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Effect of planting techniques with integrated use of organic and inorganic fertilizers on soil fertility and uptake of nutrients in rice (Oryza sativa L.) under Rice-Wheat cropping system

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Abstract

A field experiment was conducted at Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), during the Kharif *season 2019 to study the effect of planting techniques with organic and inorganic nutrient management on soil fertility and nutrient uptake of rice (*Oryza sativa *L.). The experiment laid out in split plot design with four planting techniques as main treatments and six fertility levels as subplot treatments replicated three times. The results of experimentation revealed that significantly higher nitrogen, phosphorus and potassium uptake by rice at harvest was significantly increased by M_2 (CT-TPR) along with application of S_6 (100% NPK + 25% N (FYM)) and also higher available nitrogen, phosphorus and potassium was observed with application of M_2 (CT-TPR) and S_6 (100% NPK + 25% N(FYM)).*

Keywords: Planting techniques, Fertility levels, available nutrients, nutrient uptake

Introduction

The sustainable intensification of agricultural systems is a critical need in today's world, as global population growth continues to put pressure on food production. Rice (*Oryza sativa* L.) plays a vital role in ensuring food security, particularly in regions where it serves as a staple crop. Rice is the staple food of more than 60% of the world's papulation. In India, the area, production and productivity of rice is 43.77 M ha, 112.76 mt and 2.57 t ha^{-1}, respectively. Rice contributes about 43% of total food grain production and 55% cereal production in the country. However, Uttar Pradesh is the one of the major rice crops growing state. Rice occupies an area of 5.86 M ha, produces 15.54 mt rice with a productivity of 2.46 t ha^{-1} in UP, (Directorate of Economics and Statistics, 2018-19). The Rice-Wheat cropping system is a dominant agricultural system in many parts of Asia, but it often leads to declining soil fertility and reduced crop productivity. To improve soil fertility and crop performance, the integrated use of organic and inorganic fertilizers has emerged as a potential strategy. Organic fertilizers provide essential nutrients, enhance soil structure, and improve microbial activities, while inorganic fertilizers offer precise and readily available nutrients. The combined application of organic and inorganic fertilizers increased soil microbial biomass, enzymatic activities, and nutrient availability, leading to improved rice growth and yield. Combined application of organic and inorganic fertilizers increased soil microbial biomass, enzymatic activities, and nutrient availability, leading to improved rice growth and yield (Wang *et al.*, 2020). In order to maximise nutrient uptake and overall crop production, planting techniques are also crucial. In the production of rice, these techniques have a significant impact on soil characteristics, nutrient availability, and crop performance. The three tillage methods that have distinct effects on rice's ability to absorb nutrients are conventional tillage, minimum tillage, and furrow irrigated raised beds. Optimizing agricultural management tactics and raising crop output require an understanding of how these activities affect nutrient uptake. To prepare the seedbed for rice production,

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conventional tillage entails significant soil treatment, such as ploughing and harrowing. Although this method produces a well-mixed soil profile, it can also increase soil erosion, decrease the amount of organic matter, and limit the ability of the soil to retain nutrients. The impact of conventional tillage on rice's ability to absorb nutrients has been the subject of conflicting conclusions in earlier studies. According to some studies, like Chen *et al*. (2018) conventional tillage encourages higher nitrogen and phosphorus uptake in rice due to improved nutrient availability brought on by better soil organic matter incorporation and higher mineralization rates. However, Wang *et al*. (2019) showed that conventional tillage had a lower nitrogen uptake than minimum tillage, principally because nitrogen was lost more through leaching and volatilization. By restricting ploughing and minimising the number of tillage methods, minimum tillage, sometimes referred to as conservation tillage or reduced tillage, seeks to minimise soil disturbance. This technique lessens soil erosion while preserving organic matter and soil structure. Studies looking into how rice's ability to absorb nutrients is affected by minimum tillage have produced a range of conclusions. In contrast to conventional tillage, minimum tillage increased nitrogen uptake in rice, which Ding *et al*. (2020) attributed to enhanced soil structure and the preservation of soil organic matter. The results of Zhang *et al*. (2019) indicate that other factors, such as fertiliser management and environmental conditions, may outweigh the effects of tillage practises on nutrient uptake because they found no significant difference in nutrient uptake between minimum tillage and conventional tillage in rice. An innovative method called a "furrow irrigated raised bed" (FIRB) involves building raised beds with furrows for better soil aeration and effective water management. This method reduces water loss from runoff and evaporation while improving irrigation control. According to Yang *et al*. (2018), FIRB dramatically boosted rice phosphorus uptake when compared to conventionally flooded fields. This improvement was ascribed to improved fertiliser distribution with lower losses, increased soil phosphorus availability in the elevated beds, and improved root growth. To investigate the long-term impacts of FIRB on nutrient uptake and total crop productivity in rice, more investigation is necessary.

