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Nutrient Uptake and Soil Health as Influenced by Plant Density and Age of Seedlings of Rice (*Oryza sativa* L.) under Modified SRI Method of Planting

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A B S T R A C T

Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during *samba* (August-December) seasons of 2012 and 2013 to find out the optimum crop geometry, age and number of seedlings on growth and physiological characters in relation to yield of low land rice. The experiment consisted of three mainplot treatments viz., M_1–25 x 25 cm, M_2–25 x 20 cm and M_3–25 x 15 cm and six sub-plot treatments S_1–14 day old seedlings (DOS)+1 seedling/hill, S_2–14 DOS+2 seedlings/hill, S_3–14 DOS+3 seedlings/hill, S_4–21 DOS+1 seedling/hill, S_5–21 DOS+2 seedlings/hill and S_6–21 DOS+3 seedlings/hill and replicated thrice in a split plot design. The treatment combination of M_3S_5 (25 x 15 cm spacing and 21 DOS with two seedlings hill^{-1}) recorded higher nitrogen uptake than others at panicle initiation, flowering and harvest stages. The same trend was followed on phosphorus and potassium also.

Introduction

Rice is an important staple food that provides 66-70% of body calorie intake of the consumers (Barahand Pandey, 2005). To assure food security in the rice consuming countries of the world, rice production should be increased by 50% in these countries by 2025. This additional rice will have to be produced on less land with less water, labour and chemicals (Zheng *et al.,* 2004). Similarly, to achieve the projected targets of 680 and 771 million tonnes (Mt) by 2015 and 2030, respectively, the productivity of rice has to be

increased through adoption of suitable technologies (Badawi, 2004). The system of rice intensification (SRI) is a new methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients resulting in both healthy soil and plants, supported by greater root growth and the soil microbial abundance and diversity (Kumar and Shivay 2004; Weijabhandara, 2011).

Fertilizer is the major input and one of the most important factors in rice production. Good fertilizer management can increase rice yield and reduce production cost. It is required to supply the nutrient requirements for plants and to attain high performance in the rice plant Practice of proper management strategies like adequate rate and timing of fertilizer application can increase rice yield and influence cost of production. Nitrogen (N), phosphorus (P), and potassium (K) are applied as fertilizers in large quantities to rice fields, and a deficiency of either of the nutrient leads to yield losses are many factors that influence the nutrient absorption including cultivar, soil type, fertilizer type, fertilization technology, and environmental factors. Imbalanced N, P, and K fertilization application can affect soil productivity. (Amit Kumar *et al.,* 2018).

However, rate of fertilizer application is also governed by socio-economic factors. Such factors are production cost, economic situation of the farmers, efficiency of extension service, and availability of credit to the growers. Use of adequate NPK rate is important not only for obtaining maximum economic return, but also to reduce environmental pollution. Therefore, the study was conducted to investigate nutrient uptake and soil health as influenced by plant density and age of seedlings of rice (*Oryza sativa* L.) under modified SRI method of planting.

Materials and Methods

Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during *samba* (August - December) season of 2012 and 2013. Coimbatore is situated in the Western agro-climatic zone of Tamil Nadu at 11°N latitude and 77°E longitude and at an altitude of 426.7 m above mean sea level. The soil of the experimental field was clay loam in texture belonging to *Typic Haplustalf* with low in available N (199.0 and 207.5 19 kg ha^{-1}), low in available P (9.0 and 11.0 kg ha^{-1}) and high in available K (419.0 and 426.7 kg 20 ha^{-1}) during the first and second years, respectively. International pipette method (Piper, 1966), Alkaline Permanganate method (Subbiah and Asija, 1956), Olsen's method (Olsen *et al.,* 1954) and Neutral Normal Ammonium Acetate (Stanford and English, 1949) for analyzing Soil texture, available nitrogen, phosphorus and potassium, respectively. The experiments consisted of three main-plot treatments viz., M_1 - 25 x 25 cm, M_2 - 25 x 20 cm and M_3 - 25 x 15 cm and six sub-plot treatments, S_1 - 14 Day Old Seedlings (DOS) + 1 seedling hill^{-1}, S_2 - 14 DOS + 2 seedlings hill^{-1}, S_3 14 DOS + 3 seedlings hill^{-1}, S_4 - 21 DOS + 1 seedling hill^{-1}, S_5 - 21 DOS + 2 seedlings hill^{-1} and S_6 - 21 DOS + 3 seedlings hill^{-1}. The treatments are replicated thrice in a split-plot design; the rice variety CO (R) 50 with field duration of 135 days was used in the trial. Separate nurseries were raised for conventional and SRI method of planting to transplant 21 and 14 DOS, respectively. All other package of practices were carried out as per recommendation of CPG (2012). Soil samples were collected from 0-20 cm depth at random from the experimental field prior to sowing. The collected samples were shade dried, powdered and sieved through 2 mm sieve. The soil samples were analyzed for texture, pH, EC, organic carbon content, available nitrogen, phosphorus and potassium. The

