Journal of AgriSearch 1(3): 145-150
Peer Reviewed Quarterly
ISSN : 2348-8808 (Print), 2348-8867 (Online)

Productivity and Economics of Rice-Wheat Cropping System as Affected by Methods of Sowing and Tillage Practices in the Eastern Plains

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ARTICLE INFO

Received on	: 14.04.2014
Revised received on	: 28.05.2014
Accepted on	: 07.06.2014
Published online	: 07.09.2014

ABSTRACT

The field experiments were conducted during the year 2011-2014 at farmers' fields in three villages ofPhulwarisharif Block of Patna districtto evaluate the performance of rice-wheat cropping system under different sowing methods and different tillage scenario. Four sowing methods in rice viz. zero-till-drill rice(ZT), unpuddled mechanical transplanted rice (MT), direct wet sowing and puddled transplanting whereas, in wheat three methods of sowings viz. zero-till-drill, manual line sowing and sowing with Turbo Happy seeder were carried outand compared for yield and economics of the treatment. Unpuddled Mechanical transplanting (MT) followed by manual sowing of wheat recorded least bulk density (1.51g/cm^3) at 0-15 cm of soil depth. Unpuddled mechanical transplanted rice recorded highest output: input ratio of 2.4 with a grain yield of 49.2q/ha. After harvesting of rice crop, wheatgrown in plots of MT rice and ZT, produced significantly higher yield i.e. 48.2 and 44.6 q/ha with an output: input ratio of 2.0 and 2.1 respectively. Wheat crop sown by Turbo Happy seeder performed the best and produced significantly higher grain yield (43.8q/ha) over other methods of sowing due to mulching effect. ZT rice and MT rice saved 81 and 72 percent of sowing cost and 96 and 94 percent in terms of time taken in sowing/transplanting on hectare basis, respectively. Sowing of wheat through Zero- till- drill and Turbo Happy seeder also curtailed the overall cost of cultivation by Rs. 9,800 and Rs. 8,800/ha, respectively.

Keywords: Economics, productivity, rice- wheat, cropping system, sowing methods, tillage

INTRODUCTION

In South–East Asia, rice is grown by transplanting of rice seedlings (21-30 days age) in the puddled fields which consumes 30 percent of total water requirement. Due to puddling activity, physical changes in soil take place which is detrimental for non-rice crops or the next crop i.e. wheat due to sub- soil compaction (Singh *et al.,* 2014 and Sanjeev *et al.,* 2012). Rice- wheat is the most dominant cropping system in India as well as in the Eastern Region of the country (Singh *et al.,* 2014), covering an area of about 10.0 mha and contributes about 74 percent of total foodgrains to the national food basket. Traditionally, rice is cultivated as manually transplanted crop in puddled soil which is highly complicated and consumes enormous manpower and water (Singh *et al.,* 2012). Now a day, timely availability of labour for transplanting is a burning problem in almost all Indian states. It was convinced that under puddled condition the yield of rice is high but it has its own limitations and ill effects on soil health (Mohanty *et al.,* 2006). Besides these, sowing of wheat is also delayed if conventional land preparation is carried out in wheat which resulted in linear decline in wheat productivity equivalent to 1.0-1.5 percent yield loss / hectare/day (Gathala *et al.,* 2011). Kumar and Ladha(2011)also stated that due to conventional puddling and land preparation in rice, a yield decline of 8-9 percent has been observed in wheat as compared with non- puddled rice due to disturbance in the soil physical structure. In the eastern part of the country especially in Bihar, rice is harvested upto second week of December which tends towards late sowing of wheat and a substantial decline in wheat yield. Mishra(2003) reported a decrease of 47kg/ha/day and 57kg/ha/day if sowing of wheat is done in the month of December and January, respectively. Under these circumstances, direct seeding or mechanized transplanting appears to be the wise option to save

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time; energy and laboursimultaneously.Use of long duration varieties and delay in transplanting of rice seedlings due to dependency on monsoon rain for puddling are the major reasons for delayed harvesting of rice in these areas. The conventional method of wheat sowing requires repeated tillage and operations which ultimately delay the sowing of wheat further and reduced grain yield is achieved(Meena *et al.*, 2013). Keeping above facts in view, field experimentations were conducted at farmer's field in the three villages at Phulwarisharif Block of Patnadistrict to evaluate a suitable sowing/transplanting method for rice and wheat crops under different tillage conditions in rice-wheat cropping system to increase the profitability and sustaining productivity on long term basis.