Therefore, the purpose of this study is to determine how alternative planting methods and the combined use of organic and inorganic fertilisers affect soil fertility and rice's ability to absorb nutrients in the rice-wheat cropping system. In order to determine their individual and combined impacts on the availability and uptake of nutrients by the rice crop, the study will test several combinations of planting methods and fertility levels (organic, inorganic, and their mixtures.

Materials and Methods

The field experiment was conducted at Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), during the *Kharif* season 2019. It was laid out in split plot design with three replications. The main factor consisted of four planting techniques *viz*. (M_1-Reduced Tillage-Transplanted Rice (RT-TPR), M_2-Conventional Tillage-Transplanted Rice (CT-TPR), M_3-Furrow Irrigated Raised Beds (FIRB), M_4-Unpuddled-Transplanted Rice (UP-TPR)) and sub factor six fertility levels *viz* (S_1-Control, S_2-100% NPK Chemical fertilizer, S_3-100% N (FYM), S_4-50% NPK + 50% N (FYM), S_5-75% NPK + 25% N (FYM), S_6-100% NPK + 25% N(FYM)) as subplot treatment.

Rice crop was analysed for different parameters like pH by Glass Electrode pH Meter (Jackson, 1973) pH meter (Piper, 1966), electrical conductivity by Conductometry (Jackson, 1973), organic carbon by Wet digestion method (Walkley and Black, 1934). Plant analyses was done by taking five randomly selected plants from each net plot and were oven dried and used for chemical analysis after grinding. Nitrogen content was determined by digesting the plant samples with concentrated sulphuric acid and digestion mixture. The digested samples were distilled by micro kjeldhal method in an alkaline condition and titrated against standard acid (Piper, 1966). Phosphorus and potassium contents were determined after the samples were digested with diacid mixture (Nitric acid + Perchloric acid). Phosphorus content was determined by Vanadomolybdo phosphoric yellow colour method and observation was recorded at 430 nm using Spectrophotometer instrument (Piper, 1966). Potassium content was determined from the same diacid digested extract with the Digital Flame Photometer (Piper, 1966). Soil samples were collected from 0-30 cm depth, dried under shade. The samples were analysed for available nitrogen, available phosphorus and available potassium by using alkaline potassium permanganate method, Bray's method and Neutral normal ammonium acetate method, respectively. All the results were then analysed statistically for drawing conclusion using standard statistical analysis tools.

Results and Discussion

Productivity of a crop depends on its capacity in making use of the available resources. The production and translocation of synthesized photosynthates depends upon mineral nutrition supplied either by soil or through external application. Higher nutrient uptake by plant may increase the metabolic activity of the plant leading to a greater accumulation of dry matter and subsequently increased grain yield.

Nitrogen uptake in grain and straw of rice

M2 (CT-TPR) had the greatest nitrogen intake values among the planting techniques, with 43.0 kg ha^{-1} of nitrogen in grains and 25.8 kg ha^{-1} in straw, for a total nitrogen uptake of 68.8 kg ha^{-1}. M4 (Unpuddled-TPR) came in second, with 39.8 kg ha^{-1} of nitrogen in grains and 22.8 kg ha^{-1} in straw, for a total nitrogen intake of 62.7 kg ha^{-1}. M1 (RT-TPR) and M3 (FIRB-TPR) had the lowest nitrogen uptake levels, with 35.4 kg ha^{-1} and 36.8 kg ha^{-1} of nitrogen in grains, respectively (Table 1 and Fig. 1). The differences in nitrogen uptake between planting procedures, however, were not statistically significant ($p > 0.05$). Conventional tillage aids in the preparation of the seedbed, boosting root growth and nutrient accessibility. Raised bed planting provides improved drainage and aeration, which enhances nutrient uptake efficiency. The combination of these factors likely facilitated better nitrogen uptake compared to other planting techniques. These findings similar to the Bazaya *et al*. (2009).

