Effect of Planting Techniques and Nutrient Management Options on Crop Productivity and Soil Health of Wet Rice (Oryza sativa L.) in Typic Ustochrept Soils

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT
A two years field experiment was carried out in sandy loam soil during rainy (Kharif) seasons in 2019-2020 at CRC farm of sardar vallabhbhai patel university of agricultural & technology, Meerut, Uttar Pradesh to evaluate the various Planting techniques and integrated nutrient management on yield and soil health of rice (Oryza sativa L.) under rice- wheat cropping system. The treatments comprised of two Planting techniques i.e., E1- Conventional puddled transplanted rice (CT- TPR),
Keywords: Planting techniques; nutrient management practices; yield; soil health.

1. INTRODUCTION

Rice (Oryza sativa L.) is most important staple food of more than 60% of the world's population dominantly produced and consumed in the Asia with about two-thirds of the total rice production grown under irrigation utilizes two or three times more water than other cereal crops such as maize and wheat [1]. In India, rice occupies an area of 43.79 mha with production and productivity of 116.42 mt and 2.65 t/ha, respectively [2]. In the current scenario, changes in investigations on crop establishment techniques (CETs) and management practices in rice and wheat are getting more emphasis [3]. This is mainly because of variations in CETs with respect to their resource utilization, energy requirements, capacity to act as a mitigation strategy for climate change can have far reaching implications in terms of yield and income to the farmers, besides environmental health. Among them, mainly manual transplanting of seedlings into puddle soil is practiced in India which means a process of cultivating soil in standing water, consumes a large quantity of water and labor [4]. According to Chauhan et al. [5], the long-term viability of puddle transplanted rice (PTR) is threatened by increasing production costs (particularly labour) and increasing agricultural labour scarcity, which causes crop establishment to be delayed beyond the optimal time. Transplanting is a resource and cost-intensive procedure since seedbed preparation, seedling raising, and transplanting are all labor-intensive operations [4]. Huge water inputs, labour costs and labour requirements for conventional transplanted puddle rice (CT-TPR) have reduced profit margins to the farmers [6]. To tackle this problem, the adoption of new CETs and nutrient management practices are becoming increasingly significant to address the issues related to degradation of natural resources and increasing cost of chemical and agronomic interventions or resources [3].

Fertilizer is one of the most important management factors to increase the productivity of crops. Farmers are using higher amount of fertilizer for every crop without considering crop requirement causing imbalance in the system. The imbalance usage of fertilizers is responsible for the low productivity and also the continuous use of inorganic fertilizers resulted in declining of soil fertility [7]. Continuous degradation of soil health is caused due to imbalance use of chemical fertilizer and non-recycling of organic matter [4]. The use of inorganic fertilizer in rice cultivation has been progressively increasing since its introduction. However, available reports indicate that the repeated use of chemical fertilizer alone fails to sustain desired yield, impairs soil physical condition and exhausts organic matter content leads to environmental degradation and soil health especially due to
their continuous use [8]. Hence, judicious application of inorganic fertilizer is paramount important for yield enhancement of rice [9].

Nutrient management through organics plays a major role in maintaining soil health due to build-up of soil organic matter, beneficial microbes and enzymes, besides improving soil physical and chemical properties. Application of organic manures with chemical fertilizer accelerates the microbial activity, increases nutrient use efficiency enhances the availability of the native nutrients to the plants resulting higher nutrient uptake. Integrated use of organic manures and chemical fertilizers has advantages over use of only organic manures or chemical fertilizers [10]. Biofertilizers are living microbes that enhance plant nutrition by either by mobilizing or increasing nutrient availability in soils. Despite their great potential to improve soil fertility, biofertilizers have yet to replace conventional chemical fertilizers in commercial agriculture [11]. Therefore, combined use of organic manure and inorganic fertilizers in an integrated manner will give better performance in cereals by sustaining higher yield and maintaining soil health [7,12].

The purpose of the current study was to investigate the response of rice (Oryza sativa L.) for their yield and soil health under different planting techniques and nutrient management practices in Western Uttar Pradesh.

2. MATERIALS AND METHODS

2.1 Location

The field experiment was conducted during 2019-2020 kharif seasons at the CRC Farm, College of Agriculture, of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut situated in Indo-Gangetic Plains of Western Uttar Pradesh, India. The farm is geographically situated at 29° 08’ 12” N latitude, 77° 40’ 52” E longitudes and at an elevation 232 meters above the sea level.

2.2 Treatments and Design

The experiment was laid out in a factorial randomized block design with eleven treatments consists of two Planting techniques and nine nutrient management practices as two factors and replicated thrice. The treatments combination include two Planting techniques i.e.,

E1- Conventional puddled transplanted rice (CT-TPR), E2- Wide bed Transplanted rice (W Bed-TPR) as one factor and Nine Nutrient management practices such as N1- Control, N2- 100% RDF + ZnSO4 25 kg ha⁻¹, N3- 125% RDN + ZnSO4 25 kg ha⁻¹, N4- STCR based NPK application + ZnSO4 25 kg ha⁻¹, N5- N2+ FYM (5 t ha⁻¹), N6- N2+ FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹) + Azotobacter 20 kg ha⁻¹, N7- 75% RDN + FYM (5 t ha⁻¹) + ZnSO4 25 kg ha⁻¹, N8- 75% RDN + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹) + Azotobacter 20 kg ha⁻¹ + ZnSO4 25 kg ha⁻¹, N9- Organics Practices @ FYM (30 t ha⁻¹)+PSB (5 kg ha⁻¹) + Azotobacter 20 kg ha⁻¹ + ZnSO4 25 kg ha⁻¹ as second factor respectively. The experimental plot size was 10 m x 3.0 m. The seedlings of rice variety PB-1509 at 21 days old were transplanted by adopting a spacing of 25 cm x 10 cm in conventional method and 20 cm x 10 cm in wide bed transplanted method. The experimental field was provided with proper irrigation channels and the individual plots were demarcated by bunds.

