quality parameters viz. protein content and amylose content was significantly higher at $N_{60}P_{35}K_{20}$ kg ha^{-1}. Absorption in nutrients were also more by $N_{60}P_{35}K_{15}$ kg ha^{-1}.

Vinod Kumar *et al.,* (2017) showed that using 75% RDF as inorganic fertilizers in conjunction with green manuring of dhaincha resulted in the maximum absorption in phosphorous, potassium, and nitrogen through rice crop, and also the maximum revenue (Rs. 57648 ha^{-1}) and B:C ratio (1.45).

Gill & Aulakh (2018) observed further higher K, N & P were straw & grain in uptake obtained by the application of FYM + 50 % of N suggested.

Grace *et al.,* (2018) showed that the use of 120-30-90 kg ha^{-1} NPK fertilizer on variety Serendah Merah significantly increases the yield of grain (4.39 t ha^{-1}) & thousand grain weight value of 29.98 g.

Singh *et al.,* (2018) showed that when N was administered to an amount in 120 kg ha^{-1} + cow urine, the amount of nitrogen in plants (straw and grain) and its absorption were likewise determined to be at their highest.

Reshma Bora *et al.,* (2018) disclosed that applying the required fertilizer dosage of N120P40K40 + Znf to rice resulted in increased values for the content and absorption of all three nutrients—nitrogen, phosphorous, and potassium.

Budiona *et al.*, (2019) reported that new With a mix of 15-15-15, NPK fertilizer has a greater relative agronomic effectiveness (RAE) of 101% and an economic feasibility (B: C ratio) of 1.88 that mixed to 300 kg ha^{-1} urea.

Kyi Moe *et al.*, (2019) reported that increased N, P, and K contents of leaves, panicles, sheaths, and seeds when chicken manure and chemical fertilizer were used in a 50/50 ratio, leading to improved development and production in rice, according to a study.

Qihua *et al.,* (2019) observed that, in comparison to bio-organic fertilizer + conventional fertilizer, controlled-release fertilizer, conventional fertilizer, and no fertilizer, the protein content of organic fertilizer and conventional fertilizer treatment rose by 4.67%, 3.29%, 2.61%, and 22.66%.

Papia Biswas *et al.*, (2020) reported that the maximum protein yield obtained with 100% RDF + $S_{40}Zn_5B_{1.5}$ and lowest in control.

Umesh *et al.,* (2020) observed nutrient uptake by rice was also recorded highest under 100% NPK + green manure as moong treatment.

Fitriatin *et al.*, (2021) shown that increasing the amount of phosphorus available in the soil by applying 50 kg ha^{-1} of biofertilizer with 50% NPK.

Gharieb (2021) provided the highest values of benefit-cost ratio, net return, and gross return when 123.75 kg N ha^{-1} was applied in combination with two foliar sprays of NPK or 2% nitrogen.

2.2 Press mud in rice

2.2.1. Impact of press mud on yield & growth of rice

Kumarimanimuthuveeral and Sathiya (2014) conducted a field trial, results showed that adding press mud @ 12.5 t ha^{-1} + RDF + BF enhanced the growth metrics, such as production of dry matter, LAI, tillers number m^{-2} & yield, plant height, characteristics, number of filled grains panicle^{-1} (101.44 at Kuruvai & 103.4 at Samba), number of productive tillers m^{-2} (431.51 m^{-2} at Kuruvai & 413.98 m^{-2} in Samba) and grain yield (6610 kg ha^{-1} on Kuruvai & 6942 kg ha^{-1} at Samba).

Manmohan Sharma *et al.,* (2014) conducted investigation as evaluate impact of farm yard manure (FYM) and press mud combined with zinc sulphate inorganic fertilizer. In accordance with the results, treatment T_{10} which employed press mud 5 t ha^{-1} + 0 kg $ZnSO_4$ to generate maximum yield of straw (6.67 t ha^{-1}) outperformed the other treatments. The greatest plant height, tillers per hill, grains per spike, and rice production (4.85 t ha^{-1}) were all achieved with this treatment.

Kalaivanan and Omar Hattab (2015) found that the highest quantity of productive tillers, plant height, the quantity of tillers, and output of matter of the dry were all equal between the 2.50 t ha^{-1} and 1.25 t ha^{-1} treatments with fortified press mud manure. As a result, this may be advised to apply 1.25 t ha^{-1} of compost made from enhanced press mud as a base layer and the necessary residual nitrogen from the inorganic fertilizer top dressing as 3 repeats to rice crops in order to get the highest production throughout the (Kharif) season.

Kalaivanan and Omar Hattab (2016) reported that greater grain and straw yields were obtained than 1.25 t ha^{-1} in enhanced compost of press mud treatment, which was similar to 2.50 t ha^{-1}. When 1.25 or 2.50 t ha^{-1} of enriched press mud compost was applied to rice, the nutrient availability, growth, yield, and efficiency characteristics were equivalent.

Baradhan *et al.,* (2019) conducted a field experiment, it was discovered that the treatments are distillery granules @ 125 kg ha^{-1} + 75% NPK + press mud based organic manure @ 125 kg ha^{-1} + Azophos @ 2 kg ha^{-1}had higher yield component values than the other treatments, including seed yield, number of filled grains $panicle^{-1}$ and number of tillers $hill^{-1}$.

Jat and Singh (2019) found that the highest rice plant height of 122.9 cm at 90 DAT, that tiller number meter row $length^{-1}$ (77.53), as amount of chlorophyll at 39.67 SPAD at 60 DAT, the test weight (23.02 g), and the straw yield (72.78 q ha^{-1}), grain yield (47.78 q ha^{-1}), total number of grains $panicle^{-1}$ (45.03) were all got from 70% NPK + 15% N by FYM and 15% by press mud the results showed.

Marufa Sultana *et al.*, (2021) did a field study on rice, and the treatment that produced the best results was 50% fertilizers and 10 t ha^{-1} of altered manure (which was composed of press mud of sugarcane, oil cake of mustard, and municipal solid waste in a 5:2:3 ratio). This treatment produced the highest tillers hill^{-1} (17.7), straw yield (7.80 t ha^{-1}) panicle length (24.1 cm), plant height (100.7 cm), grains panicle^{-1} (84.2) & 1000-grain weight (25.3 g).

Parvendar Sheoran *et al.,* (2021) observed that changes in yield-related and physiological features resulted from applying press mud in the amount of 10 Mg ha^{-1}. Rice yields rose with press mud treatment by 15.8% on average in sodic soils and 18.9% on average in moderately sodic soils.

2.2.2. Impact of press mud in uptake of nutrient, nutrient availability & quality of rice

Marufa Sultana *et al.,* (2021) done the experiment test on rice, with the greatest results coming from the treatment including 50% fertilizers and 10 t ha^{-1} by altered manure (made up of press mud from sugarcane, solid waste by municipal and oil cake of mustard in a proportion of 5:2:3) in S, K, N and P contents of grain in rice (1.34%, 0.311%, 0.243% & 0.127%).

2.3 Vermicompost in rice

2.3.1. Impact of vermicompost in yield & growth to rice

Mirza Hasanuzzaman *et al.,* (2010) noticed as between the different treatments, T_5 (50% of prescribed NPK + Poultry manure at 4 t ha^{-1}) provided on greatest yield of grain in rice (4.79 t ha^{-1}), that were non significant for T_9 (Vermicompost at 8 t ha^{-1} + 50% of NPK), has produced a yield of a grain of 4.51 t ha^{-1}, respectively. Vermicompost was discovered to be the finest fertilizer when used alone.

Koushal *et al.,* (2011) in the first year of the experiment, it was found that applying the full yield of rice was significantly impacted by the required amount of nitrogen from urea; however, in the second year of the experiment, rice straw & grain yield in the paddy-wheat cropping system were significantly higher when the full suggested amount of urea-derived nitrogen and vermicompost were applied.

Tharmaraj *et al.,* (2011) found that the mixture of vermiwash and vermicompost had the highest values of certain plant parameters, including the root length of the plants, leaf length, number of leaves, and height.

Ramalakshmi *et al.,* (2012) shown by the use of 75% RDF N + 2.5 t ha^{-1} of vermicompost obtained yield is more of grain (5.85 t ha^{-1}) above inorganic alone treatment.

Bejbaruah *et al.,* (2013) found vermicompost in repeat usage improved a grain yield (3.91 t ha^{-1}), the number of total spikelets per panicle (142), NUE, the number of panicles (294 m^{-2}), the number of filled grains per panicle (138), and yield of grain (3.91 t ha^{-1}) that has when vermicompost was given in 3 or 2 successive application.

Khursheed *et al.,* (2013) revealed that using vermicompost in conjunction with NPK increased rice grain production by a significant 21.8% when compared to using neither manure treatment nor NPK alone.

Ranjitha *et al.,* (2013) showed that notably, the use of 50% of the recommended nitrogen through vermicompost + 50% of the prescribed nitrogen through urea resulted in the greatest straw & grain production of rice.

Thirunavukkarasu & Vinoth (2013) revealed a use in vermicompost in 2.5 t ha^{-1} maximum recorded values in plant height as 36.8 cm in the active tillering stage, 74.3 cm in the panicle initiation stage, number of tillers 16.5 in the panicle initiation stage, 9.6 in the tillering stage is active, number of productive tillers is 11.3 and number of filled grains is 99.

Kumar *et al.,* (2014) applied 125% RDF + 5 t ha^{-1} vermicompost, when correlated to control & individual nutrient sources, enhanced weight (13.02%), the length (23.12%), grain yield (31.15%), number of panicles (20.50%) and straw output (37.12%).

Deytarafder *et al.,* (2016) reported highest that length in panicle m^{-2}, rice grains panicle^{-1} were recorded at paddy gown plot receiving 75% Recommended Dose of Fertilizer (N: P: K=80:40:40 kg ha^{-1}) + vermicompost 5 t ha^{-1}.

Noraida Mohd Radzi *et al.,* (2017) observed that in rice the combined application of NPK fertilizer and organic manure vermicompost had significantly higher values on growth parameters for plant height (59.7 cm), number of leaves (85.9), number of tiller (17.5), fresh weight (995.3 g) and dry weight (394.6 g).

Rozalin Nayak *et al.,* (2017) reportedly produced the maximum grain production (3,570 kg ha^{-1}) when with neem cake, plus Enriched Micro-organisms Spray (twice), PSM (10 kg ha^{-1}) & Azospirillum (10 kg ha^{-1}) were used.

Taheri Rahimabadi *et al.,* (2017) showed that adding cow manure and vermicompost to a crop enhanced the amount of leaf chlorophyll and other aspects of grain output, including about values of a number of grain & viable tillers. The first year's grain yield, which was

3537 kg ha^{-1}, & the second year's which was 3958 kg ha^{-1} as grain yield, were both greatest as vermicompost 10 t ha^{-1} & 30 t ha^{-1} dung from the cow was used.

Kiriya Sungthongwises and Tidarat Tanpan (2018) observed that in rice application of vermicompost 6250 kg ha^{-1} had a considerable impact on the quantity of spikelets, average grains, and grain weight.

Manivannan and Sriramachandrasekharan (2018) reported that in *kharif* (2017, 2018), it was noted that the combination of vermicompost (50% N) and urea (50% N) produced the greatest growth metrics, including straw yield (6490, 6398 kg ha^{-1}) and a grain yield (2067, 5050 kg ha^{-1}).

Ramesh (2018) found that 50% N from urea plus 50% N from press mud vermicompost significantly increased the panicle length, number of tillers hill^{-1}, the leaf area index, the root biomass, plant height, the production of dry matter & yield parameters such, as full seeds crises & productive tillers m^{-2} are all factors in rice's development and output.

Ramesh *et al.,* (2018) observed that the maximum content of chlorophyll a (8.28±0.86 µg/g), chlorophyll b (16.71±0.67 µg/g, and total chlorophyll (24.93±1.53 µg/g) recorded in *Oryza sativa* on group 6 which received Phosphobacteria + Vermicompost – 25 + 25g/pot.

Sharada and Sujathamma (2018) a study that found that the rice variety DRR Dhan 39 produced statistically significant grain higher yields of 8713 kg ha^{-1}, straw yields as 9483 kg ha^{-1} by using 50% organic fertilizers of vermicompost, Jeevamrutha 5% and Panchagavya 3% and 50% inorganic fertilizer of NPK.

Honorio *et al.,* (2019) revealed that the treatment receiving 90-60-60 NPK + 1-ton vermicompost had the tallest mature plant height, the greatest number of fruitful tillers, the longest panicle length, the greatest number of filled grains, the highest yield per plot, and the highest calculated yield per hectare.

Manivannan *et al.*, (2020) found that the maximum grain yields (4615, 5078 kg ha^{-1}) & yield of straw (5847, 6746 kg ha^{-1}) were seen in soils that received 50% of their N from vermicompost and 50% from urea fertilizer.

Nowshin Laila *et al.*, (2020) according to their observations, the combination of Binadhan-13 and 50% less inorganic fertilizer than recommended + vermicompost at 3 t ha^{-1}

is produced greatest grain yield (4.04 t ha^{-1}), effective tillers $hill^{-1}$, straw yield (6.20 t ha^{-1}), , length of panicle, number of grains $panicle^{-1}$ & number of total tillers $hill^{-1}$.

Kamaleshwaran & Elayaraja (2021) stated that the highest values for grain yield (51.79 q ha^{-1}), harvest index (45.25%), straw production (64.29 q ha^{-1}), plant height (96.10 cm) & number of tillers m^{-2} (334.26) were seen in rice grown with RDF + 100% enriched vermicompost.

Shaoyi Ruan *et al.,* (2021) observed that fragrant rice seedlings treated with vermicompost exhibit enhanced root activity, root tip number, root volume, surface area, mean diameter, and root length by 12.42–27.82%, 15.04–38.65%, 12.64–23.12, 42.41-63.58, 18.62–24.95%, and 12.01-26.29%, respectively.

2.3.2. Impact of vermicompost in uptake of nutrient & rice quality

Tejada and Gonzalez (2009) showed that in comparing the application of vermicompost made from green forages repaired soils to that made from cow dung, it was found that the latter enhanced grain starch concentration (7.8%), rice yield (7.9%), percentage of whole grains (3.1%) and grain protein concentration (5.6%).

Ranjitha *et al.,* (2013) showed a significant difference between treatments that were given individual of (136.5-23.2-125.6 kg ha^{-1}) 100% inorganic N supply & half of the nitrogen organic source by vermicompost in addition as a control group that received 58.7-6.9-61.6 kg ha^{-1}) in terms of this maximum uptake of NPK by rice in 157.9-30.7-166.0 kg ha^{-1}.

Thirunavukkarasu and Vinoth (2013) reported that when vermicompost treatment was done based on a leaf color chart critical value less than 4 on 2.5 t ha^{-1} with N addition, a greatest as 2.14 benefit-to-cost ratio was obtained in comparison to the control.

Kumar *et al.,* (2014) provided evidence and in comparison to the control, applying 125% RDF with 5 t ha^{-1} as vermicompost significantly N increased absorption in straw (428.11%) and grain (368.81%), P absorption in straw (31.56%) & grain (32.62%), & K absorption in straw (25.39%) and grain (35.46%).

Shwetha and Narayana (2014) noticed that better availability of nitrogen, phosphorous, and potassium was found when 15 or 10 tonnes of vermicompost ha^{-1} were applied, along with the recommended fertilizer dose. The amounts of accessible potassium, nitrogen, and phosphorus increased gradually during treatment and harvest, with the ranges being 173-235, 335–415, 14–23, and kg ha^{-1}.

Sultana *et al.,* (2015) noted treatment that getting from urea is 90 kg N ha^{-1} & vermicompost 30 kg N ha^{-1} obtained (92.43 kg ha^{-1}) was shown to have the greatest levels of sulphur (10.79 kg ha^{-1}), potassium (32.82 kg ha^{-1}), nitrogen (93.81 kg ha^{-1}) & phosphorus (26.07 kg ha^{-1}) absorption by grains.

Rozalin Nayak *et al.,* (2017) reported that Neem cake and 75% N (75% FYM + 25% vermicompost) were applied together with neem cake, EM Spray (twice), PSM (10 kg ha^{-1}) & Azospirillum (10 kg ha^{-1}) got maximum returns net (Rs.39,654/ha).

Sunil Kumar *et al.,* (2017) noted a treatment as 1/3 Poultry Manure + 1/3 Vermicompost + 1/3 FYM resulted in the noticeably greatest levels of straw, grain, and total potassium, nitrogen, and phosphorus absorption in rice.

Taheri Rahimabadi *et al.,* (2017) observed an amount of K, P & N in the rose grain by 8–20%, 2–23%, and 20–33% with the addition of cow dung and vermicompost.

Basanta Kumar Barmon and Sushanta Kumar Tarafder (2019) noticed that per hectare net profit and MV boro output were found to be much greater (by around 1.91 times) on farms using vermicompost than on farms not using it.

Banashree Sahariah *et al.,* (2020) observed that greatest benefit-to-cost ratio was recorded at 5.55 under NPK$_{60}$ + Vermicompost. Vermicompost made from municipal solid waste maintained soil microbial health and SOC balance, according to the research, and these factors were strongly connected with rice output.

Manivannan *et al.,* (2020) reported that fields that got 50% N from urea & 50% N from vermicompost showed best levels of nitrogen usage efficiency in terms of internal efficiency, physiological efficiency, apparent nitrogen recovery, and agronomic efficiency.

Papia Biswas *et al.,* (2020) observed that application of 75% RDF and 25% N through vermicompost registered maximum protein content, highest nitrogen, and potassium content by rice grain and straw.

Kamaleshwaran and Elayaraja (2021) found in rice 100% enriched vermicompost + RDF showed maximum values in nutrient uptake by grain such as 96.76 N kg ha^{-1}, 27.90 P kg ha^{-1}, and 24.37 K kg ha^{-1}.

2.4 Coir pith compost in rice

2.4.1. Effect of coir pith compost on rice

Elavalagan (2014) revealed that the highest grain production was obtained by applying 6 t ha^{-1} of lignite fly ash, the required amount of urea, and 10 t ha^{-1} of composted coir pith.

Husan *et al.,* (2014) found that applying coir pith compost and nitrogen fertilizer together generated a greater yield than using organic materials alone. This may have been caused by the optimal release of urea's NH4-N.

Mohd Firdaus Samsuddin *et al.,* (2014) claimed that improved results for plant development, chlorophyll content, root and shoot dry mass, & shoot to root proportion were seen in rice treatments with 80% compost and 20% coconut coir dust.

Deyra Eka Pratiwi *et al.*, (2020) claimed that for rice variety INPARI 30 Ciherang Sub-1, the highest results were achieved when the soil, compost, and biochar were used in a 2:2:1 ratio. The estimated rice production per harvest was 0.18 kg m^{-2}.

2.5 Zinc solubilizing bacteria in rice

2.5.1. Impact by ZSB on yield & growth to rice

Vaid *et al.,* (2014) revealed that in comparison to the control, zinc-solubilizing bacterial isolates were found to be successful in considerably raising the straw production plant^{-1} (12.4%), number of grains panicle^{-1} (12.8%), productive tillers plant^{-1} (15.1%), grain yield plant^{-1} (17.0%), number of panicles plant^{-1} (13.3%) and average dry matter output pot^{-1} (12.9%).

Muhammad Shakeel *et al.,* (2015) revealed that a solubilizing zinc bacteria, used are *Bacillus cereus* and *Bacillus sp.* enhanced the translocation of zinc towards an improved yield by the super basmati rice & basmati-385 varietals by 18–47% and 22-49%, in that order.

Nur Maizatul Idayu *et al.,* (2017) noted that the maximum root development and growth of rice plants were created by 0.2 mg/L of $ZnSO_4$ in *Acinetobacter sp.* isolated, and it was determined that zinc supplies, zinc rate, and inoculation of all microorganisms that solubilize zinc have an impact on rice plant development.

Hassan Zeb *et al.,* (2018) findings showed that in comparison to $ZnSO_4$, treatment of Zn-enriched composts with Zn solubilizing bacteria greatly added 15, 22, and 28%, respectively, to the root dry weight, grain yield, and grain weight at 100 grains of rice.

Manasa *et al.,* (2019) indicated that when MZSB 6, MZSB 8, and 75% of the recommended fertilizer dosage (RDF) were applied together, paddy growth and yield metrics significantly increased when correlating control and treatment of different. The conclusion also indicated that the plant was to have the maximum zinc availability of 46.18 mg kg^{-1} Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used.

Yachana Jha (2019) observed that through boosting Physiology that affects growth, including catalase (CAT) and peroxidase (PO) antioxidant enzymes and chlorophyll, carotene, and other pigments, zinc-mobilizing bacteria shield rice plants against saline damage.

Nur Maizatul Idayu *et al.,* (2020) reported that the application of zinc solubilizing bacteria due implies a notable acceleration in the growth parameters, Zn absorption, & Zn concentration of rice plants, 0.2 mg/L, and malic acid at 0.1 mM inoculation to Zn sulphate performed well.

2.5.2. Influence through zinc solubilizing bacteria on uptake of nutrient and rice quality

Sunithakumari *et al.,* (2016) concluded that *Pseudomonas aeruginosa* (ZSB-22) greatest zinc solubilization in the broth, a maximum lowering of pH from 7 to 3.3, and the largest generation of IAA were all observed.

Nur Maizatul Idayu *et al.,* (2017) noticed that rice plants given an injection of *Acinetobacter sp.* demonstrated higher zinc concentration and uptake in comparison to non-inoculation and *Serratia sp*. These observations led to the conclusion that zinc sulfate at 0.2 mg L^{-1} and Acinetobacter sp. have good potential in reducing zinc deficiency in rice and are crucial in solubilizing the insoluble zinc in soil for improved rice growth.

Mangala Devi Perumal *et al.,* (2019) found that when $ZnSO_4$ and ZSB were applied, the uptake of zinc in above-ground shoots (0.41 and 1.73 at active tillering and panicle initiation stage, respectively), roots (0.48, 0.54, and 0.74 g $plant^{-1}$ @ panicle, harvest stage, &

active tillering stage), and grain and straw (1.96 and 1.32 g plant^{-1}) was significantly higher than when ZnO and Zn-EDTA were applied.

CHAPTER III

MATERIALS AND METHODS

The present investigation was carried out to identifying the impact of inorganic, organic, and biological sources with respect to performance of nutrients in rice crop and the fertility status of Inceptisol in the Tamil Nadu state of India. An experiment was conducted at field of Annamalai University having represented clay loam soil with pH-8.1, EC-0.7 dS m^{-1} in 2022 and pH-8.0, EC-0.6 dS m^{-1} in 2023. This chapter provides an overview of the experimental techniques and analytical methods used in the current research.

3.1. MATERIALS

3.1.1. Collection of soil samples

This planned experimental site is in field of Annamalai University, surface (up to depth cm) soil samples were collected prior to transplanting rice crop for carrying on initial soil analysis. Soil samples were air dried, grind with 2mm sieve and was thoroughly blended, labeled, and used for further investigations.

3.1.2. Analysis of soil

The initial analysis of soil was conducted by adopting standard procedures to determine various physico-chemical properties (Table 1).

Table 1: Physico-Chemical properties of the initial soil samples in experimental area

S. No.	Parameters	Values	
A.	**Physical properties**		
		2022	**2023**
1.	Mechanical analysis		
	Sand (%)	38.5	38.1
	Silt (%)	18.4	18.3
	Clay (%)	41.8	42.5
	Textural class	Clay Loam	Clay Loam
	Bulk density (Mg m^{-3})	1.24	1.26
	Particle density (Mg m^{-3})	2.12	2.15
	Pore space (%)	41.51	41.40
B.	**Physico-chemical properties**		
1.	pH (1:2.5)	8.1	8.0
2.	EC (dS m^{-1})	0.7	0.6
C.	**Chemical properties**		
1.	Organic Carbon (%)	0.78	0.80
2.	Available nitrogen (kg ha^{-1})	186.3	198.6
3.	Available phosphorus (kg ha^{-1})	23.2	24.3
4.	Available potassium (kg ha^{-1})	192.25	201.2
5.	Exchangeable calcium (C mol (P^+) kg^{-1})	7.1	6.9
6.	Exchangeable magnesium (C mol (P^+) kg^{-1})	3.9	3.7
7.	DTPA extractable zinc (mg kg^{-1})	1.53	1.69

3.1.3. Collection of different organic manures

Three organic sourcesof nutrients *viz.*, Vermicompost, Coirpith compost & Pressmud were selected for the study.

3.1.4. Collection of press mud

Press mud was obtained from the M.R.K. Sugar Mills Ltd., Sethiathope, Cuddalore district, Tamil Nadu.

3.1.5. Collection of vermicompost and coirpith compost

Vermicompost and coir pith compost was obtained from John Compost Unit in Sithalapadi village, Chidambaram taluk, Cuddalore district, Tamil Nadu.

Table 2. Methods of soil analysis

S.No.	Soil Parameters	Methodology	References
A. Physical properties			
1.	Textural Classes	International pipette method	Piper (1966)
2.	Bulk density	Measuring cylinder method	Tan (1996)
3.	Particle density	Pcynometer method	Sree Ramulu (2003)
B. Physico-chemical properties			
4.	Soil reaction,Ph (1:2.5 soil: water suspension)	Using glass electrode in pH meter	Jackson (1973)
5.	Electrical conductivity,(EC) (1:2.5 soil: water suspension)	Using conductivity bridge	Jackson (1973)
6.	Exchangeable calcium and magnesium	Versenate titration method	Jackson (1973)
C. Chemical properties			
7.	Organic carbon	Wet oxidation method	Walkley and Black (1934)
8.	Available nitrogen	Alkaline potassium permanganate method	Subbiah and Asija(1956)
9.	Available phosphorus	Olsen’s method	Olsen (1954)

10.	Available potassium	Neutral normal ammonium acetetate extraction(1:5 soil neutral ammonium acetate by flame photometric method)	Stanford and English (1949)
11.	Available zinc	DTPA extractable method	Lindsay and Norvell (1978)

3.2. EXPERIMENTAL DETAILS

3.2.1. Location of Experimental site

The experimental research work was conducted at Annamalai University, Chidambaram, belonging to tropical climate of Tamil Nadu, at the latitude of 11.395224° N and longitude of 79.720181° E.