S6 (100% NPK + 25% N with FYM) had the highest nitrogen uptake of all fertility levels, with grain uptake of 54.2 kg ha^{-1}, straw uptake of 31.3 kg ha^{-1}, and total uptake of 85.6 kg ha^{-1}. This suggests that combining chemical fertiliser (NPK) and farmyard manure (N with FYM) at greater rates can greatly increase nitrogen uptake by the crop.

Significant nitrogen uptake was also seen in the S_5 treatment (75 percent NPK + 25 percent N with FYM), demonstrating the beneficial effects of a well-balanced chemical fertiliser and farmyard manure mixture. It should be emphasised, though, that even the S_2 treatment (100 percent NPK chemical fertiliser) produced respectably high nitrogen absorption, indicating the efficacy of chemical fertilisers alone in boosting nitrogen uptake. This may be because chemical fertilisers promote effective nitrogen uptake by offering readily available nutrients in forms that are simple to ingest. Farmyard manure can be added to soil as an organic supplement to improve soil structure, nutrient retention, and microbial activity. This increases the amount of nutrients that are available to plants. A balanced nutrient supply likely resulted from the use of both chemical fertiliser and farmyard manure, which boosted nitrogen uptake.

Table 1: Effect of planting techniques & fertility levels on nitrogen uptake

Treatment	Nitrogen uptake (kg ha^{-1}) Grain	Straw	Total
Planting techniques			
M_1 RT- TPR	35.4	19.0	54.5
M_2 CT- TPR	43.0	25.8	68.8
M_3 FIRB - TPR	36.8	19.4	56.2
M_4 Unpuddled -TPR	39.8	22.8	62.7
SEm±	0.30	0.12	0.34
CD (P=0.05)	1.08	0.44	1.20
Fertility levels			
S_1 Control	15.9	11.0	26.9
S_2 100% NPK Chemical fertilizer	45.9	23.7	69.7
S_3 100% N (FYM)	30.6	16.2	46.8
S_4 50% NPK+50% N(FYM)	35.2	20.9	56.2
S_5 75% NPK+25% N(FYM)	50.7	27.4	78.2
S_6 100% NPK+25% N(FYM)	54.2	31.3	85.6
SEm±	0.81	2.43	5.06
CD (P=0.05)	2.34	6.98	14.54

Phosphorus uptake in grains and straw of rice

The CT-TPR approach resulted in the maximum phosphorus uptake for all three parameters among the planting strategies studied (M_1: RT-TPR, M_2: CT-TPR, M_3: FIRB-TPR, and M_4: Unpuddled-TPR). This implies that the CT-TPR planting strategy improves phosphorus absorption more efficiently than the other planting approaches. The other planting strategies, RT-TPR, FIRB-TPR, and Unpuddled-TPR, all performed well in terms of phosphorus absorption, but significantly less so than CT-TPR. This can be attributable to conventional tillage's better nutrient accessibility and root development. When compared to other approaches, the CT-TPR methodology improves soil structure, root penetration, and nutrient availability, allowing for enhanced phosphorus uptake. By encouraging soil aeration and nutrient release from soil particles, conventional tillage contributes to the creation of an ideal soil environment for nutrient absorption.

For all metrics, the S_6 treatment (100 percent NPK + 25 percent N with FYM) had the maximum phosphorus uptake among the fertility levels (Table 2 and Fig. 1)). Chemical fertiliser (NPK) combined with

Table 2: Effect of planting techniques & fertility levels on phosphorus uptake

Treatment	Phosphorus uptake (kg ha^{-1})		
	Grain	Straw	Total
Planting techniques			
M_1 RT- TPR	10.26	5.98	16.24
M_2 CT- TPR	13.45	8.87	22.32
M_3 FIRB - TPR	11.18	6.70	17.88
M_4 Unpuddled -TPR	12.21	7.50	19.71
SEm±	0.06	0.04	0.12
CD (P=0.05)	0.22	0.15	0.43
Fertility levels			
S_1 Control	5.47	4.70	10.18
S_2 100% NPK Chemical fertilizer	13.34	7.82	21.16
S_3 100% N (FYM)	9.69	6.24	15.94
S_4 50% NPK+50% N(FYM)	11.65	7.08	18.74
S_5 75% NPK+25% N(FYM)	14.90	8.48	23.38
S_6 100% NPK+25% N(FYM)	15.59	9.24	24.83
SEm±	0.07	0.06	0.12
CD (P=0.05)	0.23	0.17	0.36

