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Performance of Rice under Various Establishment Methods and Different Cropping Systems in Indo-Gangetic Plains of Bihar

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ABSTRACT

Puddle transplanted rice has provided heavy levy on the soil health and there is need to develop suitable establishment practices. Field experiment was conducted during the wet season of 2015-16 at research farm of Bihar Agricultural University, Sabour, to study the performance of rice under different crop establishment techniques in cropping systems. The experiment consisted of nine treatment combinations of three rice establishment methods with three systems in split plot design replicated thrice. Crop establishment methods are zero tillage (T_1), permanent bed planting (T_2) and transplanted puddled rice (T_3) were kept in main plot and in sub-plots having three cropping systems, rice-wheat (C_1), rice-maize (C_2) and rice-lentil (C_3). Maximum grain (45.4 qha^{-1}) was recorded under transplanted puddled rice situation which was at par with zero tillage but significantly superior than permanent bed system. The rice-lentil cropping system was found to be superior in grain yield (44.63 qha^{-1}) than rest of systems. Maximum net return was recorded under zero tillage (Rs. 53,327 ha^{-1}) but it was at par with Permanent bed planting and transplanted puddled rice. Zero tillage was found profitable in generating income from rice under rice-lentil cropping system with maximum net return (Rs.52,089 ha^{-1}) and benefit cost ratio (1.93) which was significantly superior than rest of the cropping systems.

Key words: *Zero Tillage; Permanent Bed Planting; Conservation Agriculture; Puddle Transplanted Rice; Cropping System*

INTRODUCTION

Rice (*Oryza sativa* L.*)* is one of the most important food grains produced and consumed all over the world, it is expected to raise from 439 Mt in 2010 to 496 Mt in 2020 and further increase to 553 Mt in 2035. In India, rice is cultivated in diverse ecosystems spread over 43.97 M ha with the production and productivity of 104.32 Mt and 2.37 t ha^{-1} respectively. In Bihar, rice is cultivated in about 3.2 Mha during *wet* season with the average production and productivity of 6.04 Mt and 1.95 t ha^{-1}respectively.

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The farmers prefer manual transplanting as they did not want any type of risk with new technology. Direct seeding or zero tillage of rice is alternative option, as the researchers suggested its wide applicability in various rice growing countries of the world. In USA and Australia direct seeding and bed planting are considered as resource saving technologies in reducing environmental pollution and enhancing livelihood of the farming communities[9,10,17]. Direct seedling of rice have more benefits as compared to traditional transplanting due to less drudgery and early maturity by 7 to 10 days with less water requirement[6]. Zero tillage technique is used widely for many crops around the world and this technology has potential to allow saving in time, energy, water and labour during rice establishment[13]. Planting in bed is also effective in saving seed, water and labour, in improving grain quality and yield. Permanent raised beds might offer farmers further significant advantages such as increased opportunities for crop diversification, mechanical weeding, placement of fertilizers and reduced tillage. There are also indications that crop yields from beds can be further increased by using higher rates of N fertilizer and later irrigation because of the reduced risk of lodging.

Apart from better rice establishment method, an appropriate crop management strategy to increase the efficient use of inputs is needed to enhance the productivity. Zero and permanent bed management technology is oriented towards better utilization of organic sources. Zero tillage practices encourage use of organic instead of inorganic fertilizers to harness the optimum crop potential. However, much of the literature suggested that practices of zero tillage and permanent bed with the utilization of natural resources in field as per resources available with a farmer is best option for achieving the higher crop productivity[14]. Puddled transplanting often delayed the planting of succeeding wheat crop leads to yield reductions of 1.5% per day, particularly in sowing after November 15 in North India. The zero tillage with residues left on soil surface and adopting efficient crop rotations is very essential[7]. Moreover retention of crop residues on soil surface in combination with no tillage initiates processes that lead to improved soil quality and overall enhancement of resource use efficiency [1]. The present study was conducted to evaluate the performance of different crop establishment techniques under different rice based cropping systems with an aim to comprehend the most stable and profitable system for adoption in alluvial belt of Indo-Gangetic Plains for higher yields.