2.3 Soil properties and Fertilizer Application

The experimental soil was sandy loam in texture, moderately alkaline in reaction, non-saline, low in organic carbon content, low in available nitrogen (N- 235.8 & 242.5 kg ha⁻¹), medium in available phosphorous (P₂O₅ 18.6 & 19.8 kg ha⁻¹) and potassium (K₂O 210.5 & 215.6 kg ha⁻¹) during kharif season (2019-2020). The recommended dose of fertilizer i.e., 150 kg N, 60 kg P₂O₅ and 40 kg K₂O ha⁻¹ was applied. The amount of N, P and K will be applied through urea, SSP and muriate of potash, respectively. Half of N and full dose of P and K was applied as basal before last plough of field. The remaining 50% N will be top dressed in splits at active tilling stage and at panicle initiation stage of rice. The amount of PSB @ 5 kg ha⁻¹, Azotobacter will be applied @ 20 kg ha⁻¹ and FYM was 0.5% N, 0.2% P and 0.5% K will be applied in the soil at one week after transplanting of rice. The application of N, P and K of the basis STCR equation (developed by IARI) is followed 6.97 X T - 0.38 X SN, 5.73 X T - 4.81 X SP, 3.92 X T - 0.28 X SK [13].

2.4 Calculations and Statistical Analysis

All data obtained from the experiment, conducted under factorial randomized block design were statistically analyzed using the F-test as per the procedure given by Gomez and Gomez [14].
Critical differences (CD) values at \( P = 0.05 \) were used to determine the significance of difference between treatment means. Treatment differences that were non-significant were denoted by NS. The yield and yield attributes data were recorded, analyzed and tabulated after statistical test.

2.5 Methods of Measuring

I. Yield, nutrient uptake, soil nutrient status and physical properties of soil analysis

a) **Grain yield (q ha\(^{-1}\))**: The harvested plants from net plot area were threshed manually and each plot yield was separately sun dried, cleaned by winnowing and weighed. Grain yield was computed at 14 per cent moisture content and expressed in q ha\(^{-1}\).

b) **Straw yield (q ha\(^{-1}\))**: Dry weight of straw from each net plot was recorded after sun drying for couple of days and expressed in kg ha\(^{-1}\).

c) **Biological yield (q ha\(^{-1}\))**: The crop in each net plot will be harvested bundled, labelled and dried in the field for 4-5 days. Bundles will be weighed just before threshing to record biological yield (Grain yield + Straw yield q ha\(^{-1}\)) per plot and expressed in q ha\(^{-1}\).

d) **Harvest index (%)**: Harvest index was calculated for each treatment using the following formula:

\[
\text{Harvest index} (\%) = \frac{\text{Grain Yield (q ha}^{-1}\text{)}}{\text{Grain Yield + Straw Yield (q ha}^{-1}\text{)}} \times 100
\]

i) **Available nitrogen**: Available nitrogen estimated by alkaline KMnO\(_4\) method where the organic matter in soil would be oxidized with hot alkaline KMnO\(_4\) solution. The ammonia evolved during oxidation will be distilled and trapped in boric acid mixed indicator solution. The amount of NH\(_3\) trapped will be estimated by titrating with standard acid [15].

k) **Available phosphorus**: Available phosphorus extracted with sodium bicarbonate (0.5 M) at pH 8.5 (Olsen's reagent) and the amount of P in the extract will be estimated by using ascorbic acid as reducing agent and blue colour intensity
will be measured by using spectrophotometer at wave length of 660 nm [19].

l) **Available potassium**: Available K will be extracted with neutral normal ammonium acetate and determined using flame photometer [15].

3. **RESULTS AND DISCUSSION**

Grain yield, straw yield and harvest index of rice was significantly influenced by different Planting techniques and nutrient management practices (Fig. 1a & 1b). However, there was no significant effect of interaction between different Planting techniques and nutrient management practices.

![](image1.png)

(a) 2019

![](image2.png)

(b) 2020

*Fig. 1. Effect of different Planting techniques and nutrient sources on yield (q ha⁻¹) and harvest index (%) of rice during Kharif 2019-2020*
3.1 Yield

3.1.1 Grain Yield (q ha⁻¹):

Grain yield of rice was significantly influenced by different planting techniques and nutrient management practices (Fig. 1a & 1b). Among the different planting techniques, conventional puddled transplanted rice (E₁, CT-TPR) was recorded significantly higher grain yield (40.4 & 41.3 q ha⁻¹) than wide bed transplanted rice (E₂, W Bed-TPR) during both years of kharif 2019 & 2020. Significantly lower grain yield (38.7 & 39.7 q ha⁻¹) was recorded with wide bed transplanted rice (E₂, W Bed-TPR) during the both year of study.

