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Effect of fertilizer levels, spacing on yield and nutrient uptake of paddy (*Oryza sativa* L.)

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Abstract
A field experiment entitled "Effect of fertilizer levels, spacing on yield and nutrient uptake of Paddy (*Oryza sativa* L.)" was conducted at Agriculture Research Station, Sakoli. The experiment was laid out in split plot design with three replication. The main plot treatments comprised of two varieties (SKL-3-1-41-8-33-15 and Sakoli-6) and sub-plot treatment comprised of combinations two levels of spacing (20 × 20 and 20 × 15 cm) and three levels of fertilizer (75%, 100% and 125% RDF).
Results reveal that the rice transplanted with rice variety SKL-3-1-41-8-33-15 recorded significantly higher yield attributes resulting into significantly more grain and straw yield over Sakoli-6. Significantly higher values of nitrogen, phosphorus and Potassium content and subsequently higher uptake were recorded by rice variety SKL-3-1-41-8-33-15 as compared to Sakoli-6. The available nitrogen, phosphorus and potassium status in the soil after harvest of rice was significantly higher in the field of rice variety Sakoli-6 followed by SKL-3-1-41-8-33-15. All the growth parameters, yield contributing characters, grain and straw yield, N, P and K content and uptake were not influenced significantly by different spacing i.e 20 × 20 and 20 × 15 cm. Also availability of N, P and K in the soil after harvest of rice was not influenced significantly by different levels of spacing. Application of 125% RDF recorded significantly higher values of growth and yield contributing characters resulting into significantly more grain and straw yield than rest of the fertilizer levels. N, P and K content and uptake both in the grain and straw of rice were significantly higher under application of 125% RDF followed by application of 100 and 75% RDF in the descending order of significance, Similarly the values of available N, P and K were significantly higher under the treatment of application of 125% RDF than rest of the fertilizer levels.

Keywords: Fertilizer, spacing, paddy, nutrient, uptake

Introduction

Rice is grown under diverse soil and climatic conditions the productivity level in India is low as compared to the productivity levels of many countries in the world. Also, about 86 per cent of the cultivated land belongs to marginal and small farmers which are another constrain in increasing the productivity of rice in the country. There is wide scope to increase the productivity of rice in the country. The average productivity of rice in India is 2455 kg ha^{-1} against world is 4602 kg ha^{-1}. There is a need to implement improved varieties alongside integrated crop management system that include mechanization, nutrient, pest and water management.

Rice is also an important cereal food crop of Maharashtra state, which contributes 3.6 per cent of area and 2.8 per cent of production of rice at national level. Total area, production and productivity of rice were 15.47 lakh hectares, 31.37 lakh tons and 20.28 quintal ha^{-1} (Anonymous, 2020) [1]. Among the different rice growing states of India, there are regional imbalances with regard to the average yield. The reasons are more than 70 per cent of rice area is rainfed, depends on the irregular rainfall, less fertilizer uses, adoption of traditional varieties, insect and disease problems are responsible for limiting rice yields, Rice is the main food crop grown in Vidarbha region, which occupies an area of 8.36 lakh hectares with production of 14.52 lakh tones and productivity of 1745 kg ha' (Anonymous, 2020) [1]. The main reasons of low productivity and profitability are mainly *viz*., vagaries of monsoon, low fertilizer use efficiency, poor crop management and adherence of farmers to traditional crop management practices.

India's total rice needs are projected to rise despite a reduction in rice consumption as a result of rising income and urbanization. The 2050 vision document published by the CRRI estimated Indian rice needs to continually rice after 2030, reaching 137 million tons by 2050. The so-called 'Green Revolution' has provided enough food to meet the current country demand. However, concerns have been raised about sustainable rice production, yield stagnation and yield gaps. According to Mottaleb *et al.*, (2016) [9], India would have an additional 5-10 million tons of rice annually by 2035 under different climatic scenarios if a successful drought-tolerant variety were made available in 2015.