25% nitrogen from farmyard manure appears to improve phosphorus absorption. This suggests that a mix of chemical fertiliser and organic amendment can supply the nutrients and conditions needed for enhanced phosphorus absorption. Furthermore, treatments with greater quantities of chemical fertiliser (S_2: 100% NPK Chemical fertiliser) and the combination of NPK and FYM (S_5: 75% NPK + 25% N with FYM) demonstrated significant phosphorus absorption. This shows that chemical fertilisers on their, as well as a balanced mix of chemical fertiliser and organic amendment, can improve phosphorus absorption. These findings were consistent with those of Puli *et al*. (2017).

Potassium uptake in grains and straw of rice

The CT-TPR planting technique resulted in the maximum potassium absorption across all three planting techniques. The CT-TPR technique increased potassium intake by 18.58 kg ha^{-1} in grains, 69.98 kg ha^{-1} in straw, and 88.56 kg ha^{-1} overall. CT-TPR appears to boost potassium absorption more efficiently than the other planting strategies (Table 3 and Fig. 1).

Other planting techniques, such as RT-TPR, FIRB-TPR, and Unpuddled-TPR, showed significant potassium absorption, but significantly less than CT-TPR.

The S_6 treatment (100 percent NPK + 25 percent N with FYM) had the maximum potassium uptake among the fertility levels. Chemical fertiliser (NPK) combined with 25% nitrogen from farmyard manure appears to improve potassium absorption. This implies that a mix of chemical fertiliser and organic amendment can offer the nutrients and environment for increased potassium absorption. Treatments with greater doses of chemical fertiliser (S_2: 100% NPK Chemical fertiliser) and the combination of NPK and FYM (S_5: 75% NPK + 25% N with FYM) also demonstrated considerable potassium absorption. This lends credence to the notion that chemical fertilisers alone, or a balanced combination of chemical fertiliser and organic amendment, can improve potassium absorption. These results are in conformity with the finding of Singh *et al*. (2014).

Available nitrogen (kg ha^{-1})

After harvest of rice, available nitrogen ranged from 185.86 to 195.26 kg ha^{-1}, the highest (197.98 kg ha^{-1}) being under M_1 (RT- TPR).

Among different fertility levels significantly highest available nitrogen (202.89 kg ha^{-1}) in soil was recorded with the application of S_6 (100% NPK + 25% N (FYM)). However, the lowest value of available nitrogen was recorded under control. Similar findings also reported by Kumar *et al*. (2020).

Availability of nitrogen Increase may be attributed to higher microbial activity in the integrated nutrient management practices which favoured the conversion of the organically bound nitrogen to inorganic form. Similar increase in available N in soil due to addition of organics was also reported by Baishya et al. (2015).

Table 3: Effect of planting techniques & fertility levels on potassium uptake

Treatment	Potassium uptake (kg ha^{-1})		
	Grain	Straw	Total
Planting techniques			
M_1 RT- TPR	13.35	55.09	68.44
M_2 CT- TPR	18.58	69.98	88.56
M_3 FIRB - TPR	14.51	57.93	78.35
M_4 Unpuddled -TPR	16.79	61.56	72.45
SEm±	0.09	0.49	0.37
CD (P=0.05)	0.32	1.74	1.32
Fertility levels			
S_1 Control	6.93	46.92	53.86
S_2 100% NPK Chemical fertilizer	17.84	64.31	82.16
S_3 100% N (FYM)	12.81	58.88	71.69
S_4 50% NPK+50% N(FYM)	15.72	61.53	77.25
S_5 75% NPK+25% N(FYM)	20.07	66.20	86.28
S_6 100% NPK+25% N(FYM)	21.49	68.99	90.48
SEm±	0.12	0.50	0.55
CD (P=0.05)	0.34	1.45	1.57

