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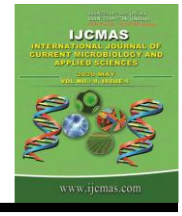

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Effect of Fertilization Modules on the Growth and Yield of Rice (*Oryza sativa* L.) in *Tarai* Region of Uttarakhand, India

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A B S T R A C T

Field experiment was conducted to evaluate effect of planting methods and fertilization modules on the growth and yield of rice (*Oryza sativa* L.) in *tarai* region of Uttarakhand at the Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, during the *Kharif* season of 2010-11. The experiment was laid out in randomized block design with four replications and comprising five treatments *i.e.* T_1- conventional method of transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_2-conventional method of transplanting with 180 kg N+Sesbania green manuring and recommended phosphorus, potassium and 0.5% $ZnSO_4$, T_3-conventional method of transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_4-direct rice seeding with recommended dose of NPK and 0.5% $ZnSO_4$ and T_5-direct rice seeding with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$.The analysis of data indicated that values of growth attributes like plant height, number of shoots /m^2 and dry matter accumulation (g/m^2) was maximum due to T_2-conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring followed by T_3-Conventional method of transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$.Whereas, the highest straw yield (67.25 q/ha), biological yield (129.54 q/ha) and grain yield (62.39 q/ha) was due to T_2-conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring followed by T_3-Conventional method of transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$ compared with other treatments. The results showed that green manuring with NPK+Zn had direct beneficial effect of growth and yield of rice.

Keywords

Tarai region, Fertilization, Growth and yield, Rice

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Introduction

Indian agriculture is now facing many problems like raising or lowering of water table, nutrient imbalance, soil degradation, salinity, resurgence of pests and diseases, environmental pollution and decline in farm profit (Pacharne, 2017). Rice is dietary and protein currency of Indian population and supplies 31% of total calories required. Rice is cultivated world-wide over an area of about 160.68 million ha with an annual production of about 650.19 million tonnes (Tomar, 2018). In India, rice occupies an area of 43.79 million ha with a production of 112.91 million tonnes with average productivity of 2578 kg/ha (Agricultural Statistics, 2018).Demand for rice growing is increasing every year and it is estimated that requirement would be 140 million tonnes by 2025 (Kumar, 2017).India has the largest area among rice growing countries and it stands second in production next to China. Rice is grown under 4 major ecosystems: irrigated, rainfed lowland, rainfed upland and flood prone. More than half of rice area (55%) is rainfed and distribution wise 80% of rainfed rice area is in eastern India, making its cultivation vulnerable to vagaries of monsoon. Continuous puddling for rice cultivation over decades has led to deterioration of soil physical properties through structural breakdown of soil aggregates and capillary pores and clay dispersion, thereby restricting germination and rooting of succeeding crops. Added to this, limited or no use of organic manures/crop residue (Ghosh *et al*., 2016) and imbalanced use of mineral fertilizers (Brar *et al*., 2013) have further soil quality deterioration. Transplanting of rice seedling being a labour-intensive and expensive operation, it need to be substituted by direct seeding which could reduce labour need by more than 20% in terms of working hour. Many Asian countries are now increasingly shifting to direct wet-seeded method of growing rice. However, the practice of direct wet seeding rice is very negligible in India. In India direct seeded rice production has been achieved about 2-12% higher grain yield than transplanting (Husain *et al*., 2003).

