Environment and Ecology 37 (1A) : 274—280, January—March 2019
Website: environmentandecology.com ISSN 0970-0420

Quality Seed Production of Rice (*Oryza sativa* L.) as Influenced by Nutrient Management During *Kharif* Season in the Lower Indo-Gangetic Plains

Ramyajit Mondal, Saumi Goswami, Sanjib Kumar Mandi, S. B. Goswami

Received 23 August 2018 ; Accepted 28 September 2018 ; Published on 19 October 2018

Abstract A field experiment was undertaken to study the effect of integrated nutrient management on crop growth, yield and seed quality of rice cv Shatabdi during *kharif* season of 2017. The experiment was conducted with eight different nutrient management practices i.e. T_1–Control, T_2–N_{60}, T_3–$N_{60}P_{30}$, T_4–$N_{60}P_{30}K_{30}$ (RDF), T_5–$N_{80}P_{40}K_{40}$, T_6–$N_{60}P_{30}K_{30}$ + $ZnSO_4$ @ 25, T_7–75% RDF + 25% MC and T_8–50% MC + 50% VC, respectively in randomized block design comprising of 3 replications. The result of experiment revealed that rice plot fertilized with the combination of NPK @ 60 : 30 : 30 + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest seed yield of 3.96 t ha^{-1} which was 6.73% more yield (3.71 t ha^{-1}) than the treatment $N_{80}P_{40}K_{40}$. Organic substitution by mustard cake (MC) and vermicompost (VC) had failed to register the significant impact on seed yield but the quality of rice seed was improved in terms of germination percentage, root length, shoot length of germinated seeds, seedling vigor index when crop was fertilized with the combined application of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1}.

Keywords Rice seed production, Integrated nutrient management, Seed quality parameters.

Ramyajit Mondal[1], Saumi Goswami[1],
Sanjib Kumar Mandi[2], S. B. Goswami[3]*
[1]PhD Scholar, [2]Subject Matter Specialist, [3]Professor
[1, 3]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741252, West Bengal, India
[2]Krishi Vigyan Kendra, Gajapati, Odisha 761016, India
[1]e-mail: ramyajitmondal93@gmail.com
[3]e-mail: sbg_bckv05@rediffmail.com
*Corresponding author

Introduction

Rice (*Oryza sativa* L.) is a principal source of food for more than half of the world's population and also is an important cereal crop next to wheat which accounts for the major dietary energy requirement of Asian rural people as more than 90% of rice is grown and consumed in Asia. It is primarily a high energy or high caloric food containing around 78.2% carbohydrate, 6.8% protein and 0.6% mineral matter. India ranks first in the world rice area but stand second position in relation to world production next to China, occupying an area of 43.39 m ha with an average production of 104.32 mt with productivity 2.40 t ha^{-1} of the country. The demand for rice continues to increase owing to continued growth of population. It is predicted that a 50—60% increase in rice production will be required to meet demand from population growth by 2025. India needs to produce 281 MT of food grains by 2020 to meet the food demand of 1.3 billion populations with an annual growth target of 2%. Among the rice producing states, West Bengal ranks first position with the acreage of 5.80 m ha with the largest production to the tune of 15.5 mt among the states in country achieving the productivity of 2.79 t ha^{-1}. Inorganic fertilizer is one of the key factors to increase the rice productivity. It is high time to search for innovative practices, which can guarantee higher yields with minimal deterioration of natural resources. Integrated nutrient management has been shown to considerably improve rice yields by minimizing nutrient losses to the environment and managing the nutrient supply and thereby results in high nutrient use efficiency (Parkinson 2013). The nutrients, their sources, method and time of application form an important component of fertilizer management strategies. In addition to N, P and K, it also supplies considerable amount of secondary and micronutrients and causes the improved growth and high yield of various crops. Besides major nutrients, Zn is the most important micronutrients particularly in our country because most of Indian soil is deficient. Zinc is directly or indirectly required by the several enzymic systems and closely involved in the nitrogen metabolism of plant. Zinc application through soil or foliar sprays and dipping of rice seedlings in ZnO (Jat et al. 2011) has been found to ameliorate Zn deficiency. Studies on Zn fertilizer proved that the application of Zn greatly influences growth, yield and quality of rice (Patnaik et al. 2011).