MATERIAL AND METHODS

Experimental site

Field experiment was conducted in the research farm of Bihar Agricultural University, Sabour, Bhagalpur (25^{o}50'N latitude, 87^{o}19′ E longitude and an elevation of 52.73 m a.s.l.), India for identifying suitable crop establishment methods for rice perfect cropping systems. The soil of the location is silty clay loam in texture and low in fertility status. The climate of Bhagalpur is characterized by hot desiccating summer, cold winter and moderate rainfall. May is the hottest month with an average maximum temperature of 35 to 39°C. January is the coldest month of the year with mean minimum temperature varies from 5 to 10°C.The site receives annual average rainfall of 1200 mm of which 70-75% occurred in the monsoon months (June to October). The average temperature varies from 19°C in December/January to 29.6°C in May/June.

Experimental details

The experiment was carried out during the wet season (June-October) of 2015in split plot design with three replications. The experiment included three establishment methods of rice in main plots, i.e. zero tillage, permanent bed and transplanted puddled rice and three cropping systems in sub-plot, i.e. rice-wheat, rice-maize and rice-lentil. Rice variety Shusk Samrat is a cross of NDR 1045-2/IET-17458 was used in the present investigation. The half dose of nitrogen and full quantity of P_2O_5 and K_2O were applied in opened furrow just before sowing in zero tillage and permanent bed.

However, it is just before the final land preparation in transplanted puddled rice. The remaining half dose of nitrogen was applied at the time of maximum tillering. The fertilizer application was applied in each plot as 100:60:40 N, P_2O_5 and K_2O, respectively. The source of N, P_2O_5 and K_2O were urea, DAP and muriate of potash. The seedlings are planted at the spacing of 10 cm × 20 cm for transplanted puddle rice and for zero tillage and permanent bed the seeds were uniformly spread on the bed and covered with paddy straw for 3 days.

Observations recorded

An area 2 m^2 from each plot was ear marked for destructive sampling and the rest of the plot was used for yield estimation. Time series biometric data were recorded at different growth stages of the crop from the ear–marked area of each plot and economic yield was estimated at final harvest. The grain yield, straw yield, number of panicles m^{-2}, number of grains $panicle^{-1}$and test weight of grain were recorded from each plot at maturity. The crop was harvested from 10 m^2 area for yield estimation in each plot. After threshing the grain and straw were dried in the sun for 3-4 days and their weights were recorded. The grain and straw yields were corrected to 12% moisture content. Harvest index was estimated dividing the grain yield by biological yield and expressed in percentage. The economics was calculated on the basis of government approved rate and prevailing market price of various inputs and outputs in the local markets. The common cultural operations cost are put under fixed cost for all the treatments and the cost like land preparation, sowing/transplanting operation, harvesting and processing are put under variable cost. The cost for harvesting and processing depends on the amount of yield. The gross return from each plot was calculated taking into account grain and straw yield multiplied by their respective price. Net return was calculated by deducting the production cost from the gross value of the produce, including by-product value.

Statistical analysis

The data were analyzed statistically by applying "Analysis of Variance" (ANOVA) technique of split plot design[5].The significance of different sources of variations was tested by Error mean square of Fisher Snedecor's 'F' test at probability level 0.05. Standard error of mean (SEm±) and least significant difference (CD) at 5% level of significance were worked out for each character and provided in the summary tables of the results to compare the difference between the treatment means.