Materials and Methods

The experiment was conducted during *Kharif* season of 2010-11 at N. E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India. The N. E. Borlaug Crop Research Centre is situated in the *Tarai* belt of Shivalik range of Himalayas with humid sub-tropical type of climate at latitude of 29°N and longitude of 79.3°E and situated at an altitude of 243.84 m above the mean sea level. The soil of experimental site was silty clay loam with neutral reaction (7.60 pH). The nutritional status of soil was rich in organic carbon (1.23 %), available nitrogen (246.00 kg/ha), available phosphorus (32 kg/ha) and available potassium (143 kg/ha) obtained by following Walkley and Black (1934), Subbiah and Asija (1956), Olsen *et al*., (1954) and Hanway and Heidel (1952). The experiment was laid out in randomized block design with four replications and comprising five treatments *i.e.* T_1- Conventional method of transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_2-Conventional method of transplanting with 180 kg N+Sesbania green manuring and recommended phosphorus, potassium and 0.5% $ZnSO_4$, T_3-Conventional method of transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_4-Direct rice seeding with recommended dose of NPK and 0.5% $ZnSO_4$ and T_5-Direct rice seeding with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$. For conventional transplanting treatments, nitrogen (150, 165 and 180 kg N/ha), phosphorus (60 kg P_2O_5/ha) and potassium (40 kg K_2O/ha) were supplied through urea, single superphosphate, and muriate of potash, respectively. Half of the nitrogen and total quantities of phosphorus and potash were applied prior to transplanting on drained puddled surface. The remained quantity of half nitrogen was top dressed in two equal splits one at active tillering followed by 5-7 days before panicle initiation stage. For direct rice seeding, mixed fertilizer NPK (12:32:16) was used @ 200 kg/ha with seed drill as basal. In addition, remaining potash was used through MOP as basal broadcast and remaining N was top dressed in two equal amounts through urea. The foliar 0.5% $ZnSO_4$ was sprayed 10 and 20 days after transplanting/seeding of rice. The certified seed of rice cultivar "PR 114" were treated with bavistin fungicide at 2.0 g/kg seed before sowing in the nursery. Seeds were soaked for 24 hrs and incubated in moist gunny bags for 2 days. Pre-germinated seeds were broadcast uniformly on nursery beds of 1 m width separated by channels of 30 cm width and 15 cm depth. Soil: farmyard manure mixture (1:1) was spread in a thin layer for covering the seeds. The beds were irrigated daily and thoroughly before lifting the seedlings. The nursery beds were irrigated a day before uprooting of seedlings so as to make the soil soft. Seedlings were uprooted one by one and the roots were washed to remove the mud. Seedlings were than transplanted in rows with the help of nylon rope at 20 cm × 10 cm. Two seedlings were transplanted per hill. The size of each net plot was 15 m^2 (5m×3m). In direct seeded rice treatment at proper tilth, one ploughing followed by two cross-harrowing and levelling was done to ensure proper germination. Harvesting of rice crop was undertaken for harvest at maturity stage with the help of sickle. Grain yield thus obtained from each net plot were converted to kg/ha. Biological yield was obtained by addition of grain and straw yields and was expressed in kg/ha. The harvest index (HI) was calculated by dividing economical yield (grain yield) by the biological yield (grain and straw) and represented in percentage (Donald and Hamblin, 1976). The experimental data were analyzed using analysis of variance technique appropriate to randomized block design with the help of computer software STPR 3 developed by the Department of Mathematics and Statistics, College of Basic Science and Humanities. The critical differences at 5% level of probability were calculated for testing the significance of difference between any two means wherever 'F' test was significant (Snedecor and Cochran, 1967).

Results and Discussion

Crop growth parameters

Plant height (cm)

The plants height of rice crop was significantly higher due to T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring than remaining treatments at 30 DAS. At 60 DAS, plant height was unaffected due to different treatments but tallest plant height was caused by T_2-conventional method of transplanting with 180 kg N+sesbania green manuring and recommended phosphorus, potassium and 0.5% $ZnSO_4$. Plant height was increased 5.83, 16.49, 19.51 and 5.14 by conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_1-conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_3-conventional method of transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$, respectively. At 90 DAS and maturity stage, plants height of rice crop was significantly higher due to T_2-conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring compared with T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$ and at par with remaining treatments. The higher plant height in conventionally puddled and transplanted crop with 180 kg N, recommended P, K and Zn and sesbania green manuring might be due to higher rate of N application which supported plant growth in terms of shoot height and decomposition of sesbania green manure made available regular available N due to mineralization to crop. In situ, sesbania green manuring on decomposition and subsequent mineralization provides 30-50 Kg N /ha (Table 1).

