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Soil fertility status and productivity of rice as influenced by different crop establishment methods under puddled condition

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Abstract

To evaluate the effect of different rice establishment methods on soil fertility status and productivity of rice, a field experiment was conducted under puddled soil during kharif season in 2015 at BAU, Ranchi, Jharkhand. Experimental soil was clay loam, slightly acidic (pH 6.1), low in organic carbon (3.6 g/kg) and available nitrogen (200.7 kg/ha), high in phosphorus (33.54 kg/ha) and medium in potassium (187.04 kg/ha). Conventional transplanting (102.60 kg/ha) and drum seeding (99.07kg/ha) being similar in nitrogen uptake by rice biomass, had edge over broadcasting of sprouted and dry seeds. Conventional transplanting (17.49 P and 98.12 K kg/ha), drum seeding (17.12 P and 97.35 K kg/ha) and mechanical transplanting (15.63 P and 90.35 K kg/ha) were similar in phosphorus and potassium uptake, respectively by rice biomass. Conventional transplanting and drum seeding had edge over broadcasting of dry seeds (14.17Pand 82.31K kg/ha).Crop established with broadcasting of dry seeds mined more soil Nand P (-42.36 kg/ha N and -12.93 kg/haP), whereas, conventional transplanting had minimum N and P loss (-28.61 kg/ha and -11.28 kg/haP). Maximum potassium balance was found under conventionally transplanted (+59.42 kg/ha) followed by drum seeded (+58.84 kg/ha), mechanically transplanted rice (+53.18 kg/ha) and broadcasting of sprouted seeds (+48.81 kg/ha) and minimum by broadcasting of dry seeds (+46.81 kg/ha). Conventional transplanting (44.18 q /ha) produced 19 and 21% higher grain yield than broadcasting of sprouted (37.13 q/ ha) and dry seeds (36.50 q /ha), respectively and was similar to that of drum seeding (43.70 q/ ha) and mechanical transplanting (39.8 q/ha). Hence, for higher nutrient utilization, restoring of soil fertility and higher productivity establishment of rice through drum seeding can be a feasible alternative to transplanting methods.

Keywords: Rice, Conventional transplanting, Nutrient utilization, Phosphorus balance, soil fertility.

1. Introduction

Rice (*Oryza sativa* L.) is considered as a staple food in Indian diet. It is grown on large scale by the farmers of subcontinent to meet the expected demand of consumption as well as exportation. A total of 42 million hectare area of the country was under rice cultivation during 2015-16 resulting in 103.61 million tonnes grain production (Anonymous, 2016 a).However, a productivity gain of 2.57 t/ha was achieved during 2014-15 from 14.94 lakh hectare area of Jharkhand (Anonymous, 2015). By 2025 AD, the rice demand of the country is projected to be 125 million tonnes, which is to be achieved by enhancing the rice production and soil fertility with good management practices thereby ensuring long-term sustainability in rice production.

Rice favours submergence for its growth and development during the crop period. Transplanting is the widely adopted method for growing rice in India. The farmers cultivating rice through transplanting method face a lot of problem on account of unwieldy practices of the technique like raising nursery, uprooting and transferring seedlings in main field, drudgery caused to women, high water requirement and huge labour demand during peak periods that results in high cost of cultivation. However, direct seeded rice offers the advantage of faster and easier planting, ensures proper plant population, reduces labour and hence less drudgery, 10-12 days earlier crop maturity, more efficient water usage and often high profit in areas with assured water supply (De Datta, 1986).

Apart from the management practices, nutrients availability in the soil rhizosphere also play a significant role in governing the crop productivity. Uptake of nutrients (N, P and K) by crop is a function of the nutrient content in the plant and the dry matter accumulation per unit area (Kanthi *et al*., 2014). Rice is reported to be an exhaustive cereal with large nutrient demand for its vigorous growth and development throughout the crop period. The submerged condition in transplanted rice facilitates the availability of more mineralized form of N, P and K and therefore its uptake (Shashikumar (1990) and Anbumani *et al*., (2004). Rice can also be grown successfully by direct sowing of sprouted seeds through drum seeder with less input, efficient utilization of nutrients and early maturity of crop without compromising on its productivity. Therefore, keeping these points in view the present investigation was undertaken to evaluate the comparative effects of different rice establishment methods on nutrient utilization and productivity of crop.