The quality and quantity of seed depend upon different factors include soil, climate and performance of agricultural operations during the growth of the mother plant from planting to harvest. Healthy seeds mean healthy seedlings that finally lead to better production. Seed is the most important input in any crop production and without healthy and quality seeds ; all expenditure incurred on other inputs is wasted. Good quality of seed is also one of the important means to increase productivity in any crop (Lamo et al. 2012). Seed vigor and germination ability directly affect yield and seed quality also affect seedling emergence. The germination, viability and vigor are considered as the most important quality characteristics of the seed and also. In case of availability of nutrient and plant uptake integrated nutrient management through use of inorganic fertilizers along with organic sources are applied to soil for increasing the status of plant available nutrients and improving the physico-chemical and biological properties of soil which directly affect soil fertility (Sannathimmappa et al. 2015). In contrast to nutrients in organic fertilizers, this required microbial metabolism to make most of them available to plants. So, inorganic fertilizers can directly affect crop growth and yields. Organic and inorganic fertilizer amendments are used primarily to increase nutrient availability to plants, but they can also affect soil microorganisms. The present experiment was carried out to study the yield performances and quality of seed of localily dominant rice variety under different combination of nutrient management in Lower Indo-Gangetic Plains of West Bengal.

Materials and Methods

Field experient was conducted at the Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal to study the effect of nutrient management on crop growth, yield and quality of seed in rice during *kharif* season of 2017. The experimental site falls under sub-tropical sub-humid climate. The average rainfall is 1450 mm, 75% of which is received during June to September. The temperature begins to rise from end of February reaching towards April-May.The relative humidity remains high during June to October. During the crop growth period maximum temperature ranged between 28.03°C to 33.67°C and minimum temperature varied between 19.34 to 24.04°C. The maximum relative humidity varied from 95 to 98.0% and minimum relative humidity varied from 50.0 to 92.0%. The total rainfall during the crop growing period was recorded 122.4 mm. The texture of the experimental soil was sandy clay loam and belongs to the order inceptisol with medium fertility and almost neutral in soil reaction. The experiment was conducted on a medium land, well-drained Gangetic alluvial soil. The experiment was laid down in randomized block design with 3 replications comprising of 8 levels of nutrient (kg ha^{-1}) viz. T_1–Control ($N_0P_0K_0$), T_2–N_{60}, T_3–$N_{60}P_{30}$, T_4–$N_{60}P_{30}K_{30}$ (RDF), T_5–$N_{80}P_{40}K_{40}$, T_6–$N_{60}P_{30}K_{30}$+ $ZnSO_4$ @ 25, T_7–75% RDF + 25% MC and T_8–50% MC + 50% VC, respectively. The size of individual plot was 6 m × 5 m. The rice seedlings were uprooted from the nursery bed and transplanted on 7th July, 2017 in main field with a row spacing of 20 cm × 20 cm with 2 seedlings per hill without damaging the seedlings. Depth of transplanting was 2–3 cm with 16.5 cm puddling depth and 33% puddling index. The treatment wise fertilizer dose were applied. It was applied in 2 splits application of which half at land preparation and rest half of the total nitrogen and full dose of phosphorus and potassium were applied through urea, SSP and MOP and the treatments of T_7 and T_8, 25% and 100% nitrogen applied through organic sources like mustard cake and vermicompost. Twenty days after transplanting (DAT) 1st top dressing was done. The crop was harvested on 24th October, 2017. Then weight of dried grains and straw of each plot were recorded. Seed quality parameters were assessed in the seed science laboratory following

Table 1. Effect of integrated nutrient management on growth parameters of rice grown during *kharif* season. MC–Mustard cake, VC–Vermicompost ; Root sampling was done at DAT.