Number of shoots /m^2

Significantly higher number of shoots /m^2 was recorded due to T_5-direct seeded rice with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$ over remaining treatments except T_2-conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring and T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$ at 30 DAS. At 60 DAS, number of shoots /m^2 was significantly more due to T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) over T_1-conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) and T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$ but at par with remaining treatments. At 90 DAS and maturity stage, significantly higher number of shoots /m^2 was caused by T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring compared with T_1-conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) and statistically at par with remaining treatments.

Data revealed that combined application of Zn with NPK+green manuring crop increased the number of shoots /m^2. It might be owing to adequate and balance application of nutrients increases the availability and uptake of other essential nutrients resulted in increased metabolic activities. Similar trend was found in the findings of Umar *et al.*, (2004).

Dry matter accumulation (g/m^2)

Dry matter accumulation of plants were significantly higher due to T_5-direct seeded rice with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$ over remaining treatments, which was at par with T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$at 30 DAS. At 60 DAS and maturity stage, the significantly maximum dry matter accumulation of plants was caused by T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_1-conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) and T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$ but at par with remaining treatments. At 90 DAS, dry matter accumulation of plants were significantly higher due to T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) as compared with T_1-conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) and T_4-direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$. It might be due to integrated nutrient management provided the balance and sufficient nutrition to crop for growth and development, which caused in higher dry matter accumulation. Similar results were obtained by Singh and Khan (2000).

Yield attributes of rice

Number of panicles /m^2

Significantly maximum number of panicles/m^2 was recorded with T_2-conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_1-conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), which is statistically at par with T_3-

conventional transplanting with 10% extra RDF (165:66:44 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK+0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively. The possible reason for higher number of panicles /m^2 in conventional method of transplanting with 180:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$+Sesbania green manuring could be the organic manure, which help to increase the soil fertility through improvement in soil physical, chemical and biological characteristics and higher N availability which is essential for crop growth and development. These results corroborate with the finding of Singh and Brar (1994).

Panicle length (cm)

Panicle length was significantly higher with T_2- conventional method of transplanting with 180:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$+Sesbania green manuring over T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, which is statistically at par with T_1-conventional transplanting with RDF (150:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$), T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$) and T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$,respectively. The increased in panicle length was 4.59 and 8.26 per cent, respectively by T_2-conventional method of transplanting with 180:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$+Sesbania green manuring over T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$.

Number of grains / panicle

Number of grains/panicle was significantly more due to T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$) as compared to T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$, which was at par with remaining treatments. Number of grains/panicle was increased 12.23, 15.83 and 9.46 per cent by T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$) over T_1-conventional transplanting with RDF (150:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively. It might be owing to application of organic manures plus fertilizers increased yields parameters of rice crop (Ahmad *et al*., 1998).

Grain weight / panicle (g)

Significantly maximum grain weight/panicle was recorded with T_2- conventional method of transplanting with 180:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$+Sesbania green manuring over T_1-conventional transplanting with RDF (150:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively and statistically at par with T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$).

Grain weight/panicle was increased 19.36 and 15.60 per cent byT_2- conventional method of transplanting with 180:60:40 kg/ha N:P_2O_5:K_2O+0.5% $ZnSO_4$+Sesbania green manuring over T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively.

Thousand grain weight (g)

Maximum thousand grain weight was recorded with T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring, which is statistically at par with T_1- conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$),T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) and T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$,respectively. Significantly minimum thousand grain weight was recorded with T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$. It might be due to the availability of higher nitrogen for chlorophyll formation and Zn influences N uptake, protein quality and photosynthesis (Pandey *et al.*, 2002).

Biological yield (q/ha)

Biological yield was significantly higher due to T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_1- conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively and statistically at par with T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$). Biological yield was increased 7.64 and 6.22 per cent by T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_4- direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively. It might be due to the presence of available nutrients from both organic and inorganic sources. Sesbania fixed the atmospheric nitrogen & supply to crop. Hence, N helps to increase the total biomass of the crop.

Grain yield (q/ha)

Significantly higher grain yield was recorded with T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_1- conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively and statistically at par with T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$). Grain yield was increased 5.83 per cent by T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_4- direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$. The higher grain yield due to adequate and balance application of nutrients increases the availability and uptake of other essential nutrients resulted in positive effect of many yield components, like number of tillers, number of panicles and 1000 grain weight (Kausar *et al.*, 2001 and Rahman *et al.*, 2001).