Among the nutrient management practices, significantly higher grain yield was recorded with N₆ (49.0 & 50.2 q ha⁻¹) treatment over rest of the other treatment and which was at par with N₅ (46.9 & 47.9 q ha⁻¹) treatment respectively. However, the treatments N₃, N₄, N₅ and N₂ were recorded higher grain yield and which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N₃, N₄, N₅ was observed similar pace of grain yield and were at par to each other respectively. The significantly lower grain yield was observed with control treatment N₁ (22.7 & 23.5 q ha⁻¹) over rest of the other treatment during both the year of study.

3.1.2 Straw Yield (q ha⁻¹):

Mean straw yield of 62.7 & 63.8 q ha⁻¹ registered under conventional puddled transplanted rice (E₁, CT-TPR) was significantly higher than the wide bed transplanted rice (E₂, W Bed-TPR) during both years of kharif 2019 & 2020 respectively. Among the different planting techniques, significantly lower straw yield (61.0 & 62.1 q ha⁻¹) was recorded with wide bed transplanted rice (E₂, W Bed-TPR) during the both year of experimental study.

Among the nutrient management practices, significantly maximum straw yield was registered with N₆ (71.2 & 72.5 q ha⁻¹) treatment over rest of the other treatment except N₃ (69.3 & 69.8 q ha⁻¹) treatment respectively. However, the treatments N₅, N₆, N₄ and N₂ were recorded higher straw yield and which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N₇: N₄, N₅ was observed similar pace of grain yield and were at par to each other respectively. The significantly minimum straw yield was recorded with control treatment N₁ (37.2 & 38.7 q ha⁻¹) over rest of the other treatment during both the year of study.

3.1.3 Biological Yield (q ha⁻¹):

The biological yield (sum of grain and straw yield) of wheat is an important index indicating the photosynthetic efficiency of crop and photosynthetic left behind after respiration which ultimately influenced the crop yield. Among the different planting techniques, conventional puddled transplanted rice (E₁, CT-TPR) was recorded significantly higher biological yield (103.1 & 105.1 q ha⁻¹) than wide bed transplanted rice (E₂, W Bed-TPR) during both years of kharif 2019 & 2020 respectively. Significantly lower biological yield (99.7 & 101.8 q ha⁻¹) was recorded with wide bed transplanted rice (E₂, W Bed-TPR) during the both years of experimentation.

Among the nutrient management practices, significantly higher biological yield was recorded with N₆ (120.2 & 122.7 q ha⁻¹) treatment over rest of the other treatment and which was at par with N₅ (116.2 & 117.7 q ha⁻¹) treatment respectively. However, the treatments N₃, N₄, N₆ and N₂ were recorded higher biological yield and which were statistically superior than rest of the other nutrient management treatments during both kharif 2019 & 2020 respectively. The treatments N₇: N₄, N₅ was observed similar pace of biological yield and were at par to each other respectively. The significantly lower biological yield was observed with control treatment N₁ (59.9 & 62.2 q ha⁻¹) over rest of the other treatment during both the years of experimental study.

3.1.4 Harvest index

The harvest index of rice ranged from 37.69 to 37.72 and 40.80 to 40.89 per cent among different nutrient sources. There is no significant variation was not observed in test weight among different nutrient sources. Among different nutrient management practices, significantly highest harvest index was recorded with N₆ (40.80 to 40.89 %) treatment over rest of the other treatment except N₃ (40.36 & 40.75 %) and N₅ (39.35 & 39.59 %) treatment during kharif 2019 & 2020 respectively. However, the treatments N₆ and N₅ were recorded highest harvest index and which were statistically superior than remaining other nutrient management treatments during both the year of
experimentation. Moreover, the treatments N7, N2, N4, and N6 were observed similar to that of harvest index and were at par to each other respectively. The lowest harvest index was noticed in control treatment N1 (37.69 to 37.72 q ha⁻¹) than rest of the other treatment during both the years of study.

Yield is the resultant of growth characters and yield attributes. Grain and straw yield were significantly influenced by Planting techniques and nutrient management practices. Higher grain & straw yield noticed in E2 (CT-TPR) and lowest grain and straw yield observed in E1 (RT-TPR). Higher grain & straw yield significantly shown with application of N6 (100% RDF + ZnSO₄ 25 kg ha⁻¹ + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹)+ Azotobactor 20 kg ha⁻¹) treatment. The increase in yield was further attributed to better translocation of photosynthates from source to sink due to higher uptake of NPK which are responsible for quick and easy translocation of photosynthetetic products. The better vegetative growth coupled with high yield attributes resulted in higher grain and straw yield of rice. Higher level of fertilizers FYM and Biofertilizer significantly influenced the growth development yield attributes and yield of rice reported by Gautam et al., [20]; Singh and Walia [21]; Kumar et al. [22].

3.2 Nutrient (NPK) Uptake

3.2.1 Nitrogen uptake (kg ha⁻¹)

The nitrogen content and uptake in grain and straw as influenced by various treatments (Table 1). Among the Planting techniques there was a significant variation was found in various treatment. Among them, conventional puddled transplanted rice (E1, CT-TPR) registered significantly higher nitrogen uptake in grain (51.63 & 53.39 kg ha⁻¹) and straw (28.36 & 32.01 kg ha⁻¹) over wide bed transplanted rice (E2, W Bed-TPR) during both years of kharif 2019 & 2020 respectively. Significantly lower nitrogen uptake in grain (48.37 & 50.00 kg ha⁻¹) and in straw (25.83 & 29.41 kg ha⁻¹) was observed with wide bed transplanted rice (E2, W Bed-TPR) during both the year of experimental study.