Treatments	Growth parameters: Plant height (cm)	Tiller $hill^{-1}$ (60 DAT)	Dry matter production at harvest ($g\ m^{-2}$)	Days to 100% flowering	Root dry weight ($g\ hill^{-1}$)	Root volume (cc $hill^{-1}$)	Root length density (cm cm^{-3})
T_1–Control	96.7	5.2	386.0	61	3.96	19.5	1.66
T_2–N_{60}	97.1	5.9	447.5	60	4.27	20.7	1.75
T_3–$N_{60}P_{30}$	101.2	8.1	597.7	57	5.00	23.9	2.12
T_4–$N_{60}P_{30}K_{30}$	106.7	9.0	649.5	54	5.07	24.4	2.14
T_5–$N_{80}P_{40}K_{40}$	111.8	9.4	731.2	54	5.73	26.4	2.25
T_6–$N_{60}P_{30}K_{30}$+Zn_{25}	109.4	10.8	671.8	53	5.39	25.8	2.17
T_7–75% RDF+25% (MC)	103.4	7.7	582.5	56	4.82	22.4	2.06
T_8–50% (MC) + 50% (VC)	105.5	7.1	584.6	59	4.45	21.7	2.01
SEm (±)	0.69	0.12	4.79	0.39	0.07	0.37	0.03
CD (p = 0.05)	2.11	0.36	14.67	1.18	0.20	1.13	0.07

standard methods and soil available nutrient and plant uptake also determine in soil testing laboratory. Statistical analysis was done for determining the standard error of mean (SEm±) and the value of CD (Critical difference) at 5% level of significance using standard methodology.

Results and Discussion

Crop growth and yield

The crop growth in terms of plant height of rice cultivated with different nutrient management practices was found significant and the variation in plant height among the treatment ranged from 34.32 to 15.60% at different growth stages (Table 1). Among the different nutrient management schedules, NPK @ 80:40:40 kg ha^{-1} recorded the tallest plant height (111.8 cm) followed by the dose of NPK @ 60.30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (109.4 cm). The increase in plant height with increasing nitrogen might be attributed to the effect of nitrogen fertilizer which encourage and improve plant growth and accelerate cell division which reflected the increase in plant height (Mohadesi

Table 2. Effect of integrated nutrient management on yield attributes and seed yield of rice grown during *kharif* season.

Treatments	Yield attributes and seed yield: Panicle m^{-2}	Panicle weight (g)	Filled grains $panicle^{-1}$	Chaffs (%)	1000-seed weight (g)	Seed yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index
T_1–Control	195	2.74	71.23	45.93	18.8	2.04	4.91	0.29
T_2–N_{60}	224	3.19	79.97	43.61	19.2	2.58	5.43	0.32
T_3–$N_{60}P_{30}$	248	3.20	101.17	34.29	19.5	3.08	5.78	0.35
T_4–$N_{60}P_{30}K_{30}$	278	3.36	107.57	33.32	19.8	3.22	5.53	0.37
T_5–$N_{80}P_{40}K_{40}$	311	3.77	114.93	29.35	19.9	3.71	5.94	0.38
T_6–$N_{60}P_{30}K_{30}$+ Zn_{25}	320	4.09	118.87	27.47	20.2	3.96	5.41	0.42
T_7–75% RDF+25% (MC)	255	3.32	99.00	38.10	19.5	2.64	5.51	0.32
T_8–50% (MC)+50% (VC)	234	3.50	97.71	39.04	19.1	2.30	5.06	0.31
SEm (±)	2.55	0.21	4.17	2.02	0.01	0.26	0.47	0.01
CD (p = 0.05)	7.81	0.64	12.78	6.20	0.07	0.79	1.42	0.04

Table 3. Effect of integrated nutrient management on seed quality and plant nutrient uptake of rice grown during *kharif* season.

Treatments	Seed quality					Plant nutrient uptake		
	Germination (%)	Root length (cm)	Shoot length (cm)	Seedlings dry wt (mg)	Seedling vigor index	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1–Control	76.67	9.43	4.16	6.62	1038	52.26	8.02	80.25
T_2–N_{60}	86.67	9.57	5.63	7.72	1318	62.31	8.84	94.31
T_3–$N_{60}P_{30}$	88.33	11.10	5.64	8.61	1479	84.06	12.11	131.01
T_4–$N_{60}P_{30}K_{30}$	90.00	10.18	5.18	8.16	1382	89.94	12.59	152.83
T_5–N80$P_{40}K_{40}$	95.33	12.65	7.62	9.48	1929	108.06	14.04	172.86
T_6–$N_{60}P_{30}K_{30}$+Zn_{25}	91.33	14.05	7.90	9.90	2004	93.02	12.74	149.10
T_7–75% RDF+25% (MC)	83.33	13.41	7.50	9.55	1751	80.08	11.31	128.74
T_8–50% (MC)+50% (VC)	86.67	12.77	6.94	9.50	1694	70.06	9.75	108.51
SEm (±)	2.62	0.87	0.21	0.14	25.22	0.67	0.04	1.63
CD (p = 0.05)	8.05	2.65	0.61	0.41	77.24	2.06	0.12	4.99