available N, P and K were expressed in kg ha^{-1} and the organic carbon content was expressed in g kg^{-1}. Post harvest soil samples were also collected plot-wise from a depth of 0-20 cm and analyzed the available N, P and K. Methods adopted for analysis of the soil samples are indicated in Table 1.

Results and Discussion

Nitrogen uptake (Table 2)

The nitrogen uptake (kg ha^{-1}) by rice was increased with the crop growth. The pooled statistical analysis at different stages indicated that the crop geometry, age and number of seedlings exerted significant influence on N uptake of rice.

The closer crop geometry of 25 x 15 cm (M$_3$) recorded significantly more nitrogen uptake (29.7, 75.8, 100.1 and 106.9 kg ha^{-1}) at tillering, panicle initiation, flowering and harvest stages, respectively than M$_2$ (25 x 20 cm) and M$_1$ (25 x 25 cm). Wider spacing of 25 x 25 cm (M$_1$) resulted in the least nitrogen uptake (24.7, 61.8, 85.3 and 87.8 kg ha^{-1}) at tillering, panicle initiation, flowering and harvest stages, respectively.

At tillering stage, conspicuously more nitrogen uptake (32.1 kg ha^{-1}) was observed with 21 DOS with three seedlings hill^{-1} (S$_6$) over others. Transplanting of 14 day aged seedlings with one seedling hill^{-1} (S$_1$) resulted the least nitrogen uptake (22.4 kg ha^{-1}).

At panicle initiation stage, 14 DOS with one seedling hill^{-1} (S$_1$) foraged higher N (73.0 kg ha^{-1}) over others and was on par with S$_5$ (21 DOS with two seedlings hill^{-1}). Invariably, 21 DOS with three seedlings hill^{-1} (S$_6$) had showed the lowest response with regard to nitrogen uptake (65.6 kg ha^{-1}). Similar trend was followed at flowering and harvest stages of rice growth.

Crop geometry, age and number of seedlings had significant interaction on N uptake at all the crop growth stages during both the years. At tillering stage, seedling age of 21 day old with three seedlings hill^{-1} planted at closer spacing of 25 x 15 cm (M$_3$S$_6$) registered higher nitrogen uptake (36.1 kg ha^{-1}) than other combination of treatments and was on par with M$_2$S$_6$ and M$_3$S$_3$. The lowest nitrogen uptake (20.8 kg ha^{-1}) was noted with M$_1$S$_1$ (25 x 25 cm and 14 DOS with one seedling hill^{-1}).

In pooled analysis, at panicle initiation, flowering and harvest stages, M$_3$S$_5$ (25 x 15 cm spacing and 21 DOS with two seedlings hill^{-1}) recorded higher nitrogen uptake (83.2, 113.1 and 116.3 kg ha^{-1}, respectively) than others. It was comparable with M$_3$S$_3$ and M$_2$S$_1$ at panicle initiation stage, M$_1$S$_1$, M$_2$S$_1$, M$_2$S$_5$ and M$_3$S$_5$ at flowering and harvest stages. Wider spacing of 25 x 25 cm and age old seedling of 21 days with three seedlings (M$_1$S$_6$) resulted the lowest nitrogen uptake (49.9, 71.6 and 81.9 kg ha^{-1}) at panicle initiation, flowering and harvest stages, respectively.