Nutrient management practices exhibited significant effect on nitrogen uptake of grain and straw in rice. Perusal of data presented in Table - & depicted in Figure ___ revealed that all the nutrient management practices increased nitrogen uptake in grain and straw over control conditions. Nitrogen uptake in rice grain ranged from 26.23 to 66.55 and 27.43 to 68.65 kg/ha while in straw from 12.44 to 38.93 & 14.47 to 43.99 kg/ha respectively, during both the years among different treatments. Significantly maximum nitrogen uptake in grain (66.55 & 68.65 kg/ha) and straw (38.93 & 43.99 kg/ha) was recorded with N6 treatment over rest of the other treatment during both years of kharif 2019 & 2020 respectively. However, the treatments N3, N5, N6, and N7 were recorded greater nitrogen uptake in grain and straw of rice which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N5, N6, and N7 were recorded higher nitrogen uptake in grain and straw which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the
treatments N₁, N₄, N₆ was observed similar trend of phosphorus uptake in grain and N₄, N₆ in straw were at par to each other respectively. Significantly minimum phosphorus uptake in grain (6.08 & 6.48 kg/ha) and straw (4.04 & 4.18 kg/ha) of rice was recorded under control conditions among rest of the other treatment during both the year of study.

3.2.3 Potassium uptake (kg ha⁻¹)

The potassium uptake in grain and straw (%) of rice revealed that there was a significant variation was found in various treatments under different Planting techniques and nutrient management practices (Table 1).

The potassium uptake in rice grain and straw differed significantly based on the Planting techniques. Conventional puddled transplanted rice (E₁, CT-TPR) was recorded higher potassium uptake in grain (17.79 & 19.09 kg ha⁻¹) and straw (100.82 & 105.60 kg ha⁻¹) than wide bed transplanted rice (E₂, W Bed-TPR). During both years of the experimental study, wide bed transplanted rice (E₂, W Bed-TPR) had significantly lower potassium uptake in grain (15.79 & 17.19 kg ha⁻¹) and straw (95.01 & 99.18 kg ha⁻¹) respectively.

Nutrient management practices exhibited significant effect on potassium uptake of grain and straw in rice. Significantly higher maximum potassium uptake in grain (22.71 & 24.68 kg/ha) and straw (120.94 & 124.14 kg/ha) was recorded with N₂ treatment over rest of the other treatment in 2019 except N₁ in kharif 20202 respectively. However, the treatments N₂, N₄ and N₆ were recorded greater nitrogen uptake in grain and straw of rice which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N₁, N₄, N₆ was observed similar trend of potassium uptake in grain and straw and were at par to each other respectively. Significantly lower nitrogen uptake in grain (7.71 & 8.59 kg/ha) and straw (51.97 & 56.14 kg/ha) of rice was recorded under control conditions (N₀) among rest of the other treatment during both the year of study.

The uptake of nutrients like nitrogen, phosphorus and potassium by rice grain and straw were determined separately using their content in respective part and their production on hectare basis. Total uptake of NPK was worked out by summation of uptake NPK by grain and straw. Among crop management methods, higher content of NPK in grain and straw and higher total uptake of NPK noticed under E₂ (CT-TPR) and the lowest total nitrogen, phosphorus and potassium uptake was noticed with E₁ (Wide bed-TPR). Nutrient management practices also significantly influenced on total uptake NPK. Higher content of NPK in grain and straw and higher total uptake of NPK recorded with application of N₀ (100% RDF + ZnSO₄ 25 kg ha⁻¹ + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹) + Azotobactor 20 kg ha⁻¹) respectively. This is attributed to the higher tillers number and dry matter production by younger seedlings ultimately resulting in higher straw and grain yield and nutrient removal. This result is in line with the findings of Tomar et al. [23] and Puli et al. [24].

3.3 Soil Nutrient Status

The data pertaining to soil nutrient status as influence by different Planting techniques and Nutrient management practices (Table 2).

3.3.1 Available nitrogen (kg ha⁻¹)

The effect of Planting techniques on available nitrogen was found to be significant. Among them, conventional puddled transplanted rice (E₁, CT-TPR) registered significantly higher nitrogen availability in soil (225.91 & 228.80 kg ha⁻¹) compared to wide bed transplanted rice (E₂, W Bed-TPR) during both years of kharif 2019 & 2020 respectively. Significantly lower nitrogen availability in soil (219.18 & 221.86 kg ha⁻¹) was observed with wide bed transplanted rice (E₂, W Bed-TPR) during the both year of experimental study.