et al. 2011). The tiller number of transplanted *kharif* rice at 30, 45 and 60 DAT growth stages varied significantly (Table 1) with variation of different nutrient management practices. At 60 DAT, the maximum tiller number $hill^{-1}$ (10.8) was obtained in the plot fertilized with combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} followed by the higher dose of NPK @ 80:40:40 kg ha^{-1} (9.4 $hill^{-1}$). The lowest tiller number $hill^{-1}$ (5.20) was noticed under the treatment T_1 (control). Similar observation of tiller increase with the zinc fertilization in rice was reported by Jat et al. (2011). Crop growth in terms of the dry matter production of transplanted *kharif* rice at 30 and 60 DAT and harvest was significantly influenced by nutrient management treatments (Table 1). At 30, 60 DAT and harvesting stage, the application of higher dose of NPK @ 80:40:40 kg ha^{-1} recorded the highest dry matter production with a value of 167.4 g m^{-2}, 445.60 g m^{-2} and 731.23 g m^{-2}. Corroborated with the findings of Choudhary and Pandey (2009) in which observed that increasing level of N up to 120 kg ha^{-1} increased the growth components like plant height, tillers m^{-2} and dry matter production. The requirement of days after transplanting to 1st flowering, 50% flowering and 100% flowering of rice with different nutrient management varied from 44 to 51 days (Table 1). Earliest first flowering, 50% flowering and 100% flowering was observed in the plot fertilized with the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1}. A considerable effect of varying fertilizer treatments was noted in the root growth (Table 1) and at 60 DAT the root dry weight of the crop was found to vary between 3.96 to 5.73 g $hill^{-1}$ with the variation of 44.69%. Amongst all treatments, the application of higher dose of NPK @ 80:40:40 kg ha^{-1} recorded higher value of root dry mass (5.73 g $hill^{-1}$) and the least value of root dry matter accumulation was recorded by the control treatment. The fresh root volume of the rice crop was found to vary from 19.5 to 26.4 cc $hill^{-1}$ with the variation of 35.38%. The higher dose of NPK @ 80:40:40 recorded maximum root volume of 26.4 cc $hill^{-1}$. The combined use of NPK @ 60.30:30 +$ZnSO_4$ @ 25 kg ha^{-1} was found statistically at per with the treatment NPK @ 80:40:40 kg ha^{-1}. Similar observation was noted in the root length density (RLD) at 60 DAT with the variation of 1.66 to 2.25 cm cm^{-3} with the increase of 35.54% over control. In the experiment, the higher dose of NPK @ 80:40:40 kg ha^{-1} applications gave the highest RLD value of 2.25 cm cm^{-3} and the least value was recorded by control treatment where no fertilizer was added.