3.2.2. Climate

The climate data were collected from Agro meteorology Observatory, Annamalai University, Tamil Nadu.

Table 3. Climate data (2022)

Date (Duration)	Average RH (%)	Average Temperature (°C)		Average Wind velocity (km hr^{-1})	Average rainfall (mm)
		Maximum	Minimum		
Jan 13 – Jan 15	81.6	33.3	21.2	5.1	0.0
Jan 16 – Jan 22	82.3	31.8	17.8	4.7	0.0
Jan 23 – Jan 29	83.0	33.4	17.8	6.7	0.0
Jan 30 – Feb 5	81.8	32.9	18.5	5.5	0.0
Feb 6 – Feb 12	83.5	33.2	19.3	6.1	0.0

Feb 13 – Feb 19	82.6	33.8	21.7	4.8	0.3
Feb 20 – Feb 26	84.3	35.4	22.5	5.3	0.0
Feb 27 – Mar 5	80.7	35.4	22.3	10.2	0.0
Mar 6 – Mar 12	82.4	37.6	23.1	8.2	0.0
Mar 13 – Mar 19	83.6	37.7	23.5	5.6	0.0
Mar 20 – Mar 26	82.6	38.2	25.5	5.9	0.0
Mar 27 – Apr 2	83.7	37.8	22.9	11.8	0.0
Apr 3 – Apr 9	84.3	37.7	24.2	7.0	0.0
Apr 10 – Apr 16	82.8	39.2	24.4	7.0	0.0
Apr 17 – Apr 23	83.0	38.6	25.3	7.4	0.0
Apr 24 – Apr 27	82.6	39.3	24.8	7.6	0.0

Table 4. Climate data (2023)

Date (Duration)	**Average RH (%)**	**Average Temperature (°C)**		**Average Wind velocity (km hr^{-1})**	**Average rainfall (mm)**
		Maximum	**Minimum**		
Jan 9 – Jan 14	85.6	32.8	22.8	7.6	0.0
Jan 15 – Jan 21	86.3	35.5	23.3	3.9	0.0
Jan 22 – Jan 28	85.4	34.2	22.9	4.8	0.0
Jan 29 – Feb 4	83.8	35.5	24.5	5.1	0.0
Feb 5 – Feb 11	82.9	35.3	24.9	4.5	0.0
Feb 12 – Feb 18	83.6	32.2	23.7	3.9	0.0
Feb 19 – Feb 25	84.7	34.7	23.4	3.6	0.4

Feb 26 – Mar 4	85.8	33.9	23.3	3.6	0.0
Mar 5 – Mar 11	85.2	34.2	22.6	3.3	0.0
Mar 12 – Mar 18	84.9	35.2	23.2	4.2	0.2
Mar 19 – Mar 25	85.3	32.5	23.0	3.7	0.0
Mar 26 – Apr 1	86.8	32.4	22.8	3.8	0.0
Apr 2 – Apr 8	87.2	32.2	21.7	3.8	0.0
Apr 8 – Apr 15	86.5	34.2	22.1	3.3	0.0
Apr 16 – Apr 23	83.5	33.4	22.0	4.5	0.0

3.2.3. Experiment Design

Table 5. Details of the field experiment

Particulars	**Details**	
	2022	**2023**
Crop	Rice	Rice
Season	Rabi	Rabi
Variety	ADT 37	ADT 37
Design	Randomized block design	Randomized block design
Plot size	5 x 4 m	5 x 4 m
Replications	Three	Three
Treatments	Nine	Nine

Spacing	15x10 cm	15x10 cm
Date of sowing	13.01.2022	09.01.2023
Date of transplanting	11.02.2022	08.02.2023
Date of harvest	27.04.2022	23.04.2023

3.2.4. Design and Layout of the Experiment

Nine treatments spread across three replications comprised the randomized block design of the rice experiment. Experimental setup is given at Fig.1 & 2 for two years.

T_3	**IRRIGATION CHANNEL**	**T_6**	**IRRIGATION CHANNEL**	**T_9**	**IRRIGATION CHANNEL**
T_9		**T_2**		**T_5**	
T_1		**T_5**		**T_3**	
T_4		**T_9**		**T_7**	
T_8		**T_3**		**T_1**	
T_6		**T_7**		**T_8**	
T_5		**T_1**		**T_4**	
T_7		**T_8**		**T_2**	
T_2		**T_4**		**T_6**	
R_1		**R_2**		**R_3**	

Fig 1: Layout of the experimental field (2022)

T_4	IRRIGATION CHANNEL	T_5	IRRIGATION CHANNEL	T_3	IRRIGATION CHANNEL
T_2		T_9		T_7	
T_7		T_4		T_5	
T_3		T_2		T_4	
T_5		T_6		T_8	
T_9		T_1		T_6	
T_6		T_8		T_2	
T_1		T_7		T_9	
T_8		T_3		T_1	
R_3		R_2		R_1	

Fig 2: Layout of the experimental field (2023)

3.2.5. Field preparation and planting

Three puddlings were done in the primary field to minimize soil nutrient leaching and thereby increasing the availability of plant nutrients in colloidal soil. Plots were levelled and then set out in accordance with the specifications of plot size (5x4 m^2), treatments and replications. The bunds of the plots were raised and strengthened in between the replications in an effort to stop water nutrients from seeping onto adjacent plots. Rice crop var. ADT 37 of thirty days old seedling was pulled out from the nursery and transplanted in the experimental plots. Transplanting was done at rate of two seedlings hill^{-1}. Uniform plant spacing was adopted at 15x10 cms. Gap filling was done on 7 DAT with seedlings of same age.

3.2.6. Treatment details

The following is the treatment details pertaining to rice crop.

T_1 - Control

T_2 - 100% RDF

T_3 - 125% RDF

T_4 - 100% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria

T_5 - 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria

T_6 - 100% RDF + Coir pith compost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria

T_7 - 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria

T_8 - 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria

T_9 - 125% RDF + Coir pith compost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria

Plot size : 5 x 4 m

Design : Randomized Block Design

Replications : Three

Recommended dose of fertilizer : 120:40:40 kg N, P_2O_5, K_2O ha^{-1}

3.3. BIOMETRIC OBSERVATIONS

The representative samples of six in number were peg marked randomly for recording periodical observations. The details of various observations made on the growth and yield of characters listed below.

3.3.1. GROWTH CHARACTERS

3.3.1.1. Plant height

A measurement of plant height involved taking six plants' heights from the soil's surface to the tips of their highest leaves, and a mean value was determined. This was observed at harvest, panicle initiation a& tillering stage and recorded as cm.

3.3.1.2. Number of productive tillers hill^{-1}

Number of productive tillers hill^{-1} were recorded by counting a tillers at maximum tillering stage for six plants and mean value has recorded, was also measured is number of productive tillers hill^{-1}.

3.3.1.3. Leaf area index (LAI)

It was calculated during panicle initiation stage using the following formula

$$\text{LAI} = \frac{\text{K (L x W)}}{\text{Area occupied by plant}}$$

Where,

K = Constant factor

L = Length of the leaf (cm)

W = Maximum width of the leaf (cm)

3.3.1.4. Dry matter production (DMP)

Plants of six collected per plot after harvest. They kept & dired air kept at oven with hot air @ 60°C for 72 hours. The dry weight in the oven was noted & noted as kg ha^{-1}.

3.3.1.5. Chlorophyll content

The method of extracting 80% of the acetone from leaves was used to determine the total chlorophyll concentration by Arnon (1949).

3.4. YIELD CHARACTERS

3.4.1. Number of panicles m^{-2}

This was collected as six plants plot^{-1} and mentioned as numbers.

3.4.2. Number of grains plant^{-1}

Number of grains plant^{-1} were calculated using six plants plot^{-1} following which grains were counted and sorted. The calculated mean value was noted as number of grains plant^{-1}.

3.4.3. Grain & straw yield

The grain yield were obtained by kg per plot divided by area of plot (m^{2}) multiplied with 10000. To obtain straw yield six plants were collected recorded weight after drying through sun. The yield was referred as kg ha^{-1}.

3.5. QUALITY ANALYSIS

3.5.1. Hulling per cent

One hundred grams of raw rice taken from every plot were thoroughly dried up in hulled miniature "Satake Rice Medium" as well as a brown rice's weight being recorded. Hulling % was calculated by:

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice (g)}}{\text{Weight of rough rice (g)}} \text{ x } 100$$

3.5.2. Milling per cent

The representative samples of brown rice hulled were ground for 5 minutes in a "Satake Rice and Caking Machine". The quantity of polished rice was measured, and the milling percentage were determined as given below:

$$\text{Milling (\%)} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of rough rice (g)}} \text{ x } 100$$

3.5.3. Head Rice Recovery (HRR)

Spreading whole grains and 3/4-grain rice. Then pericarp completely removed rice picked manually by hand, which was stated as a percentage:

$$\text{HRR}\ (\%) = \frac{\text{Weight of whole milled rice (g)}}{\text{Weight of rough rice (g)}} \text{ x } 100$$

3.5.4. Protein content

The protein content of paddy was determined by multiplying % of N of the grain as a constant factor of 6.25 (A.O.A.C., 1970).

3.6. PLANT ANALYSIS

The plant samples six in number were collected after harvest (straw & grain) of rice crop. The plant samples were air dried and oven dried at 60 to 70°C after being cleaned with 0.1N HCl and distilled water. The Wiley mill was used to grind the plant samples and analysed for N, P, K and micronutrients content in rice.

3.6.1. Nitrogen content & uptake

Plant samples were evaluated for their nitrogen levels using a microkjeldahl method of Yoshida *et al.*, (1976) & recorded as percentage. The total N uptake was estimated by multiplying N content per cent with straw & grain yield then divided by 100 & mentioned as kg ha^{-1}.

3.6.1.1. Estimation of plant nitrogen

3.6.1.1.1. Materials required

a.) 100 ml conical flask, b.) 100 ml volumetric flask, c.) Funnel, d.) Sand bath, e.) Diacid mixture = 9:4 of HNO_3:$HClO_4$, f.) 40% NaOH-40g/100ml of distilled water, g.) 2% Boric acid – 2g/100 ml distilled water and Bromocresol green-Methyl red double indicator.

3.6.1.1.2. Procedure

3.6.1.1.3. Digestion

Weigh 0.5 g of the plant sample into a 100 ml conical flask and add 15 ml of diacid mixture. Keep the flask over night and digest over a sand bath till a clear solution is obtained. Filter the solution using Whatman No.1 filter paper and make up the volume to 100 ml. This extract can be used for other nutrient estimation *viz.,* P, K, Fe, Mn, Cu and Zn.

3.6.1.1.4. Distillation

Pipette out 10 ml of the solution into the microkjeldahl distillation flask. Add 10 ml of 40% NaOH to the distillation flask. Allow the steam from the boiler to pass through the sample, distilling of the ammonia into the flask containing boric acid and mixed indicator solution (20 ml Boric acid). Distill the sample for 7 minutes. Then lower the flask and allow the solution to drop from the condenser into the flask for about 1 minute. Wash the tip of the condenser outlet with distilled water. Titrate the solution of boric acid and mixed indicator containing the distilled off ammonia with the standardized HCl or H_2SO_4.

3.6.1.1.5. Calculation

Weight of the plant sample taken (W) = W g

Volume of extract made up (V) = V ml

Volume of sample taken for analysis (V_1) = V_1 ml

Volume of N/50 H_2SO_4 used for back titration (TV) = T V ml

1 ml of N/50 H_2SO_4 used up (F) = 0.00028 g of N

(TV) ml of N/50 H2SO4 used up = 0.00028 TV g of N

V_1 ml of the extract = 0.00028 x TV g of N

V ml of extract contains = 0.00028 x TV x V/V_1 g of N

W g of the plant sample = 0.00028 x TV x V/V_1 g of N

Percentage of N in the sample = $0.00028xTVxV/V_1x100/W$

3.6.2. Phosphorus content & uptake

Phosphorus content of plant samples were determined by calometrically method according to the triple acid digestion procedure recommended by Jackson (1973) with photo-electric colorimeter. A standard curve drawn, a P_2O_5 concentration of the crop were measured and P content per cent multiplying with straw & grain then divided by 100 to find uptake, that was computed as kg ha^{-1}.

3.6.2.1. Estimation of plant phosphorus

3.6.2.1.1. Reagents

a.) Barton's reagent: (Molybdate – Vanadate solution)

Solution A – Dissolve 25 g ammonium Molybdate $(NH_4)_6$ MO_7O_{24} 4 $H_2O)$ in 400 ml distilled water.

Solution B – Dissolve 1.25 g ammonium meta vanodate (NH_4VO_3) in 300 ml conc. HNO_3.

Add solution A to solution B and make up the volume to 1 litre.

b.) **Standard P solution:** (50 ppm)

Dissolve 0.2195 g of AR grade potassium dihydrogen orthophosphate (KH_2PO_4) in 400 ml distilled water. Add 25 ml 7 M H_2SO_4 and make up the volume to one litre. This represents 50 ppm of P. This can be further diluted to lower concentration from 2 to 20 ppm as standards.

Develop yellow colour with Barton's reagent as detailed above and read in the colorimeter. Plot the meter reading in X axis (absorbance) and concentration (in ppm) in Y axis. The concentration of P in the test solution can be known by referring to this curve.

3.6.2.1.2. Procedure

Pipette 5 ml of di-acid extract into a 25 ml volumetric flask. Add 5 ml of Barton's reagent and shake well. Make up the volume to the 25 ml mark with distilled water and again shake well. After 10 minutes, the intensity of yellow colour is read in a colorimeter at a set wavelength of 470 nm. A blank must be prepared and read with the sample.

3.6.2.1.3. Calculation

Weight of plant sample taken for digestion (W) = 0.5 g

Volume of diacid extract prepared (V) = 100 ml

Volume of aliquot taken for colour development (V_1) = 5 ml

Volume of aliquot made during colour development (V_2) = 25 ml

Concentration of P from the standard curve = A ppm

Amount of P present in the given plant sample % = $A/10^6 \times V_2/V_1 \times V \times 100/W$

3.6.3. Potassium content & uptake

The potassium content in plant samples was determined by procedure as outlined by (Jackson, 1973) using triple acid digestion method by use of (Elico CL 22D) flame photometer. The sample's content was computed using the specified standard curve. The calculation of the uptake included multiplying K content (%) with straw & grain yield of that treatment then divided by 100 and recorded in kg ha^{-1}.

3.6.3.1. Estimation of plant potassium

3.6.3.1.1. Materials required

a.) Potassium standard 1000 ppm stock solution

Dissolve 1.907 g of dried AR grade KCl in one litre of distilled water.

b.) Preparation of secondary standard

Prepare each of standards (below) by placing the amount of 1000 ppm solution indicated in 100 ml volumetric flask. Make up the volume with distilled water.

3.6.3.1.2. Procedure

Prepare a series of K standard ranging from 0 to 100 ppm and feed into a flame photometer through the atomizer. Plot the reading of the galvanometer as a function of K concentration (in ppm).

Transfer a small quantity of the diacid extract after neutralising with dilute ammonia, into a vial and feed the solution into the flame photometer. Note the reading. The concentration of K in the solution can be known by referring to the standard curve.

3.6.3.1.3. Calculation

Weight of plant sample taken = 0.5 g

Volume of diacid extract prepared (V) = 100 ml

Flame photometer reading = X

Equivalent ppm of K from the standard curve = A

Amount of K present in the given plant sample (%) = $A/10^6 \times V \times 100/W$

3.6.4. Micronutrients content & uptake

The micronutrient content was determined from di acid digested sample using atomic absorption spectrophotometer to obtain micronutrients content and multiplying it 100 (dilution factor) and divided by 0.5 (weight of sample taken) and express it in mg kg^{-1}. Multiplying the micronutrient content with grain & straw yield then divided by 1000 to express in g ha^{-1} (Page *et al.*, 1982).

3.6.4.1. Estimation of micronutrients in plants

3.6.4.1.1. Materials required

a.) Standard solutions

From the stock solution, prepare 5 working standards for Fe, Zn, Mn and Cu with a range from 0.2, 0.5, 1, 2.5 and 5 ppm should be prepared.

3.6.4.1.2. Procedure

Weigh 0.5 g of grain and straw sample and transfer into a 100 ml conical flask. Add 15 ml of diacid (HNO_3:$HClO_4$ in the ratio 9:4) and keep it overnight. Digest it on next day. Filter the solution through whatman No.42 filter paper. Make up the volume to 100 ml in volumetric flask. This is used for the estimation of micronutrients using appropriate hollow cathodes lamp in the AAS. Construct a separate calibration curve for each element by preparing standard solutions of varying concentrations after setting the AAS with suitable hollow cathode lamp. Using the digested sample, measure the concentration of particular element in the plant.

3.6.4.1.3. Calculation

Concentration (ppm) of element observed through AAS = C

Available micronutrient in the plant sample = $C \times 100/0.5$ mg kg^{-1}

3.7. SOIL ANALYSIS

Plot wise soil samples were collected before transplanting and after harvest of rice. Soil samples were air dried and ground into a powder to pass through 2mm sieve. These, processed soil samples were used to estimate soil parameters pertaining to physio chemical and chemical analysis and to determine contents of available nitrogen, phosphorus, potassium, exchangeable calcium & magnesium, available zinc and organic carbon.

3.7.1. Available nitrogen

The soil N was predicted to be accessible through (Subbiah and Asija, 1956) alkaline potassium permanganate method & noted in kg ha^{-1}.

3.7.1.1. Estimation of available nitrogen in soil

3.7.1.1.1. Materials required

a.) 0.32% $KMnO_4$ b.) 2.5% NaOH c.) 2% boric acid d.) 0.02N H_2SO_4 e.) Double indicator (methyl red and bromocresol green) f.) liquid paraffin and g.) glass beads.

3.7.1.1.2. Procedure

Weigh 20 g of soil and transfer to a distillation flask. Add 20 ml of distilled water and 1 ml of liquid paraffin (to control frothing). Put few glass beads (to prevent bumping) and then add 100 ml of 0.32% $KMnO_4$ and 100 ml of 2.5% NaOH solution. Distill the contents in a kjeldahl assembly at a steady rate collecting the liberated ammonia in a 250 ml beaker containing 20 ml of boric acid with the mixed indicator. Continue the distillation for about 30 minutes or until a 100 ml of the distillate is collected in the beaker. Titrate the contents of the beaker against the standard 0.02N H_2SO_4 to the original shade. From the titre value, calculate the available N content for the soil.

3.7.1.1.3. Calculation

Weigh of the soil taken for analysis = W g

Volume of 0.02N H_2SO_4 consumed in titration = TV ml

1 ml of 0.02N H_2SO_4 = 0.00028 g of N

TV ml of 0.02N H_2SO_4 = 0.00028 x TV g of N

W g of soil contains = 0.00028 x TV g of N

Available N in kg/ha = 0.00028 x TV x 2 $x10^6$/W g of N

3.7.2. Available phosphorus

An phosphorus available was determined using olsen's method (Olsen *et al.,* 1954) and noted in kg ha^{-1}.

3.7.2.1. Estimation of available phosphorus in soil

3.7.2.2. Materials required

a.) 0.5 M $NaHCO_3$ adjusted to 8.5 pH b.) Darco-G-60 c.) Reagent A – (mixture of ammonium Molybdate and antimony potassium tartarate)

d.) Reagent B – Dissolve 1.056 g of ascorbic acid in 200 ml of reagent A

e.) Preparations of standard curve – Dissolve 0.2195 g of potassium dihydrogen phosphate in 400 ml of distilled water and then add 25 ml of 1N H_2SO_4 and make up to 100 ml of 50 ppm of P to 1000 ml to give 5 ppm P. From this various concentration of 0.1 to 1.0 ppm P is prepared. To this add 5 ml of Olsen's reagent extractant (depending upon soil type). Add distilled water up to 20 ml and add 4 ml of reagent B. Make up to the mark. After waiting for 10 minutes read the intensity of blue colour in the colorimeter using red filter (660 nm) and record absorbance, plot the value of absorbance in the Y-axis and the concentration of P in the X-axis. The standard curve is used for finding out the concentration of P in the sample extract.

g.) Shaking bottle h.) Shaker i.) Volumetric flask and j.) 100 ml beaker

3.7.2.3. Extraction

Weigh 5 g of soil and transfer to a 100 ml polythene shaking bottle. Add a pinch of Darco-G-60 to make the extract solution colourless. Add 50 ml of 0.5M $NaHCO_3$ and shake in a reciprocating shaker for 30 minutes. Filter through whatman No.40 dry filter paper collecting the filtrate in a clean beaker.

3.7.2.4. Analytical determination

Pipette out 5 ml of filtrate into a clean 25 ml volumetric flask. Dilute the solution to about 20 ml with distilled water. Add 4 ml of freshly prepared reagent B and make up the volume to 25 ml. Wait for 10 minutes for the colour development and there after measure the intensity of the colour in a colorimeter using a red filter (660 nm). From the standard curve for P, find out the concentration of P (ppm) in the solution.

3.7.2.5. Calculation

Weight of the soil taken for analysis = 5 g

Volume of 0.5M $NaHCO_3$ used for extraction = 50 ml

Volume of extractant solution used for P estimation = 5 ml

Final volume made up after colour developed = 25 ml

Colorimeter reading = T

Concentration of P read from the standard curve = A

1 ml of extractant solution contains = $A/10^6 \times 25/5$ g

50 ml of extractant solution = $A/10^6 \times 25/5 \times 50$

5 g of soil contains = A/106 x 25/5 x 50

Available P in kg ha^{-1} = $A \times 25 \times 50 \times 2 \times 10^6/10^6 \times 5 \times 5$

3.7.3. Available potassium

A available potassium in soil were determined through neutral normal ammonium acetate extract using flame photometer (Jackson, 1973) & noted as kg ha^{-1}.

3.7.3.1. Estimation of available potassium in soil

3.7.3.1.1. Materials required

a.) Neutral normal ammonium acetate b.) Standard K solution – Primary K standard – Dissolve KCl in distilled water and make up to 1000 ml c.) Secondary standard (100 g ml^{-1}) – Dilute 100 ml of 1000 ppm K standard to one litre d.) Working standards – from 100 ppm K standard 20, 40, 60, 80 ppm K standards are prepared e.) Injection vials f.) Filter paper g.) Flame photometer h.) Shaking bottle.

3.7.3.1.2. Procedure

Weigh 5 g of soil into a 100 ml polythene shaking bottle. Add 25 ml of neutral normal ammonium acetate. Shake in a mechanical shaker for 5 minutes. Filter through whatman No.40 filter paper collecting the filtrate in a dry test tube or in a beaker. Measure the amount of K in the filtrate using the flame photometer. Prepare different K standards of 20, 40, 60, 80 and 100 ppm. Feed the solution of various concentrations into the flame photometer and note the corresponding galvanometer reading on the Y axis and concentration of K (ppm) in X axis. Using the standard curve, concentration of K in the extract is found out. From the concentration measurement, the amount of K in the sample is calculated.

3.7.3.1.3. Calculation

Weight of soil taken for analysis = 5 g

Volume of neutral ammonium acetate added = 25 ml

Galvanometer reading of the flame photometer = G

Concentration of K read from standard curve = A ppm

Concentration of K in soil = A x 25/5 ppm

Available K in kg ha^{-1} = $A \times 25 \times 2 \times 10^6/10^6 \times 5$

3.7.4. Exchangeable calcium and magnesium

The exchangeable calcium and magnesium of soil was obtained by titration to 0.02 N EDTA solution using Muroxide as indicator to estimate calcium alone and Eriochrome Black T as indicator to estimate Ca + Mg by Versanate titration method. Exchangeable magnesium obtained by subtracting values of magnesium from Ca + Mg values (Jackson, 1973) and expressed in C mol kg^{-1}.

3.7.4.1. Estimation of calcium and magnesium in soil

3.7.4.1.1. Apparatus required

a.) Pipette 10 ml

b.) Burette 50 ml

c.) Porcelain basin

d.) Measuring cylinder 10 ml

3.7.4.1.2. Reagents required

a.) 0.02N EDTA

b.) 10% sodium hydroxide

c.) Ammonium chloride – Ammonium hydroxide buffer solution

d.) Murexide indicator

e.) Eriochrome black – T indicator

3.7.4.1.3. Procedure

a.) Pipette out 10 ml of sesquioxides filtrate into a porcelain basin

b.) Add 10 % sodium hydroxide solution drop by drop to neutralize the acidity (red litmus turns blue) and another 5 ml excess to maintain the pH at 12.

c.) Add a pich (50 mg) of murexide indicator and titrate with 0.02 N EDTA till the colour changes from pinkish red to purple or violet.

3.7.4.1.4. Calcium + magnesium

a.) Pipette out 10 ml of sesquioxides filtrate into a porcelain basin

b.) Add ammonium chloride – ammonium hydroxide buffer solution drop by drop to neutralize the acidity (use red litmus paper) and 5 ml excess to maintain the pH at 10.

c.) Add 2 – 3 drops of Eriochrome black – T indicator solution and titrate with 0.02 N EDTA till the colour changes from purple red to sky blue.

3.7.4.1.5. Calculation

Weight of soil sample taken = W g

Volume of filtrate pipetted out for

calcium estimation = 10 ml

Volume of 0.02 N EDTA used for Ca + Mg = a ml

Volume of 0.02 N EDTA used for Ca alone = b ml

Volume of 0.02 N EDTA used for Mg alone = (a – b) ml

1 ml of 0.02 N EDTA = 0.0004 g of Ca

1 ml of 0.02 N EDTA = 0.00024 g of Mg

Therefore calcium in soil = 0.0004 x b x 10 x 100/W

Therefore magnesium in soil = 0.00024 x (a – b) x 10 x 100/W

3.7.5. Available zinc

Estimation of available zinc by DTPA extractable method (Lindsay and Norvell, 1978).