Phosphorus uptake (Table 3)

Effect of crop geometry, age and number of seedlings brought out a significant influence on P uptake of rice at different stages during the course of experimentations. In pooled analysis, the uptake of P recorded higher values (7.7, 16.6, 21.1 and 26.4 kg ha^{-1}) in M$_3$ (25 x15 cm) at tillering, panicle initiation, flowering and harvest stages, respectively than others. Rice transplanted at 25 x 25 cm spacing (M$_1$) recorded the lowest P uptake (4.5, 10.0, 16.1 and 19.2 kg ha^{-1}) at tillering, panicle initiation, flowering and harvest stages, respectively.

Age and number seedlings also had significant influence on P uptake. At tillering stage, seedling age of 14 days with three

seedlings hill^{-1} (S_3) recorded higher P uptake (7.3 kg ha^{-1}) than other age and number of seedlings. The lowest P uptake (4.9 kg ha^{-1}) was recorded in S_1 (14 DOS with one seedling hill^{-1}).

At panicle initiation stage, distinctly higher phosphorus uptake (15.2 kg ha^{-1}) was noticed with 21 DOS with two seedlings hill^{-1} (S_5) and it was comparable with S_1 (14 DOS with one seedling hill^{-1}). The lowest phosphorus uptake (12.5 kg ha^{-1}) was witnessed with 21 DOS combined with three seedling hill^{-1} (S_6). Similar results were followed at flowering and harvest stages also.

The interaction effect between crop geometry, age and number of seedlings was significant on P uptake at different stages during both the years. At tillering stage, the combination of closer spacing 25 x 15 cm and 14 DOS with three seedlings hill^{-1} (M_3S_3) was found to record higher P uptake (9.0 kg ha^{-1}) and it was at par with M_3S_6 than others. The lowest P removal (3.6 kg ha^{-1}) was observed in combination of M_1S_1 (25x 25 cm and 14 DOS with one seedling hill^{-1}).

Closer spacing of 25 x 15 cm and 21 DOS with two seedlings hill^{-1} (M_3S_5) recorded higher phosphorus uptake (18.9, 24.5 and 29.8 kg ha^{-1}) at panicle initiation, flowering and harvest stages, respectively and was comparable with M_3S_3 at panicle initiation, M_2S_1 and M_3S_3 at flowering, M_2S_1 and M_2S_5 at harvest stages. The lowest phosphorus uptake (7.7, 12.3 and 14.2 kg ha^{-1}) was evident with wider spacing of 25 x 25 cm in association of 21 DOS with three seedlings hill^{-1} (M_1S_6) at panicle initiation, flowering and harvest stages, respectively.

Potassium uptake (Table 4)

During these experiments, transplanting of rice with 25 x 15 cm spacing (M_3) recorded

distinctly higher potassium uptake (15.0, 51.4, 84.3 and 98.6 kg ha^{-1}) at tillering, panicle initiation, flowering and harvest stages, respectively than others. Whereas, wider spacing of 25 x 25 cm (M_1) recorded lucidly the lowest potassium uptake (12.5, 39.5, 72.0 and 81.6 kg ha^{-1}) at tillering, panicle initiation, flowering and harvest stages, respectively.

Age and number of seedlings had marked influence on the K uptake at all the stages of observation. At tillering stage, 14 DOS with three seedlings hill^{-1} (S_3) recorded higher K uptake (16.8 kg ha^{-1}) these experiments than other treatments. The lowest K uptake (11.2 kg ha^{-1}) was registered with S_1 (14 DOS with one seedling hill^{-1}). Whereas, at panicle initiation stage, S_1 (14 days with one seedling hill^{-1}) was registered perceptibly higher potassium uptake (51.9 kg ha^{-1}) during these study and was on par with S_5. Transplanting of 21 day old seedlings with three seedlings hill^{-1} (S_6) recorded the lowest potassium uptake (38.0 kg ha^{-1}). Similar results were reported at flowering and harvest stages of rice too.