Materials and Methods

A field experiment was conducted during *kharif* season of 2015 at agronomical research farm of Birsa Agricultural University, Ranchi. The experimental soil was clay loam in texture with 38.1% sand, 30.6% silt and 31.3% clay and was slight acidic in reaction (pH 6.1), low in organic carbon (3.6 g/kg) as well as in available nitrogen (200.7 kg/ha), high in available phosphorus (33.54 kg/ha) and medium in potassium (187.04 kg/ha). The agronomical research farm falls under sub zone V of Agro-climatic zone VII of India i.e. Eastern Plateau and Hill Region. This place is characterized by hot summer and cold winter and receives rainfall from both the streams of monsoon i.e. South-West monsoon and North-East monsoon. The experiment was laid out in Randomized Block Design with four replication and the rice variety used was Naveen (CR-749-20-2). The treatments comprised of five different rice establishment methods – conventional transplanting, mechanical transplanting, drum seeding of sprouted seeds, broadcasting of sprouted seeds and broadcasting of dry seeds. Uniform fertilization (120: 60: 40 kg N: P_2O_5: K_2O ha^{-1}) was done for all the rice establishment methods through urea, diammonium phosphate (DAP) and muriate of potash(MOP), respectively. After ploughing and leveling layout of field was done which followed puddling with the help of tractor drawn puddler, 5 days before as well as on the day of sowing/transplanting and then leveling was done.

Fertilization comprising of half dose of nitrogen and full dose of phosphorus and potassium were applied as basal in the main field. Rest of the nitrogen was top dressed in two equal splits at 25 days after sowing/transplanting (tillering stage) and at 50 days after sowing/transplanting (panicle initiation stage). Whereas, in nursery fertilizers was applied @ 12: 6: 4 kg N: P_2O_5: K_2O per 1000 sq m. In conventional transplanting, half dose of N and full dose of P_2O_5 and K_2O were applied as basal and remaining N was top dressed at 15 DAS. While, in case of rice nursery for mechanical transplanting full dose of N was applied as basal. For conventional transplanting, seeds were sown in nursery and seedlings were raised by wet nursery method and 2-3 seedlings/hill (21 days old) were transplanted at 20 x 15 cm spacing. Whereas, in case of mechanical transplanting seedlings were prepared on mat type nursery and 4-5 seedlings/hill (15 days old) were transplanted at 25 x 15 cm spacing. Sprouted seeds were used for direct seeding by broadcasting and drum seeding with 20 cm row spacing. Direct seeding was done on the same day i.e. the day seeds were placed in nursery.

Soil fertility was determined based on analysis of nutrients available in soil before the experimentation, uptake of nutrients by the crop(grain+ straw) and estimation of residual nutrient safter harvest of the crop. The oven dried grinded grain and straw samples were analyzed for Nby Kjeldahl method of digestion and distillation as outlined by Jackson (1973) and described by Tondon (1999).Grinded grain and straw samples were digested in diacid mixture (HNO_3: $HClO_4$ in 10:4 ratio on volume basis) for determining phosphorus and potassium content in extractant which were determined calorimetrically using 440 nm filter following vanadomolybdate nitric acid yellow colour method (Jackson, 1973). Nitrogen, phosphorus and potassium content of grain and straw were multiplied with grain and straw yield for obtaining N, P and K uptake (kg/ha) by grain and straw.

Pre-sowing and post harvest soil of experimental plot were subjected to analysis for which soil samples (0-15 cm depth) were collected from five different places from each plot and mixed thoroughly for preparing composite soil sample. The composite samples were then air dried, grinded, sieved and used for the estimation of initial and residual nutrient status of soil. Soil pH was determined in a soil water suspension of 1:2.5 w/v, stirred at regular intervals for 30 minutes using fritz glass pH meter (Jackson, 1973). Organic carbon was determined by rapid titration method given by Walkley and Black (1934). Mineralisable nitrogen in the soil sample was determined by distillating the soil in alkaline permanganate method given by Subbiah and Asija (1956).Available phosphorus was determined using Bray P_1 reagent (Bray and Kurtz, 1945) and estimated calorimetrically by ascorbic acid method. Exchangeable potassium was extracted from soil by neutral normal ammonium acetate method (Hanway and Heidel, 1952) and was estimated in accordance with that described by Tondon (1999).Total quantity of N, P and Kremoved by crop was subtracted from the sum of the nutrient applied and initial nutrient status of soil to prepare the balance sheet of nutrients. Crop yield was recorded as per the standard procedures. Collected data were statistically analyzed as per the methods by Gomez and Gomez, 2003.