3.7.5.1. Estimation of available zinc in soil

3.7.5.1.1. Materials required

a.) DTPA extracting solution

The DTPA extracting solution was prepared to contain 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M triethanolamine (TEA) and was adjusted to pH 7.30. The DTPA extracting solution is prepared by dissolving 13.1 ml of TEA, 1.967 g of diethylenetriamine penta acetic acid (DTPA) and 1.47 g of $CaCl_2 2H_2O$ in 100 ml glass distilled water. Allow sufficient time for the DTPA to dissolve and dilute to approximately 900 ml. Adjust the pH to 7.3 with 1:1 HCl while stirring and dilute to one liter. This solution is stable for several months.

b.) Standard solutions

From the stock solution, prepare 5 working standards of zinc with a range from 0.2, 0.5, 1, 2.5 and 5 ppm should be prepared in the same matrix as used for the extraction in soil samples.

3.7.5.1.1. Procedure

Weigh 10 g of soil sample and transfer into a 100 ml polythene shaking bottle. Add 20 ml of extracting solution and shake vigorously for 2 hours. Filter the solution through whatman No.42 filter paper. The filtrate is used for the estimation of Zn using appropriate hollow cathodes lamp in the AAS. Construct a separate calibration curve for each element by preparing standard solutions of varying concentrations after setting the AAS with suitable hollow cathode lamp. Using the soil extract, measure the concentration of particular element in the soil.

3.7.5.1.2. Calculation

Weigh of soil taken (W)	=	10 g
Volume of 0.005 M DTPA added for extractions (V)	=	20 ml
Concentration (ppm) of element observed through AAS	=	C
Available micronutrient in the soil	=	C x 20/10 mg kg^{-1}

3.7.6. Estimation of organic carbon in soil

3.7.6.1. Reagents

a.) 1N $k_2Cr_2O_7$

b.) 0.5N Ferrous ammonium sulphate or ferrous sulphate

c.) Concentrated H_2SO_4

d.) Orthophosphoric acid (85%)

e.) Diphenylamine indicator

3.7.6.2. Procedure

Weight 1 g of soil sample (finely powdered and sieved through 0.2 mm sieve) into a 500 ml conical flask. Add 10 ml $K_2Cr_2O_7$ and swirl. Keep the flask on an asbestos mat or on a wire gauge. Add 20 ml of concentrated H_2SO_4 and swirl the flask. Allow it to stand for 30 minutes. Add 200 ml of distilled water (to arrest further oxidation) 10 ml of orthophosphoric acid (to stabilize the oxidation potential of $FeSO_4$ during titration) and 1 ml of diphenylamine indicator. Titrate with ferrous ammonium sulphate or ferrous suphate solution till the blue colour turns green. Run a blank (without soil) simultaneously.

3.7.6.3. Calculation

Weight of soil taken = 1 g

Volume of 1N K_2CrO_7 = 10 ml

Volume of 0.5 N Ferrous ammonium sulphate used in sample titration = S ml

Volume of 0.5 N Ferrous ammonium sulphate used in reaction with 10 ml of 1N $K_2Cr_2O_7$ = B ml

B ml of ferrous ammonium suphate = 10 ml of 1 N $K_2Cr_2O_7$

S ml of ferrous ammonium sulphate = 10/B x S ml of 1 N $K_2Cr_2O_7$

Now the actual volume of 1N $K_2Cr_2O_7$ used for oxidizing the organic matter = 10 x (B-S)/B ml

1000 ml of 1N $K_2Cr_2O_7$ = 3 g of carbon

1 ml of 1 N $K_2Cr_2O_7$ = 0.003 g of carbon

10/B x S ml of 1 N $K_2Cr_2O_7$ = 0.003 x 10 x (B – S)/B g Carbon

1 g of soil contains = 0.03 x (B – S)/B

Therefore percentage of organic carbon in soil = 0.03 x (B – S)/B x 100/1 x 1.32

3.7.7. Estimation of pH in soil

3.7.7.1. Procedure

a.) Take 10 g of soil sample in 50 or 100 ml beaker.

b.) Add 25 ml of distilled water, stir well for about five minutes and keep for half an hour.

c.) Again stir just before immersing the electrodes and take the pH reading.

3.7.8. Estimation of EC in soil

3.7.8.1. Reagent

a.) 0.01N Potassium chloride solution

Dry a small quantity of AR grade potassium chloride at 60°C for 2 hours in a hot-air oven. Weigh 0.7456 g of it and dissolve in freshly prepared distilled water and make to one litre. This solution gives an electrical conductivity of 1.41 dS m^{-1} at 25°C.

3.7.8.2. Procedure

a.) Transfer 20 g of soil sample in a 100 ml beaker.

b.) Add 40 ml of distilled water and shake intermittently for 1 hour on a shaker.

c.) Allow to stand until the clear supernatant liquid is obtained. Alternatively, the clear extract after the pH measurement can also be used for EC measurement.

d.) Calibrate the conductivity bridge with the help of standard KCl solution and determine the cell constant.

e.) Determine the conductivity of the supernatant liquid with the help of the conductivity meter.

3.7.9. Estimation of bulk density in soil

3.7.9.1. Equipments

a.) Core sampler with sectional cylinders and guard rings.

b.) Aluminium cup, knife, balance and hot air oven.

3.7.9.2. Procedure

a.) Drive the core sampler into the soil gently with the help of a hammer, so that the entire ring goes into the soil.

b.) Remove the soil surrounding the ring with the help of spade.

c.) Now remove the ring with the soil by using a crowbar in such a way that the soil in the ring is intact.

d.) The excess soil on both the sides of the ring is removed gently by using a sharp knife.

e.) Transfer the soil in the ring to an aluminium cup and dry it an oven at 105°C for 16-18 hours. Cool it in the dessicator and weight. Measure the diameter of the ring and height of the sectional cylinder and calculate the volume of the soil.

3.7.9.3. Calculation

Diameter of the ring = d cm

Radius of the ring = d/2 cm

Height of the sectional cylinder = h cm

Volume of the soil = $\pi r^2 h$

Weight of oven dry soil = W g

Bulk density of the soil (Mass/Volume) = $W/ \pi r^2 h$

Bulk density of the soil = ____g cm^{-3}

3.7.10. Estimation of particle density in soil

3.7.10.1. Equipments

a.) Pycnometers (density of specific gravity bottles of 50 ml capacity)

b.) Analytical balance

3.7.10.2. Procedure

a.) Weight a 50 ml specific gravity bottle (W_1 g) and then fill it with water completely, wipe out all moisture from outside and weight again.

b.) Put 10 g of air dry soil into a sample beaker and add few ml of water and boil for a shor (W_2 g) time in order to exper all air.

c.) Empty the bottle and fill it with the soil transforming from the beaker with a jet of water (W_3 g).

d.) Allow it to cool to the room temperature and fill it with water and wipe out all moisture from outside and find it’s weight.

e.) The weight of the soil divided by the weight of water displaced gives the density of soil.

3.7.10.2. Calculation

Weight of empty specific gravity bottle = W_1 g

Weight of specific gravity bottle + water = W_2 g

Weight of specific gravity bottle + water + soil = W_3 g

Weight of soil taken = 10 g

Weight of water displaced from soil = $W_2 + 10 – W_3$

Particle density of soil = $10/(W_2 + 10) – W_3$

Particle density of soil = ____g cm^{-3}

3.8. Estimation of soil texture in soil

3.8.1. Apparatus required

a.) Tall beaker 1000 ml

b.) Buchner flask

c.) Buchner funnel

d.) Hamilton Beach stirrer

e.) Robinson pipette

f.) Measuring cylinder (1000 ml)

g.) Stop watch

h.) Silica basin

3.8.2. Procedure

Transfer 20 g air dry soil (2 mm) to a tall 1000 ml beaker. Add 5-10 ml of 30% H_2O_2. Mix well and allow the reaction to proceed for 5 minutes and then place it on a hot water bath for about 15 minute. Cover the beaker with a water glass. After 15 minute immerse the beaker into the water bath for 5 minute. Continue stirring to avoid frothing over. Remove to add a further 25-40 ml of H_2O_2 and after a minute or two replace the beaker on top of the path for 10 minute and then immerse again for 5 minute. Dilute the contents to about 150 ml with water. Bring it to boil on a burner and keep repeating treatment with H_2O_2 till most of the organic matter is oxidized. H_2O_2 treatment is to oxidize the organic matter in the soil. In case of our soils one treatment with H_2O_2 may do and in many it may even be omitted.

3.8.2.1. Acid treatment

When the content of the beaker are cold clean the sides of the beaker with a rubber and add 25 ml of 2 N HCl. If more than 2% $CaCO_3$ is present add an extra 25 ml acid for each percent. Dilute to approximately 250 ml and thoroughly rub the soil with a rubber pestle. Allow the reaction to proceed for an hour rubbing at intervals. After one hour, test to make sure than an excess of acid is present and then filter through a Buchner funnel using hardened filter paper. Wash the soil with there separate portions of 100 ml of distilled water. Don't attempt to wash the soil to bottom of the filter as this decreases the rate of filtration and may cause some of the fine particles to pass through the filter. Wash with cold water till the filtrate runs free of chloride. The filtrate and the washing contain calcium carbonate, sesquioxide and silica which are precipitated by the addition of NH_4Cl and NH_4OH filter dry, ignite and weight and report it as loss by solution.

3.8.2.2. Dispersion

Transfer the soil on the filter and beaker to a one litre shaking bottle, add 8 to 10 ml of 1 N NaOH and make up the volume to 500 ml with water, shake in Hamilton beach stirrer for 20 minutes.

3.8.2.3. Estimation of clay and silt

Transfer the suspension to a 1000 ml measuring cylinder, with a rubber stopper, shake the suspension by repeated inversions of the cylinder. Remove the stopper and place the cylinder immediately in position under the Robinson pipette. Then lower the pipette so as to touch the surface of the liquid and note the reading on the scale. After about 3 minutes, lower the pipette in the suspension with the stopclock closed exactly to a depth of 10 cm and on the expiry of the period calculated for the temperature of the suspension. Open the stopclock and pipette out the suspension without causing anything in the cylinder. When the necessary quality of suspension has been drawn into the pipette, close the stopclock, raise the pipette above the cylinder and remove the cylinder from under the instrument. Adjust the contents of the pipette to the mark and deliver intoa weight porcelain basin. Evaporate the liquid, dry the residue at 105°C, cool in a dessicator and weigh. Calculate and report the result as percentage of clay and silt.

3.8.2.4. Estimation of clay

Shake the contents of the cylinder and keep it undistributed and away from any surface of heat, pipette out another volume of the suspension as before after an interval of period calculated for the temperature of the suspension. Evaporate the liquid dry the residue at 105°C, cool the basin in a dessicator and weigh. Calculate and report the result as percentage of clay.

3.8.2.5. Estimation of sand

Pour away the bulk of the supernatant liquid from the cylinder and transfer the sediment to a tall from beaker of 250 ml capacity, making with distilled water to a height of 10 cm above the base. Stir well and allow to stand for the requisite period taken from the silt column in the table against the observed temperature. Then pour away the turbid suspension. Fill the beaker again to the mark with water and repeat this process until the liquid is no longer turbid at the end of the period. Transfer the residue to silica basin , dry at 105°C. Cool in a dessicators and weigh. Calculate the percentage of sand.

3.8.3. Calculation

Weight of an empty silica basin = W g

Weight of silica + clay and silt = W_1 g

Therfore weight of clay and silt = (W_1 – W) g

20 ml of soil suspension will contain (clay + silt) = (W1 – W) g

Therfore 1000 ml soil suspension contains = W_1 – W/20 x 1000 (clay + silt)

3.8.3.1. Clay alone

Weight of an empty silica basin = W g

Weight of silica + clay = W_1 g

Therfore weight of clay = (W_1 – W) g

20 ml of soil suspension will contain = $(W_1 – W)$ g

Therefore 1000 ml soil suspension contains = $(W_1 – W) / 20 \times 1000$ g

20 g of soil contain = $(W_1 – W) / 20 \times 1000$ g

100 g soil contains = $(W_1 – W) \times 1000 \times 100/20 \times 20$

100 g soil contains = ____%

3.8.3.2. Silt alone

Percentage of silt = % (Clay + Silt) - % Clay

Percentage of silt = ____%

3.8.3.3. Sand alone

Weight of an empty silica basin = W g

Weight of silica basin + sand = W_1 g

Weight of sand = $(W_1 – W)$ g

20 g soil contain = $(W_1 – W)$ g

100 g soil contains = $(W_1 – W) / 20 \times 100$

100 g soil contains = ____%

3.9. Statistical analysis

AGRES software performed a statistical analysis on the data related to the experimental outcomes in order to interpret the findings.

3.10. Economic alalysis

The net return was worked out for different treatments by subtracting the cost of cultivation for gross return. The B:C ratio was calculated as follows,

Net Income = Gross return in Rs. ha^{-1} – Cost of cultivation in Rs. ha^{-1}

$$\text{B:C ratio} = \frac{\text{Gross return in Rs./ha}}{\text{Cost of cultivation in Rs./ha}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The results derived during present experimental findings were statistically analyzed and presented in this chapter under appropriate headings along with data, figures and tables.

4.0. Impact of different sources of nutrients on rice

4.1. Growth attributes

4.1.1. Plant height

The data on plant height was recorded and presented in Table 6.

At tillering stage during 2022 among various combinations of the experimental treatments, the higher plant height of 54.1 cm was noted in the treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria and the observations were comparable with plant height of 53.2 cm recorded under treatment T_7 (125% RDF + Press mud at 10 t ha^{-1} + 2% Zinc solubilizing bacteria) and significantly ($p=0.05$) higher than all other treatments. The height was followed by treatments T_9, T_5, T_4, T_6, T_3, T_2 registering the plant height of 50.1, 45.9, 45.1, 41.5, 42.8, 42.5 cm, respectively. The treatment T_9 is significantly higher than T_5. The treatment T_5 was comparable with T_4. The lowest plant height 41.1 cm was observed in the control (T_1).

At panicle initiation stage during 2022 among various combinations experimented, the higher plant height of 88.3 cm was observed in the treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria and it was comparable 86.8 cm in treatment T_7 (125% RDF + Press mud at 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) and significantly ($p=0.05$) higher than all other treatments. The following in sequence of treatment were T_9, T_5, T_4, T_3, T_6, T_2 registering the plant height of 82.1, 76.0, 74.8, 72.6, 69.8, 64.2 cm, respectively. The treatment T_9 is significantly higher than T_5. The treatment T_5 was comparable with T_4. The treatment T_4 and T_6 were comparable with T_3. The plant height was the lowest (58.2 cm) in the control T_1.

At harvest stage during 2022 among various combinations of experiments, the highest plant height of 106.8 cm was observed in the treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria which was comparable to T_7 (125% RDF + Press mud

@ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) od 105.2 cm and significantly ($p=0.05$) higher than all other treatments. The following in sequence of treatment were T_9, T_5, T_4, T_3, T_6, T_2 registering the plant height of 99.4, 92.7, 91.7, 88.2, 86.5, 80.3 cm, respectively. The treatment T_9 is significantly higher than T_5. The treatment T_5 was comparable with T_4. The treatment T_4 and T_6 were comparable with T_3. The plant's lowest known height of 73.4 cm, was in the control T_1.

At tillering stage during 2023 among various combinations of the experiments treaments, the best plant height of 56.3 cm was noticed in a treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria and the observations were comparable with plant height of 55.2 cm recorded under treatment T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria) and significantly ($p=0.05$) higher than all other treatments. The height was followed by treaments were T_9, T_5, T_4, T_3, T_2, T_6 registering the plant height of 52, 47.9, 46.6, 44.1, 43.7, 43 cm, respectively. The treatment T_9 is significantly higher than T_5. The treatment T_4 was comparable with T_5 and T_6. The lowest plant height 41.6 cm was observed in control (T_1).

At panicle initiation stage during 2023 among various combinations experimented, that best plant height of 87.7 cm was observed in the treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria and it was comparable 86.3 cm in treatment T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) and significantly ($p=0.05$) higher than all other treatments. The following in sequence of treatment were T_9, T_5, T_4, T_3, T_6, T_2 registering the plant height of 81.5, 75.4, 74.2, 72.1, 69.4, 63.5 cm, respectively. The treatment T_9 is significantly higher than T_5. The treatment T_5 were comparable with T_4. The treatment T_4 and T_6 was comparable with T_3. The plant height was lowest (59.4cm) in control (T_1).

At harvest stage during 2023 among various combinations of experiments, that ultimate plant height of 116.2 cm was noticed in that treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria which was comparable to 114.7 cm in treatment T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria) and significantly ($p=0.05$) higher than all other treatments. The following in sequence of treatment were T_9, T_5, T_4, T_3, T_6, T_2 registering the plant height of 109.1, 102.5, 102.1, 97.7, 97.1, 89.6 cm, respectively. The treatment T_9 is significantly higher than T_5. The treatment

T_5 was comparable with T_4. The treatment T_4 and T_6 was comparable with T_3. The plant height was lowest (74.1cm) in the control (T_1).

Table 6. Impact of inorganic, organic, and biological origin of nutrients on plant height (cm) at various phases of development of rice

Treatments details	Plant height (cm)					
	2022			2023		
	TS	**PIS**	**HS**	**TS**	**PIS**	**HS**
T_1 – Control	41.1	58.2	73.4	41.6	59.4	74.1
T_2 – 100% RDF	42.5	64.2	80.3	43.7	63.5	89.6
T_3 – 125% RDF	42.8	72.6	88.2	44.1	72.1	97.7
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	45.1	74.8	91.7	46.6	74.2	102.1
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	45.9	76.0	92.7	47.9	75.4	102.5
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	41.5	69.8	86.5	43.0	69.4	97.1
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	53.2	86.8	105.2	55.2	86.3	114.7
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	54.1	88.3	106.8	56.3	87.7	116.2
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	50.1	82.1	99.4	52.0	81.5	109.1
S.Ed	**0.92**	**1.55**	**1.87**	**1.03**	**1.54**	**2.05**
CD (p=0.05)	**1.96**	**3.28**	**3.97**	**2.18**	**3.26**	**4.35**

4.1.2. Leaf Area Index

Data on the leaf area index displayed in Table 7.

In 2022, as a different sources of nutrients more LAI as 8.02 was noted in treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria) & it is comparable to 7.77 as noted under treatment T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria) and significantly (p=0.05) higher than all other treatments. This is the followed in sequence of other treatments T_9, T_5, T_4, T_6, T_3 and T_2 registering the leaf area index of 7.45, 7.14, 6.85, 6.53, 6.32 and 6.05, respectively. The treatment T_5 was comparable with T_4. The treatment T_6 was comparable with T_3. The treatment T_3 was comparable with T_2. The least LAI 5.30 was observed in control (T_1).

During 2023, high LAI (8.29) was noted in treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria) which was comparable to T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria) having LAI of 8.21 and significantly (p=0.05) higher than all other treatments. This was followed in treatments were T_9, T_5, T_4, T_6, T_3 and T_2 registering the leaf area index of 8.00, 7.29, 7.10, 6.71, 6.45 and 6.15, respectively. The treatment T_6 was comparable with T_3. The treatment T_3 was comparable with T_2. The least leaf area index 5.34 was reported in control (T_1).

Table 7. Impact of inorganic, organic and biological sources of nutrients on leaf area index of rice

Treatment	**Leaf area index**	
	2022	**2023**
T_1 – Control	5.30	5.34
T_2 – 100% RDF	6.05	6.15
T_3 – 125% RDF	6.32	6.45
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	6.85	7.10
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	7.14	7.29
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	6.53	6.71
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	7.77	8.21
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	8.02	8.29
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	7.45	8.00
S.Ed	**0.13**	**0.14**
CD (p=0.05)	**0.29**	**0.30**

4.1.3. Chlorophyll content

The values of chlorophyll content were showed on Table 8.

The results revealed that during 2022 through a different treatments, usage of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_8) found that the chlorophyll concentration was highest (1.285 mg g^{-1}) and comparable to a treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_7) of 1.240 mg g^{-1} & relatively more to rest of treatments and significantly (p=0.05) higher than all other treatments. The trend was followed in treatment T_9, T_5, T_4, T_6, T_3 and T_2 registering the chlorophyll content of 1.183, 1.141, 1.102, 1.069, 0.913 and 0.879 mg g^{-1}, respectively. The treatment T_9 is comparable with T_5. The treatment T_5 was comparable with T_4. The treatment T_6 was comparable with T_4. The treatment T_3 was comparable with T_2. The least amount of chlorophyll of 0.650 mg g^{-1} was observed in T_1.

The results revealed that during 2023 through a different treatments, usage of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_8) found that the chlorophyll concentration was highest (1.402 mg g^{-1}) and comparable to T_7 and T_9 as 1.396 and 1.368 mg g^{-1} and significantly (p=0.05) higher than all other treatments. The trend was followed in treatment T_5, T_4, T_6, T_3 and T_2 registering the chlorophyll content of 1.267, 1.237, 1.191, 1.034 and 0.979 mg g^{-1}. The treatment T_5 was comparable with T_4. The treatment T_6 was comparable with T_4. The treatment T_3 was comparable with T_2. The least amount of chlorophyll of 0.730 mg g^{-1} was observed in T_1.

Table 8. Impact of inorganic, organic and biological sources of nutrients on chlorophyll content (mg g^{-1}) of rice

Treatment	**Chlorophyll content (mg g^{-1})**	
	2022	**2023**
T_1 – Control	0.650	0.730
T_2 – 100% RDF	0.879	0.979
T_3 – 125% RDF	0.913	1.034
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	1.102	1.237
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	1.141	1.267
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	1.069	1.191
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	1.240	1.396
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	1.285	1.402
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	1.183	1.368
S.Ed	**0.021**	**0.024**
CD (p=0.05)	**0.044**	**0.051**

4.2. Yield attributes

4.2.1. Number of productive tillers hill^{-1}

Values on number of productive tillers hill^{-1} are presented in Table 9.

In 2022 through a different sources, a utilization of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) noted a higher number of productive tillers hill^{-1} as 14.50 and significantly (p=0.05) higher than all other treatments. A following in sequence of treatment were T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering a number of productive tillers hill^{-1} were 13.72, 12.94, 12.08, 11.14, 10.13, 9.44 and 8.70. A lowest number of productive tillers hill^{-1} was noticed at a control T_1 as 6.55.

In 2023 through a different treatments, that utilization a 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) observed that maximum number of productive tillers hill^{-1} of 15.11 and significantly (p=0.05) higher than all other treatments. It was following in treatments T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering a number of productive tillers hill^{-1} was 14.33, 13.56, 12.51, 11.76, 10.75, 10.32 and 9.46, respectively. The treatment T_6 was comparable with T_3. Less number of productive tillers hill^{-1} 7.26 were noticed at a control T_1.

Table 9. Impact of inorganic, organic and biological sources of nutrients on number of productive tillers hill^{-1} of rice

Treatment	**Number of productive tillers hill^{-1}**	
	2022	**2023**
T_1 – Control	6.55	7.26
T_2 – 100% RDF	8.70	9.46
T_3 – 125% RDF	9.44	10.32
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	11.14	11.76
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	12.08	12.51
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	10.13	10.75
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	13.72	14.33
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	14.50	15.11
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	12.94	13.56
S.Ed	**0.23**	**0.24**
CD (p=0.05)	**0.50**	**0.52**

4.2.2. Number of panicles m^{-2}

Values on number of panicles m^{-2} are given in Table 10.

In 2022 through a different treatments, a maximum number of panicles m^{-2} of 585 were noted in treatment T_8 (125% RDF + Vermicompost + 2% Zinc solubilizing bacteria) & statistically similar to T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria) of 568 and significantly ($p=0.05$) higher than all other treatments. It was followed in treatments T_9, T_5, T_4, T_6, T_3 and T_2 registering a number of panicles m^{-2} of 552, 534, 519, 501, 481 and 464, respectively. The results of T_7 were comparable with T_9. The treatment T_9 was comparable with T_5. The treatment T_5 was comparable with T_4. The treatment T_6 was comparable with T_4. The treatment T_6 comparable with T_3. The treatment T_3 were comparable with T_2. Lowest number of panicles m^{-2} (423)were noticed in control T_1.

In 2023 through a different treatments, a more number of panicles m^{-2} as 603 were noticed in the treatment T_8 (125% RDF + Vermicompost + 2% Zinc solubilizing bacteria) which was comparable to T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria) of 581 and significantly ($p=0.05$) higher than all other treatments. It was followed by treatments T_9, T_5, T_4, T_6, T_3 and T_2, registering a number of panicles m^{-2} of 566, 539, 534, 513, 493 and 475, respectively. The results of treatment T_7 was comparable with T_9. The treatment T_5 was comparable with T_4. The treatment T_6 was comparable with T_4. The treatment T6 was comparable with T_3. The treatment T_3 was comparable with T_2. Minimum number of panicles m^{-2} 436 were reported in a control T_1.

Table 10. Impact of inorganic, organic and biological sources of nutrients on number of panicles m^{-2} of rice

Treatment	Number of panicles m^{-2}	
	2022	**2023**
T_1 – Control	423	436
T_2 – 100% RDF	464	475
T_3 – 125% RDF	481	493
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	519	534
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	534	539
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	501	513
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	568	581
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	585	603
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	552	566
S.Ed	**10.19**	**10.46**
CD (p=0.05)	**21.60**	**22.18**

4.2.3. Number of grains plant^{-1}

Values on number of grains plant^{-1} were given in Table 11.

In 2022 through a different treatments, a maximum number of grains panicle^{-1} of 227 weas noticed in a treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria) & comparable to T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) as 219 and significantly ($p=0.05$) higher than all other treatments. The following in sequence of treatment were T_9, T_5, T_4, T_6, T_3 and T_2 registering the number of grains panicle^{-1} of 213, 205, 197, 186, 171 and 162. The treatment T_7 comparable with T_9. The treatment T_9 were comparable with T_5. The treatment T_5 were comparable with T_4. A less number of grains plant^{-1} were observed on control T_1 of 140 respectively.