A significant interaction effect was observed between crop geometry, age and number of seedlings at all stages of observations during both the years. At tillering stage, rice transplanted at 25 x 15 cm and 21 DOS with three seedlings hill^{-1} (M_3S_6) recorded significantly higher K uptake (17.8 kg ha^{-1}) compared to all other treatment combinations. It was comparable with M_2S_3, M_2S_6 and M_1S_3. The lowest K uptake (9.0 kg ha^{-1}) was recorded under the treatment combination of M_1S_1 (25 x 25 cm and 14 DOS with one seedling hill^{-1}).

At later stages (panicle initiation, flowering and harvest stages), obviously higher K uptake (62.1, 98.9 and 119 kg ha^{-1}, respectively) was observed in M_3S_5 (25 x 15

cm and 21 DOS with two seedlings hill[-1]) and was comparable with M_2S_1 at panicle initiation stage; and M_2S_1, M_2S_5 and M_3S_4 at flowering stage. Crop geometry of 25 x 25 cm and 21 DOS with three seedlings hill[-1] (M_1S_6) recorded the least potassium uptake (30.3, 53.5 and 58.7 kg ha^{-1}) at panicle initiation, flowering and harvest stages, respectively.

Influence of crop geometry, age and number of seedlings on nutrient uptake of rice

Nitrogen is very essential for the growth and development of crops, it enhances biomass and seed yield subject to the efficient water supply. Nitrogen absorbed by rice during the vegetative growth stages contributed to growth during reproduction and grain-filling through translocation (Norman *et al.,* 1992; Bufogle *et al.,* 1997).

Drymatter production and its conversion to economic yield is a cumulative effect of various physiological processes occurring during the life cycle of plants. An increase in yield of rice with increasing rate of nitrogen has been reported earlier Khan *et al.,* (1994). Nitrogen uptake differed significantly due to various levels of planting geometry at all the growth stages during both years. The closer spacing of 25 x 15 cm favoured in crop to absorbed more amount of N throughout the growth stages (Fig. 1). Higher biomass gain and total above ground N content were the driving factors for N uptake. The results are in conformity with the findings of Borkar *et al.,* (2008). Similarly, P and K uptake was also higher with 25 x 15 cm spacing compared to others at all the growth stages during the course of experimentation (Fig. 1). The discussion made for N uptake holds good here also. This is in conformity with the findings of Bezbaruha *et al.,* (2011); Amit Kumar *et al.,* (2018).

Age and number of seedlings had significant influence on the N uptake by the crop at all growth stages. At initial tillering stage, 21 day old three seedlings hill[-1] produced higher DMP and more N concentration in biomass that have increased nutrient uptake. At later stages, 14 day old one seedling hill[-1] and which was on par with 21 day old two seedlings hill[-1] in term of N, P and K uptake (Fig. 1). This might be due to enhanced root activity as evidenced from lengthier roots subsequently increased nutrient uptake and total DMP. Higher uptake was mainly attributed to the better root activity and increased DMP besides less competition among plants.

Perhaps profuse and robust root system due to early seedling vigour might have facilitated greater ability to mobilize more nutrients, concomitant with higher absorption and translocation of nutrients. A well developed and healthy root system plays an important role in uptake (N, P and K) and translocation of nutrients from soil particularly with planting younger seedlings (Gobi *et al.,* 2019).

Younger seedling with better root activity supplied essential nutrients for the plant, which ultimately increased the nutrient uptake. Similar findings were made by Sridevi (2006). Transplanting younger seedlings i.e., less than 15 day old seedlings had higher tillering capacity and more vigour which in turn helped in extracting nutrients from soil (Manjunatha *et al.,* 2010).