Result and Discussion

Nutrient uptake by rice crop

Rice establishment methods under puddled soil significantly influenced the nutrient uptake (N, P and K) by grain and straw. Rice crop established through conventional transplanting (17.49 kg/ha P and 98.12 kg/ha K), drum seeding of sprouted seeds (17.12 kg/ha P and 97.35 kg/ha K) and mechanical transplanting (15.63 kg/ha P and 90.35 kg/ha K) were on par in P and K removal by rice biomass whereas nitrogen removal was similar between conventionally transplanted (102.60 kg/ha N,) and drum seeded rice (99.07 kg/ha N). In case of P removal by rice biomass, conventional transplanting and drum seeding were significantly higher by 23.4 and 20.8%, respectively over broadcasting of dry seeds. Whereas, conventionally transplanted and drum seeded rice showed markedly increase of 19.2 and 18.3%, respectively over broadcasting of dry seeds in K removal. Conventional transplanting had significant edge of 27.8, 25.1 and 15.3% in nitrogen uptake by rice biomass over broadcasting of dry seeds, broadcasting of sprouted seeds and mechanical transplanting, respectively. This is attributed to the submerged conditions in transplanted rice that facilitate availability of more mineralized form of N, P and K and therefore its uptake in transplanted rice is higher than that of direct sowing which encouraged tiller production in addition contributed to higher dry matter production and grain yield as observed by Shashikumar (1990) and Anbumani *et al*., (2004). Whereas, drumseeded rice was significantly higher by 20.8 and 23.4% over broadcasting of either sprouted or dry seeds, respectively (Table-1). Establishment of rice through transplanting and drum seeding removed higher amount of nutrients because of better environment available around the eco-rhizosphere as a result of thorough pulverization of soil under a film of water and transplanting of rice seedlings in such an ideal environment might have enabled the crop to absorb native as well as applied nutrients incessantly to give an early lead to the growth of individual plants as well as higher nutrient content that resulted in higher nutrient uptake by transplanted and drum seeded rice as stated by Kanthi *et al.,* (2014). The uptake of nutrients is also closely associated with the metabolism and specially root respiration which in turn is governed by desired spacing as in case of transplanted and drum seeded rice, hence absorbing higher nutrient content. Varied levels of absorption of nutrients under different methods of crop establishment has also been reported by Jaiswal and Singh, 2001; Singh *et al.*,(2007) ;Singh *et al.*,(2008); Parameshwari and Srinivas, 2014.

Soil chemical properties

Fertility status parameters of the soil was not influenced from its initial value by various methods of rice establishment under puddled condition (Table- 2). The soil pH and organic carbon content after crop harvest were in the range of (5.8 to 5.9) and (3.5 to 3.4 g/kg soil), respectively. Whereas, the nutrient status of the soil N, P and K was in the range of 189.49 to 198.07 in N, 30.97 to 32.64 in P and 181.54 to 184.74 kg/ha in K.

Balance sheet of nutrients

The data related to nutrient balance in 0-15 cm soil depth as affected by different rice establishment methods under puddled soil have been presented in the table 3,4 and 5. Total quantity of N, P and K removed by crop was subtracted from the sum of the nutrient applied and initial nutrient status of soil. The deviation from this balance gave the actual change in fertility status of the soil. Positive balance indicates soil build up and negative balance indicates depletion.Nitrogen balance in soil was negative among all the establishment methods tested (Table-3). N fertilizer application is the most important source of soil N, and one of the major paths of N losses is through ammonia volatilization which are all influenced by N application, soil moisture state, and tillage practice (Xu *et al.,*1999).Crop established with broadcasting of dry seeds mined more soil N(- 42.36 kg/ha). Whereas, conventional transplanting had minimum N loss (-28.61 kg/ha) as compared to remaining establishment methods. Phosphorus balance in soil was also negative among all the establishment methods tested (Table-4). Broadcasting of dry seeds mined more soil P (-12.93 kg/ha). While, conventional transplanting had minimum P loss (-11.28 kg/ha).Gupta *et al.*,(2007) argued that in most lowland rice soils, P availability initially increased on flooding and rice may meet its P requirement from the residual P applied to the preceding wheat. Whereas, potassium balance in soil was positive among all the establishment methods tested (Table-5). Maximum potassium balance was found under conventionally transplanted (+59.42 kg/ha) followed by drum seeded (+58.84 kg/ha), mechanically transplanted rice (+53.18 kg/ha) and broadcasting of sprouted seeds (+48.81 kg/ha).Whereas, minimum potassium was added by broadcasting of dry seeds (+46.81 kg/ha).