In 2023 through a different treatments researched, a maximum number of grains panicle^{-1} as 246 were observed in a treatment T_8 (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria) and significantly ($p=0.05$) higher than all other treatments. The following in sequence of treatment were T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the number of grains panicle^{-1} of 233, 228, 222, 213, 199, 184 and 174. The treatment T_7 comparable with T_9. The treatment T_6 were comparable with T_3 and T_4. The treatment T_3 comparable with T_2. The least number of grains plant^{-1} were found a absolute control T_1 as 148 respectively.

Table11. Impact of inorganic, organic, and biological sources of nutrients on number of grains plant^{-1} of rice

Treatment	Number of grains plant^{-1}	
	2022	2023
T_1 – Control	140	148
T_2 – 100% RDF	162	174
T_3 – 125% RDF	171	184
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	197	213
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	205	222
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	186	199
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	219	233
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	227	246
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	213	228
S.Ed	**3.88**	**4.16**
CD (p=0.05)	**8.22**	**8.83**

4.2.4. Dry matter production

The data on production of dry matter is given in Table 12.

In 2022 maximum dry matter production is 5720 kg ha-1 was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) registered which was comparable to the results of 5584 kg ha^{-1} as obtained in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) and significantly ($p=0.05$) higher than all other treatments. This was followed by treatments T_9, T_5, T_4, T_6, T_3 and T_2 registering the dry matter production of 5444, 5302, 5163, 5024, 4874 and 4728 kg ha^{-1}, respectively. The lowest dry matter production 4480 kg ha^{-1} was noticed in control.

In 2023 maximum dry matter production as 5991 kg ha^{-1} was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) noted a more which was comparable to treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) with dry matter production of 5812 kg ha^{-1} and significantly ($p=0.05$) higher than all other treatments. It was followed by T_9, T_5, T_4, T_6, T_3 & T_2 registering a dry matter production as 5709, 5565, 5322, 5214, 5036 and 4859 kg ha^{-1}, respectively. The least dry matter production 4527 kg ha^{-1} was found in control T_1.

Table 12. Impact of inorganic, organic, and biological sources of nutrients on dry matter production (kg ha^{-1}) of rice

Treatment	Dry matter production (kg ha^{-1})	
	2022	**2023**
T_1 – Control	4480	4527
T_2 – 100% RDF	4728	4859
T_3 – 125% RDF	4874	5036
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	5163	5322
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	5302	5565
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	5024	5214
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	5584	5812
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	5720	5991
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	5444	5709
S.Ed	**98**	**104**
CD (p=0.05)	**208**	**222**

4.2.5. Grain yield

The data of grain yield is given in Table 13.

During the year 2022, highest grain yield of 6293 kg ha^{-1} was observed, in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) and significantly (p=0.05) higher than all other treatments. It was followed by treatments T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the grain yield of 6012, 5715, 5430, 5143, 4864, 4552 and 4260 kg ha^{-1}, respectively. The control plot T_1 received the lowest grain yield of 3204 kg ha^{-1}.

During 2023 highest value as grain yield of 6344 kg ha^{-1} in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) was recorded and significantly (p=0.05) higher than all other treatments. It was followed in treatments T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the grain yield of 6059, 5770, 5482, 5194, 4911, 4594 and 4298 kg ha^{-1}, respectively. The lowest grain yield 3276 kg ha^{-1} was obtained in control (T_1).

Grain yield in both the years was maximum when vermicompost was applied with 125% RDF and 2% zinc solubilizing bacteria. The grain yield was ranged from 3204 to 6293 kg ha^{-1} in 2022 and 3276 to 6344 kg ha^{-1} in 2023. The highest grain yield was noticed with T_8 and it is significantly higher than other treatements in both the years.

Table 13. Impact of inorganic, organic, and biological sources of nutrients on grain yield (kg ha^{-1}) of rice

Treatment	**Grain Yield (kg ha^{-1})**	
	2022	**2023**
T_1 – Control	3204	3276
T_2 – 100% RDF	4260	4298
T_3 – 125% RDF	4552	4594
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	5143	5194
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	5430	5482
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	4864	4911
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	6012	6059
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	6293	6344
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	5715	5770
S.Ed	**105.10**	**106.03**
CD (p=0.05)	**222.81**	**224.79**

4.2.6. Straw yield

The data on straw yield is were shown on Table 14.

During the year 2022, the highest straw yield of 8943 kg ha^{-1} was obtained in treatment of 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) and significantly ($p=0.05$) higher than all other treatments. It was in treatments T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the straw yield of 8598,8237, 7863, 7471, 7059, 6607 and 6262 kg ha^{-1}, respectively. The lowest smallest straw yield appropriate to 5750 kg ha^{-1} was recorded in control plot (T1).

In 2023 highest value in straw yield of 9081 kg ha^{-1} was observed, in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) which are similar (8789 kg ha^{-1}) to the result as obtained in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) and significantly ($p=0.05$) higher than all other treatments. It was followed in treatments T_9, T_5, T_4, T_6, T_3 and T_2 registering the straw yield of 8457, 8083, 7590, 7212, 6737 and 6365 kg ha^{-1}, respectively. The lowest straw yield 5820 kg ha^{-1} was recorded in control.

Straw yield in both the years was maximum when vermicompost was applied with 125% RDF and 2% zinc solubilizing bacteria. The straw yield was ranged from 5750 to 8943 kg ha^{-1} in 2022 and 5800 to 9081 kg ha^{-1} in 2023. The highest straw yield was noticed with T_8 and it is significantly higher than other treatements in 2022 and comparable to T_7 in 2023.

Table 14. Impact of inorganic, organic, and biological sources of nutrients on straw yield (kg ha^{-1}) of rice

Treatment	Straw Yield (kg ha^{-1})	
	2022	2023
T_1 – Control	5750	5800
T_2 – 100% RDF	6262	6365
T_3 – 125% RDF	6607	6737
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	7471	7590
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	7863	8083
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	7059	7212
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	8598	8789
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	8943	9081
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	8237	8457
S.Ed	**150.74**	**153.97**
CD (p=0.05)	**319.56**	**326.41**

4.3. Quality attributes

The data on quality attributes in 2022 & 2023 were presented in Table 15 & 16.

4.3.1. Hulling per cent

During the year 2022, highest hulling per cent of 84.3% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar 83.2% to the result obtained in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) and significantly (p=0.05) higher than all other treatments. It followed in treatments T_9, T_5, T_4, T_6, T_3 and T_2 registering the hulling per cent of 79.9, 79.5, 77.7, 77.2, 76.9 and 76.0 %, respectively. The treatment T_6 comparable with T_9, T_5, T_4, T_3 and T_2. The lowest hulling per cent 71.4% was recorded in control.

During the year 2023, highest hulling per cent of 84.8% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar 83.7% to the result obtained in treatement 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) and significantly (p=0.05) higher than all other treatments. It followed in treatments T_5, T_9, T_6, T_4, T_3 and T_2 registering the hulling per cent of 80.4, 80.3, 80, 78.6, 77.1 and 76.7%, respectively. The treatment T_6 comparable with T_9, T_5, T_4 and T_3. The treatment T_4 comparable with T_3 and T_2. The lowest hulling per cent 72.2% was recorded in control.

4.3.2. Milling per cent

During the year 2022, highest milling per cent of 76.2% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar 75.3 and 75.1% to the result obtained in treatment T_7 and T_9 and significantly (p=0.05) higher than all other treatments. It followed in treatments T_5, T_4, T_6, T_3 & T_2 registering the milling per cent of 72.7, 70.4, 69.1, 68.6 and 67.6 %, respectively. The treatment T_9 comparable with T_5 and T_4. The treatment T_6 comparable with T_4, T_3 and T_2. The lowest milling per cent 64.4% was recorded in control.

During the year 2023, highest milling per cent of 76.8% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar 75.9 and 75.7% to the result obtained in treatment T_7 and T_9 and significantly (p=0.05) higher than all other treatments. It followed in treatments T_5, T_4, T_6, T_3 and T_2 registering the milling per cent of 73.1, 71.0, 69.7, 69.5 and 68.4 %, respectively. The treatment T_9 comparable with T_5 and T_7. The treatment T_5 comparable with T_4. The treatment T_6 comparable with T_4, T_3 and T_2. The lowest milling per cent 66.1% was recorded in control.

4.3.3. Head rice recovery

During the year 2022, highest head rice recovery of 60.3% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar 59.3, 58.4 and 58.2 % to the result obtained in treatment T_7, T_9 and T_5 and significantly (p=0.05) higher than all other treatments. It followed in treatments T_4, T_6, T_3 and T_2 registering the head rice recovery of 56.5, 55.4, 54.3 and 53.6 %, respectively. The treatment T_9 comparable with T_4. The treatment T_6 comparable with T_4, T_3 and T_2. The lowest head rice recovery 52.9% was recorded in control.

During the year 2023, highest head rice recovery of 60.4% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar to 59.5, 58.9 and 58.8% to the result obtained in treatment T_7, T_5 and T_9 and significantly (p=0.05) higher than all other treatments. It followed in treatments T_4, T_6, T_3 and T_2 registering the head rice recovery of 57.4, 56.3, 55.0 and 54.5 %, respectively. The treatment T_9 comparable with T_7, T_5 and T_4. The treatment T_6 comparable with T_4, T_3 and T_2. The lowest head rice recovery 54.2% was recorded in control.

4.3.4. Protein content

During the year 2022, highest protein content of 7.43% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) which are similar to 7.37, 7.25 and 7.18 % to the result obtained in treatment T_7, T_9 and T_5 and significantly (p=0.05) higher than all other treatments. It followed in treatments T_4, T_6, T_3 and T_2 registering the protein content of 7.06, 6.93, 6.75 and 6.62 %, respectively. The treatment T_9 comparable with T_4. The treatment T_6 comparable with T_5, T_4 and T_3. The treatment T_3 comparable with T_2. The lowest protein content 5.37% was recorded in control.

During the year 2023, highest protein content of 8.00% was observed in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} (T_8) and significantly (p=0.05) higher than all other treatments. It followed in treatments T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the protein content of 7.50, 7.18 6.50, 6.25, 6.06, 5.81 and 5.62 %, respectively. The treatment T_9 comparable with T_5 and T_4. The treatment T_6 comparable with T_5, T_4 and T_3. The treatment T_3 comparable with T_2. The lowest protein content 5.43% was recorded in control.

Table 15. Impact of inorganic, organic, and biological sources of nutrients in quality characters in rice (2022)

Treatment	**Quality parameters**			
	Hulling (%)	**Milling (%)**	**Head rice recovery (%)**	**Protein content (%)**
T_1 – Control	71.4	64.4	52.9	5.37
T_2 – 100% RDF	76.0	67.6	53.6	6.62
T_3 – 125% RDF	76.9	68.6	54.3	6.75
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	77.7	70.4	56.5	7.06
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	79.5	72.7	58.2	7.18
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	77.2	69.1	55.4	6.93
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	83.2	75.3	59.3	7.37
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	84.3	76.2	60.3	7.43
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	79.9	75.1	58.4	7.25
S.Ed	**1.51**	**1.37**	**1.08**	**0.13**
CD (p=0.05)	**3.21**	**2.92**	**2.29**	**0.28**

Table 16. Impact of inorganic, organic, and biological sources of nutrients in quality characters in rice (2023)

Treatment	**Quality parameters**			
	Hulling (%)	**Milling (%)**	**Head rice recovery (%)**	**Protein content (%)**
T_1 – Control	72.2	66.1	54.2	5.43
T_2 – 100% RDF	76.7	68.4	54.5	5.62
T_3 – 125% RDF	77.1	69.5	55.0	5.81
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	78.6	71.0	57.4	6.25
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	80.4	73.1	58.9	6.50
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	80.0	69.7	56.3	6.06
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	83.7	75.9	59.5	7.50
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	84.8	76.8	60.4	8.00
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	80.3	75.7	58.8	7.18
S.Ed	**1.52**	**1.38**	**1.09**	**0.13**
CD (p=0.05)	**3.23**	**2.94**	**2.31**	**0.27**

4.4. Nutrient content and Nutrient uptake

4.4.1. NPK contents

The data on NPK contents in 2022 & 2023 were presented in Table 17 & 18.

4.4.1.1. Nitrogen content in grain

In 2022, the highest nitrogen content in grain (1.19%) was observed in the plot with the treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) having nitrogen content 1.18 % and significantly ($p=0.05$) higher than other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 and T_2 registering the nitrogen content in grain of 1.16, 1.15, 1.13, 1.11, 1.08 and 1.06 %, respectively. The results of treatment T_7 were comparable with T_9, T_5 and T_4. The treatment T_2 was comparable with T_3. The lowest nitrogen content of 0.86% in grain was noted in control T_1.

During 2023, the highest nitrogen content in grain (1.28%) was noted in treatment 125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) and which is significantly ($p=0.05$) higher than all other treatements. The trend was followed in other treatments of were T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering regards to nitrogen content in grain of 1.20, 1.15, 1.04, 1.00, 0.97, 0.93 and 0.90 %, respectively. The results in treatment T_4 were comparable with T_5 and T_6, T_3 and T_2. The lowest nitrogen content was noted in control T_1 as 0.87%.

4.4.1.2. Nitrogen content in straw

In 2022, the highest nitrogen content in straw (0.68%) was observed in the plot with treatment 125% RDF + Vermicompost + 2% Zinc solubilizing bacteria (T_8) and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering a grain yield of 0.66, 0.65, 0.63, 0.61, 0.58, 0.55 and 0.52 %, respectively. The lowest nitrogen content of 0.43% in straw was noted in control T_1.

During 2023, the highest nitrogen content in straw (0.79%) was noted in treatment 125% RDF + Vermicompost + 2% Zinc solubilizing bacteria (T_8) and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering the grain yield of 0.74, 0.70, 0.69, 0.67, 0.64, 0.61 and 0.57

%, respectively. The results of treatment T_9 were comparable with T_5 and T_4. The lowest nitrogen content in straw was noted in control T_1 as 0.49%.

4.4.1.3. Phosphorus content in grain

In 2022, the highest phosphorus content in grain (0.24%) was observed in the plot with treatment 125% RDF + Vermicompost at 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) having phosphorus content 0.23 % and significantly ($p=0.05$) higher than other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 and T_2 registering the phosphorus content in grain of 0.21, 0.20, 0.18, 0.16, 0.15 and 0.13 %, respectively. The results of treatment T_9 were comparable with T_5. The treatment T_6 were comparable with T_3. The lowest phosphorus content of 0.08% in grain was noted in control T_1**.**

During 2023, the highest phosphorus content in grain (0.36%) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) and it is significantly ($p=0.05$) higher than all other treatements. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering an phosphorus content in grain of 0.32, 0.29, 0.27, 0.24, 0.21, 0.20, 0.17 and 0.11 %, respectively. The results in treatment T_6 were comparable with T_3. The lowest phosphorus content was noted in control T_1 as 0.11%.

4.4.1.4. Phosphorus content in straw

In 2022, the highest phosphorus content in straw (0.21%) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) having phosphorus content 0.20 % and which is significantly ($p=0.05$) higher than all other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 and T_2 registering the phosphorus content in grain of 0.18, 0.17, 0.16, 0.15, 0.13 and 0.12 %, respectively. The results of treatment T_9 was comparable with T_5, T_6 and T_4. The results of treatment T_3 were comparable with T_2. The lowest phosphorus content of 0.07% in straw was noted in control T_1**.**

During 2023, the highest phosphorus content in straw (0.33%) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatements of T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering a phosphorus content in grain of 0.27, 0.25, 0.24, 0.22, 0.18, 0.17 and 0.14 %, respectively. The results of treatment T_6 were comparable with T_3. The lowest phosphorus content was noted in control T_1 as 0.08%.

4.4.1.5. Potassium content in grain

In 2022, the highest potassium content in grain (0.56%) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) having potassium content 0.54 % and significantly ($p=0.05$) higher all other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium content in grain of 0.53, 0.52, 0.50, 0.48, 0.45 and 0.42 %, respectively. The results of treatment T_5 were comparable with T_4. The lowest potassium content of 0.29% in grain was noted in control T_1.

During 2023, the highest potassium content in grain (0.71%) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) and which is significantly ($p=0.05$)higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium content in grain of 0.65, 0.61, 0.61, 0.58, 0.56, 0.51 and 0.49 %, respectively. The results in treatment T_9 were comparable with T_5. The treatment T_6 were comparable with T_4. The treatment T_3 were comparable with T_2. The lowest potassium content was noted in control T_1 as 0.34 %.

4.4.1.6. Potassium content in straw

In 2022, the highest potassium content in straw (1.34%) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparble in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) having potassium content 1.32 % and which is significantly ($p=0.05$) higher than all other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium content in straw of 1.29, 1.27, 1.24, 1.21, 1.17 and 1.14 %, respectively. The results of treatment T_7 were comparable with T_9. The results of treatment T_5 were comparable with T_4, T_6 and T_3. The lowest potassium content of 0.76% in straw was noted in control T_1.

During 2023, the highest potassium content in straw (1.49%) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered and which is comparable to the treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilising bacteria (T_7) having potassium content 1.43 % and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments of T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium content in straw of 1.39, 1.36, 1.32, 1.28, 1.24 and 1.20 %, respectively. The results in treatment T_7 were comparable with T_9, T_5 and T_4. The results in treatment T_6 were comparable with T_4 and T_3. The lowest potassium content in straw was noted in control T_1 as 0.81 %.

Table 17. Impact of inorganic, organic and biological sources of nutrients on NPK content (%) in rice (2022)

Treatment	Nutrient content (%)					
	N content		P content		K content	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 – Control	0.86	0.43	0.08	0.07	0.29	0.76
T_2 – 100% RDF	1.06	0.52	0.13	0.12	0.42	1.14
T_3 – 125% RDF	1.08	0.55	0.15	0.13	0.45	1.17
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	1.13	0.61	0.18	0.16	0.50	1.24
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	1.15	0.63	0.20	0.17	0.52	1.27
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	1.11	0.58	0.16	0.15	0.48	1.21
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	1.18	0.66	0.23	0.20	0.54	1.32
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	1.19	0.68	0.24	0.21	0.56	1.34
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	1.16	0.65	0.21	0.18	0.53	1.29
S.Ed	**0.022**	**0.011**	**0.005**	**0.005**	**0.010**	**0.023**
CD (p=0.05)	**0.047**	**0.025**	**0.011**	**0.011**	**0.021**	**0.050**

Table 18. Impact of inorganic, organic and biological sources of nutrients on NPK content (%) in rice (2023)

Treatment	Nutrient content (%)					
	N content		P content		K content	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 – Control	0.87	0.49	0.11	0.08	0.34	0.81
T_2 – 100% RDF	0.90	0.57	0.17	0.14	0.49	1.20
T_3 – 125% RDF	0.93	0.61	0.20	0.17	0.51	1.24
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	1.00	0.67	0.24	0.22	0.58	1.32
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	1.04	0.69	0.27	0.24	0.61	1.36
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	0.97	0.64	0.21	0.18	0.56	1.28
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	1.20	0.74	0.32	0.27	0.65	1.43
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	1.28	0.79	0.36	0.33	0.71	1.49
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	1.15	0.70	0.29	0.25	0.61	1.39
S.Ed	**0.021**	**0.012**	**0.005**	**0.005**	**0.011**	**0.026**
CD (p=0.05)	**0.044**	**0.027**	**0.012**	**0.011**	**0.025**	**0.056**

4.4.2. Micronutrient contents

The data on micronutrient contents 2022 & 2023 were presented in Table 19 & 20.

4.4.2.1. Iron content in grain

In 2022, the highest iron content in grain (15.28 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_5) having iron content 15.19 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 and T_2 registering regards to iron content in grain of 14.65, 14.60, 14.45, 14.41, 11.44 and 11.32 mg kg^{-1}, respectively. The results of treatment T_5 were comparable with T_7. The results of treatment T_4 were comparable with T_6, T_7 and T_9. The results of treatment T_3 were comparable with T_2. The lowest iron content of 10.07 mg kg^{-1} in grain was noted in control T_1.

During 2023, the highest iron content in grain (16.03 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_5) having iron content 15.90 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_4, T_9, T_6, T_2 & T_3 registering regards to iron content in grain of 15.34, 15.06, 14.89, 14.45 10.72 and 10.33 mg kg^{-1}, respectively. The results in treatment T_7 were comparable with T_9 and T_4. The results in treatment T_6 were comparable with T_9 and T_3. The results in treatment T_3 were comparable with T_2. The lowest iron content was noted in control T_1 as 9.13 mg kg^{-1}.

4.4.2.2. Iron content in straw

In 2022, the highest iron content in straw (22.23 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment T_5 and T_7 of 21.91 and 21.31 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_4, T_9, T_6, T_2 & T_3 registering regards to iron content in straw of 21.28, 21.08, 20.84, 17.90 and 17.70 mg kg^{-1}. The results of treatment T_7 were comparable with T_9 and T_5. The results of treatment T_3 were comparable with T_2. The lowest iron content of 14.96 mg kg^{-1} in straw was noted in control.

During 2023, the highest iron content in straw (22.96 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_5) having iron content T_5 having iron content 22.60 mg kg^{-1} and which was significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_4, T_9, T_6, T_2 and T_3 registering regards to iron content in straw of 21.92, 21.75, 21.50, 21.13, 15.98 and 15.85 mg kg^{-1}, respectively. The results of treatment T_7 were comparable with T_4, T_6, and T_9. The results of treatment T_3 were comparable with T_2. The lowest iron content in straw was noted in control T_1 as 15.00 mg kg^{-1}.

4.4.2.3. Manganese content in grain

In 2022, the highest manganese content in grain (11.89 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment T_5, T_7 and T_4 of 11.83, 11.79 and 11.43 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment were T_9, T_6, T_3 and T_2 registering the manganese content in grain of 11.39, 11.36, 8.30 and 7.88 mg kg^{-1}, respectively. The results of treatment T_7 were comparable with T_9, T_6, T_5 and T_4. The results of treatment T_3 were comparable with T_2. The lowest manganese content of 5.94 mg kg^{-1} in grain was noted in control T_1.

During 2023, the highest manganese content in grain (12.66 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment T_5 and T_7 of 12.56 and 12.38 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_4, T_9, T_6, T_3 & T_2 registering the manganese content in grain of 12.06, 11.89, 11.72, 8.49 and 8.00 mg kg^{-1}, respectively. The results of treatment T_7 were comparable with T_9 and T_4. The results of treatment T_6 were comparable with T_9. The results of treatment T_3 were comparable with T_2. The lowest manganese content of 6.02 mg kg^{-1} in grain was noted in control T_1.

4.4.2.4. Manganese content in straw

In 2022, the highest manganese content in straw (30.29 mg kg^{-1}) in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilising bacteria (T_5) having manganese content 29.71 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_6, T_9, T_2 and T_3 registering regards to manganese content in straw of 27.48, 26.52, 26.49, 26.46, 21.75 and 21.26 mg kg^{-1}, respectively. The results of treatment T_7 were comparable with T_4. The results of treatment T_6 were comparable with and T_9. The results of treatment T_3 were comparable with T_2. The lowest manganese content of 18.69 mg kg^{-1} in straw was noted in control T_1.

During 2023, the highest manganese content in straw (31.04 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilising bacteria (T_5) having manganese content 30.42 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_4, T_9, T_6, T_2 & T_3 registering the manganese content in straw of 29.09, 27.97, 27.47, 26.80, 21.85 and 21.85 mg kg^{-1}, respectively. The results in treatment T_4 were comparable with T_7. The results in treatment T_9 were comparable with T_4 and T_6. The results in treatment T_2 were comparable with T_3. The lowest manganese content was noted in control T_1 as 20.55 mg kg^{-1}.

4.4.2.5. Zinc content in grain

In 2022, the highest zinc content in grain (18.68 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost a@ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilising bacteria (T_5) having zinc content 18.23 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 and T_2 registering the zinc content in grain of 17.77, 17.26, 16.62, 15.92, 12.20 and 12.11 mg kg^{-1}, respectively. The results of treatment T_7 were comparable with T_4. The results of treatment T_3 were comparable with T_2. The lowest zinc content of 10.56 mg kg^{-1} in grain was noted in control T_1.

During 2023, the highest zinc content in grain (19.47 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilising bacteria (T_5) having zinc content 18.98 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_4, T_9, T_6, T_3 & T_2 registering regards to zinc content in grain of 18.36, 17.79, 17.10, 16.27, 13.41 and 13.25 mg kg^{-1}, respectively. The results in treatment T_9 were comparable with T_4. The lowest zinc content was noted in control T_1 as 11.06 mg kg^{-1}.

4.4.2.6. Zinc content in straw

In 2022, the highest zinc content in straw (47.88 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilising bacteria (T_5) having zinc content 47.15 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_2 and T_3 registering regards to zinc content in straw of 47.52, 45.72. 44.56, 43.51, 39.86 and 39.62 mg kg^{-1}, respectively. The results of treatment T_4 were comparable with T_7 and T_9. The results of treatment T_6 were comparable with T_9, T_3 and T_2. The lowest zinc content of 34.11 mg kg^{-1} in straw was noted in control T_1.

During 2023, the highest zinc content in straw (48.70 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilising bacteria (T_5) having zinc content 47.93 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatment T_7, T_4, T_9, T_6, T_3 & T_2 registering regards to zinc content in straw of 46.34, 45.53, 45.07, 43.89, 39.86 and 39.03 mg kg^{-1}, respectively. The results in treatment T_4 were comparable with T_7. The results in treatment T_9 were comparable with T_4. The lowest zinc content was noted in control T_1 as 37.24 mg kg^{-1}.

4.4.2.7. Copper content in grain

In 2022, the highest copper content in grain (7.30 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment T_5 & T_7 of 7.21 and 7.14 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_4, T_9, T_6, T_3 & T_2 registering regards to copper content in straw of 6.86, 6.69, 6.56, 4.27 and 4.32 mg kg^{-1}, respectively. The results of treatment T_4 were comparable with T_9 and T_6. The results of treatment T_6 were comparable with T_3 and T_2. The lowest copper content of 3.26 mg kg^{-1} in straw was noted in control T_1.