Available nitrogen in soil was also significantly influence by nutrient management practices. Among the nutrient management practices, significantly higher available nitrogen in soil was recorded with N₀ (241.89 & 244.91 kg ha⁻¹) treatment over rest of the other treatment and which was at par with N₂ treatment respectively. However, the treatments N₂, N₄ and N₆ were recorded higher available nitrogen in soil and which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N₁, N₄, N₆ was observed similar pace of available nitrogen in soil and were at par to each other respectively. The significantly lower available nitrogen in soil was observed with control treatment N₁ (195.56 & 197.90 kg ha⁻¹) over rest of the other treatment during both the years of study.
### Table 1. Effect of different Planting techniques and nutrient sources on NPK uptake (kg ha⁻¹) in grain and straw of rice

| Treatment | Nitrogen (N) uptake (kg ha⁻¹) | Phosphorous (P) uptake (kg ha⁻¹) | Potassium (K) uptake (kg ha⁻¹) |
|-----------|-------------------------------|----------------------------------|-------------------------------|
|           | Grain 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| **Planting techniques** | | | | | | | | | | | | |
| E₁: Conventional puddled transplanted rice (CT- TPR) | 51.63 | 53.39 | 28.36 | 32.01 | 14.33 | 15.47 | 11.97 | 12.74 | 17.79 | 19.09 | 100.82 | 105.60 |
| E₂: Wide bed Transplanted rice (W Bed-TPR) | 48.37 | 50.00 | 25.83 | 29.41 | 12.68 | 13.87 | 10.42 | 10.94 | 15.79 | 17.19 | 95.01 | 99.18 |
| SEM± | 0.57 | 0.67 | 0.43 | 0.57 | 0.22 | 0.25 | 0.16 | 0.19 | 0.26 | 0.33 | 1.20 | 1.59 |
| CD (p=0.05) | 1.65 | 1.93 | 1.23 | 1.64 | 0.63 | 0.71 | 0.45 | 0.55 | 0.73 | 0.94 | 3.46 | 4.57 |
| **Nutrient sources** | | | | | | | | | | | | |
| N₁: Control (No N,P,K) | 26.00 | 27.43 | 12.44 | 14.47 | 6.08 | 6.48 | 4.04 | 4.18 | 7.71 | 8.59 | 51.97 | 56.14 |
| N₂: 100% RDF + ZnSO₄ 25 kg ha⁻¹ | 49.44 | 50.89 | 27.52 | 31.56 | 13.55 | 14.74 | 11.81 | 12.41 | 17.06 | 18.26 | 101.27 | 104.34 |
| N₃: 125% RDN + ZnSO₄ 25 kg ha⁻¹ | 61.55 | 63.30 | 34.44 | 38.40 | 17.10 | 18.19 | 13.67 | 14.22 | 20.62 | 23.00 | 113.89 | 117.66 |
| N₄: STCR based NPK application + ZnSO₄ 25 kg ha⁻¹ | 46.19 | 47.05 | 23.04 | 26.17 | 12.44 | 13.36 | 10.42 | 10.90 | 15.26 | 15.83 | 94.10 | 98.28 |
| N₅: N₂+ FYM (5 t ha⁻¹) | 56.38 | 58.36 | 32.51 | 35.29 | 15.29 | 16.96 | 12.89 | 13.85 | 19.23 | 21.31 | 109.55 | 113.96 |
| N₆: N₂+ FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹) + Azotobactor 20 kg ha⁻¹ | 66.55 | 68.65 | 38.93 | 43.99 | 17.98 | 19.21 | 14.42 | 15.25 | 22.71 | 24.68 | 120.94 | 124.14 |
| N₇: 75% RDN + FYM (5 t ha⁻¹) + ZnSO₄ 25 kg ha⁻¹ | 47.93 | 49.62 | 24.45 | 28.23 | 13.03 | 14.36 | 11.48 | 12.03 | 16.31 | 16.80 | 97.33 | 102.57 |

Chandra et al.; IJPSS, 33(22): 39-54, 2021; Article no.IJPSS.76122
Treatment | Nitrogen (N) uptake (kg ha\(^{-1}\)) | Phosphorous (P) uptake (kg ha\(^{-1}\)) | Potassium (K) uptake (kg ha\(^{-1}\))
---|---|---|---
| Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |

**N\(_8\):** 75% RDN + FYM (5 t ha\(^{-1}\)) + PSB (5 kg ha\(^{-1}\)) + Azotobacter 20 kg ha\(^{-1}\) + ZnSO\(_4\) 25 kg ha\(^{-1}\)

|  | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Grain | 52.74 | 54.95 | 28.95 | 33.09 | 14.46 | 15.94 | 12.26 | 13.06 |
| Straw | 18.26 | 19.84 | 105.40 | 110.03 |

**N\(_9\):** Organics Practices @ FYM (30 t ha\(^{-1}\)) + PSB (5 kg ha\(^{-1}\)) + Azotobacter 20 kg ha\(^{-1}\) + ZnSO\(_4\) 25 kg ha\(^{-1}\)

|  | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Grain | 43.21 | 45.04 | 21.59 | 25.17 | 11.61 | 12.79 | 9.73 | 10.66 |
| Straw | 13.94 | 14.95 | 86.79 | 94.38 |

**SEm±**

|  | 1.22 | 1.42 | 0.91 | 1.21 | 0.47 | 0.53 | 0.33 | 0.41 |
|---|---|---|---|---|---|---|---|---|
| CD (p =0.05) | 3.50 | 4.09 | 2.62 | 3.49 | 1.34 | 1.51 | 0.95 | 1.17 |
|  | 1.55 | 1.99 | 7.34 | 9.70 |