The development of advanced rice technology and the adaptation of improved high yielding varieties to Indian environment offer new approach to the problems of matching food supply to the expected increased demand. Under the improved HYV rice research programme in Maharashtra state released Sakoli-6, Sakoli-7, Sakoli-8, Sakoli-9, PKV-Ganesh and many other HYV of rice for commercial cultivation. This improved high yielding variety having higher nitrogen use efficiency, higher yield potential and high photosynthetic ability. The nutrient requirement of the improved varieties may be different. It is, therefore, very essential to work out the nutrient management package of improved rice cultivation under different agro-ecosystem, so as to increase the nutrient use efficiency for maximization of rice yield. This could be achieved by balanced use of fertilizers particularly major nutrients *viz*., Nitrogen (N), Phosphorous (P) and Potassium (K).

Nitrogen is an essential plant nutrient being a component of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes, and hormones. N promotes rapid plant growth and improves grain yield and grain quality through higher tillering, leaf area development, grain formation, grain filling, and protein synthesis. N is highly mobile within the plant and soil. Nitrogen taken up during early growth stages accumulates in the vegetative parts of the plant and it is utilized for grain formation. A large portion of the nitrogen is absorbed during differentiation. The leaves and stems contain a large portion of the nitrogen taken up by the plant. Suitable doses of N promote rapid growth and increase number of spikelet's panicle^{-1}, and number of filled grains per cent.

Phosphorus is particularly important in early growth stages. It is mobile within the plant and promotes root development (Particularly the development of fibrous roots), tillering and early flowering. It also increases resistance to disease and strengthens the stems of cereal plants, thus reducing their tendency to lodge. It offsets the harmful effects of excess nitrogen in the plant. It serves as important constituents of nucleic acid.

Potassium (K) is also very important for achieving good rice yields. Potassium (K) contributes to plants' disease resistance, root enlargement, and thickness, leaf durability, panicle initiation and development. Potassium deficiencies have a great impact on crop growth. Potassium enhances the ability of the plants to resist diseases, insect attacks, cold and other adverse conditions. It plays an essential part in the formation of starch and in the production and translocation of sugars, and is thus of special value to carbohydrate-rich crops.

In densely populated rice field, the inter-specific competition between the plants is high in which sometimes results in gradual shading and lodging and thus favor increased production of straw instead of grain. Profuse tillering of the improved rice may compensate the yield due to reduction in plant population. It is therefore necessary to determine the optimum plant spacing for obtaining high yield of rice.

Among the different factors of rice productivity, desired number of plant and spacing per unit area is an important one for getting higher yield. Improper spacing reduces rice yield up to 20-30 per cent (IRRI, 1997) [4], while optimum spacing ensures better plant growth through efficient utilization of solar radiation and nutrients (Mohaddesi *et al.*, 2011) [8]. Plant spacing directly affects the normal physiological activities through intra-specific competition. Proper planting geometry has more advantages such as maximizes light utilization efficiency, improves aeration within crop canopy, enhances soil respiration and provides better weed control thereby higher crop yield. Maintenance of a critical level of rice plant population in field is necessary to maximize grain yield.

Methodology

Experiment was conducted at Agronomy farm, Agriculture Research Station, Sakoli Dist. Bhandara (M.S.) during *Kharif* season of the year 2020-21. The soil of experimental plot was clay loam in texture, slightly acidic in reaction with high organic carbon content. It was medium in available nitrogen, low in available phosphorus and high in available potassium during the years of experimentation. Geographically it is situated in the subtropical region at 21° 08' N latitude and 79°.98' E longitude having elevation of about 233 m above mean sea level. The climate is sub-tropical which is characterized by warm and humid atmosphere. The relative humidity during entire crop season ranged from 65 to 93 per cent during morning and 30 to 72 per cent during afternoon, respectively during the *kharif* 2020. An amount of 1519.40 mm of annual rainfall was received during the cropping season from June-2020 onward against the average of annual rainfall 1716.40 mm. During the crop growth period, an amount of 1520 mm of rainfall in 100 rainy days was received throughout the crop growth during 2020. A highest intensity rainfall recorded during 33 and 34 Meteorological Week (345.2 and 180.0 mm), respectively