During 2023, the highest copper content in grain (8.06 mg kg^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment T_5 7.94 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_2 and T_3 registering regards to copper content in grain of 7.77, 7.38, 7.15, 6.62, 4.38 and 4.74 mg kg^{-1}, respectively. The results of treatment T_4 were comparable with T_7. The results of treatment T_9 were comparable with T_6. The results of treatment T_2 were comparable with T_3. The lowest copper content in grain of 3.84 mg kg^{-1} was noted in control T_1.

4.4.2.8. Copper content in straw

In 2022, the highest copper content in straw (12.69 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) registered which was comparable in treatment T_5 of 12.56 mg kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 & T_2 registering regards to copper content in straw of 11.92, 11.79, 11.68, 11.26, 10.89 and 9.60 mg kg^{-1}, respectively. The results of treatment T_4 were comparable with T_9 and T_7. The results of treatment T_6 were comparable with T_9 and T_3. The lowest copper content of 8.98 mg kg^{-1} in straw was noted in control T_1.

During 2023, the highest copper content in straw (13.89 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_5, T_7, T_4, T_9, T_6, T_3 & T_2 registering the copper content in straw of 13.21, 12.70, 12.18, 12.11, 12.04, 9.46 and 8.74 mg kg^{-1}, respectively. The results of treatment T_4 were comparable with T_9 and T_6. The lowest copper content of 7.28 mg kg^{-1} in straw was noted in control T_1.

Table 19. Impact of inorganic, organic and biological sources of nutrients on micronutrient content (mg kg^{-1}) in rice (2022)

Treatment	Micronutrient content (mg kg^{-1})							
	Fe content		Mn content		Zn content		Cu content	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_1 – Control	10.07	14.96	5.94	18.69	10.56	34.11	3.26	8.98
T_2 – 100% RDF	11.32	17.90	7.88	21.75	12.11	39.86	4.32	9.60
T_3 – 125% RDF	11.44	17.70	8.30	21.26	12.20	39.62	4.27	10.89
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	14.60	21.28	11.39	26.52	17.26	45.72	6.86	11.79
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	15.19	21.91	11.83	29.71	18.23	47.15	7.21	12.56
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	14.41	20.84	11.36	26.49	15.92	43.51	6.56	11.26
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	14.65	21.31	11.79	27.48	17.77	45.72	7.14	11.92
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	15.28	22.23	11.89	30.29	18.68	47.88	7.30	12.69
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	14.45	21.08	11.43	26.46	16.62	44.56	6.69	11.68
S.Ed	**0.28**	**0.40**	**0.22**	**0.65**	**0.32**	**0.86**	**0.12**	**0.22**
CD (p=0.05)	**0.60**	**0.86**	**0.47**	**1.38**	**0.69**	**1.82**	**0.26**	**0.47**

Table 20. Impact of inorganic, organic and biological sources of nutrients on micronutrient content (mg kg^{-1}) in rice (2023)

Treatment	Micronutrient content (mg kg^{-1})							
	Fe content		Mn content		Zn content		Cu content	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_1 – Control	9.13	15.00	6.02	20.55	11.06	37.24	3.84	7.28
T_2 – 100% RDF	10.72	15.98	8.00	21.85	13.25	39.03	4.74	8.74
T_3 – 125% RDF	10.33	15.85	8.49	21.43	13.41	39.86	4.38	9.46
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	15.06	21.75	12.06	27.97	17.79	45.53	7.38	12.18
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	15.90	22.60	12.56	30.42	18.98	47.93	7.94	13.21
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	14.45	21.13	11.72	26.80	16.27	43.89	6.62	12.04
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	15.34	21.92	12.38	29.09	18.36	46.34	7.77	12.70
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	16.03	22.96	12.66	31.04	19.47	48.70	8.06	13.89
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	14.89	21.50	11.89	27.47	17.10	45.07	7.15	12.11
S.Ed	**0.30**	**0.41**	**0.23**	**0.54**	**0.34**	**0.87**	**0.13**	**0.22**
CD (p=0.05)	**0.64**	**0.89**	**0.49**	**1.15**	**0.72**	**1.84**	**0.28**	**0.48**

4.4.3. NPK uptake

The data on NPK uptake in 2022 & 2023 were presented in Table 21 & 22.

4.4.3.1. Nitrogen uptake by grain

In 2022, the highest nitrogen uptake by grain (74.88 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the nitrogen uptake by grain of 70.94, 66.29, 62.44, 58.11, 53.99, 49.16 and 45.15 kg ha^{-1}, respectively. The lowest nitrogen uptake was noted in control T_1 of 33.57 kg ha^{-1}.

During 2023, the highest nitrogen uptake by grain (81.20 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the nitrogen uptake by grain of 72.70, 66.35, 57.01, 51.94, 47.63, 42.72 and 38.68 kg ha^{-1}, respectively. The lowest nitrogen uptake was noted in control T_1 of 34.06 kg ha^{-1}.

4.4.3.2. Nitrogen uptake by straw

In 2022, the highest nitrogen uptake by straw (60.81 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the nitrogen uptake by straw of 56.74, 53.54, 49.53, 45.57, 40.94, 36.33 and 32.56 kg ha^{-1}, respectively. The lowest nitrogen uptake was noted in control T_1 of 24.72 kg ha^{-1}.

During 2023, the highest nitrogen uptake by grain (71.73 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the nitrogen uptake by straw of 65.03, 59.19, 55.77, 50.85, 46.15, 41.09 and 36.28 kg ha^{-1}, respectively. The lowest nitrogen uptake was noted in control T_1 of 28.42 kg ha^{-1}.

4.4.3.3. Phosphorus uptake by grain

In 2022, the highest phosphorus uptake by grain (15.10 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the phosphorus uptake by grain of 13.82, 12.00, 10.86, 9.25, 7.78, 6.82 and 5.53 kg ha^{-1}, respectively. The lowest phosphorus uptake was noted in control T_1 3.12 kg ha^{-1}.

During 2023, the highest phosphorus uptake by grain (22.83 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the phosphorus uptake by grain of 19.38, 16.73, 14.80, 12.46, 10.31, 9.18 and 7.30 kg ha^{-1}, respectively. The lowest phosphorus uptake was noted in control T_1 of 4.30 kg ha^{-1}.

4.4.3.4. Phosphorus uptake by straw

In 2022, the highest phosphorus uptake by straw (18.78 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the phosphorus uptake by straw of 17.19, 14.82, 13.36, 11.95, 10.58, 8.58 and 7.51 kg ha^{-1}, respectively. The lowest phosphorus uptake was noted in control T_1 of 4.02 kg ha^{-1}.

During 2023, the highest phosphorus uptake by straw (29.96 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly ($p=0.05$) higher than all other treatments. The trend was followed in other treatments of T_9, T_7, T_5, T_4, T_6, T_3 and T_2 registering the phosphorus uptake by straw of 22.83, 21.97, 19.39, 16.69, 12.98, 12.12 and 8.91 kg ha^{-1}, respectively. The results of treatment T_9 were comparable with T_7. The results of treatment T_6 were comparable with T_3. The lowest phosphorus uptake was noted in control T_1 of 4.64 kg ha^{-1}.

4.4.3.5. Potassium uptake by grain

In 2022, the highest potassium uptake by grain (35.24 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium uptake by grain of 32.46, 30.28, 28.23, 25.71, 23.34, 20.48 and 17.89 kg ha^{-1}, respectively. The lowest potassium uptake was noted in control T_1 of 11.32 kg ha^{-1}.

During 2023, the highest potassium uptake by grain (45.04 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium uptake by grain of 39.98, 35.15, 33.44, 30.12, 27.50, 23.41 and 21.06 kg ha^{-1}, respectively. The lowest potassium uptake was noted in control T_1 of 13.31 kg ha^{-1}.

4.4.3.6. Potassium uptake by straw

In 2022, the highest potassium uptake by straw (119.83 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium uptake by straw of 113.49, 106.25, 99.86, 92.64, 85.41, 77.30 and 71.38 kg ha^{-1}, respectively. The lowest potassium uptake was noted in control T_1 of 43.70 kg ha^{-1}.

During 2023, the highest potassium uptake by straw (135.30 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the potassium uptake by straw of 125.68, 117.55, 109.92, 100.18, 92.31, 83.53 and 76.38 kg ha^{-1}, respectively. The lowest potassium uptake was noted in control T_1 of 46.98 kg ha^{-1}.

Table 21. Impact of inorganic, organic and biological sources of nutrients on NPK uptake (kg ha^{-1}) in rice (2022)

Treatment	Nutrient uptake (kg ha^{-1})					
	N uptake		P uptake		K uptake	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 – Control	33.57	24.72	3.12	4.02	11.32	43.70
T_2 – 100% RDF	45.15	32.56	5.53	7.51	17.89	71.38
T_3 – 125% RDF	49.16	36.33	6.82	8.58	20.48	77.30
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	58.11	45.57	9.25	11.95	25.71	92.64
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	62.44	49.53	10.86	13.36	28.23	99.86
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	53.99	40.94	7.78	10.58	23.34	85.41
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	70.94	56.74	13.82	17.19	32.46	113.49
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	74.88	60.81	15.10	18.78	35.24	119.83
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	66.29	53.54	12.00	14.82	30.28	106.25
S.Ed	**1.23**	**0.98**	**0.23**	**0.29**	**0.56**	**1.98**
CD (p=0.05)	**2.61**	**2.08**	**0.50**	**0.61**	**1.20**	**4.20**

Table 22. Impact of inorganic, organic and biological sources of nutrients on NPK uptake (kg ha^{-1}) in rice (2023)

Treatment	Nutrient uptake (kg ha^{-1})					
	N uptake		P uptake		K uptake	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 – Control	34.06	28.42	4.30	4.64	13.31	46.98
T_2 – 100% RDF	38.68	36.28	7.30	8.91	21.06	76.38
T_3 – 125% RDF	42.72	41.09	9.18	12.12	23.41	83.53
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	51.94	50.85	12.46	16.69	30.12	100.18
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	57.01	55.77	14.80	19.39	33.44	109.92
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	47.63	46.15	10.31	12.98	27.50	92.31
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	72.70	65.03	19.38	21.97	39.98	125.68
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	81.20	71.73	22.83	29.96	45.04	135.30
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	66.35	59.19	16.73	22.83	35.19	117.55
S.Ed	**1.24**	**1.12**	**0.33**	**0.42**	**0.68**	**2.19**
CD (p=0.05)	**2.63**	**2.37**	**0.71**	**0.89**	**1.46**	**4.66**

4.4.4. Micronutrient uptake

The data on micronutrient uptake in 2022 & 2023 were presented in Table 23 & 24.

4.4.4.1. Iron uptake by grain

In 2022, the highest iron uptake by grain (96.21 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the iron uptake by grain of 88.07, 82.58, 82.48, 75.08, 70.09, 52.07 and 48.22 g ha^{-1}, respectively. The lowest iron uptake was noted in control T_1 of 32.26 g ha^{-1}.

During 2023, the highest iron uptake by grain (101.69 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the iron uptake by grain of 92.86, 87.21, 85.91, 78.22, 70.96, 47.45 and 46.07 g ha^{-1}, respectively. The lowest iron uptake was noted in control T_1 of 29.90 g ha^{-1}.

4.4.4.2. Iron uptake by straw

In 2022, the highest iron uptake by straw (198.87 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the iron uptake by straw of 183.22, 173.63, 172.27, 158.98, 147.16, 116.94 and 112.08 g ha^{-1}, respectively. The lowest iron uptake was noted in control T1 of 86.02 g ha^{-1}.

During 2023, the highest iron uptake by straw (208.49 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the iron uptake by straw of 192.65, 182.67, 181.82, 165.08, 152.38, 106.78 and 101.71 g ha^{-1}, respectively. The lowest iron uptake was noted in control T_1 of 87.00 g ha^{-1}.

4.4.4.3. Manganese uptake by grain

In 2022, the highest manganese uptake by grain (74.83 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 and T_2 registering the manganese uptake by grain of 70.88, 65.32, 64.23, 58.57, 55.40, 37.78 and 33.56 g ha^{-1}, respectively. The lowest manganese uptake was noted in control T_1 of 19.03 g ha^{-1}.

During 2023, the highest manganese uptake by grain (80.31 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the manganese uptake by grain of 74.94, 68.85, 68.60, 62.63, 57.55, 39.00 and 34.38 g ha^{-1}, respectively. The lowest manganese uptake was noted in control T_1 of 19.72 g ha^{-1}.

4.4.4.4. Manganese uptake by straw

In 2022, the highest manganese uptake by straw (270.88 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the manganese uptake by straw of 236.27, 233.60, 217.95, 198.13, 186.99, 140.46 and 136.19 g ha^{-1}, respectively. The lowest manganese uptake was noted in control T_1 of 107.46 g ha^{-1}.

During 2023, the highest manganese uptake by straw (281.87 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the manganese uptake by straw of 255.67, 245.88, 232.31, 221.29, 193.28, 144.37 and 139.07 g ha^{-1}, respectively. The results of treatment T_5 were comparable with T_6 and T_3. The lowest manganese uptake was noted in control T_1 of 119.19 g ha^{-1}.

4.4.4.5. Zinc uptake by grain

In 2022, the highest zinc uptake by grain (117.58 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the zinc uptake by grain of 106.83, 98.98, 94.98, 88.76 77.44, 55.53 and 51.58 g ha^{-1}, respectively. The lowest zinc uptake was noted in control T_1 of 33.83 g ha^{-1}.

During 2023, the highest zinc uptake by grain (123.51 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the zinc uptake by grain of 111.15, 104.04, 98.66, 92.40, 79.90, 61.60 and 56.94 g ha^{-1}, respectively. The lowest zinc uptake was noted in control T_1 of 36.23 g ha^{-1}.

4.4.4.6. Zinc uptake by straw

In 2022, the highest zinc uptake by straw (427.29 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the zinc uptake by straw of 393.10, 370.74, 367.04, 341.57, 307.13, 261.76 and 249.60 g ha^{-1}, respectively. The lowest zinc uptake was noted in control T_1 of 196.13 g ha^{-1}.

During 2023, the highest zinc uptake by straw (442.24 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the zinc uptake by straw of 407.28, 387.41, 381.15, 345.57, 316.53, 268.53 and 248.42 g ha^{-1}, respectively. The lowest zinc uptake was noted in control T_1 of 215.99 g ha^{-1}.

4.4.4.7. Copper uptake by grain

In 2022, the highest copper uptake by grain (45.93 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the copper uptake by grain of 42.92, 39.15, 38.23, 35.28, 31.90, 19.43 and 18.40 g ha^{-1}, respectively. The results of treatment T_9 were comparable with T_5. The results of treatment T_3 were comparable with T_2. The lowest copper uptake was noted in control T_1 of 10.44 g ha^{-1}.

During 2023, the highest copper uptake by grain (51.13 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_2 and T_3 registering the copper uptake by grain of 47.07, 43.52, 41.25, 38.33, 32.51, 20.37 and 20.12 g ha^{-1}, respectively. The results of treatment T_3 were comparable with T_2. The lowest copper uptake was noted in control T_1 of 12.57 g ha^{-1}.

4.4.4.8. Copper uptake by straw

In 2022, the highest copper uptake by straw (113.48 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the copper uptake by straw of 102.48, 98.75, 96.20, 88.08, 79.48, 71.95 and 60.11 g ha^{-1}, respectively. The results of treatment T_7 were comparable with T_5. The results of treatment T_9 were comparable with T_5. The lowest copper uptake was noted in control T_1 of 51.63 g ha^{-1}.

During 2023, the highest copper uptake by straw (126.13 g ha^{-1}) was noted in treatment 125% RDF + Vermicompost + 2% Zinc Solubilizing bacteria (T_8) registered and which is significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_5, T_9, T_4, T_6, T_3 and T_2 registering the copper uptake by straw of 111.62, 106.77, 102.41, 92.44, 86.83, 63.73 and 55.63 g ha^{-1}, respectively. The lowest copper uptake was noted in control T_1 of 42.22 g ha^{-1}.

Table 23. Impact of inorganic, organic and biological sources of nutrients on micronutrient uptake (g ha^{-1}) in rice (2022)

Treatment	Micronutrients uptake (g ha^{-1})							
	Fe uptake		Mn uptake		Zn uptake		Cu uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1 – Control	32.26	86.02	19.03	107.46	33.83	196.13	10.44	51.63
T_2 – 100% RDF	48.22	112.08	33.56	136.19	51.58	249.60	18.40	60.11
T_3 – 125% RDF	52.07	116.94	37.78	140.46	55.53	261.76	19.43	71.95
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	75.08	158.98	58.57	198.13	88.76	341.57	35.28	88.08
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	82.48	172.27	64.23	233.60	98.98	370.74	39.15	98.75
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	70.09	147.16	55.40	186.99	77.44	307.13	31.90	79.48
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	88.07	183.22	70.88	236.27	106.83	393.10	42.92	102.48
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	96.21	198.87	74.83	270.88	117.58	427.29	45.93	113.48
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	82.58	173.63	65.32	217.95	94.98	367.04	38.23	96.20
S.Ed	**1.52**	**3.25**	**1.21**	**4.09**	**1.83**	**6.58**	**0.73**	**1.80**
CD (p=0.05)	**3.23**	**6.91**	**2.58**	**8.68**	**3.88**	**14.52**	**1.56**	**3.83**

Table 24. Impact of inorganic, organic and biological sources of nutrients on micronutrient uptake (g ha^{-1}) in rice (2023)

Treatment	Micronutrients uptake (g ha^{-1})							
	Fe uptake		Mn uptake		Zn uptake		Cu uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1 – Control	29.90	87.00	19.72	119.19	36.23	215.99	12.57	42.22
T_2 – 100% RDF	46.07	101.71	34.38	139.07	56.94	248.42	20.37	55.63
T_3 – 125% RDF	47.75	106.78	39.00	144.37	61.60	268.53	20.12	63.73
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	78.22	165.08	62.63	221.29	92.40	345.57	38.33	92.44
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	87.21	182.67	68.85	245.88	104.04	387.41	43.52	106.77
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	70.96	152.38	57.55	193.28	79.90	316.53	32.51	86.83
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	92.86	192.65	74.94	255.67	111.15	407.28	47.07	111.62
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	101.69	208.49	80.31	281.87	123.51	442.24	51.13	126.13
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	85.91	181.82	68.60	232.31	98.66	381.15	41.25	102.41
S.Ed	**1.59**	**3.31**	**1.29**	**4.36**	**1.91**	**7.06**	**0.80**	**1.93**
CD (p=0.05)	**3.39**	**7.03**	**2.74**	**9.24**	**4.05**	**14.93**	**1.70**	**4.11**

4.5. Nutrient availability in the post harvest soil

4.5.1. Available NPK

The data on available NPK in soil samples after harvesting the crop as recorded during the years 2022 & 2023 are presented in Tables 25 & 26.

4.5.1.1. Available nitrogen

In 2022, the highest available nitrogen in post harvest soil (179.3 kg ha^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_7) having available nitrogen 173.6 kg ha^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 & T_2 registering available nitrogen in post harvest soil of 167.5, 161.5, 156.4, 153.3, 149.5 and 146.8 kg ha^{-1}, respectively. The results of T_9 were comparable with T_7 and T_5. The results of treatment T_4 were comparable with T_5 and T_6. The results of treatment T_6 were comparable with T_3 and T_2. The lowest available nitrogen of 141.1 kg ha^{-1} in post harvest soil was noted in control T_1.

During 2023, the highest available nitrogen in post harvest soil (187.0 kg ha^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment T_7 (125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria) as 180.4 kg ha^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_9, T_5, T_4, T_6, T_3 & T_2 registering regards to available nitrogen as 175.4, 167.8, 162.4, 159.1, 155.1 and 153.5 kg ha^{-1}, respectively. The results of treatment T_9 were comparable with T_7. The results of treatment T_4 were comparable with T_5 and T_6. The results of treatment T_6 were comparable with T_3 & T_2. The lowest available nitrogen of 146.7 kg ha^{-1} in post harvest soil was noted in control T_1.

4.5.1.2. Available phosphorus

In 2022, the highest available phosphorus in post harvest soil (26.8 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering regards to available phosphorus of 25.4, 24.5, 23.0, 21.9, 21.3, 19.9 and 19.5 kg ha^{-1}, respectively. The lowest available phosphorus was noted in control T_1 as 13.4 kg ha^{-1}.

During 2023, the highest available phosphorus in post harvest soil (25.4 kg ha^{-1}) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_7, T_9, T_5, T_4, T_6, T_3 & T_2 registering regards to available phosphorus of 23.9, 22.8, 21.6, 20.3, 19.7, 17.8 and 17.6 kg ha^{-1}, respectively. The lowest available phosphorus was noted in control T_1 as 12.0 kg ha^{-1}.

4.5.1.3. Available potassium

In 2022, the highest available potassium in post harvest soil (204.3 kg ha^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment T_7, T_9 and T_5 of 201.7, 199.8 and 197.4 kg ha^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_4, T_6, T_3 and T_2 registering the available potassium of 195.7, 192.6, 185.2 and 181.4 kg ha^{-1}, respectively. The results of treatment T_9 were comparable with T_5, T_4 and T_6. The results of treatment T_3 were comparable with T_6 and T_2. The lowest available potassium of 171.8 kg ha^{-1} in post harvest soil was noted in control T_1.

During 2023, the highest available potassium in post harvest soil (219.2 kg ha^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment T_7, T_9, T_5 and T_4 of 218.1, 216.4, 213.6 and 212.0 kg ha^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_6, T_3 & T_2 registering the available potassium of 209.6, 202.2 and 193.3 kg ha^{-1}, respectively. The results of treatment T_9 were comparable with T_7, T_5, T_4 and T_6. The results of treatment T_3 were comparable with T_6. The lowest available potassium of 179.1 kg ha^{-1} in post harvest soil was noted in control T_1.

Table 25. Available NPK (kg ha^{-1}) in post harvest soil as influenced by the impact of inorganic, organic and biological sources of nutrients (2022)

Treatments details	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1 – Control	141.1	13.4	171.8
T_2 – 100% RDF	146.8	19.5	181.4
T_3 – 125% RDF	149.5	19.9	185.2
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	156.4	21.9	195.7
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	161.5	23.0	197.4
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	153.3	21.3	192.6
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	173.6	25.4	201.7
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	179.3	26.8	204.3
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	167.5	24.5	199.8
S.Ed	**3.10**	**0.45**	**3.70**
CD (p=0.05)	**6.59**	**0.96**	**7.86**

Table 26. Available NPK (kg ha^{-1}) in post harvest soil as influenced by the impact of inorganic, organic and biological sources of nutrients (2023)

Treatments details	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1 – Control	146.7	12.0	179.1
T_2 – 100% RDF	153.5	17.6	193.3
T_3 – 125% RDF	155.1	17.8	202.2
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	162.4	20.3	212.0
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	167.8	21.6	213.6
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	159.1	19.7	209.6
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	180.4	23.9	218.1
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	187.0	25.4	219.2
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	175.4	22.8	216.4
S.Ed	**3.23**	**0.42**	**4.03**
CD (p=0.05)	**6.85**	**0.89**	**8.54**

4.5.2. Exchangeable Ca & Mg, available Zn and organic carbon

The data on exchangeable Ca & Mg content, Zn and Organic carbon content in 2022 & 2023 in post harvest soil were presented in Table 27 & 28.

4.5.2.1. Exchangeable calcium

In 2022, the highest exchangeable calcium in post harvest soil (6.53 C mol kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment T_5 and T_7 of 6.42 and 6.31 C mol (P^+) kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_4, T_9, T_6, T_3 & T_2 registering the exchangeable calcium of 6.12, 5.98, 5.79, 5.60 and 5.51 C mol (P^+) kg^{-1}, respectively. The results of treatment T_4 were comparable with T_9. The results of treatment T_9 were comparable with T_6. The results of treatment T_3 were comparable with T_6 and T_2. The lowest exchangeable calcium of 5.26 C mol (P^+) kg^{-1} in post harvest soil was noted in control T_1.

During 2023, the highest exchangeable calcium in post harvest soil (6.31 C mol (P^+) kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment T_5 and T_7 of 6.20 and 6.11 C mol (P^+) kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_4, T_9, T_6, T_3 & T_2 registering the exchangeable calcium of 5.93, 5.77, 5.57, 5.36 & 5.26 C mol (P^+) kg^{-1}, respectively. The results of treatment T_9 were comparable to T_6. The results of treatment T_6 were comparable with T_3 and T_2. The results of treatment T_6 were comparable with T_3 & T_2. The lowest exchangeable calcium of 4.99 C mol (P^+) kg^{-1} in post harvest soil was noted in control T_1.

4.5.2.2. Exchangeable magnesium

In 2022, the highest exchangeable magnesium in post harvest soil (3.84 C mol (P^+) kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_5) as 3.79 C mol (P^+) kg^{-1} and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 & T_2 registering regards to exchangeable magnesium of 3.66, 3.59, 3.46, 3.26, 3.15 and 3.08 C mol (P^+) kg^{-1}, respectively. The results of treatment T_9 were comparable with T_7

and T_5. The results of treatment T_4 were comparable to T_5. The lowest exchangeable magnesium of 2.97 C mol (P^+) kg^{-1} in post harvest soil was noted in control T_1.

During 2023, the highest exchangeable magnesium in post harvest soil (3.59 C mol (P^+) kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_5) of 3.53 C mol (P^+) kg^{-1} and significantly ($p=0.05$) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 and T_2 registering the exchangeable magnesium of 3.41, 3.33, 3.20, 3.11, 3.03 and 2.95 C mol (P^+) kg^{-1}, respectively. The results of treatment T_9 were comparable with T_7 and T_5. The results of treatment T_4 were comparable with T_5 and T_6. The results of treatment T_6 were comparable with T_3 and T_2. The lowest exchangeable magnesium of 2.82 C mol (P^+) kg^{-1} in post harvest soil was noted in control T_1.

4.5.2.3. Available zinc

In 2022, the highest available zinc in post harvest soil (2.14 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatmen 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_5) of 2.10 mg kg^{-1} and significantly ($p=0.05$) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 and T_2 registering the available zinc of 1.91, 1.84, 1.69, 1.58, 1.42 and 1.38 mg kg^{-1}, respectively. The results of treatment T_7 were comparable with T_4. The results of treatment T_3 were comparable with T_2. The lowest available zinc of 1.29 mg kg^{-1} in post harvest soil was noted in control T_1.