RESULTS AND DISCUSSION

Yield attributes: The effective tillers of the plant under puddled transplanted method (281) were significantly higher than permanent bed (195) but it was statistically at par with plant height recorded under zero tillage (262). Among different cropping system effective tillers of the rice recorded under rice-lentil system (260) was significantly higher than rice-maize system (231) but it was statistically at par with effective tillers of the rice plant recorded under rice-wheat (246) (Table 1). The maximum effective tillers/m^2 (281) and panicle length (26.6 cm) were in conventional puddled methods as well as in rice-lentil system. This might be due to better root growth and early establishment of plant which ultimately helped in enhancing the number of effective tillers. These results are in agreement with those of Naresh *et al*[11] and Laary *et al*[8]. The filled grains/panicle under permanent bed (175) was significantly higher than zero tillage (165) and transplanted puddled methods (153). Rice-lentil system recorded significantly higher filled grain/panicle (183) as compared to that of rice-maize system (149) but it was statistically at par with rice-wheat system (162). The test weight did not vary significantly among the treatments; however, it was maximum in permanent bed and in rice-lentil system (Table 1). This might be due to balanced and regular supply of nutrients and efficient utilization of other environmental resources from soil particularly at grain formation stage[11].

Yield and harvest index: The puddled transplanted methods recorded the maximum grain yield (45.40 q/ha) which was significantly superior and 14.3% higher to permanent bed (39.71 q/ha) but was at par with zero tillage (44.19 q/ha). The continuous better environment of puddled transplanted rice induced improvement in effective tillers m^{-2}, grains per panicle/spike, and test-weight led to increase in grain yield of rice crops. These results are in accordance with the findings of Naresh *et al*[11], Sidhu *et al*[18] and Ali *et al*[3]. The lower yield of rice under permanent bed might be due to higher spacing on the beds (2 rows planted on 67.5 cm bed) than that on zero tillage (20cm)[19]. Similar observations of lower yields of rice under direct seeding on permanent beds were also reported by Bhushan *et al*[4]. Rice-lentil system also recorded significant higher yield (44.63 q/ha) as compared to rice-maize and rice-wheat cropping system (Table 1). The interaction effect was found non-significant. Straw yield was followed the similar trend of grain yield. The maximum straw yield was recorded under puddled transplanted method (67.21 q/ha) and in rice-lentil system (2.51 q/ha). Among different establishment methods, the effect on harvest index was found non-significant. However, the maximum harvest index (40.30) was recorded in transplanted puddled method and in rice-maize system (Table 1).

Economics: Among different rice establishment methods gross return under puddled transplanted methods (Rs. 80402/ha) was significantly higher than permanent bed (Rs. 71464/ha) but was at par with zero tillage (Rs. 78606/ha). This might be owing to higher grain and straw yields of puddled transplanted rice. This confirms the finding of Saharawat *et al*[16] and Akbar & Ehsanullah[2]. The rice-lentil system recorded significantly higher gross return than the other systems (Table 1). The scenario was quite different in case of net return and it was found non-significant within crop establishment methods. However, among different cropping system, rice-lentil system recorded significantly higher net return (Rs. 52089/ha) as compared to rice-wheat (Rs. 49311/ha) and rice-maize (Rs. 47033/ha). The different trend was observed in benefit:cost ratio (B:C ratio) of the study and it was significantly higher under zero tillage than permanent bed and transplanted puddled method (Table 1). This is due to the production cost, which was lower in the zero tillage and permanent bed compared to puddled transplanted rice. The puddle transplanted rice incurred 24.5% higher production cost as compared to zero tillage and permanent bed system and this is due to transplanting manually in puddle method. Similar findings were also reported by Naresh *et al*[11] and Sidhu *et al*[18]. Among different cropping systems, rice followed by lentil system recorded significant higher B:C ratio (1.93) as compare to rice-wheat (1.82) and rice-maize (1.74). The higher income and benefit cost ratio in rice followed by lentil was a combination of higher yield of grain and straw.