The field experiment was laid out is split plot design comprising of 36 treatment combination replicated thrice. The main plot comprising of two varieties (SKL-3-1-41-8-33-15 and Sakoli-6) and sub plot comprising of three levels of fertilizes (75, 100 and 125% RDF) against RDF: 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} and two spacing (20 X 20 and 20 X 15 cm). The nursery area for raising the seedlings of SKL-3-1-41-8-33-15 was ploughed and subsequently brought under fine tilth with the help of tractor drawn rotavator. The raised bed of 10 m length, 1 m breadth and 10 cm height were prepared. A well decomposed FYM @ 1 kg sq.m^{-1} was spread over the beds and mixed with the soil. Urea @ 1 kg and single super phosphate @ 3 kg per 100 sq.m^{-1} were applied at the time of sowing. The seed of rice SKL-3-1-41-8-33-15 which was treated with thiram @ 3 g kg^{-1} was sown in the lines 10 cm apart at 2-3 cm depth on 13 July, 2020. Germination started from the third day and completed by the fifth day. Top dressing with urea @ 1 kg per 100 m area was done 15 days after sowing. The required plant protection and weed control measures were carried out in the nursery during the seasons land preparation as per recommended tillage. Fertilizer applications were done as per the treatment. Basal dose of 50 per cent nitrogen (urea) along with full dose of phosphorus (single super phosphate) and potash (muriate of potash) was applied at the time of transplanting. The remaining 25 per cent nitrogen was applied at maximum tillering stage and another 25 per cent at panicle emergence stage as per the treatments.

Imidacloprid 17.8 SL @20 ml per 10 liter of water and lambda Cyhalothrin 5% EC @ 20 ml per 10 liter of water was sprayed to protect the crop against Rice Brown plant Hopper and rice stem borer respectively. The harvest index (%) was calculated as

HI (%) = Grain yield / Total biological yield x 100

data collected were subjected to the statistical analysis by using Analysis of variance' technique. Wherever 'F' test revealed significant treatment effects, critical difference was worked out at five per cent level of probability for the treatment comparison (Panse and Sukhatme, 1967). Data have been suitably illustrated with graphs at appropriate places in the text. Chemical analysis particularly, nitrogen, Phosphorus and Potassium content in the rice grain and straw was determined by modified Micro kjeldahl's, Calorimetric and Flame photometer (Jackson, 1973) method. Total nitrogen, phosphorus and potassium uptake (kg ha^{-1}) was calculated by addition of nitrogen, phosphorus and potassium accumulation in grain and straw on hectare basis recorded under the individual treatment.

Result and Discussion

Table 1: Yield contributing characters of rice as influenced by different treatments

Treatments	Numbers of effective tillers $plant^{-1}$	Length of panicle (cm)	Numbers of filled grains $panicle^{-1}$	Numbers of unfilled grains $panicle^{-1}$	Test weight (g)
A] Main plot					
1] Varieties					
V_1- SKL-3-1-41-8-33-15	15.38	25.07	228.42	11.85	26.33
V_2- Sakoli-6	12.49	23.67	176.72	9.91	22.20
S.E (m) ±	0.47	0.23	2.31	0.30	0.25
C.D at 5%	2.86	1.40	14.03	1.81	1.50
2] Spacing					
S_1- 20 × 20 cm	13.51	24.28	200.86	9.63	23.95
S_2- 20 × 15 cm	14.36	24.46	204.28	12.13	24.58
S.E (m) ±	0.47	0.23	2.31	0.30	0.25
C.D at 5%	NS	NS	NS	NS	NS
B} Sub plot					
3] Fertilizer levels					
F_1 – 75% RDF	11.39	23.44	178.97	13.83	22.02
F_2 - 100% RDF	14.94	24.68	213.99	9.78	24.93
F_3 – 125% RDF	15.49	24.99	214.75	9.03	25.86
S.E (m) ±	0.65	0.41	10.12	0.68	0.83
C.D at 5%	1.92	1.21	29.86	2.02	2.45

The length of panicle (cm) of rice variety SKL-3-1-41-8-33-15 was significantly more as compared to the second variety of rice Sakoli-6. The highest length of panicle (cm) of rice variety SKL-3-1-41-8-33-15 was 25.07 cm recorded at harvest while the lowest length of panicle (cm) was 23.67 cm observed with Sakoli-6. Similar results were confirmed by Mamun *et al*. (2010) [7] and Damor (2017) [3]. The length of panicle (cm) of rice was not significantly influence by different type of spacing. Application of 125% RDF recorded significantly a highest length of panicle (cm) than all the remaining levels of fertilizer at harvest. However, the treatment with application of 125% RDF and 100% RDF were at par. The highest length of panicle 24.99 (cm) of rice was noted at harvest with 125% RDF. Similar results were recorded by Banerjee and Pal (2011) [2].