During 2023, the highest available zinc in post harvest soil (2.25 mg kg^{-1}) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatmen 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_5) of 2.20 mg kg^{-1} and significantly ($p=0.05$) higher than all other treatments. It was followed in treatment T_7, T_4, T_9, T_6, T_3 & T_2 registering the available zinc of 2.02, 1.92, 1.78, 1.66, 1.49 and 1.45 mg kg^{-1}, respectively. The results of treatment T_3 were comparable with T_2. The lowest available zinc of 1.35 mg kg^{-1} in post harvest soil was noted in control T_1.

4.5.2.4. Organic carbon

In 2022, the highest organic carbon in post harvest soil (0.87%) was noted in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) and significantly (p=0.05) higher than all other treatments. The trend was followed in other treatments of T_5, T_7, T_9, T_4, T_6, T_3 and T_2 registering regards to organic carbon of 0.83, 0.78, 0.77, 0.75, 0.74, 0.71 and 0.68 %, respectively. The lowest organic carbon was noted in control T_1 as 0.59 % respectively.

During 2023, the highest organic carbon in post harvest soil (0.83 %) was observed in the plot with treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_8) registered which was comparable in treatment 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria (T_5) as 0.81 % and significantly (p=0.05) higher than all other treatments. It was followed in treatment T_7, T_9, T_4, T_6, T_3 and T_2 registering the organic carbon of 0.74, 0.73, 0.71, 0.70, 0.66 and 0.64 %, respectively. The results of treatment T_9 were comparable with T_7 and T_4. The results of treatment T_6 were comparable with T_4. The results of treatment T_3 were comparable with T_2. The lowest organic carbon was noted in control T_1 as 0.55%.

Table 27. Exchangeable Ca & Mg, available Zn, Organic carbon in post harvest soil as influenced by the impact of inorganic, organic and biological sources of nutrients (2022)

Treatments details	Ca (C mol (P^+) kg^{-1})	Mg (C mol (P^+) kg^{-1})	Zn (mg kg^{-1})	Organic carbon (%)
T_1 – Control	5.26	2.97	1.29	0.59
T_2 – 100% RDF	5.51	3.08	1.38	0.68
T_3 – 125% RDF	5.60	3.15	1.42	0.71
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	6.12	3.59	1.84	0.75
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	6.42	3.79	2.10	0.83
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	5.79	3.26	1.58	0.74
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	6.31	3.66	1.91	0.78
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	6.53	3.84	2.14	0.87
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	5.98	3.45	1.69	0.77
S.Ed	**0.11**	**0.06**	**0.03**	**0.01**
CD (p=0.05)	**0.24**	**0.14**	**0.06**	**0.03**

Table 28. Exchangeable Ca & Mg, available Zn, organic carbon in post harvest soil as influenced by the impact of inorganic, organic and biological sources of nutrients (2023)

Treatments details	**Ca (C mol (P^+) kg^{-1})**	**Mg (C mol (P^+) kg^{-1})**	**Zn (mg kg^{-1})**	**Organic carbon (%)**
T_1 – Control	4.99	2.82	1.35	0.55
T_2 – 100% RDF	5.26	2.95	1.45	0.64
T_3 – 125% RDF	5.36	3.03	1.49	0.66
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	5.93	3.33	1.92	0.71
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	6.20	3.53	2.20	0.81
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	5.57	3.11	1.66	0.70
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	6.11	3.41	2.02	0.74
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	6.31	3.59	2.25	0.83
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	6.57	3.20	1.78	0.73
S.Ed	**0.11**	**0.06**	**0.03**	**0.01**
CD (p=0.05)	**0.23**	**0.13**	**0.07**	**0.02**

4.5.3. Economics of rice

The data on economics of rice during the years 2022 & 2023 are presented in Tables 29 & 30.

In both the years the highest cost of cultivation was noticed in the treatment T_8 & T_9 (Rs. 43,100) followed by the treatment T_5 & T_6 (Rs. 42,600), T_7 (Rs. 42,100), T_4 (Rs. 41,600), T_3 (Rs. 33,000) and T_2 (Rs. 32,500). The lowest cost of cultivation was recorded in the treatment T_1 (Rs. 30,500).

In 2022, the highest gross income was observed in the treatment T_8 (Rs. 1,13,274) followed by T_7 (Rs. 1,08,216), T_9 (Rs. 1,02,870), T_5 (Rs. 97,740), T_4 (Rs. 92,574), T_6 (Rs. 87,552), T_3 (Rs. 81,936) and T_2 (Rs. 76,680). The lowest gross income was observed in the treatment T_1 (Rs. 57,672). In the view of B:C ratio was observed in the treatment T_8 (2.62) followed by treatments T_7 (2.57), T_3 (2.48), T_9 (2.38), T_2 (2.35), T_5 (2.29), T_4 (2.22) and T_6 (2.05). The lowest B:C ratio was observed in the treatment T_1 (1.89).

In 2023, the highest gross income was observed in the treatment T_8 (Rs. 1,14,192) followed by T_7 (Rs. 1,09,062), T_9 (Rs. 1,03,860), T_5 (Rs. 98,676), T_4 (Rs. 93,492), T_6 (Rs. 88,398), T_3 (Rs. 82,692) and T_2 (Rs. 77,364). The lowest gross income was observed in the treatment T_1 (Rs. 58,968). In the view of B:C ratio was observed in the treatment T_8 (2.64) followed by treatments T_7 (2.59), T_3 (2.50), T_9 (2.40), T_2 (2.38), T_5 (2.31), T_4 (2.24) and T_6 (2.07). The lowest B:C ratio was observed in the treatment T_1 (1.93).

Table 29. Impact of inorganic, organic and biological sources of nutrients on economics of rice (2022)

Treatment	**Economics**			
	Cost of cultivation (Rs.)	**Gross Income (Rs.)**	**Net income (Rs.)**	**B:C ratio**
T_1 – Control	30,500	57,672	27,172	1.89
T_2 – 100% RDF	32,500	76,680	44,180	2.35
T_3 – 125% RDF	33,000	81,936	48,936	2.48
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	41,600	92,574	57,974	2.22
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	42,600	97,740	55,140	2.29
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	42,600	87,552	44,952	2.05
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	42,100	1,08,216	73,116	2.57
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	43,100	1,13,274	70,714	2.62
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	43,100	1,02,870	59,770	2.38

Table 30. Impact of inorganic, organic and biological sources of nutrients on economics of rice (2023)

Treatment	Economics			
	Cost of cultivation (Rs.)	Gross Income (Rs.)	Net income (Rs.)	B:C ratio
T_1 – Control	30,500	58,968	28,468	1.93
T_2 – 100% RDF	32,500	77,364	44,864	2.38
T_3 – 125% RDF	33,000	82,692	49,692	2.50
T_4 – 100% RDF + PM at 10 t ha^{-1} + 2% ZSB	41,600	93,492	58,892	2.24
T_5 – 100% RDF + VC at 6 t ha^{-1} + 2% ZSB	42,600	98,676	56,076	2.31
T_6 – 100% RDF + CPC at 6 t ha^{-1} + 2% ZSB	42,600	88,398	45,798	2.07
T_7 – 125% RDF + PM at 10 t ha^{-1} + 2% ZSB	42,100	1,09,062	73,962	2.59
T_8 – 125% RDF + VC at 6 t ha^{-1} +2% ZSB	43,100	1,14,192	71,092	2.64
T_9 – 125% RDF + CPC at 6 t ha^{-1}+ 2% ZSB	43,100	1,03,860	60,760	2.40

4.6. DISCUSSION

Neither organic manure nor chemical fertilizers alone is not enough to meet the demand of soil plant system. Emerging evidence indicated that integrated soil fertility management involve the judicious use of combined organic and inorganic resources as a feasible approach to overcome soil fertility constraint (Patra *et al.,* 2000; Mahajan *et al*., 2008; Aulakh and Grant, 2008; Tilahun Tadesse *et al*., 2013; Ghosh, 2015). More recently, attention is given on the utilization of organic wastes like press mud, vermicompost and coir pith compost as the most effective measure for improving soil fertility and thereby crop production. A suitable combination of organic and inorganic sources of nutrients are necessary for higher crop production in an intensive cropping system, since, the combination will maintain soil fertility and to balance nutrient supply to boost up the crop yield per unit area (Ali *et al*., 2009). Thus the yield of rice and soil productivity can be substantially increased with judicious application of organic manures with chemical fertilizers (Hossaen *et al*., 2011). The results emanated from the study through organics and chemical fertilizers are discussed under.

4.6.1. Plant height

Through a various sources of treatment, usage of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) compared to control and other treatments at the level of significance p=0.05, increased plant heights were observed at the tillering stage (54.1 cm), panicle initiation stage (88.3 cm), and harvest stage (106.8 cm). Growth promoting effect of N on plant can be explained on the basis of the fact that N supply increases the number and size of meristematic cells which leads to formation of new shoot (Lawlor, 2002). Furthermore, N application is known to increase the levels of cytokinins which affect cell wall extensibilities (Arnold *et al*., 2006). Nutrient availability from organic sources is due to microbial action and improved physical condition of soil (Sarkar *et al*., 2004). Vermicompost might have increased the soil moisture content, soil porosity and other plant enhancing characters for that reason; it increased plant height (Banik and Bejbaruah, 2004). Increase in plant height in response to recommended dose of fertilizer might be primarily due to improved vegetative growth and supplementary contribution of N (Sharma *et al.,* 2007; Ayan *et al*., 2011). Increase in plant height due to integrated dose of organics and chemical fertilizer was similarly echoed by (Babu *et al*., 2001), (Sudha and Chandini, 2003), (Usman *et al*., 2003) and (Roy and Singh, 2006). The continuous availability of major and trace minerals might be the reason behind response in improved plant height as derived from vermicompost which help to increase the content of several growth harmones such as cytokinin, gibberellins, and NAA, which led to a rise in plant height. Additionally, this was supported by (Thirunavukkarasu and Vinoth 2013) and (Tharmaraj *et al.*, 2011). In control plots (T_1), the lowest plant height was recorded.

Fig. 3. Impact of different nutrient sources on plant height (2022)

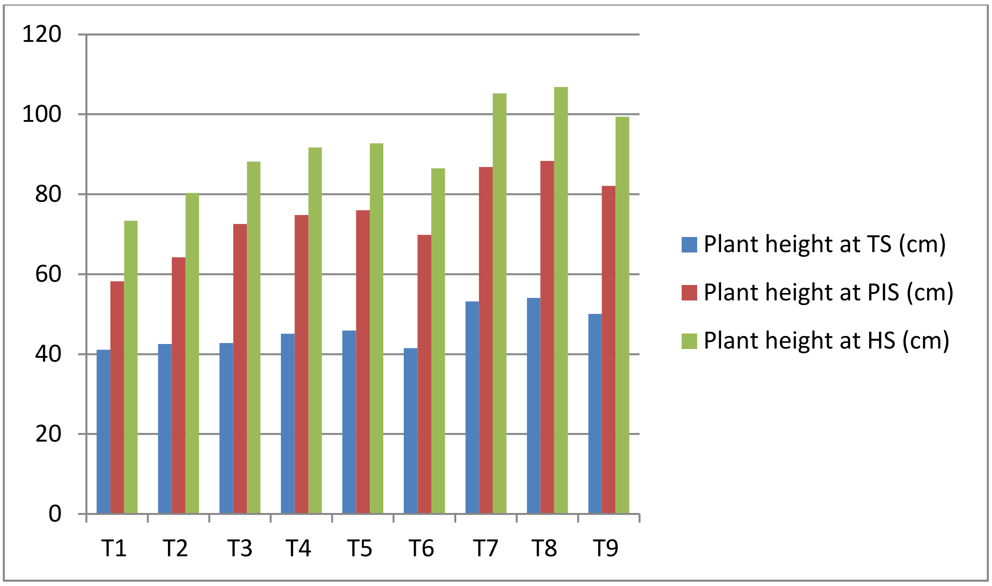
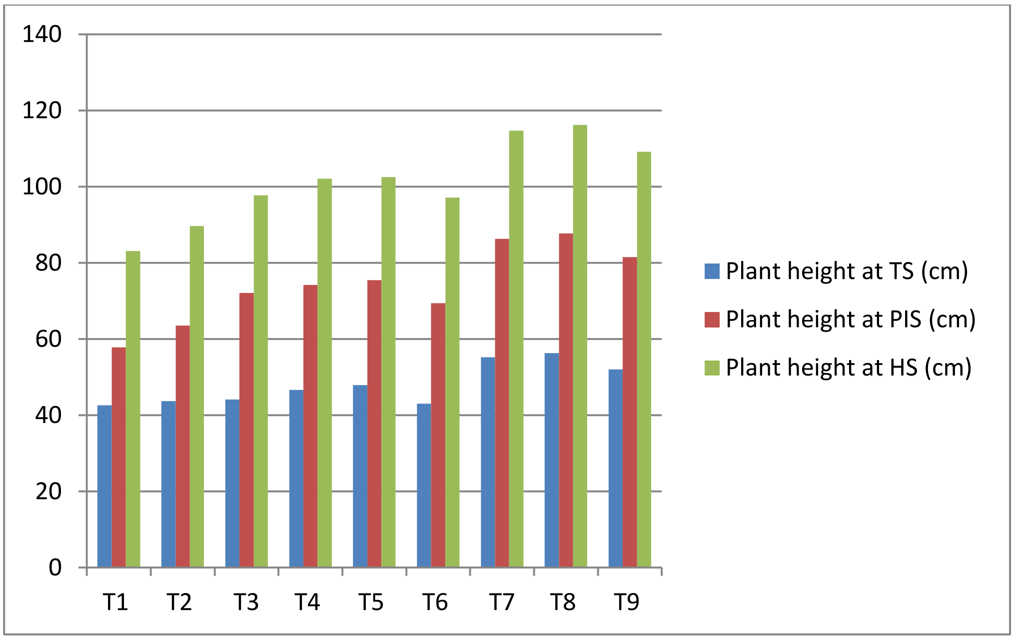


Fig. 4. Impact of different nutrient sources on plant height (2023)

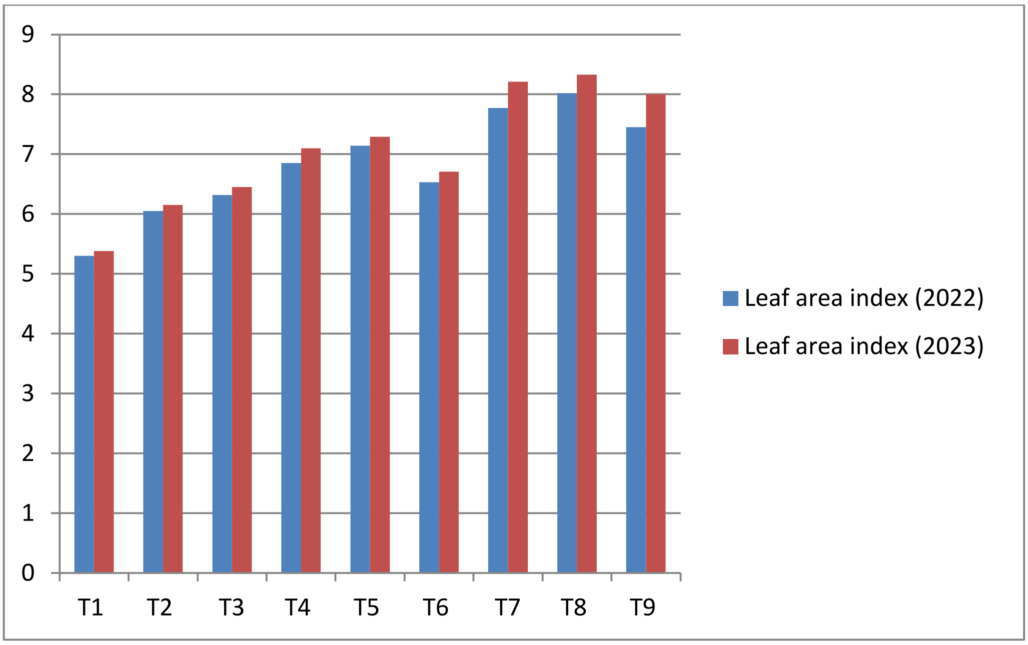


4.6.2. Leaf Area Index

The treatment with the highest leaf area index of 8.02 out of all the combinations was tested in treatment 125% RDF + Vermicompost at 6 t ha^{-1} + Zinc solubilizing bacteria (T_8) at the level of significance p=0.05. (Mirza *et al.*, 2010) and (Morteza Siavoshi *et al.*, 2013) also reported similar results. The lowest leaf area index 5.30 was observed in control (T_1).

The increasing trend of LAI with INM can be attributed to the positive effect of nitrogen on both leaf development and leaf area duration of the crop (Fageria, 2007; Fageria and Baligar, 2005). Increased plant life may be the cause of higher LAI, metabolism that might was encouraged activity of meristematic and led to apical development. Hence, as a result of the application of vermicompost, plants are using more nitrogen, which increases photosynthesis and, ultimately, the leaf area index. It has been demonstrated that vermicompost contains many humic acid derivatives which improves morphological traits of crop and thus increase LAI (Atarzadeh *et al.*, 2013). Humic acid increases LAI and leaf expansion rate because of increased plant nitrogen (Albayrak and Camas, 2005).

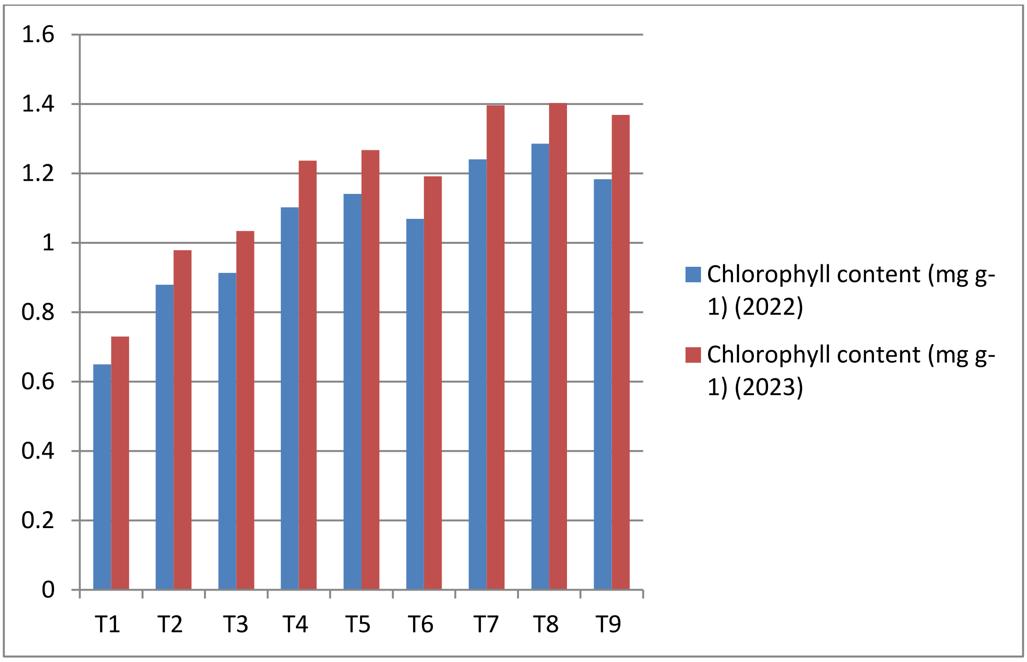
Fig. 5. Impact of different nutrient sources on leaf area index



4.6.3. Chlorophyll content

Among the several treatments, maximum chlorophyll content and effectively higher than other treatments at the level of significance p=0.05 found in treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc solubilizing bacteria (T_8) measured 1.285 mg g^{-1}. The greater chlorophyll value in leaves treated with organic manures + NPK are of importance because photosynthetic activity and crop yield may increase with chlorophyll content of leaves (Ramesh *et al.*, 2002). (Morteza Siavoshi *et al.*, 2013) reported higher chlorophyll with ½ RDF and organics. (Berova and Karanatsidis 2009) and (Fernandez Luqueno *et al.*, 2010) studied the effect of organic manures on amount of chlorophyll pigments and rate of photosynthesis. They reported that organic manure not only enhance the synthesis and amount of chlorophyll but also increase rate of photosynthesis. (Roy and Singh, 2006) also reported increase in chlorophyll content in barley leaves with vermicompost application. Perhaps by providing nutrients and raising chlorophyll, vermicompost encourages plant development, which in turn enhances photosynthesis. This results are according to the reported by (Ramesh *et al.*, 2018). An absolute control T_1 had the lowest chlorophyll content.

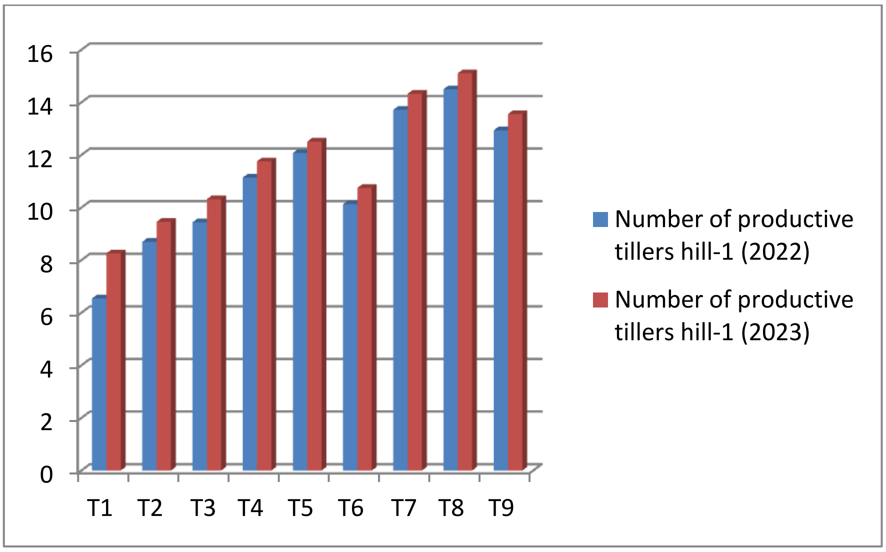
Fig. 6. Impact of different nutrient sources on chlorophyll content



4.6.4. Number of productive tillers hill^{-1}

Utilization of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8), which produced the highest number of producing tillers, outperformed other treatments by a significant margin. Higher tiller count could be due to higher nitrogen supply from organics and organic sources offer more balanced nutrition to plants especially micronutrients, which has caused better affectivity of tiller in plant grown vermicompost (Rakshit *et al.*, 2008). Effective tillering depends primarily on soil physical conditions that were superior due to addition of organic manures (Usman *et al.*, 2003). It was for perhaps as a result of enhanced growth and photosynthesis when necessary nutrients are present in appropriate amounts, as well as improved photosynthetic translocation to sink due to the balanced NPK nutrients in vermicompost. Higher tiller counts may be attributed to a sufficient zinc supply, which may have improved plant metabolism by increasing the absorption and availability of other vital minerals. This outcome is consistent with the findings of (Noraida Mohd Radzi *et al.*, 2017) and (Kamaleshwaran and Elayaraja, 2021). The present result on the influence of INM on tiller count was in harmony with (Satyanarayana *et al.*, 2002), (Nayak *et al.*, 2007), (Mohandass *et al.*, 2008) and (Naing *et al.*, 2010). An absolute control T_1 had the fewest productive tillers hill^{-1}.

Fig. 7. Impact of different nutrient sources on number of productive tillers hill^{-1}

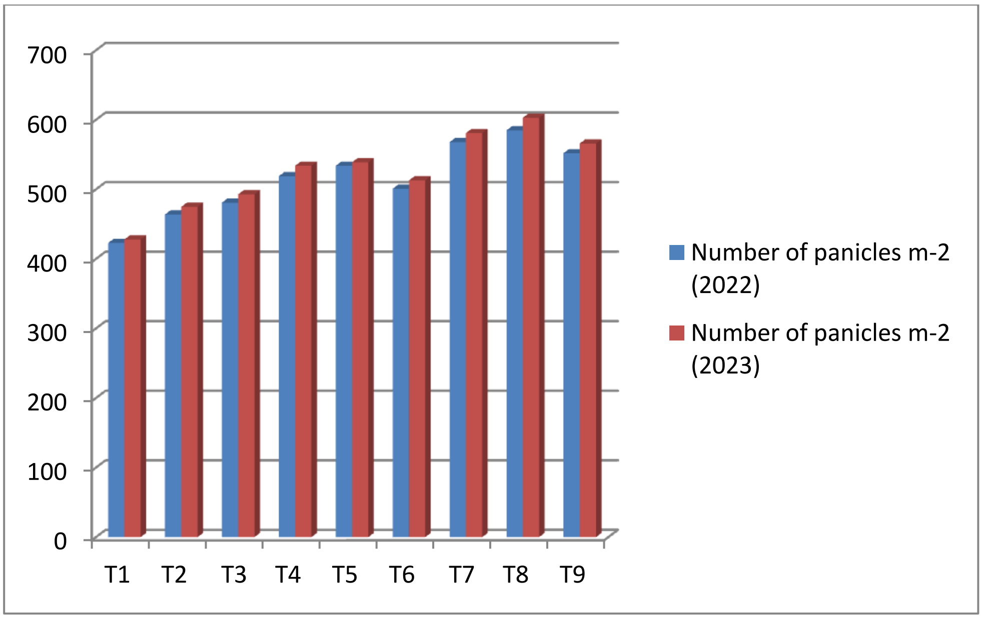


4.6.5. Number of panicle m^{-2}

Utilization a 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) was a more number of panicles m^{-2} in 585 out in all a combinations tested (T_8) at the level of significance p=0.05. Higher number of panicles m^{-2} could be because the vermicompost provides a better and more consistent source of nutrients. Similar results were also as reported by (Bejbaruah *et al.*, 2013) and (Kumar *et al.*, 2014). Higher number of panicles m^{-2}

due to N might be due to higher N absorption which favored formation of higher number of panicle m^{-2} (Rahman *et al*., 2007). The higher yield attributes in application of inorganic fertilizer might have brought about better mobilization of nutrients towards panicles producing more number of panicles m^{-2} (Awal *et al*., 2011). The control T_1 has the least number.