Table 4: Effect of planting techniques & fertility levels on availability of NPK

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic carbon (%)
Planting techniques				
M_1 RT- TPR	197.98	15.25	181.84	0.63
M_2 CT- TPR	195.26	14.9	179.39	0.47
M_3 FIRB - TPR	192.55	14.26	178.17	0.61
M_4 Unpuddled -TPR	185.86	13.81	175.57	0.58
SEm±	0.58	0.10	1.01	0.011
CD (P=0.05)	2.05	0.38	3.5	0.035
Fertility levels				
S_1 Control	180.63	10.62	170.56	0.54
S_2 100% NPK Chemical fertilizer	196.00	16.1	180.75	0.55
S_3 100% N (FYM)	187.53	11.97	174.18	0.65
S_4 50% NPK + 50% N(FYM)	191.29	13.9	178.07	0.61
S_5 75% NPK + 25% N(FYM)	199.13	17.05	183.58	0.56
S_6 100% NPK + 25% N(FYM)	202.89	17.7	185.32	0.53
SEm±	1.36	0.11	1.27	0.010
CD (P=0.05)	3.90	0.33	3.65	0.310

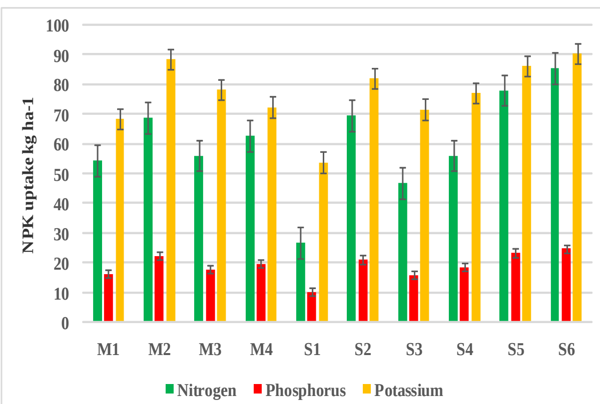

Fig. 1: Effect of planting techniques and fertility levels on NPK uptake (kg ha^{-1}), bar represents SE.

Available phosphorus (kg ha^{-1})

Planting techniques caused significant variation in available phosphorus in soil (Table 4). After harvest of rice, available phosphorus ranged from 13.81 to 15.25 kg ha^{-1}, being highest (15.25 kg ha^{-1}) under M_1 (RT- TPR). Among different fertility levels significantly highest available phosphorus (17.7 kg ha^{-1}) in soil was recorded with the application of S_6 (100% NPK + 25% N (FYM). However, the lowest value (10.62 kg ha^{-1}) of available phosphorus was recorded under control. Availability of Phosphorus increased This could be due to release of organic acids during the decomposition of organic matter, which helped in the solubility of native phosphates as a result of which the available phosphorus content in the soil was increased. Similar results also reported by Kumar *et al*. (2012)

Available potassium (kg ha^{-1})

After harvest of rice, available potassium ranged from 175.57 to 181.84 kg ha^{-1}, and the highest available potassium (181.84 kg ha^{-1}) was recorded under M_1 (RT- TPR), whereas the lowest potassium content was associated with M_4 (UP-TPR). Among different fertility levels significantly highest value of available potassium (185.32 kg ha^{-1}) in soil was recorded with the application of S_6 (100% RDF + 25% N (FYM)). However, the lowest value (170.56 kg ha^{-1}) of available potassium was recorded under control. The beneficial effect of application of FYM have resulted in increasing exchangeable K leading to augmented concentration of K in available form, thereby increasing absorption of K

Soil organic carbon (%)

After harvest of rice crop the values of soil organic carbon did not influence significantly due to different planting techniques and fertility levels however, the highest and lowest values of soil organic carbon was noticed in M_4 (RT- TPR) and M_2 (CT- TPR) treatments, respectively. Amongst the various fertility levels, the highest value of soil organic carbon (0.65%) was recorded with S_3 (100% N (FYM)), while lowest organic carbon was noticed in Control treatment. Similar findings also reported by Singh *et al*. (2019) and Powlson *et al*. (2012). Combined use with fertilizers was significantly reflected in the build up of available N, P, K, organic carbon also reported by Mukesh *et al*. (2012).

Conclusion

Based on results of experiment during kharif season (2019), most of the findings revealed that some valuable benefits of integrated nutrient management over sole application of the individual fertilizer sources in improving yield and nutrient uptake and physico-chemical properties of the soil in rice under different tillage conditions. Overall, grain yield was increased with conventional tillage practices due to significant improvement in plant establishment & tillering and chlorophyll content and photosynthesis rate of crop than crops grown with conventional method. In association with this, most of the scientist concluded that 50% from organic sources and 50% from inorganic sources is the best combination in rice-wheat cropping system to improve soil physico-chemical properties, availability and uptake of nutrients.

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