Soil fertility: The effect of different establishment methods on organic carbon content of the soil after harvest was non-significant, but the maximum organic carbon was in zero tillage and permanent bed (Table 2). Among different systems, the organic carbon content was recorded significantly higher in rice-lentil system (0.59%) as compare to rice-wheat and rice-maize. Direct seeding of crops under zero tillage and permanent bed resulted in higher residual soil moisture availability which led to higher C: N in wheat residue compared to lower C: N ratio in lentil residue. Lentil crop, being leguminous, as well as the lower C: N ratio in the residue resulted in higher mineralization and greater availability of nutrients in the soil over time. This was also due to legume effect. Singh and Kaur[19] and Paudel *et al*[12] also reported that under conservation tillage practices higher amounts of soil organic matter can be obtained than that of conventional practices. Among different rice establishment methods, maximum available N after harvest was under permanent bed (168 kg ha^{-1}) and it was at par with available N present in the zero tillage). However, rice under puddle transplanted method recorded significantly lower available N kg ha^{-1} as compared to other methods (Table 2). The rice-lentil cropping system recorded significantly superior available soil N status (178 kg ha^{-1}) than rest other cropping systems. The increase in available nitrogen status of soil was higher than its initial value which was due to direct seeding of crops under zero tillage and permanent bed resulted in higher residual soil moisture availability. The available phosphorus and potassium were also maximum under permanent bed followed by zero tillage and among the cropping system the rice-lentil performed significantly higher result than rest other systems (Table 2). Sah *et al* [15] reported that zero-tillage combined with residue retention enhanced P and K availability to plants and improved productivity of the rice-wheat system.

Table 1: Effect of cropping system and establishment methods on grain yield, straw yield and harvest index of rice

Rice establishment methods (Main plot)	Panicles m^{-2}	Grains $panicle^{-1}$	Test Weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index	Gross return ($Rsha^{-1}$)	Net return (Rs ha^{-1})	B:C ratio
T_1- Zero tillage	262	165	22.91	44.19	66.71	39.86	78606	53327	2.11
T_2- Permanent bed	195	175	23.42	39.71	62.34	38.98	71464	46184	1.83
T_3- Transplanted puddled rice	281	153	22.97	45.40	67.21	40.30	80402	48922	1.55
SEm (±)	11.2	3.4	0.45	1.70	1.74	0.62	2642	2642	0.10
CD (P=0.05)	31.0	9.6	NS	4.72	4.82	NS	7334	NS	0.27
Cropping systems (sub-plot)									
C_1- Rice-wheat	246	162	22.69	42.90	65.99	39.44	76658	49311	1.82
C_2- Rice-maize	231	149	23.18	41.77	62.53	40.03	74380	47033	1.74
C_3- Rice-lentil	260	183	23.43	44.63	67.74	39.68	79436	52089	1.93
SEm (±)	9.9	10.3	0.49	0.40	1.15	0.43	648	648	0.02
CD (P=0.05)	21.5	22.5	1.07	0.88	2.51	0.93	1411	1411	0.05
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of cropping system and establishment methods on grain yield, straw yield and harvest index of rice

Rice establishment methods(Main plot)	Organic carbon (%)		N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T_1- Zero tillage	0.57	0.57	164	166	28.19	28.42	222	221
T_2- Permanent bed	0.57	0.57	168	168	31.72	32.01	231	231
T_3- Transplanted puddled rice	0.56	0.56	157	157	23.28	23.66	209	209
SEm (±)	0.01	0.01	5.7	5.6	0.40	0.32	3.2	3.1
CD (P=0.05)	NS	NS	NS	NS	1.12	0.89	8.9	8.5
Cropping systems (sub-plot)								
C_1- Rice-wheat	0.56	0.56	159	160	26.68	26.96	217	217
C_2- Rice-maize	0.56	0.56	153	154	26.09	26.26	211	212
C_3- Rice-lentil	0.58	0.59	177	178	30.42	30.88	234	233
SEm (±)	0.01	0.01	1.9	1.9	0.75	0.66	4.5	4.0
CD (P=0.05)	0.02	0.02	4.1	4.0	1.63	1.44	9.8	8.8
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

CONCLUSION

On the basis of the one year of experimentation under different cropping system and establishment methods it may be concluded that for getting higher B:C ratio and net return, among different establishment methods zero tillage and among different cropping systems, rice-lentil system may be a good option. Since the results are based on one year of experimentation, no definite recommendation can be made and it should be further validated to check its wider applicability under different climatic conditions.

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