*RDF–recommended dose of fertilizer (150:60:40:: N:P\(_2\)O\(_5\)::K\(_2\)O kg ha\(^{-1}\)); *STCR– Soil test crop response; *FYM–Farm yard manure; *PSB– Phosphate solubilising bacteria.
3.3.2 Available phosphorous (kg ha\(^{-1}\))

The influence of Planting techniques on phosphorus availability in soil was revealed to be significant. Conventional puddled transplanted rice (E\(_1\), CT-TPR) had substantially higher phosphorus availability in soil (16.52 & 18.41 kg ha\(^{-1}\)) than wide bed transplanted rice (E\(_2\), W Bed-TPR). During both years of the experimental study, wide bed transplanted rice (E\(_2\), W Bed-TPR) had significantly lower phosphorus availability in soil (15.6 & 16.31 kg ha\(^{-1}\)) respectively.

Available phosphorus in soil was also significantly influence by nutrient management practices. Among the nutrient management practices, significantly higher available phosphorus in soil was recorded with N\(_6\) (18.73 & 20.32 kg ha\(^{-1}\)) treatment over rest of the other treatment and which was at par with N\(_5\) and N\(_3\) treatment respectively. However, the treatments N\(_6\) and N\(_2\) were recorded higher available phosphorus in soil and which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N\(_7\), N\(_4\), N\(_5\) was observed similar pace of available

### Table 2. Effect of different Planting techniques and nutrient management practices on soil health of rice

| Treatment                                                                 | Nitrogen (N) | Available nutrients (kg ha\(^{-1}\)) | Organic carbon (%) |
|--------------------------------------------------------------------------|--------------|------------------------------------|-------------------|
|                                                                          | 2019         | 2020                               |                   |
|                                                                          | 2019         | 2020                               |                   |
|                                                                          | 2019         | 2020                               |                   |
|                                                                          | 2019         | 2020                               |                   |
| Planting techniques                                                      |              |                                    |                   |
| E\(_1\): Conventional puddled transplanted rice (CT-TPR)                 | 225.91       | 228.80                             | 16.52             |
|                                                                          |              |                                    | 18.41             |
|                                                                          |              |                                    | 205.07            |
|                                                                          |              |                                    | 206.55            |
|                                                                          |              |                                    | 0.47              |
|                                                                          |              |                                    | 0.48              |
|                                                                                                      | 15.62        | 18.41                             |                   |
|                                                                                                      | 205.07       | 206.55                            |                   |
|                                                                                                      | 0.47         | 0.48                             |                   |
| E\(_2\): Wide bed Transplanted rice (W Bed-TPR)                          | 219.18       | 221.86                             | 15.06             |
|                                                                          |              |                                    | 16.31             |
|                                                                          |              |                                    | 200.66            |
|                                                                          |              |                                    | 202.97            |
|                                                                                                      | 0.46         | 0.47                             |                   |
| Nutrient sources                                                          |              |                                    |                   |
| N\(_1\): Control (No N P K)                                              | 195.56       | 197.90                             | 10.54             |
|                                                                          |              |                                    | 12.38             |
|                                                                          |              |                                    | 184.43            |
|                                                                          |              |                                    | 186.01            |
|                                                                                                      | 0.40         | 0.41                             |                   |
|                                                                                                      | 16.52        | 18.41                             |                   |
|                                                                                                      | 205.07       | 206.55                            |                   |
| N\(_2\): 100% RDF + ZnSO\(_4\) 25 kg ha\(^{-1}\)                          | 225.19       | 227.79                             | 16.76             |
|                                                                          |              |                                    | 18.30             |
|                                                                          |              |                                    | 203.67            |
|                                                                          |              |                                    | 204.98            |
|                                                                                                      | 0.48         | 0.48                             |                   |
| N\(_3\): 125% RDN + ZnSO\(_4\) 25 kg ha\(^{-1}\)                          | 239.71       | 242.48                             | 18.26             |
|                                                                          |              |                                    | 19.87             |
|                                                                          |              |                                    | 211.65            |
|                                                                          |              |                                    | 215.94            |
|                                                                                                      | 0.50         | 0.51                             |                   |
| N\(_4\): STCR based NPK application + ZnSO\(_4\) 25 kg ha\(^{-1}\)       | 214.75       | 217.48                             | 14.39             |
|                                                                          |              |                                    | 15.97             |
|                                                                          |              |                                    | 199.08            |
|                                                                          |              |                                    | 200.95            |
|                                                                                                      | 0.44         | 0.45                             |                   |
| N\(_5\): N\(_6\) + FYM (5 t ha\(^{-1}\)) + PSB (5 kg ha\(^{-1}\))        | 225.58       | 233.25                             | 17.21             |
|                                                                          |              |                                    | 19.10             |
|                                                                          |              |                                    | 207.38            |
|                                                                          |              |                                    | 206.88            |
|                                                                                                      | 0.49         | 0.50                             |                   |
| N\(_6\): Azotobacter 20 kg ha\(^{-1}\)                                   | 241.89       | 244.91                             | 18.73             |
|                                                                          |              |                                    | 20.32             |
|                                                                          |              |                                    | 216.42            |
|                                                                          |              |                                    | 219.42            |
|                                                                                                      | 0.51         | 0.52                             |                   |
| N\(_7\): 75% RDN + FYM (5 t ha\(^{-1}\)) + ZnSO\(_4\) 25 kg ha\(^{-1}\)  | 219.33       | 222.10                             | 15.68             |
|                                                                          |              |                                    | 16.91             |
|                                                                          |              |                                    | 200.68            |
|                                                                          |              |                                    | 204.21            |
|                                                                                                      | 0.45         | 0.46                             |                   |
| N\(_8\): 75% RDN + FYM (5 t ha\(^{-1}\)) + PSB (5 kg ha\(^{-1}\)) +      | 229.44       | 227.87                             | 16.98             |
| Azotobacter 20 kg ha\(^{-1}\) + ZnSO\(_4\) 25 kg ha\(^{-1}\)             |              |                                    | 18.35             |
|                                                                          |              |                                    | 205.75            |
|                                                                          |              |                                    | 206.06            |
|                                                                                                      | 0.49         | 0.50                             |                   |
| N\(_9\): Orgamics Practices @ FYM (30 t ha\(^{-1}\)) + PSB (5 kg ha\(^{-1}\)) + Azotobacter 20 kg ha\(^{-1}\) + ZnSO\(_4\) 25 kg ha\(^{-1}\) | 211.47       | 214.20                             | 13.61             |
|                                                                          |              |                                    | 15.07             |
|                                                                          |              |                                    | 196.73            |
|                                                                          |              |                                    | 198.45            |
|                                                                                                      | 0.44         | 0.43                             |                   |