The highest mean number of filled grains $panicle^{-1}$ of rice variety SKL-3-1-41-8-33-15 was 228.42 recorded at harvest while the lowest mean number of filled grains $panicle^{-1}$ was 176.72 recorded with Sakoli-6 at harvest observation. Similar findings were recorded by Kumar *et al*. (2017) [6]. The number of filled grains $panicle^{-1}$ of rice was not significantly influence by different type of spacing. Application of 125% RDF recorded significantly a highest number of filled grains $panicle^{-1}$ than the remaining levels of fertilizer at harvest. However, the treatment 125% RDF and 100% RDF were at par with each other. Similar findings were noted by Pawar (2017) [12].

The significantly highest mean number of unfilled grains $panicle^{-1}$ of rice variety SKL-3-1-41-8-33-15 was 11.85 recorded at harvest while the mean number of filled grains $panicle^{-1}$ was 9.91 recorded with Sakoli-6 at harvest observation. Similar results were recorded by Damor (2017) [3]. Same parameter was not significantly influence by different type of spacing. Application of 125% RDF recorded significantly a lesser number of unfilled grains $panicle^{-1}$fallowed by application of 100% and 75% RDF. Similar findings were recorded by Kumar *et al*. (2017) [6].

The mean test weight of rice variety SKL-3-1-41-8-33-15 was significantly more as compared to the second variety of rice Sakoli-6, the test weight of rice was not significantly influence by different type of spacing. Application of 125% RDF recorded significantly higher test weight fallowed by application of 100% and 75% RDF except application of 100% RDF which was statistically at par with 125% RDF. The number of filled grains $panicle^{-1}$ of rice was not significantly influence by different type of spacing. Similar findings were confirmed by Paramasivan *et al*. (2016) [11].

Table 2: Grain yield, straw yield (q ha^{-1}) and harvest index (%) of rice as influenced by the different treatments.

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index (%)
A] Main plot			
1] Varieties			
V_1- SKL-3-1-41-8-33-15	52.76	62.73	45.68
V_2- Sakoli-6	42.60	51.44	45.29
S.E (m) ±	0.64	1.05	-
C.D at 5%	3.88	6.37	-
2] Spacing			
S_1- 20 × 20 cm	46.33	56.32	45.13
S_2- 20 × 15 cm	49.04	57.86	45.87
S.E (m) ±	0.64	1.05	-
C.D at 5%	NS	NS	-
B} Sub plot			
3] Fertilizer levels			
F_1 – 75% RDF (75:37:37 kg ha^{-1})	42.08	52.06	44.70
F_2 - 100% RDF (100:50:50 kg ha^{-1})	49.80	58.82	45.85
F_3 – 125% RDF (125:63:63 kg ha^{-1})	51.16	60.38	45.87
S.E (m) ±	2.17	2.30	-
C.D at 5%	6.39	6.79	-

The rice variety SKL-3-1-41-8-33-15 was recorded 52.76 q ha^{-1} mean grain yield followed by 42.60 q ha^{-1} with Sakoli-6. Similar results were recorded by Kumar *et al*. (2017) [6]. The mean grain yield of rice was not significantly influence by different type of spacing. The mean grain yield of rice at spacing 20 × 20 cm was 46.33 (q ha^{-1}) and for 20 × 15 cm was 49.04 (q ha^{-1}) at harvest. Application of 125% RDF recorded significantly highest mean grain yield (q ha^{-1}), while application of 125% RDF was statistically at par with application 100% RDF. The mean grain yield of rice was 42.08, 49.80 and 51.16 q ha^{-1} at 75, 100 and 125% RDF respectively. Similar findings were confirmed by Shende *et al*. (2019) [13].

The rice variety SKL-3-1-41-8-33-15 (V1) gave significantly higher straw yield over Sakoli-6. The mean straw yield of rice variety SKL-3-1-41-8-33-15 was recorded 62.73 q ha^{-1} while the mean straw yield was recorded 51.44 q ha^{-1} with Sakoli-6 The mean grain yield (q ha^{-1}) of rice was not significantly influence by different type of spacing. The mean straw yield of rice was significantly influence due different levels of fertilizer. With application of 125% RDF was statistically at par with application 100% RDF. The mean straw yield of rice was 52.06, 58.82 and 60.38 q ha^{-1} at 75,100 and 125% RDF respectively. Similar findings were recorded by Shende *et al*. (2019) [13]. The harvest index was higher in rice variety SKL-3-1-41-8-33-15 than rice variety sakoli-6, 20 × 15 cm and application of 125% RDF.