Yield

Different rice establishment methods under puddled soil had significant effect on both grain and straw yield except the harvest index of rice. Conventionally transplanted, drum seeded and mechanically transplanted rice had similar grain and straw yield (Table-6). Conventional transplanting (44.18 q ha^{-1}) had edge by 19 and 21%, respectively over broadcasting of either sprouted (37.13 q ha^{-1}) or dry seeds (36.50 q ha^{-1}) whereas drum seeding of sprouted seeds (43.70 q ha^{-1}) was significantly higher by 17.7 and 19.7%, respectively over broadcasting of either sprouted (37.13 q ha^{-1}) or dry seeds (36.50 q ha^{-1}) in grain production. Further, among the direct seeded rice, broadcasting of dry seeds being similar to broadcasting of sprouted seeds recorded the lowest grain yield. Rice established through transplanting and drum seeding recorded significantly higher paddy yield because the beneficial effects of puddling in transplanting as well as in drum seeding together with uniform stand establishment, ideal rhizosphere environment might have contributed to higher nutrient uptake which resulted in the production of greater source and efficient translocation of photosynthates into the larger sink as indicated by higher yield attributes. In case of straw yield, crop established through conventional transplanting (68.43 q ha^{-1}) and drum seeding of sprouted seeds (67.90 q ha^{-1}) showed significant edge by 15.3 and 14.5%, respectively over broadcasting of dry seeds (59.32q ha^{-1}). Further, rice established through broadcasting of dry seeds being similar to that of sprouted seeds recorded the minimum straw yield. Transplanting method of establishment recorded significantly higher straw yield compared to direct sowing of rice under puddled condition due to less crop weed competition in transplanting method which led to taller plants, more number of tillers and dry matter production which in turn resulted in higher straw yield (Parameshwari and Srinivas, 2014). Subramanyam *et al*., (2007) also reported similar results. Being a varietal character, harvest index was not influenced by different rice establishment methods under puddled condition, however highest harvest index was recorded with conventional transplanting (39.19%) followed by drum seeding of sprouted seed (39.13%), mechanical transplanting (38.38%), broadcasting of sprouted seeds (38.18%) and broadcasting of dry seeds (38.13%).This confirms the findings of Jha *et al.,* 2011.

Conclusion

Therefore, in order to meet the projected rice demand of the nation in near future, drum seeding can be a feasible alternative to transplanted rice which will not only have a positive effect on rural economy by reducing the cost of cultivation but also contribute in efficient utilization of soil nutrient through higher uptake thereby increasing the crop productivity.

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Table 1: Nutrient uptake by rice grain, straw and biomass (grain+ straw) as influenced by rice establishment methods.

Treatments	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
	Grain	Straw	Biomass	Grain	Straw	Biomass	Grain	Straw	Biomass
T_1 Conventional Transplanting	64.74	37.86	102.60	12.16	05.34	17.49	11.90	86.22	98.12
T_2 Mechanical Transplanting	56.47	32.47	88.95	10.87	04.76	15.63	10.37	79.98	90.35
T_3 Drum seeding of sprouted seeds	62.88	36.19	99.07	11.96	05.16	17.12	11.65	85.70	97.35
T_4 Broadcasting of sprouted seeds	52.25	29.76	82.01	10.08	04.41	14.49	9.55	75.23	84.78
T_5 Broadcasting of dry seeds	50.59	29.67	80.27	9.93	04.24	14.17	9.30	73.01	82.31
SEm ±	2.98	1.88	4.41	0.68	0.22	0.87	0.63	4.21	4.72
CD (P=0.05)	9.14	5.77	13.54	2.08	0.67	2.68	1.92	12.92	14.50

Note: All the treatments are under puddled condition

Table 2: Soil fertility status after harvest as influenced by rice establishment methods