*NDF= recommended dose of fertilizer (150:60:40; N\(_2\)O\(_3\): K\(_2\)O kg ha\(^{-1}\)); STCR- Soil test crop response; FYM- Farm yard manure; PSB- Phosphate solubilising bacteria.
phosphorus in soil and were at par to each other respectively. The significantly lower available phosphorus in soil was observed with control treatment N₀ (10.54 & 12.38 kg ha⁻¹) over rest of the other treatment during both the years of study.

3.3.3 Available potassium (kg ha⁻¹)

The available potassium in soil was found to be significant under different planting techniques. Conventional puddled transplanted rice (E₁, CT-TPR) had substantially higher potassium availability in soil (205.07 & 206.355 kg ha⁻¹) than wide bed transplanted rice (E₂, W Bed-TPR). Wide bed transplanted rice (E₂, W Bed-TPR) had significantly lower potassium availability in soil (200.66 & 202.97 kg ha⁻¹) during both years of study.

Available potassium in soil was also significantly influenced by nutrient management practices. Among the nutrient management practices, significantly higher available potassium in soil was recorded with N₀ (216.42 & 219.42 kg ha⁻¹) treatment over rest of the other treatment except N₃ treatment respectively. However, the treatments N₉, N₁₀ and N₁₂ were recorded higher available potassium in soil and were at par to each other respectively. The significantly lower available potassium in soil was observed with control treatment N₀ (184.43 & 186.01 kg ha⁻¹) over rest of the other treatment during both the years of experimental study.

3.3.4 Organic carbon (%)

Effect of Planting techniques on organic carbon in soil was found significant. The highest organic carbon recorded in conventional puddled transplanted rice (E₁, CT-TPR) (0.47 & 0.46 %) than wide bed transplanted rice (E₂, W Bed-TPR). The lowest organic carbon (0.48 & 0.47 %) was observed in wide bed transplanted rice (E₂, W Bed-TPR) during both years of study.

The organic carbon in soil was also significantly influenced by nutrient management practices. Among the nutrient management practices, significantly highest available potassium in soil was recorded with N₆ (0.51 & 0.52 %) treatment over rest of the other treatment except N₃ and N₉ treatment respectively. However, the treatments N₆ and N₉ were recorded higher available organic carbon in soil and which were statistically superior than remaining other nutrient management treatments during both the year of experimentation. Moreover, the treatments N₇, N₉, N₀ was observed similar trend of available organic carbon in soil and were at par to each other respectively. The significantly lowest available organic carbon in soil was observed with control treatment N₀ (0.40 & 0.41 %) over rest of the other treatment during both the years of experimental study.

The maximum available soil nutrients (NPK) recorded in E₁ (CT-TPR) at harvest which was significantly higher than the minimum available nutrients (NPK) were recorded in E₂ (Wide bed-TPR) plot at harvest when applied organic and inorganic sources of nutrients continuously. Integration of organic sources with inorganic fertilizer were found more effective as compared to single application in building up fertility and improving physical status of soil. The higher availability of nutrient NPK in soil after harvest were recorded under all the INM modules as compared to inorganic fertilizer application. Organic carbon status in soil after harvest of crop was significantly influenced by different treatment however; maximum values observed in E₁ (CT-TPR) treatment. This might be due to use of conventional method is ascribed to greater and healthy root growth, increased availability and efficient absorption from the soil and transport of nutrient from roots to shoots and grains, which ultimately improved growth and yield. Among the nutrient management practices with application of N₉ (100% RDF + ZnSO₄ 25 kg ha⁻¹ + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹)+ Azotobactor 20 kg ha⁻¹) treatment was resulted into more organic carbon status in soil due to FYM and biofertilizers adds organic carbon to soil. The buildup of neutral soil pH and EC were recorded under INM modules as compared to sole inorganic fertilizer treatment (N₉) whereas, maximum reduction in pH was also observed with the application of N₆ (100% RDF + ZnSO₄ 25 kg ha⁻¹ + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹)+ Azotobactor 20 kg ha⁻¹) respectively. Similar results were also reported by Bharose et al., [25] and Dubey et al. [26].