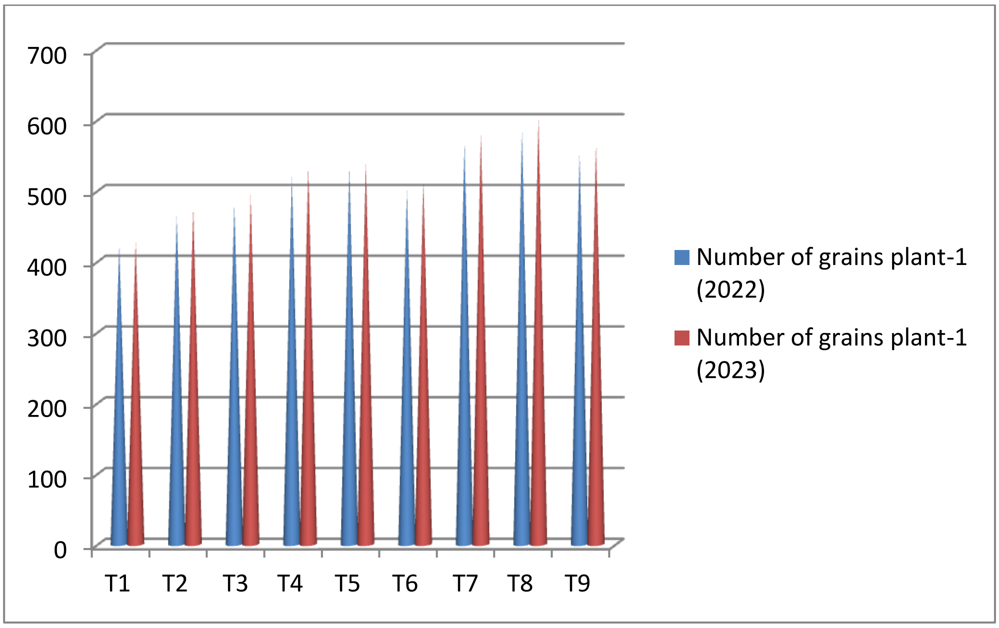
Fig. 8. Impact of different nutrient sources on number of panicles m^{-2}



4.6.6. Number of grains plant^{-1}

The highest number of grains plant^{-1}, were observed in the treatment, 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) at the level of significance p=0.05. Because organics results in an increased and ongoing supply of nutrients, which improves number of grains plant^{-1}. This findings is similar with the earlier reports of (Sitajanaki and Sreehari, 1997), (Taheri Rahimabadi *et al.*, 2017), (Kiriya Sungthongwises and Tidarat Tanpan, 2018) and (Honorio *et al.*, 2019). Inorganic, organic and bio fertilizers are the main source for replenishing plant nutrients in agricultural soils (Masarirambi *et al*., 2012), (Lawal and Lawal, 2002) reported adequate supply of nitrogen is essential for grain development of rice and to increase filled grains plant^{-1}. The lowest grains plant^{-1} were recorded in control.

Fig. 9. Impact of different nutrient sources on number of grains plant^{-1}

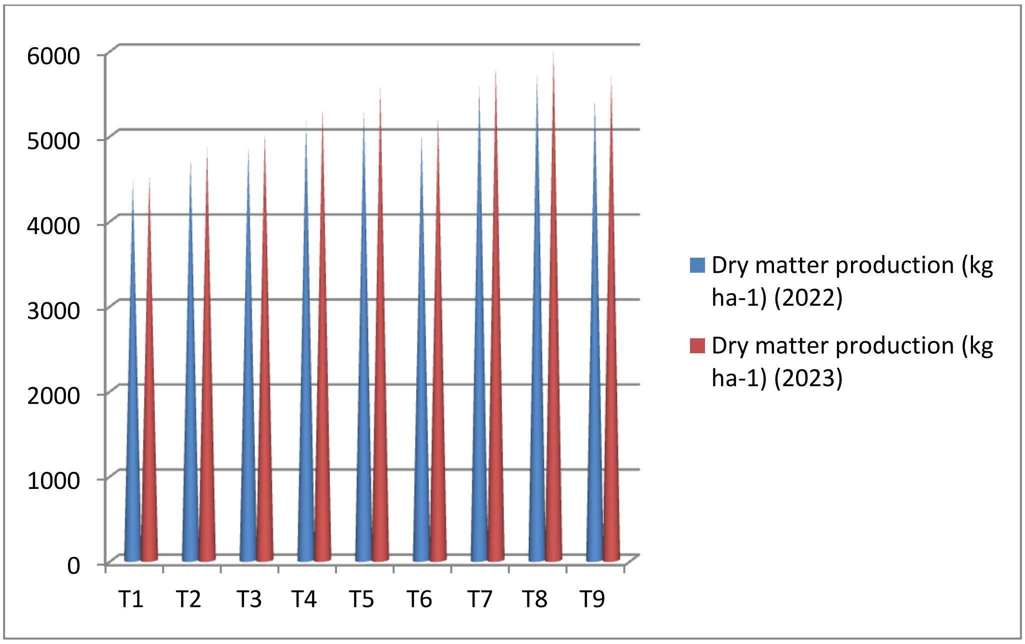


4.6.7. Dry matter production

Treatment of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) recorded highest DMO as 5720 kg ha^{-1} at the level of significance p=0.05. These findings are in accordance to reports by Ramesh, 2018. The lowest dry matter production was recorded in control T_1.

Elevated nitrogen supply can boost DMP through production of photo assimilates via leaves which is the center of plant growth during vegetative stage and later distribution of assimilates to the reproductive organs (Azarpour *et al*., 2014). Furthermore, DMP in rice is significantly related to intercept photo synthetically active radiation (Kiniry *et al*., 2001). The increased leaf area caused by improved nutrient available through combination by vermicompost & inorganic fertilisers resulted in improved production better biomass and, higher Dry matter production. Integrated application of organic manures and chemical fertilizers helped in accumulation of foliage N, improved growth and controlled senescence of whole plant that could ultimately lead to higher DMP in meeting the need of larger sink (Huang *et al*., 2008; Sharma *et al*., 2009; Mondal *et al*., 2016).

Fig. 10. Impact of different nutrient sources on dry matter production



4.6.8. Grain yield and straw yield

Treatment of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) recorded highest grain and straw yield and significantly (p=0.05) higher than all other treatments. This may be because additional nutrients were added to the soil through vermicompost and inorganic fertiliser, increasing the amount of nutrients available for plant absorption and increasing photosynthetic efficiency as measured by increased LAI, which in turn enhanced grain yield & straw yield. It's outcome was consistent to findings by (Prakash and Bhadoria, 2002, Jatinder Kumar, 2007, Mirza Hasanuzzaman *et al.*, 2010, Koushal *et al.*, 2011, Khursheed *et al.*, 2013, Manivannan and Sriramachandrasekharan, 2018). The joint application of organics and fertilizer recorded higher yield reflecting the soil amendment might have supplied the adequate nutrients needed especially nitrogen which enhanced the vegetative growth, in addition organics would have improved the soil biophysical condition for better ramification, nutrient absorption and uptake by rice (Mondal *et al.*, 2016). Higher grain yield due to various organics over control could be due to supply of nutrients especially macro and micronutrients which induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency, regulation of water to cells, facilitating better aeration, root activity and nutrient absorption (Singh *et al.*, 2004). It could be due to the satisfaction of nutrient requirement from inorganic sources during initial stages of crop growth and from slow releasing organic sources at subsequent stages (Bhattacharya *et al.*, 2003). The better performance of vermicompost could be due to presence of readily available N (NH_4-N) from the assimilate products of excretion, mineralization of body tissues of earthworm led to greater availability of nutrients causing more uptake of nutrients and diverting them to reproductive organ. (Rajni Rani and Srivastava, 2001) found that applying one third or one fourth of N as vermicompost increased straw yield. The lowest grain and straw was recorded in control (T_1).

Fig. 11. Impact of different nutrient sources on grain yield

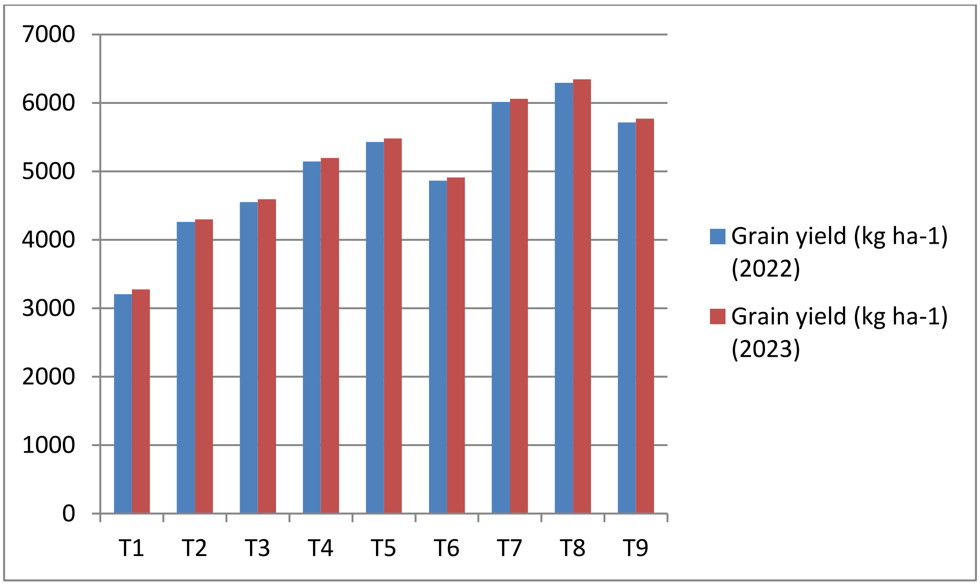
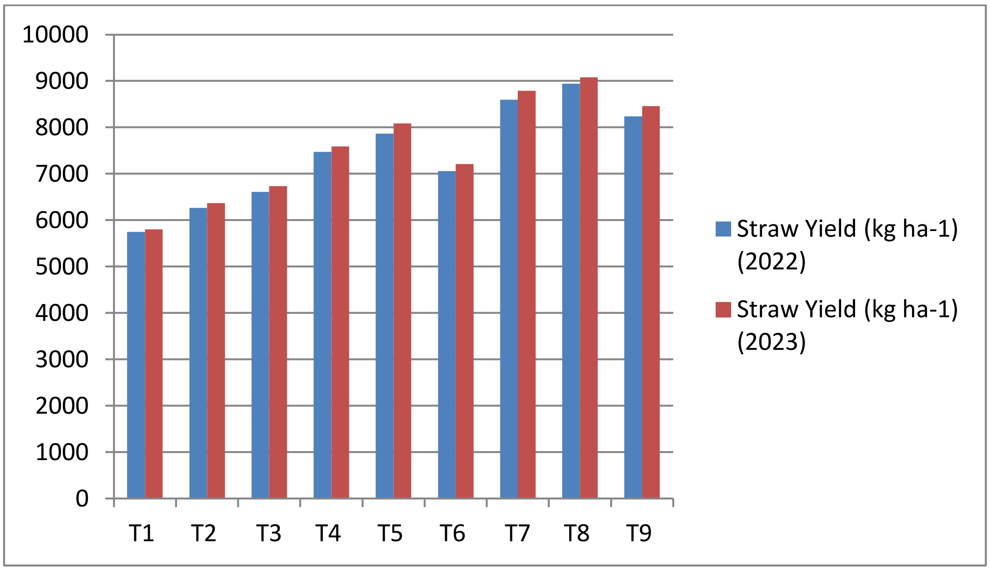


Fig. 12. Impact of different nutrient sources on straw yield



4.6.9. Quality attributes

Treatment of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) recorded higher results in protein content, head rice recovery per cent, milling per cent and hulling per cent content over control and other treatments at the level of significance p=0.05. The least values reported in control plots (T_1). Current research on quality characteristics may be the consequence of improved soil conditions, such as higher levels of available nutrients that released nutrients throughout a long length of time, leading to improved levels of N, P, and K uptake. This, in turn, may promote better growth and development when vermicompost is supplied with both inorganic and biological nutrients. This observation is consistent with the conclusions of (Singh *et al.*, 2007, Moola Ram *et al.*, 2011 and Davari and Sharma, 2010) they noticed a in plots treated with organic manure as opposed to plots treated with artificial fertilizers, marketing-oriented characteristics such as hulling, milling, and head rice recovery were greater. It was also noted that rice has higher protein levels by (Tejada and Gonzalez, 2009 and Hemalatha *et al.*, 2000).

Fig. 13. Impact of different nutrient sources on quality attributes (2022)

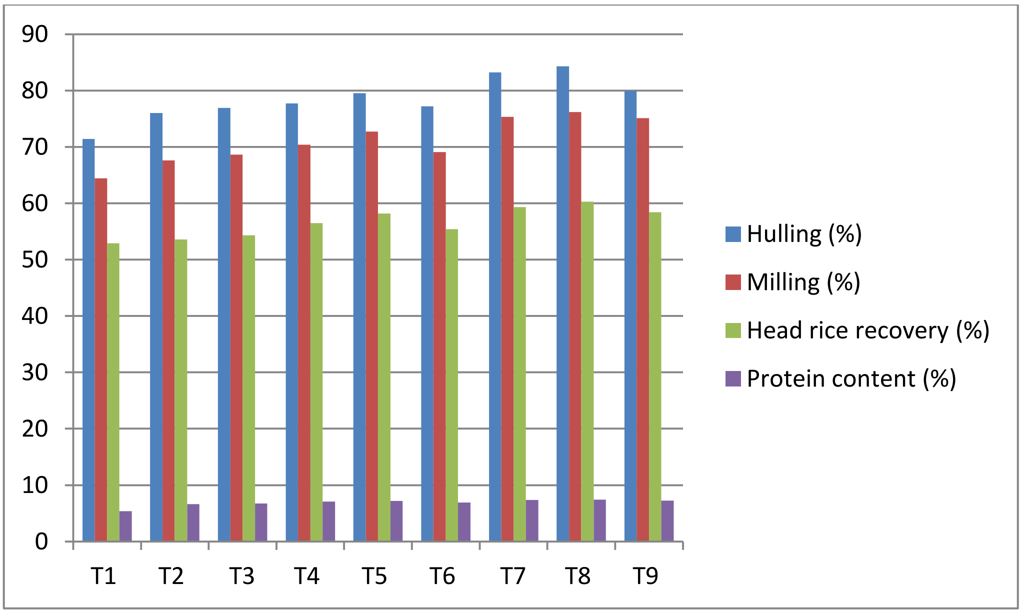
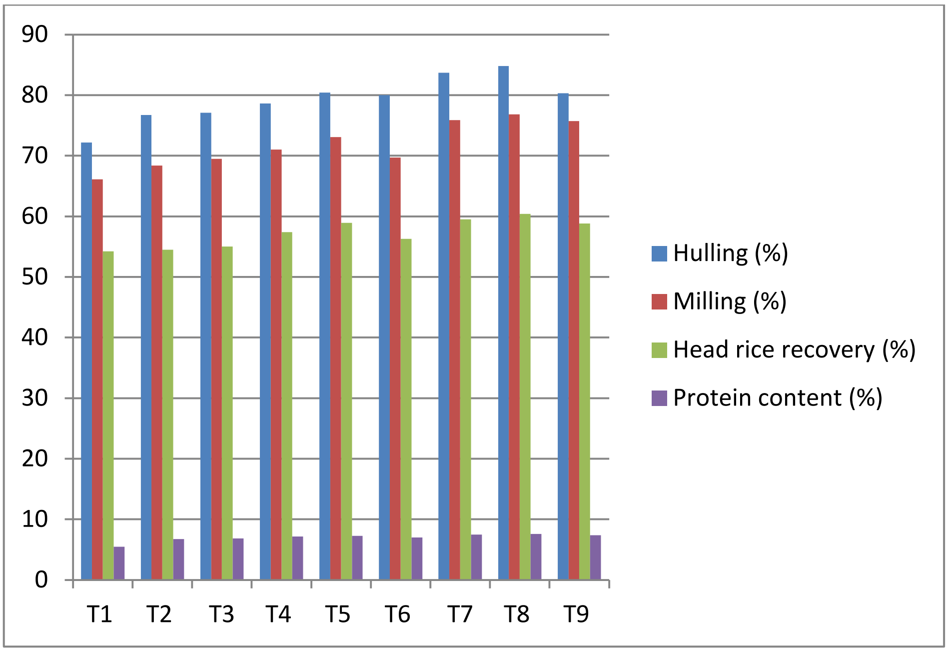


Fig. 14. Impact of different nutrient sources on quality attributes (2023)



4.6.10. Nutrient content and Nutrient uptake

In present study, addition of vermicompost and NPK recorded higher nutrient content compared to other treatments. The productivity of a plant can be influenced by its elemental composition. The chemical composition of any plant is an important parameter to compare the performance of applied treatment. Adoption of different nitrogen management practices significantly enhanced the nutrient content and its uptake (N,P,K) over control at all stages of crop growth in both soils and in both years. Nutrient content and uptake was higher when organics and chemical fertilizer was applied compared to their individual additions. Further nutrient concentration and uptake by organics were lower compared to chemical fertilizer alone but greater over control. Uptake of nutrients depend upon crop yield and their concentration. The value of nutrient uptake followed the pattern of yield obtained in different treatments. Organic manures increased the absorption power of the soil for cations and anions, particularly nitrogen and phosphorus. These ions are released gradually during entire growing period of crop. Further, additions of organic manures are known to improve soil environment that encourage the proliferation of roots resulting in more absorption of water and nutrients from larger area of soil depth, which might have increased the concentration and uptake of major nutrients with use of organics (Minhas and Sood, 1994; Singh *et al*., 2000). Higher nutrient uptake in conjoint application of inorganics and organics may mainly due to continuous availability of N, P and K throughout crop growth period and the nutrients from the inorganic sources were available to the crop in early stages and nutrients released from organic sources become available at the later stages of crop growth. This implies that balanced supply of nutrients was ensured by INM practices (Panigrahi *et al.,* 2014). Higher uptake of nutrients due to inorganics alone compared to organics could be due to greater availability of nutrients to plant in quick manner at early stages of crop growth leading to higher concentration and biomass production (Banik *et al*., 2008), whereas application of organics alone immobilized the available nutrients temporarily at early stage of growth thereby releasing nutrients slowly and at lower concentration. Increased nitrogen uptake could be ascribed to slow and continual supply of N coupled with reduced N losses which might have improved synchrony between plant N demand and supply of N in soil. This proposition is consistent with that of (Hale *et al*., 2002). Higher P uptake could be attributed to increased utilization of native P added through organics due to organic acids produced during decomposition of organic manures (Aziz *et al.,* 2010). The appropriate C:N ratio under their organic supplements as a ready source of nutrients for the soil microbes and when applied with urea, they ensure a sufficient as well as constant supply of essential nutrients. The plant nutrients are adsorbed on the humic acid molecule and are released slowly and gradually into soil solution and made available for plant growth and development processes (Arancon *et al*., 2005).

Higher availability and uptake of macro and micronutrients and active participation in carbon assimilation, photosynthesis, starch formation, translocation of protein and sugar, entry of water into plant roots and development, etc., It also enhances the process of tissue differentiation from somatic to reproductive phase leading to higher grain yield. Greater response obtained with vermicompost is probably related to relatively better fertility status of vermicompost which influenced their comparative efficiency in increasing the nutrient efficiency of soil (Chaoui *et al*., 2003). Organic fertilizers produce significant CEC to hold cations such as K^+. The change in CEC of organics by acidification might have enhanced K availability (Magdoff and Bartlett, 1985) thereby more K concentration in plant leading to higher K uptake (Bhadoria and Prakash, 2001; Sreelatha *et al*., 2006). The higher concentration and uptake of nutrients in vermicompost amended soils could be due to readily available N coupled with rich source of their macronutrients, vitamins, plant growth regulators and beneficial microflora which made a good organic source to supply nutrients to soil in adequate manner for the plant to absorb and assimilate in their tissues (Jayakumar *et al.*, 2014).

4.6.11. NPK content

Treatment of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) recorded higher NPK content at the level of significance p=0.05. The application of vermicompost, which is an abundant supply of nutrients and enhances regards to availability of macronutrients in soil, is responsible for the increase in nutritional concentration. Same outcomes was discovered about (Taheri Rahimabadi *et al.*, 2017 & Papia Biswas *et al.*, 2020). The control plots were found to have the lowest NPK concentration in grain and straw (T_1).

Fig. 15. Impact of different nutrient sources on NPK content (2022)

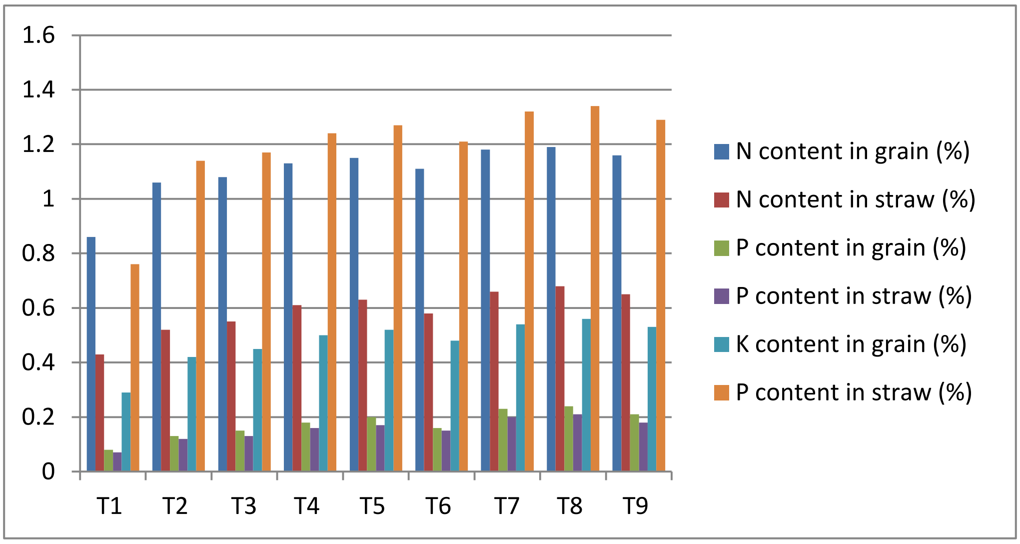
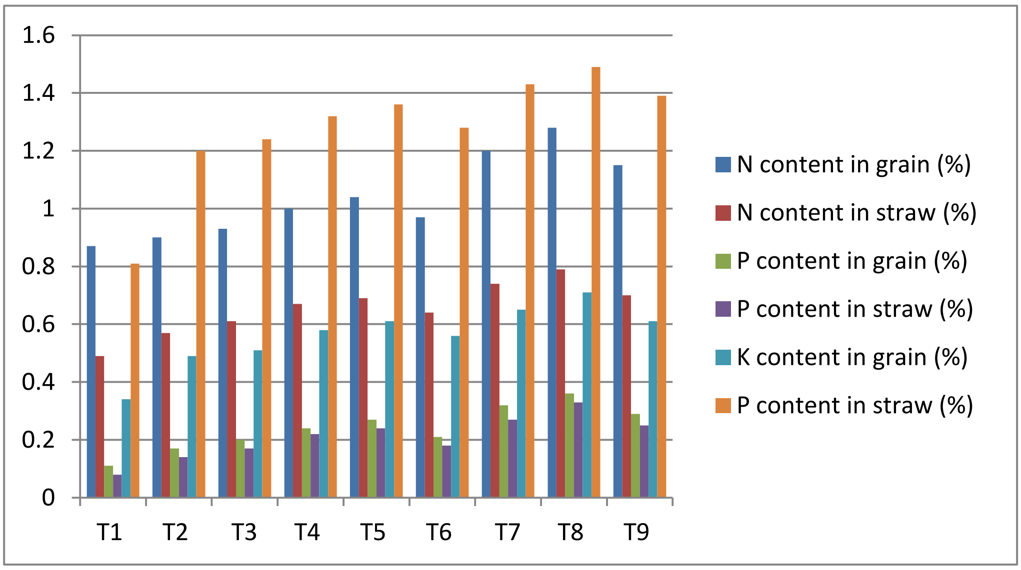


Fig. 16. Impact of different nutrient sources on NPK content (2023)



4.6.12. Micronutrient content

Treatment of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) recorded higher micronutrient content at the level of significance p=0.05. These treatments had effects on micronutrient content that were comparable to those on macronutrient content. The application of vermicompost, which is a plentiful supply of nutrients and enhances regards to availability of micronutrients to the soil, is responsible for the rise in micronutrient concentrations. Moreover, this was supported by Sharma *et al.,* (2015). The control plots were found to have the lowest micronutrient content in grain and straw (T_1).