Interaction effect of treatments on nutrient uptake of rice

Interaction effect between crop geometry, age and number of seedlings was significant on N uptake at all growth stages. Rice planted at 25 x 15 cm with 21 day old three seedlings hill[-1] removed higher amount of N compared to

other combinations at initial stage. At later stages, combination of 25 x 15 cm spacing and 21 day old two seedlings hill[-1] had better N uptake. Higher LAI and increased tillers unit area[-1] exhibited higher biomass and in turn influenced the vegetative N uptake. This result was confirmed with Nandhakumar *et al.,* (2016). Planting two seedlings hill[-1] recorded higher nutrient uptake than others and it was mainly attributed to better root activity and increased drymatter production. Similar findings are made by Bommayasamy *et al.,* (2020). Similarly, combination of 25 x 15 cm spacing and 21 day old two seedlings hill[-1] had significantly increased the P and K uptake at panicle initiation, flowering and harvest stages during both the years of study. The detailed discussion made for N uptake holds good here too.

Table.1 Details of analytical methods employed in soil analysis

Particulars	Methods	References
I. Mechanical composition		
Textural analysis	International pipette method	Piper (1966)
II. Soil Chemical Analysis		
pH (1:2 soil : water suspension)	Potentiometry	Jackson (1973)
EC (dSm[-1])	Conductometry	Jackson (1973)
Organic carbon (g kg^{-1})	Chromic acid wet digestion	Walkley and Black (1934)
Available nitrogen (kg ha^{-1})	Alkaline Permanganate	Subbiah and Asija (1956)
Available phosphorus (kg ha^{-1})	Olsen's	Olsen *et al.,* (1954)
Available potassium (kg ha^{-1})	Neutral normal Ammonium acetate	Stanford and English (1949)

Table.2 Influence of crop geometry, age and number of seedlings on nitrogen uptake (kg ha^{-1}) at various growth stages of rice (Pooled analysis)

Treatments	Tillering stage				Panicle initiation stage				Flowering stage				Harvest stage			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	20.8	22.1	24.2	**22.4**	71.6	76.9	70.6	**73.0**	96.5	110.1	98.3	**101.6**	106.3	109.8	102.9	**106.4**
S_2	23.5	25.1	26.9	**25.2**	63.0	70.7	72.1	**68.6**	95.5	91.8	95.8	**94.4**	95.0	101.0	101.1	**99.0**
S_3	26.9	27.9	32.9	**29.3**	59.2	71.0	77.1	**69.1**	78.1	88.3	99.2	**88.5**	78.8	90.5	109.8	**93.0**
S_4	24.2	25.2	28.1	**25.8**	67.6	55.5	76.0	**66.3**	90.6	98.7	94.7	**94.6**	92.0	93.7	107.9	**97.9**
S_5	26.8	29.9	30.4	**29.1**	59.6	72.7	83.2	**71.8**	79.7	102.0	113.1	**98.3**	81.9	107.9	116.3	**102.0**
S_6	26.2	34.1	36.1	**32.1**	49.9	70.7	76.1	**65.6**	71.6	88.7	99.4	**86.5**	72.9	90.8	103.5	**89.0**
Mean	**24.7**	**27.4**	**29.7**		**61.8**	**69.6**	**75.8**		**85.3**	**96.6**	**100.1**		**87.8**	**98.9**	**106.9**	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.7	0.9	1.5	1.5	1.5	1.8	3.2	3.0	1.9	2.1	4.2	4.1	2.2	2.5	4.6	4.4
CD (P=0.05)	1.8	1.7	3.3	3.0	4.2	3.5	6.9	6.1	5.3	4.8	9.1	8.3	6.2	5.2	10.2	8.9

M_1 - 25 x 25 cm	S_1 - 14 DOS + one seedling hill^{-1} S_4 - 21 DOS + one seedling hill^{-1}
M_2 - 25 x 20 cm	S_2 - 14 DOS + two seedlings hill^{-1} S_5 - 21 DOS + two seedlings hill^{-1}
M_3 - 25 x 15 cm	S_3 - 14 DOS + three seedlings hill^{-1} S_6 - 21 DOS + three seedlings hill^{-1}

Table.3 Influence of crop geometry, age and number of seedlings on phosphorus uptake (kg ha^{-1}) at various growth stages of rice (Pooled analysis)