Treatments	pH	Organic C (g/kg soil)	Available nutrient status (kg/ha)		
			N	P	K
T_1 Conventional Transplanting	5.8	3.4	189.49	30.97	181.54
T_2 Mechanical Transplanting	5.8	3.5	193.88	31.90	183.07
T_3 Drum seeding of sprouted seeds	5.9	3.4	192.36	31.15	181.73
T_4 Broadcasting of sprouted seeds	5.9	3.5	197.11	32.48	184.27
T_5 Broadcasting of dry seeds	5.9	3.5	198.07	32.64	184.74
SEm ±	0.11	0.1	5.18	0.89	4.63
CD (P=0.05)	NS	NS	NS	NS	NS
Initial	6.1	3.6	200.70	33.54	187.04

Note: All the treatments are under puddled condition

Table 3: Nitrogen balance sheet (kg/ha) after crop harvest as influenced by rice establishment methods

Treatments	Soil initial nitrogen\ (kg/ha)	Added through fertilizer (kg/ha)	A+B=C	Crop removal (kg/ha) D	Expected balance (kg/ha) C-D=E	Final available N(kg/ha) F	Gain/Loss (kg/ha) F-E=G
T_1 Conventional Transplanting	200.7	120	320.7	102.6	218.1	189.49	-28.61
T_2 Mechanical Transplanting	200.7	120	320.7	88.95	231.75	193.88	-37.87
T_3 Drum seeding of sprouted seeds	200.7	120	320.7	99.07	221.63	192.36	-29.27
T_4 Broadcasting of sprouted seeds	200.7	120	320.7	82.01	238.69	197.11	-41.58
T_5 Broadcasting of dry seeds	200.7	120	320.7	80.27	240.43	198.07	-42.36

Table 4: Phosphorus balance sheet (kg/ha) after crop harvest as influenced by rice establishment methods

Treatments	Soil initial phosphorus (kg/ha)	Added through fertilizer (kg/ha)	A+B=C	Crop removal (kg/ha) D	Expected balance (kg/ha) C-D=E	Final available P (kg/ha) F	Gain/Loss (kg/ha) F-E=G
T_1 Conventional Transplanting	33.54	26.2	59.74	17.49	42.25	30.97	-11.28
T_2 Mechanical Transplanting	33.54	26.2	59.74	15.63	44.11	31.9	-12.21
T_3 Drum seeding of sprouted seeds	33.54	26.2	59.74	17.12	42.62	31.15	-11.47
T_4 Broadcasting of sprouted seeds	33.54	26.2	59.74	14.49	45.25	32.48	-12.77
T_5 Broadcasting of dry seeds	33.54	26.2	59.74	14.17	45.57	32.64	-12.93

Table 5: Potassium balance sheet (kg/ha) after crop harvest as influenced by rice establishment methods

Treatments	Soil initial potassium (kg/ha)	Added through fertilizer (kg/ha)	A+B=C	Crop removal (kg/ha) D	Expected balance (kg/ha) C-D=E	Final available K (kg/ha) F	Gain/Loss (kg/ha) F-E=G
T_1 Conventional Transplanting	187.04	33.2	220.24	98.12	122.12	181.54	+59.42
T_2 Mechanical Transplanting	187.04	33.2	220.24	90.35	129.89	183.07	+53.18
T_3 Drum seeding of sprouted seeds	187.04	33.2	220.24	97.35	122.89	181.73	+58.84
T_4 Broadcasting of sprouted seeds	187.04	33.2	220.24	84.78	135.46	184.27	+48.81
T_5 Broadcasting of dry seeds	187.04	33.2	220.24	82.31	137.93	184.74	+46.81

Table 6: Grain and Straw yield and Harvest index as influenced by rice establishment methods

Treatments	Yield (q ha^{-1})		Harvest Index (%)
	Grain	Straw	
T_1 Conventional Transplanting	44.18	68.43	39.19
T_2 Mechanical Transplanting	39.80	63.76	38.38
T_3 Drum seeding of sprouted seeds	43.70	67.90	39.13
T_4 Broadcasting of sprouted seeds	37.13	60.21	38.18
T_5 Broadcasting of dry seeds	36.50	59.32	38.13
SEm ±	1.90	2.62	0.60
CD (P=0.05)	5.82	8.05	NS

Note: All the treatments are under puddled condition

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