Table 3: Nutrient uptake (kg ha^{-1}) by rice as influenced by different treatments

Treatments	Total uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
A] Main plot			
1] Varieties			
V_1- SKL-3-1-41-8-33-15	111.97	29.22	102.06
V_2- Sakoli-6	96.44	23.37	89.89
S.E (m) ±	1.10	0.25	0.94
C.D at 5%	6.69	1.55	5.69
2] Spacing			
S_1- 20 x 20 cm	100.00	24.67	93.11
S_2- 20 x 15 cm	108.42	27.92	98.83
S.E (m) ±	1.10	0.25	0.94
C.D at 5%	NS	0.75	NS
B} Sub plot			
3] Fertilizer levels			
F_1 – 75% RDF (75:37:37 kg ha^{-1})	94.54	21.83	86.79
F_2 - 100% RDF (100:50:50 kg ha^{-1})	105.13	26.13	97.33
F_3 – 125% RDF (125:63:63 kg ha^{-1})	112.96	30.92	103.79
S.E (m) ±	3.48	1.34	2.67
C.D at 5%	10.25	3.94	7.88

The different varieties significantly influenced total uptake nitrogen, phosphorus and potassium. The significantly highest nitrogen, phosphorus and potassium uptake was observed in rice variety SKL-3-1-41-8-33-15 as compare to Sakoli-6. Similar result were noted by Shende *et al*. (2019) [13] and Pawar (2017) [12].

The total uptake by rice was influenced significantly due to the different levels of fertilizers, the total uptake of nitrogen, phosphorus and potassium was recorded when fertilized with125% RDF fallowed by the application of 75% RDF in the descending order of significance, while application of 125% RDF was statistically at par with application 100% RDF. Similar results were recorded by Murthy *et al*. (2015) [10] and Shende *et al*. (2019) [13].

The mean nitrogen, phosphorus and potassium uptake in grain, straw and total uptake of rice did not find to be significant due to the different type of spacing.

Table 4: Effect of different treatments on available nitrogen, phosphorus and potassium in soil after harvest of rice

Treatments	Available nutrient (kg ha^{-1})		
	Available N	Available P	Available K
A] Main plot			
1] Varieties			
V_1- SKL-3-1-41-8-33-15	206.44	22.44	262.78
V_2- Sakoli-6	194.67	20.44	247.94
S.E (m) ±	1.94	0.25	2.42
C.D at 5%	11.78	1.49	14.74
2] Spacing			
S_1- 20 × 20 cm	201.61	21.89	258.28
S_2- 20 × 15 cm	199.5	21	252.44
S.E (m) ±	1.94	0.25	2.42
C.D at 5%	NS	NS	NS
B} Sub plot			
3] Fertilizer levels			
F_1 – 75% RDF (75:37:37 kg ha^{-1})	189.92	18.17	245
F_2 - 100% RDF (100:50:50 kg ha^{-1})	201.42	22.08	256.42
F_3 – 125% RDF (125:63:63 kg ha^{-1})	210.33	24.08	264.67
S.E (m) ±	2.73	0.52	3.45
C.D at 5%	8.07	1.54	10.17

Available nitrogen, phosphorus and potassium values in the soil after harvest of the rice were significantly higher in variety SKL-3-1-41-8-33-15 (V_1), than Sakoli-6. Similar results were recorded by Kumar *et al*. (2017) [6] and Shende *et al*. (2019) [13].

The available nitrogen, phosphorous and potassium in the soil after harvest of the crop were found to be non-significant due to the different types of spacing during the years of field experimentation. However, numerically higher available nitrogen, phosphorous and potassium values were recorded in 20 x 20 cm than 20 x 15 cm.

The higher available nitrogen, phosphorous and potassium in the soil after harvest of the rice were observed by application of 125% RDF over application of 100 and 75% RDF. While application of 125% RDF was statistically at par with application 100% RDF in respect of potassium availability in soil. Similar results were confirmed by Pawar (2017) [12], Kumar *et al*. (2017) [6] and Shende *et al*. (2019) [13].

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