Treatments	Tillering stage				Panicle initiation stage				Flowering stage				Harvest stage			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	3.6	5.0	6.1	4.9	12.8	16.0	15.0	14.6	18.6	23.6	17.9	20.1	24.0	27.6	23.6	25.1
S_2	4.1	5.8	8.0	5.9	9.8	15.0	17.0	13.9	18.4	20.9	20.5	19.9	20.3	22.9	25.1	22.8
S_3	5.4	7.5	9.0	7.3	9.0	12.5	17.7	13.1	13.9	15.0	23.4	17.4	18.6	21.4	25.8	22.0
S_4	4.2	5.5	6.9	5.5	10.9	12.9	15.1	13.0	17.1	16.7	20.4	18.1	19.8	22.7	25.1	22.5
S_5	4.6	7.4	8.1	6.7	9.7	17.0	18.9	15.2	16.4	20.9	24.5	20.6	18.1	28.7	29.8	25.5
S_6	5.1	7.0	8.4	6.9	7.7	13.8	16.1	12.5	12.3	14.2	19.9	15.5	14.2	20.1	27.5	20.6
Mean	4.5	6.4	7.7		10.0	14.5	16.6		16.1	18.6	21.1		19.2	23.7	26.4	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.13	0.17	0.30	0.29	0.32	0.39	0.69	0.68	0.41	0.50	0.89	0.87	0.51	0.60	1.08	1.04
CD (P=0.05)	0.37	0.34	0.65	0.59	0.87	0.80	1.52	1.38	1.14	1.02	1.96	1.77	1.41	1.23	2.37	2.12

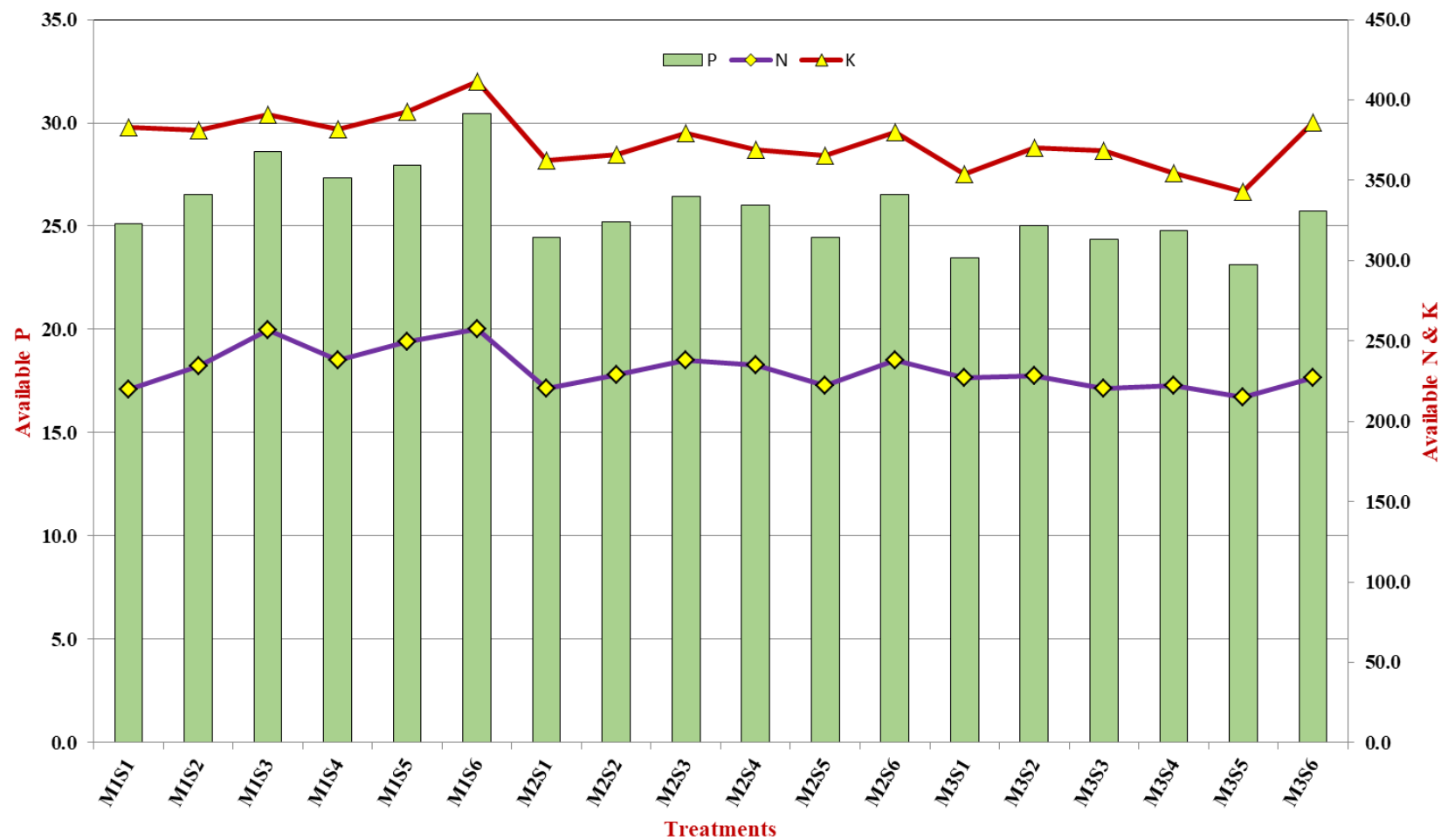|	
M_1 - 25 x 25 cm	S_1 - 14 DOS + one seedling hill^{-1} S_4 - 21 DOS + one seedling hill^{-1}
M_2 - 25 x 20 cm	S_2 - 14 DOS + two seedlings hill^{-1} S_5 - 21 DOS + two seedlings hill^{-1}
M_3 - 25 x 15 cm	S_3 - 14 DOS + three seedlings hill^{-1} S_6 - 21 DOS + three seedlings hill^{-1}