The yield component of rice in terms of panicle per square meter area was found statistically significant as influenced by nutrient management practices (Table 2). It has been observed that the panicles m^{-2} was to tune of 195 to 320 with a variation of 64.10%. Among the treatments the rice plot fertilized with the combination of NPK and zinc i.e. NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest number of panicles m^{-2} (320 m^{-2}) followed by fertilizer dose of NPK @ 80:40:40 kg ha^{-1} (311 m^{-2}). Panicle length of rice was also influenced by significantly different with nutrient management practices. However, the average panicle weight of rice increased from 2.74 to 4.09 g with diversified nutrient management with increment of 49.27% over control. The rice plot fertilized with the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest panicle weight of 4.09 g which was statistically at par to the higher dose of NPK @ 80 : 40 : 40 kg ha^{-1} (3.77 g). The improvement in panicle length and panicle weight due to the application of fertilizer and zinc might be attributed to physiological stimulation for increasing the panicle length (Saha et al. 2013). Filled grain $panicle^{-1}$ of transplanted *kharif* rice was significantly influenced by nutrient management practices. However, the number of filled grains $panicle^{-1}$ varied from 71 to 119 and the variation was recorded at 67.60%. The highest number of filled grain $panicle^{-1}$ (119) in the rice was achieved in plot fertilized with the combination of NPK @ 60:30 : 30 + $ZnSO_4$ @ 25 kg ha^{-1} which was significantly superior to all the other treatment of rice followed by treatment plot fertilized with NPK @ 80:40:40 kg ha^{-1} (115) and the least number (71) of filled grain $panicle^{-1}$ was recorded in the control plot. The application of zinc significantly increased the plant height, number of productive tillers, filled grains per panicle, panicle length and 1000 grain weight as compared to NPK fertilization alone (Sudha and Stalin 2015). It had been observed that grain filling in terms of percentage of chaffy grains varied significantly among different nutrient management practices. Chaff percentage of rice varied from 27.47 to 45.93% and the variation was recorded to the tune of 67.20%. The control plot where no fertilizer was added showed the highest value of chaffiness (45.93%) followed by the treatment N @ 60 kg ha^{-1} (43.61%). Combined application of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} was recorded the lowest percentage of chaffiness (27.47%). Among all the treatment, control plot recorded the highest percentage of chaffy grains due to less nutrient supplied from source to sink. The plumpness or boldness of seed in terms of test weight (1000 grain weight) of rice grown under diversified nutrient management was found significant. However, the test weight of rice varied from 18.8 to 20.2 g with variation 7.4%. The combine application of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest test weight (20.2 g) followed by the higher dose of NPK @ 80:40:40 kg ha^{-1}. The control plot recorded the lowest test weight (18.8 g).

The land productivity in terms of seed yield of *kharif* rice from foundation to certified class, transplanted on 30th Meteorological Week (27 July, 2017) was significantly influenced by the nutrient management practices in the new alluvial soils of Lower Indo-Gangetic Plains of West Bengal (Table 2). Differential fertility gradient created in *kharif* rice by the application of fertilizer had resulted significant seed yield variation of rice cv IET4786 (Shatabdi) ranging from 2.04 to 3.96 t ha^{-1} and the yield increase was to tune of 12.74 to 94.11% over the control. In the experiment, rice plot fertilized with the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest seed yield (3.96 t ha^{-1}) followed by the dose of NPK @ 80:40:40 kg ha^{-1} (3.71 t ha^{-1}) and the lowest seed yield (2.04 t ha^{-1}) was recorded in the control plot having no NPK fertilizer. Similar results of zinc application has been reported by Farooq et al. (2018) where rice seed yield of both direct seeded rice and transplanted rice has been increased by 30% over the control. The straw yield of *kharif* rice varied significantly with variation of nutrient management practices. The straw yield of rice significantly increased from 4.91 to 5.94 t ha^{-1} and the variation was recorded by 20.97%. Among the treatments, the rice plot fertilized with higher dose of NPK @ 80:40:40 kg ha^{-1} recorded the maximum straw yield of 5.94 t ha^{-1} followed by NP @ 60:30 kg ha^{-1} (5.78 t ha^{-1}) and the lowest straw yield of 4.91 t ha^{-1} was recorded in the control plot where no fertilizer was given. The harvest index of *kharif* rice was found statistically significant with nutrient management practices. The harvest index of rice increased from 0.29 to 0.42 and the increment was noted up to 44.82%. Among the different treatment, the rice plot fertilized with the combination of NPK @ 60:30:30 +$ZnSO_4$ @ 25 kg ha^{-1} recorded the highest harvest index of 0.42 followed by the higher dose of NPK @ 80:40:40 kg ha^{-1} (0.38). The lowest harvest index of 0.29 was recorded in the plot where no fertilizer was added. The higher value of harvest index of combined use of NPK and zinc was attributed to the more economic yield. On the other hand, crop in the control plot recorded the lowest value of harvest index owing to the poor economic yield.