Straw yield (q/ha)

Significantly higher straw yield was recorded with T_2- conventional method of transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$+Sesbania green manuring over T_1- conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$), T_4-direct seeded rice with recommended dose of NPK+ 0.5% $ZnSO_4$ and T_5-direct seeded rice with 10% extra recommended dose of NPK 0.5% $ZnSO_4$, respectively and statistically at par with T_3-conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$) (Table 2).

Table.1 Growth parameters of rice as influenced by different treatments at different stages

Treatments	Shoot height (cm)				Number of shoots /m				Dry matter accumulation (g/m^2)			
	30DAS	60DAS	90DAS	Maturity	30DAS	60DAS	90DAS	Maturity	30DAS	60DAS	90DAS	Maturity
T_1	32.04	71.08	87.08	81.10	200	282	223	220	38.0	140.0	262.8	814.7
T_2	37.28	75.40	96.40	90.70	234	317	258	257	40.5	152.0	310.4	1014.9
T_3	22.96	62.96	86.32	81.10	213	319	256	254	39.5	148.0	327.4	962.2
T_4	21.33	60.69	83.64	76.71	229	295	237	233	63.4	135.0	273.2	846.9
T_5	29.62	71.52	90.52	86.60	236	313	254	251	67.3	146.0	298.0	923.8
SEM ±	1.14	1.47	3.11	3.20	6.53	7.88	9.70	7.77	2.06	2.66	13.32	41.32
CD at 5%	3.43	4.41	9.39	9.60	19.57	23.98	29.09	23.31	6.19	8.00	39.95	123.87

T_1-Conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$)
T_2-Conventional transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$,+Sesbania as green manuring
T_3-Conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$)
T_4-Direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$
T_5-Direct seeded rice with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$

Table.2 Yield attributes and yield of rice as influenced by different treatments

Treatments	Number of panicles/m^2	Panicle length (cm)	Number of grains / panicle	Grain weight / panicle (g)	Thousand grain weight (g)	Biological yield (q/ha)	Grain yield (q/ha)	Straw yield (q/ha)
T_1	218	26.08	85.4	2.92	29.55	121.47	58.75	62.72
T_2	255	26.98	92.6	3.46	30.94	129.54	62.39	67.15
T_3	252	26.11	97.3	3.30	30.18	127.06	61.27	65.79
T_4	231	25.74	81.9	2.79	28.94	119.64	57.92	61.71
T_5	245	24.75	88.1	2.92	26.50	121.47	58.75	62.72
SEM ±	9.21	0.71	4.28	0.12	1.16	1.83	0.82	1.08
CD at 5%	27.61	2.14	12.85	0.37	3.49	5.59	2.47	3.02

T_1-Conventional transplanting with RDF (150:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$)
T_2-Conventional transplanting with 180:60:40 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$,+Sesbania as green manuring
T_3-Conventional transplanting with 10% extra RDF (165:66:44 kg/ha $N:P_2O_5:K_2O$+0.5% $ZnSO_4$)
T_4-Direct seeded rice with recommended dose of NPK and 0.5% $ZnSO_4$
T_5-Direct seeded rice with 10% extra recommended dose of NPK and 0.5% $ZnSO_4$

It might be due to the favorable effect of integrated nutrient management on the proliferation of roots and thereby increasing the uptake of plant nutrients from the soil and ultimately the vegetative growth of plants.

On the basis of the present investigation, it is concluded that 180 kg N/ha coupled with green manuring was reflected superior performance among all other treatments. But repeated tillage and puddling system conventionally over years of this treatment, deteriorating the soil structure and ultimately declining the productivity. So, sustainability still remains the issue with this treatment for the future. Though, direct seeded rice with recommended dose of fertilizer and 10% extra dose of fertilizer was inferior in many aspects but it certainly promises to better productivity of rice crop when the conditions are projected in the future. Moreover, it will helps for increase farm-level productivity, build soil rather than banish soil, conserve natural resources and limit negative environmental impacts which is essential for the sustainability of the system.

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