Table.4 Influence of crop geometry, age and number of seedlings on potassium uptake (kg ha^{-1}) at various growth stages of rice (Pooled analysis)

Treatments	Tillering stage				Panicle initiation stage				Flowering stage				Harvest stage			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	9.0	13.1	11.9	11.2	47.4	57.3	51.0	51.9	83.9	94.8	85.7	83.1	92.8	98.8	107.7	99.8
S_2	13.1	12.9	14.0	13.6	42.0	46.8	47.8	45.6	78.4	81.2	78.0	79.2	91.4	95.3	90.4	92.4
S_3	17.8	16.5	15.8	16.8	39.6	44.9	51.6	45.4	69.6	68.5	80.1	72.7	79.5	81.4	92.8	84.5
S_4	11.8	12.1	14.6	12.9	38.9	42.0	53.4	44.7	80.0	72.5	93.1	81.9	89.1	88.5	107.0	94.9
S_5	10.7	13.1	16.1	13.4	38.6	49.2	62.1	50.0	66.5	90.0	98.9	85.1	78.2	96.0	119.0	97.7
S_6	12.6	16.9	17.8	15.8	30.3	41.1	42.4	38.0	53.5	66.3	64.3	66.4	58.7	80.8	74.7	71.4
Mean	12.5	14.1	15.0		39.5	46.9	51.4		72.0	77.9	84.3		81.6	90.1	98.6	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.3	0.4	0.8	0.7	1.0	1.2	2.1	2.0	1.6	2.0	3.5	3.4	1.9	2.2	4.0	3.9
CD (P=0.05)	0.9	0.9	1.6	1.5	2.7	2.4	4.5	4.1	4.5	4.0	7.8	7.0	5.4	4.6	9.0	8.0

M_1 - 25 x 25 cm	S_1 - 14 DOS + one seedling hill^{-1}		S_4 - 21 DOS + one seedling hill^{-1}
M_2 - 25 x 20 cm	S_2 - 14 DOS + two seedlings hill^{-1}		S_5 - 21 DOS + two seedlings hill^{-1}
M_3 - 25 x 15 cm	S_3 - 14 DOS + three seedlings hill^{-1}		S_6 - 21 DOS + three seedlings hill^{-1}