Seed quality

Seed quality parameter like germination percentage which is an estimate of the viability of a population of seeds, was found statistically significant with the nutrient management practices (Table 3). It has been observed that germination percentage of rice seed increased significantly with the increase of nutrient levels of rice grown during *kharif* season and variation was from 76.67 to 95.33% over the control and increment was to the tune of 24.33%. Seed germination count was escalated with the higher dose of NPK @ 80:40:40 kg ha^{-1} (95.33%) followed by the plot fertilized with combined application of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (91.33%). The lowest value of seed germination percentage (76.67%) was noted in the seed from control plot where no fertilizer was added. The root length study of sprouted rice seeds was carried out in germination chamber. It has been observed that root length of seedlings varied significantly with 8 diversified nutrient management (Table 3). However, the root length of seedlings of rice improved from 9.43 to 14.05 cm over control and the increment was to the tune of 48.99%. Root length was maximum (14.05 cm) in the rice seeds fertilized with the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} followed by treatment 75% RDF + 25% vermicompost (13.41 cm) and the shortest root length recorded in the control plot (9.43 cm). The study of shoot length of sprouted rice seeds was carried out in germination chamber. It has been observed that shoot length of rice seedlings varied significantly among themselves with diversified nutrient management. However, the shoot length of rice seedlings improved from 4.16 to 7.90 cm over control and the increment was to the tune of 89.90%. Shoot length was maximum (13.58 cm) in the rice seed fertilized with the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} followed by the plot fertilized with higher dose of NPK @ 80:40:40 kg ha^{-1} (7.62 cm). The shortest shoot length recorded in the control plot. The seedling dry weight of sprouted rice seed was found statistically significant with different nutrient management practices. However, the seedling dry weight of rice seedling improved from 6.62 to 9.90 mg over control and the increment was to be tune of 49.54%. Seedling dry weight was maximum (9.90 mg) in the rice seed fertilized with the combination NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} followed by the seed fertilized with 75% RDF + 25% vermicompost (9.55 mg). The lowest seedling dry weight was recorded in the control plot (6.62 mg). The concentration of Zn in seed had clear effects on seedling growth as measured with the dry weight of roots and coleoptile. There was a progressive increase in seedling weight with increasing seed Zn. High concentration of seed Zn also promoted roots and shoot growth during the first few days of germination, although this effect disappeared later (Boonchuay et al. 2013). Seed vigor is an important quality parameter which needs to be assessed to supplement germination and viability tests to gain insight into the performance of a seed lot in the field or in storage. The seedlings vigor index of rice seed varied significantly with different nutrient management practices. However, the vigor index of rice seedling increased from 2004 to 1038 over control and the increment was to the tune of 93.06%. Seedlings vigor index was maximum (2004) in the rice seed fertilized with the combination of NPK @ 60:30:30 +$ZnSO_4$ @ 25 kg ha^{-1} followed by the higher dose of NPK @ 80:40:40 kg ha^{-1} (1929). The lowest seedlings vigor index recorded in the control plot (1038).

Nutrient uptake

Total nutrient uptake by rice crop was varied significantly with different nutrient management practices (Table 3). The N, P and K uptake was varied from 52.26 to 108.06 kg ha^{-1} with the increment of 106.77%, 8.02 to 14.04 kg ha^{-1} with the variation of 75.06% and 80.25 to 172.86 kg ha^{-1} with the variation of 115.40% respectively during *kharif* season. Rice crop nutrient uptake of N, P and K in different treatment combinations was more than control one. Maximum N, P and K uptake of nutrients was observed in the plot fertilized with higher dose of NPK @ 80:40:40 kg ha^{-1}. The highest N uptake was 108.06 kg ha^{-1} in the NPK @ 80:40:40 kg ha^{-1} followed by the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (93.02 kg ha^{-1}) and the lowest nitrogen uptake (52.26 kg ha^{-1}) was recorded in the control plot, where no fertilizer were added. In the treatments of organic substitution by mustard cake and vermicompost by 100% of RDF (T_8) recorded small amount of nitrogen uptake (70.06 kg ha^{-1}) because of slow decomposition of organic matter. The highest P uptake was 14.04 kg ha^{-1} in the plot fertilized with NPK @ 80:40:40 kg ha^{-1} followed by combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (12.74 kg ha^{-1}) and the lowest P uptake was recorded in the control plot (8.02 kg ha^{-1}) where no fertilizer were added. In case of K uptake, the higher dose of NPK @ 80:40:40 kg ha^{-1} recorded highest uptake (172.86 kg ha^{-1}) followed by the NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (149.10 kg ha^{-1}) and the lowest K uptake recorded in the control plot where no fertilizer were added. In case of N, P and K uptake treatment recommended dose of NPK 60:30:30 kg ha^{-1} was not improved but statistically at par with NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1}.