Fig. 17. Impact of different nutrient sources on micronutrient content (2022)

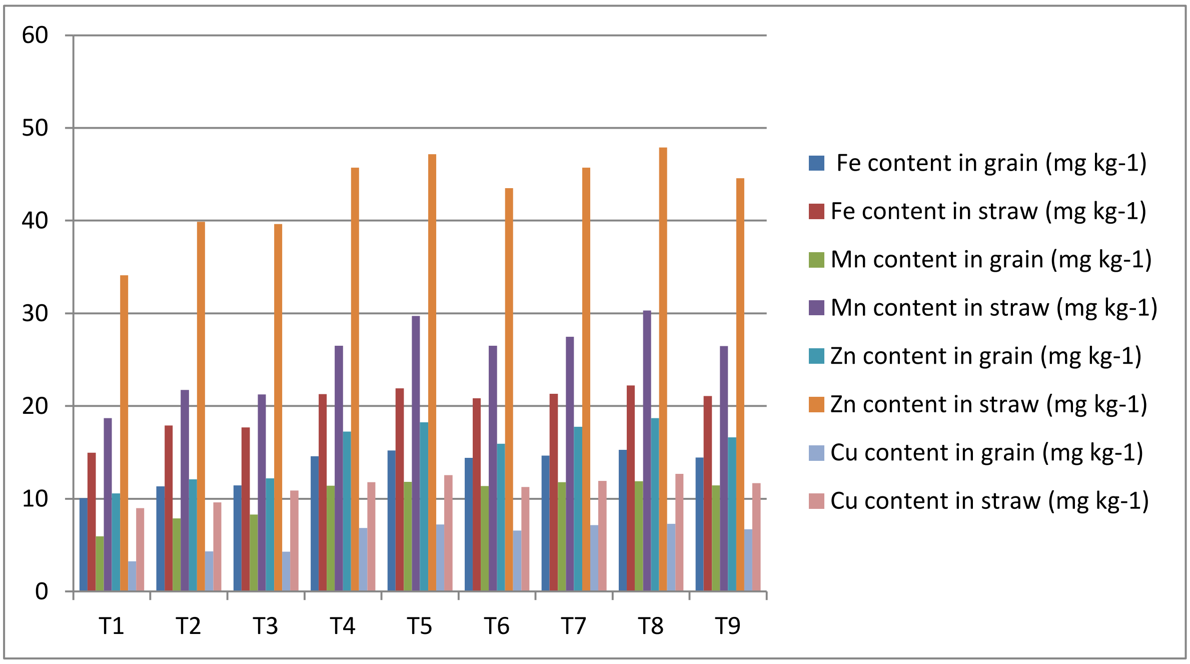
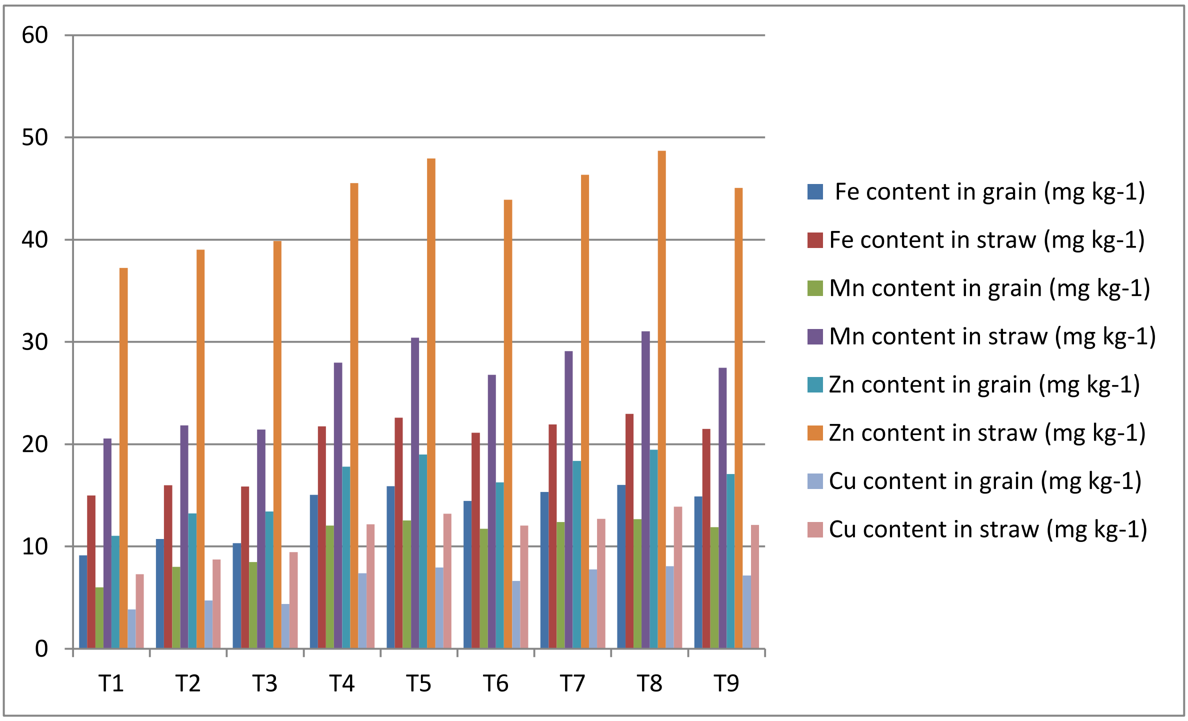


Fig. 18. Impact of different nutrient sources on micronutrient content (2023)



4.6.13. NPK uptake

While applying 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) produced noticeably higher values for Potassium, Phosphorus, and Nitrogen uptake in straw and grain which is significantly (p=0.05) higher than all other treatments. This is because the concentration of nutrients in the soil was raised by using vermicompost in conjunction with chemical fertilisers. Parallel findings was given by (Jadhav *et al.*, 1997), (Sunil Kumar *et al.*, 2017) and (Kamaleshwaran and Elayaraja, 2021). The least Potassium, Phosphorus and Nitrogen absorption in straw & grain were observed in control plots (T_1).

Fig. 19. Impact of different nutrient sources on NPK uptake (2022)

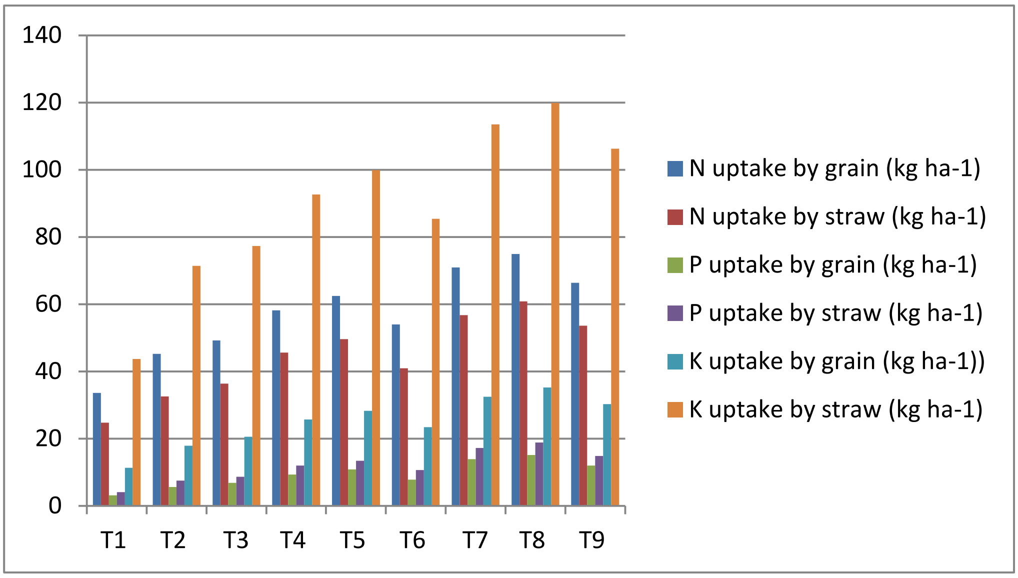
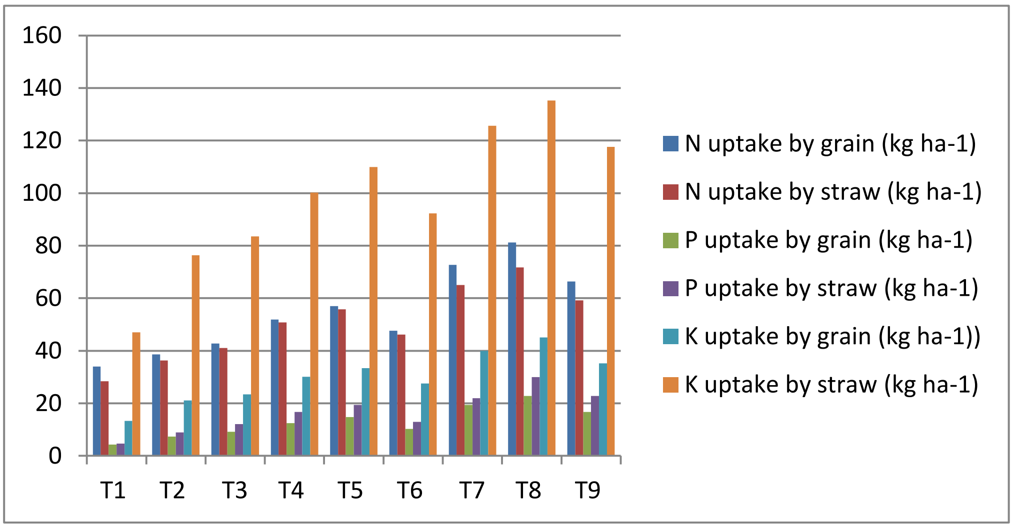


Fig. 20. Impact of different nutrient sources on NPK uptake (2023)



4.6.14. Micronutrient uptake

Utilization a 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T$_8$) registered significantly (p=0.05) higher than all other treatments for Copper, Zinc, Manganese and Iron uptake by grain & straw. These treatments had a comparable impact on micronutrient uptake as they did on macronutrients. The improvement in root proliferation and higher nutrient concentration in the soil may be the cause of the significant improvement in nutrient uptake as a result of the combination of vermicompost and chemical fertilizers. Additionally, this was supported by (Sharma *et al.*, 2015). Lowest amount of Copper, Zinc, Manganese and Iron absorption through straw & grain was observed in plots of absolute control (T$_1$).

Fig. 21. Impact of different nutrient sources on micronutrient uptake (2022)

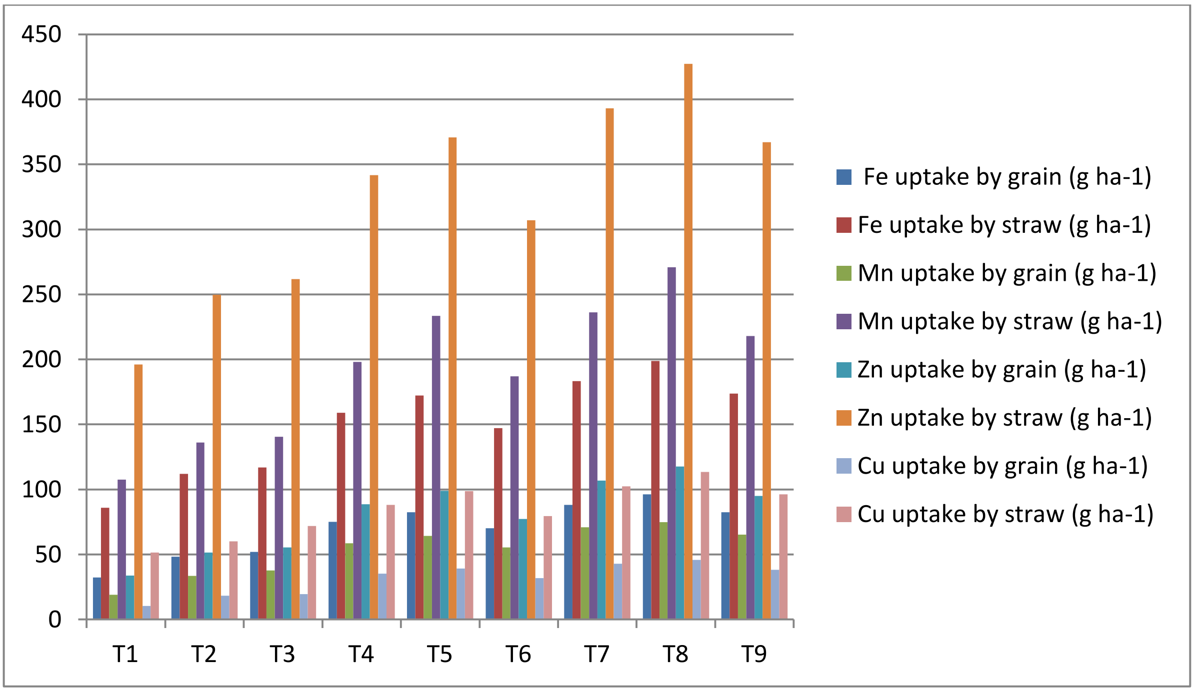
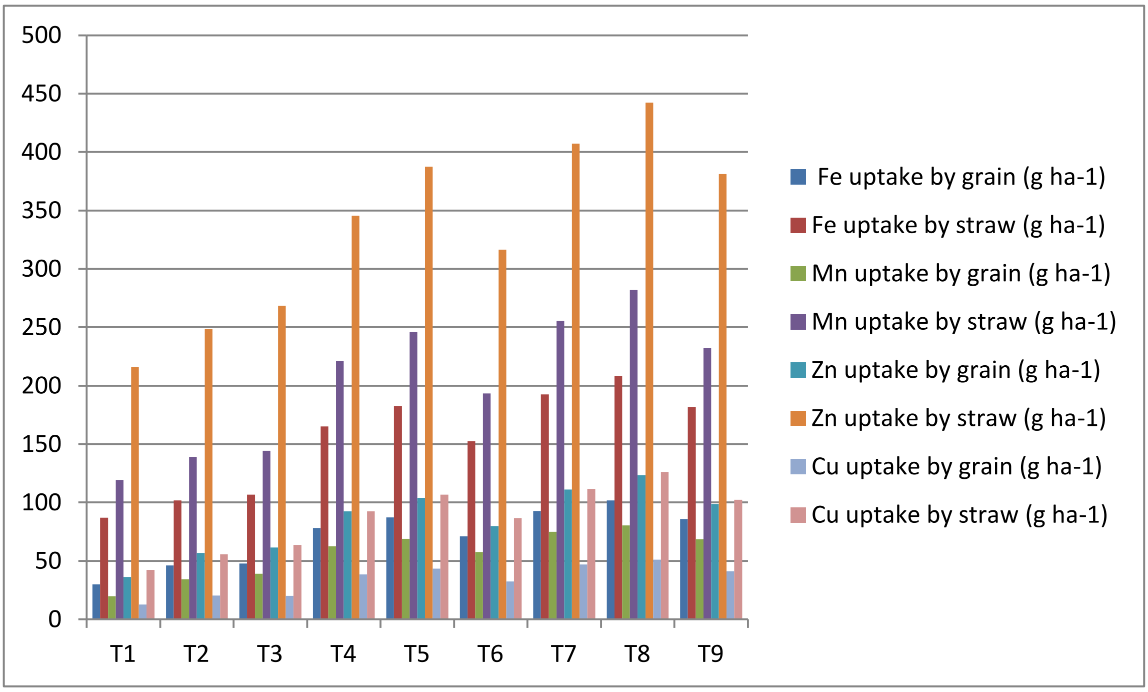


Fig. 22. Impact of different nutrient sources on micronutrient uptake (2023)



4.6.14. Post harvest fertility status of soil

Through a the various nutrient sources, utilization of 125% RDF + Vermicompost @ 6 t ha^{-1} + Zinc Solubilizing Bacteria (T_8) registerd more value on available NPK, exchangeable Ca & Mg, available Zn and organic carbon in post harvest soil over control and all other treatments at (p=0.05) level of significance. Enhanced microbial mineralization of organic matter universally augmented soil available nitrogen. Higher availability of nitrogen at early stage is due to enhanced mineralization of nutrients on decomposition of organic manures (Lal *et al*., 2003) and decrease in later stages may be due to utilization of N by increasing microbial population and loss through denitrification (Saha *et al*., 1995). Higher available N in soil due to organics may be attributed to high retention of N as NH_4-N in soil. Variation in available N are mainly due to mineralization of organic matter and net amount mineralized is varying according to the source that use less or more N for mineralization and greater multiplication of microbes which favours the conversion of organically bound N to inorganic form (Maharudrappa *et al*., 2000).

Nitrogen and phosphorus were more readily available when vermicompost and the prescribed fertilizer dosage were applied. Evidence suggests that the soil grew more stable year after year following the addition of organic matter. Additionally, the soil's biological activity increased and was impacted to keep the soil's accessible nitrogen levels stable. Thus, vermicompost clearly enhances the amount of nutrients that are accessible by a large amount. This was also reported by (Shweta and Narayana 2014). (Blair *et al*., 2006) recorded that earthworm can increase N availability by reducing microbial immobilization and enhancing mineralization. (Koushal *et al*., 2011) reported higher available N, P, K and O.C with 100% vermicompost alone. Higher availability of nitrogen under INM treatments could be due to the fact that faster release of N from inorganic source (100% soluble N) which is met for immediate crop requirement (Dixit and Gupta, 2000, Laxminarayana, 2006; Senthilvelu and Prabha, 2007). Mineralization of organic manures is likely to play a major role in P release for plant growth. The organic acid being anions might enhance P release by competing for exchange sites. Further, decomposition of organic manures, release organic carbon and CO_2 both leading to lower pH and cause solubility of calcium phosphate leading to higher available P (Urukurkar *et al*., 2012). (Reddy and Mahesh, 1995) and (Kumarjit Singh *et al*., 2005) reported higher available K in soil incorporated with vermicompost and fertilizer. Incorporation of organic sources as well as fertilizer helps in rapid decomposition and higher microbial activity caused higher organic carbon in soil (Pradhan and Mondal, 1997; Srilatha *et al*., 2015; Rudrappa *et al*., 2006). (Moharana *et al*., 2012) noticed that higher soil organic carbon could be due to direct addition of organic manure in soil but also due to better growth of roots resulting in higher biomass from stubbles and residues and subsequent decomposition of these materials might have resulted on the enhanced carbon content of soil. The least values in post harvest soil were reported in control plots (T_1).

Fig. 23. Impact of different nutrient sources on post harvest fertility status of soil (2022)

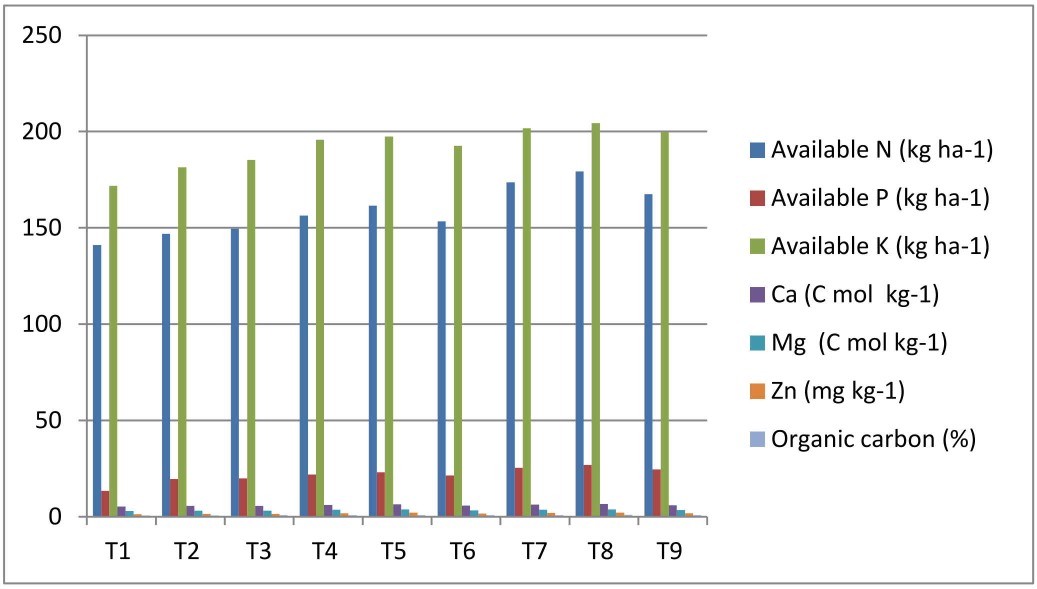
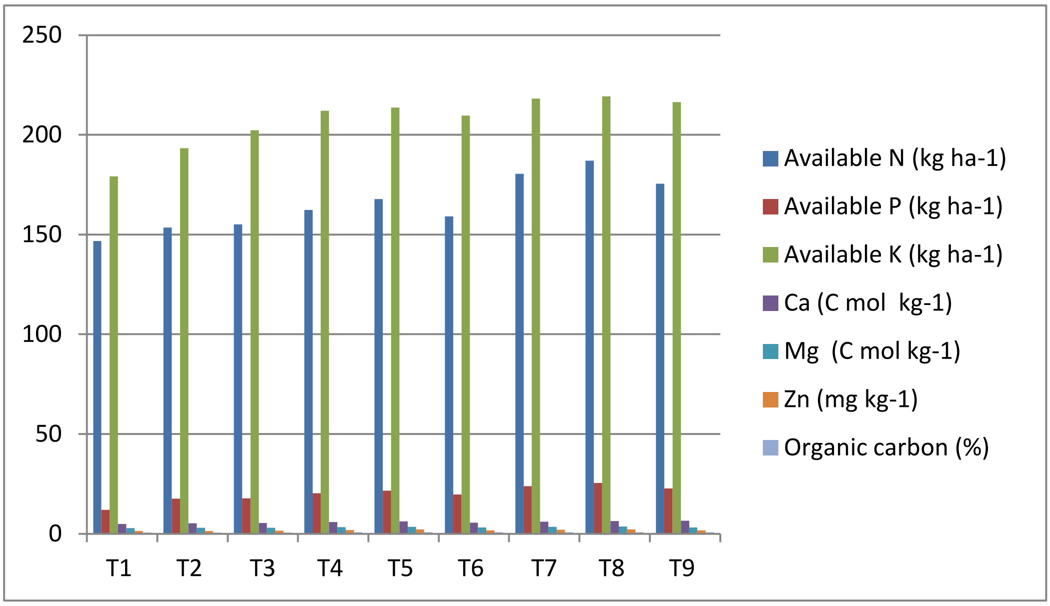


Fig. 24. Impact of different nutrient sources on post harvest fertility status of soil (2023)



CHAPTER - V

SUMMARY AND CONCLUSION

The present experiments wer conducted on clay loam soil belonging to tropical climate in Tamil Nadu state, India during years 2022 & 2023 (January – April) to ascertain the impact exerted by various nutrient sources on quality and quantity parameters of rice crop (Var. ADT-37) and soil fertility status. Nine nutrient sources *viz.,* T_1 – Control, T_2 - 100% RDF, T_3 - 125% RDF , T_4 - 100% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_5 – 100% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_6 – 100% RDF + Coirpith Compost at 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_7 – 125% RDF + Press mud at 10 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_8 – 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria, T_9 – 125% RDF + Coirpith Compost at 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria were used in three replications in randomized block design (RBD). The results were statistically analysed and reported accordingly.

The data on growth and yield characters like leaf area index, straw yield, number of panicles m^{-2}, number of productive tillers $hill^{-1}$, number of grains $plant^{-1}$, DMP, chlorophyll content, grain yield and plant height were registered. Quality attributes like *viz.,* protein content, head rice recovery, milling per cent and hulling per cent were also registered. For uptake of nutrient and to determine available soil nutrients in pre sowing and post harvest soil samples. The salient findings and inference drawn from the results are summarized as below.

6.1.SUMMARY

6.1.1. GROWTH AND YIELD PARAMETERS

Discernible variations in growth parameters due to different sources of nutrients applied treatments were found during the entire agricultural cycle growth over control. Among the various treatments, higher values growth and yield parameters *viz.,* grain yield, plant height, LAI, number of productive tillers $hill^{-1}$, number of grains $plant^{-1}$, chlorophyll content, number of panicles m^{-2}, dry matter production, and straw yield were recorded in the treatment 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_7), which is followed by treatment with 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria (T_7). Next in order was with 125% RDF + Coirpith Compost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_6). Absolute control had the lowest values reported.

6.1.2. QUALITY PARAMETERS

Among various treatments, utilization regards to 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_8) showed remarkable influence on parameters of quality *viz.,* protein content, head rice recovery, hulling percent & milling percent it were sequenced to 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_7). In absolute control, the lowest values were noted.

6.1.3. NUTRIENT UPTAKE

An uptake regarding NPK and micronutrients was impacted through 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_8) and recorded significantly higher values that it was consequently, the use of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria (T_7). The lowest uptake of NPK and micronutrients was recorded under control.

6.1.4. POST HARVEST FERTILITY STATUS OF SOIL

Higher available nutrients *viz.,* NPK, exchangeable Ca & Mg, Zn, and organic carbon in post-harvest soil were noted in (T_8) 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria. The least available nutrients *viz.,* NPK, exchangeable Ca & Mg, available Zn, and organic carbon in post-harvest soil were registered in the control plot (T_1).

6.1.5. ECONOMICS

Among the various treatments, higher gross income, net return and B:C ratio were noticed in (T_8) 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria. The least gross income, net return and B:C ratio were observed in control plot (T_1).

6.2. CONCLUSION

Different sources of nutrients significantly influence agronomical and physiological traits in rice. Using 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria gave increased yield & and growth characters *viz.,* straw yield, number of grains plant^{-1}, chlorophyll content, LAI, number of productive tillers hill^{-1}, number of panicles m^{-2}, DMP, grain yield and plant height.

Further, this treatment (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria) were found to record significantly higher values of NPK and micronutrients uptake, post-harvest fertility status of soil, followed by using 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria.

Further, this treatment (125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc solubilizing bacteria) were found to recorded highest B:C ratio followed by using 125% RDF + Press mud @ 10 t ha^{-1} + 2% Zinc solubilizing bacteria.

6.3. RECOMMENDATION

- Application of all the three organic sources namely vermicompost, press mud and coirpith compost to rice showed significant improvement in yield & growth with respect to rice compared with inorganic fertilzers alone.
- From the above mentioned experimental findings, it is concluded that application of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing Bacteria was found be agronomically sound method of enhancing increased output and B:C ratio.
- It is the best combination for rice crop to increase nutrient uptake, yield, quality, growth of rice & to maintain fertility status of post-harvest soil in the future period.
- Therefore, it is advised and suggested to the farmers to adopt this application of organic sources to enhance yield and maintain quality of rice crop, maintain soil fertility status on sustainable basis and to increase income.

Plate 1. Seed variety of rice ADT-37

Plate 2. Seeds sowing

Plate 3. Nursery

Plate 4. Ploughing

Plate 5. Layout of the experimental field

Plate 6. Organic source of nutrients

Plate 7. Inorganic source of nutrients

Urea

Di-ammonium phosphate (DAP)

Muriate of potash (MOP)

Plate 8. Biological source of nutrient

Plate 9. Transplanting

Plate 10. Biometric observation

Plate 11. Lab works

Plate 12. Micronutrients analysis in Atomic Absorption Spectrophotometer (AAS)

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