Table.5 Influence of crop geometry, age and number of seedlings on post harvest available N, P and K status (kg ha^{-1}) of rice (Pooled analysis)

Treatments	Nitrogen				Phosphorus				Potassium			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	219.7	220.7	226.9	**222.4**	25.1	24.5	23.5	**24.4**	383.2	362.4	353.8	**366.4**
S_2	234.3	228.7	228.6	**230.5**	26.6	25.2	25.0	**25.6**	381.4	365.8	370.6	**372.6**
S_3	257.0	238.2	220.7	**238.7**	28.6	26.5	24.4	**26.5**	391.2	379.4	368.2	**379.6**
S_4	238.3	235.3	222.4	**232.0**	27.4	26.0	24.8	**26.1**	381.9	369.3	354.4	**368.5**
S_5	249.4	222.5	214.8	**228.9**	28.0	24.5	23.2	**25.2**	392.5	365.2	343.0	**366.9**
S_6	257.6	237.9	227.3	**240.9**	30.5	26.6	25.8	**27.6**	411.3	379.8	385.8	**392.3**
Mean	**242.7**	**230.5**	**223.5**		**27.7**	**25.5**	**24.5**		**390.3**	**370.3**	**362.7**	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	4.7	5.4	9.8	9.4	0.6	0.7	1.2	1.2	7.1	7.8	14.2	13.5
CD (P=0.05)	13.0	11.1	NS	NS	1.7	1.4	NS	NS	19.6	15.9	NS	NS

M$_1$ - 25 x 25 cm	S$_1$ - 14 DOS + one seedling hill^{-1}	S$_4$ - 21 DOS + one seedling hill^{-1}
M$_2$ - 25 x 20 cm	S$_2$ - 14 DOS + two seedlings hill^{-1}	S$_5$ - 21 DOS + two seedlings hill^{-1}
M$_3$ - 25 x 15 cm	S$_3$ - 14 DOS + three seedlings hill^{-1}	S$_6$ - 21 DOS + three seedlings hill^{-1}

Fig. 1. Effect of crop geometry, age and number of seedlings on post harvest available N, P and K status (kg ha^{-1}) of rice

Post harvest soil available nutrients (Table 5)

Crop geometry showed a significant variation on available N in soil after harvest of rice. Higher values of available N were registered (242.7 kg ha^{-1}) under wider geometry of 25 x 25 cm (M$_1$) than M$_2$ and M$_3$. Closer crop geometry of 25 x 15 cm (M$_3$) registered the lowest soil available N (223.5 kg ha^{-1}). The same trends were noticed in phosphorus and potassium too.

Age and number of seedlings treatments showed marked variations on soil available N. During the experiments, seedling age of 21 days with three seedlings hill^{-1} (S$_6$) left more available N in the soil (240.9 kg ha^{-1}) and superior over others. Transplanting of 14 DOS with one seedling hill^{-1} (S$_1$) observed the least soil available N (222.4 kg ha^{-1}). Similar results were found on P and K.

Crop geometry had significant variations on post-harvest soil N, P and K status during the study. Wider spacing of 25 x 25 cm (M$_1$) reported higher amount of available N, P and K compared to others (Fig. 1). This might be due to lower plant population, comparatively less competition, reduced nutrient uptake and loss of these nutrients from the soil resulted in increased soil available nutrients. This is in accordance with the findings of Baskar (2009).

During investigation of the experiments, among the age and number of seedlings 21 day old three seedlings hill^{-1} (S$_6$) recorded higher soil available N, P and K over others (Fig. 1). This might be due to poor root growth, less competition for light and lower nutrient absorption. Similar results were observed by Rajendran (2009). Available nutrient status gets depleted as a consequence of biomass production under best combination of non-monetary inputs (Bommayasamy *et al.,* 2020). There was no significant interaction among treatment combinations on post-harvest soil available N, P and K status.

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