3.4 Soil Physical Properties

3.4.1 Bulk density (Mg m⁻³)

The effect of different treatments on bulk density (Mg m⁻³) are found to be significant (Table 3).
Table 3. Effect of different Planting techniques on physical properties of soil

| Treatments   | Bulk density (Mg m⁻³) | EC (dSm⁻¹) | pH   |
|--------------|-----------------------|------------|------|
|              | 2019                  | 2020       |      |
|              | 0-5 cm  | 5-10 cm | 10-15 cm | 15-20 cm | 0-5 cm  | 5-10 cm | 10-15 cm | 15-20 cm | 2019 | 2020 | 2019 | 2020 |
| E1: CT-TPR   | 1.61     | 1.64    | 1.71    | 1.82    | 1.58    | 1.61    | 1.64    | 1.76    | 0.26 | 0.25 | 7.9  | 7.8  |
| E2: WB-TPR   | 1.45     | 1.50    | 1.54    | 1.65    | 1.48    | 1.52    | 1.54    | 1.70    | 0.22 | 0.21 | 7.4  | 7.3  |
| SEM±         | 0.02     | 0.02    | 0.01    | 0.02    | 0.02    | 0.02    | 0.03    | 0.02    | 0.004| 0.003| 0.029| 0.021|
| CD (P=0.05)  | 0.07     | 0.05    | 0.03    | 0.06    | 0.05    | 0.06    | 0.08    | 0.06    | 0.010| 0.008| 0.084| 0.061|
In general, the upper 15 cm (0-5, 5-10 and 10-15 cm) layer contributed about 7.2, 7.6 and 8.8 per cent of total bulk density and the second 15-20 cm about 6.9 per cent E1 over E2 in the both year of experimentation, thus the maximum bulk density recorded from top 0-15 cm depth, whereas the contribution of bulk density to 15-20 cm soil layer was about 36.8 per cent. It was observed that E1 treatment recorded higher bulk density and more contribution was from top layer 0-15 cm and less from deeper layer 15-20 cm. Among tillage planting techniques, plots under conventional till puddled plot E1 had about 10.4 and 5.60 % higher soil bulk density (M g m⁻³) than E2 plots (Table 3). Unlike land configuration, tillage had greater impacts on soil bulk density. The bulk density did varied significantly due to planting techniques and it was significantly reduced under raised wide beds planting techniques (E2) compared to conventional tillage puddled transplanting (E1). Treatment (E2) transplanted rice on wide raised beds recorded lower bulk density under different soil layers as compared to E1 conventional till transplanted rice treatment during the years of experimental study.

3.4.2 Soil electric conductivity (EC)

After wheat harvest the data in respect to electric conductivity is given in (Table 3). Effect of planting techniques on electric conductivity (dSm⁻¹) was found significant among treatments. The electric conductivity was recorded maximum 0.26 and 0.25 dSm⁻¹ under conventional till puddled transplanting technique (T1) treatment and minimum values 0.22 and 0.21 dSm⁻¹ also obtained under wide beds transplanting technique (T2) during 2019 and 2020, respectively.

3.4.3 Soil pH

Effect of planting techniques on soil pH was found significant. The results revealed that pH was registered lowest values (7.4 and 7.3) under transplanted rice on wide beds (T2) land configuration treatments and highest (7.9 and 7.8) under conventional till puddled transplanting technique (T1) treatment during both the years of experimental study.

Increases in the bulk density usually result in large decreases in water flow through the soil and conservation tillage practices i.e. furrow irrigated raised bed (FIRB) and conventional transplanted rice would reduce evapotranspiration and increase infiltration rate. The adoption of wide bed transplanted rice resulted in the greatest increase in neutral soil pH and EC when compared to conventional till puddled transplanting technique. Similar result have been reported by Gangwar and Singh [27] and Naresh et al. [28].

4. CONCLUSION

It can be concluded that among the different planting techniques, conventional puddled transplanted rice (E1, CT-TPR) was recorded significantly higher yield, NPK content and uptake and also improved soil health status i.e., available NPK, organic carbon and other physical properties i.e, Bulk density, EC, pH in soil than wide bed transplanted rice (E2, W Bed-TPR) during both years of kharif 2019 & 2020 respectively. Among the nutrient management practices, significantly higher yield, NPK content and uptake and also improved soil health status i.e., available NPK, organic carbon in soil was recorded with N6 (100% RDF + ZnSO₄ 25 kg ha⁻¹ + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹)+ Azotobactor 20 kg ha⁻¹) treatment over rest of the other treatment and which was at par with N3 treatment and lowest was observed in control treatment respectively. Thus, the results suggest that inclusion of inorganic fertilizer along with organic manure (FYM) enhance the productivity of rice. Therefore, application of conventional puddled transplanted rice (E2, CT-TPR) along with N6 (100% RDF + ZnSO₄ 25 kg ha⁻¹ + FYM (5 t ha⁻¹) + PSB (5 kg ha⁻¹)+ Azotobactor 20 kg ha⁻¹) found beneficial to increase yield, NPK content and uptake and also improved soil health of rice crop compared to other establishment methods and nutrient management practices.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.
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