Seed production economics

The cost of cultivation varied with the fertilizer management. The highest gross return, net return and benefit cost ratio recorded in the plot fertilized was the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1}. In terms of expenditure incurred for cultivation, the highest cost of cultivation was recorded in the plot 50% mustard cake + 50% vermicompost because to substitute the recommended dose of fertilizer through organic nutrition and the high cost of mustard cake increase the cost of cultivation also recorded less seed yield also reduce the benefit cost ratio. The highest gross return earned in NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (Rs 1,24,210 per ha) followed by higher dose of NPK @ 80:40:40 kg ha^{-1} (Rs 1,17,240 per ha) and lowest gross return was observed in organic treatment 50% mustard cake + 50% vermicompost. In case of benefit cost ratio, the highest B : C was obtained in the NPK @ 60.30:30 + $ZnSO_4$ @ 25 kg ha^{-1} (2.60) followed by the treatment NPK @ 80:40:40 kg ha^{-1} (2.54) and the lowest B : C was obtained in the plot fertilized with organic nutrition i.e. 50% mustard cake + 50% vermicompost.

Conclusion

The integrated nutrient management had significant effect on the growth, yield component, seed yield and seed quality of rice in *kharif* season. The crop fertilized with the combination of NPK @ 60:30:30 + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest seed yield of 3.96 t ha^{-1} followed by dose of NPK @ 80:40:40 kg ha^{-1} (3.71 t ha^{-1}). Organic substitution by mustard cake (MC) and vermicompost (VC) had failed to register the significant impact on seed yield but the quality of rice seed was improved in terms of germination percentage, root length, shoot length of germinated seeds, seedling vigor index of multiplication of rice seed of siperior quality can be done with the combined application of NPK @ 60:30:30 +$ZnSO_4$ @ 25 kg ha^{-1}.

References

Boonchuay P, Cakmak I, Rerkasem B, Prom-U-Thai C (2013) Effect of different foliar zinc application at different growth stages on seed zinc concentration and its impact on seedling vigor in rice. Soil Sci Pl Nutr 59 (2) : 180—188.

Choudhary SK, Pandey DN (2009) Response of rice genotypes to levels of nitrogen in lowland. *Oryza*-An Int J Rice 46 (1) : 42—44.

Farooq M, Ullah A, Rehman A, Nawaz A, Nadeem A, Wakeel A, Siddique KH (2018) Application of zinc improves the productivity and bio-fortification of fine grain aromatic rice grown in dry seeded and puddled transplanted production systems. Field Crops Res 216 : 53—62.

Jat SL, Shivay YS, Parihar CM (2011) Dual purpose summer legumes and zinc fertilization for improving productivity and zinc utilization in aromatic hybrid rice (*Oryza sativa*). Ind J Agron 56 (4) : 328—333.

Lamo KB, Korla N, Ahukla YR (2012) Effect of different organic and inorganic nutrient sources on seed production of radish *(Raphanus sativus* cv Chinese pink). Leaf Sci Leaflets 2 : 38—44.

Mohadesi A, Abbasian A, Bakhshipour S, Aminpanah H (2011) Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high yield rice. Am Eur : J Agric Environ 10 : 893—900.

Parkinson R (2013) System based integrated nutrient management. Soil Use Manage 29 (4) : 608.

Patnaik MC, Raju AS, Raj GB (2011) Zinc requirement of hybrid rice-bhendi and its influence on zinc fractions in an Alfisol of Hyderabad, Andhra Pradesh. J Ind Soc Soil Sci 59 (4) : 368—375.

Saha B, Saha S, Roy PD, Hazra GC, Das A (2014) Zinc fertilization effects on agro morphological and quality parameters of commonly grown rice. SAARC J Agric 11 (1) : 105—120.

Sannathimmappa HG, Gurumurthy BR, Jayadeva HM, Rajanna D, Shivanna MB (2015) Effect of paddy straw based integrated nutrient management practices for sustainable production of rice. IOSR J Agric Vet Sci 8 : 74—77.

Sudha S, Stalin P (2015) Effect of zinc on yield, quality and grain zinc content of rice genotypes. Int J Farm Sci 5 (3) : 17—27.