MATERIALS AND METHODS

Field experiments were conducted during 2009-10, 2010-11 and 2011-12 at Simra, Mahangupur and Azadnagar villages of the Phulwarisharif Block of Patna district in participatory mode. The soil of the experimental field was clay loam in all the three villages, with pH 6.8, 7.1 and 6.6 and organic carbon content 0.51, 0.48, 0.52 percent, respectively. The design of the experimental field was Randomized Block design for rice (Pusa-1176) and Split Plot Design for wheat crop (PBW-343). The main plot treatments comprised of 4 sowing/transplanting methods in rice viz. i) Zero tilled rice ii) Direct wet sowing by drum seeder, iii) Unpuddled transplanting of rice with self-propelled rice transplanter (UMT) and iv) Manual/conventional transplanting of rice in puddled condition (CT).After harvest of rice in the last week of November during all the three years, each main plot was divided into 3 sub-plots to facilitate sowing of wheat under three tillage practices viz. i) Conventional tillage (CT), ii) Turbo- Happy seeder (HS) and iii) Zero- till drill. Eighteen days old rice seedlings (raised through mat nursery) were used for mechanical transplanting of rice by transplanter machine, whereas 25 days old seedlings were used for manual transplanting at a spacing of 20 ×10 cm. Yield assessment of rice and wheat were done on the basis of net plot yield. Recommended doses of fertilizers (120 kg N + 60 kg P_2O5 + 60 Kg K_2O) were applied in both the crops. Full dose of P and K were applied as basal while N- fertilizer was applied in three splits in both the crops (1/3 N as basal + 1/3 N at active tillering in rice and at CRI in wheat + 1/3 N at PI stage in rice and at booting stage in wheat). Need based intercultural operations like weeding, irrigation etc. and plant protection measures were carried out in both the crops A mean rainfall of 1143.5 mm (mean over three experimental years) was recorded. One irrigation of 6 cm depth was applied to rice crop sown by ZT machine, wet sowing drum seeded rice and manually transplanted rice after 10 days of sowing/transplanting due to less soil moisture in the soil while an irrigation depth of 2 cm was applied in case of unpuddled mechanical transplanted rice during each year of experimentation. However, in *rabi* season, 3 irrigations were provided to the wheat crop to meet out the crop water demand. Bulk density of soil tilled by different methods were also determined by core method as defined by Blake and Hartage, 1986 while, penetration resistance (cone resistance) was measured by using Hand Penetrometer (equation 1). The resistance was read in N (Newton) and noted for the appropriate depth. The base area was also noted because the cone resistance generally expressed in N/cm² and converted into MPa.

$$\text{Cone Resistance} = \frac{\text{Manometer reading (N)}}{\text{Base area of cone (cm}^2)} \quad \text{[Eq.1]}$$

All growth and yield parameters were recorded by adopting standard procedures. The yield was calculated on the basis of net plot yield. The data collected were statistically analyzed in split- plot design as per the analysis of variance technique described by Panse and Sukhatme(1985).

RESULTS AND DISCUSSIONS

Effect of Tillage on Soil Strength

The bulk density under different tillage and residue management treatments has been presented in Fig.1.The graph shows a significantly different value of bulk density in upper 15 cm soil layer and differences was reduced down the profile. The treatment that received zero tillage in both the season (ZT-ZT) recorded highest bulk density values (1.59 g/ cm³) followed by CT-HS. The MT-CT treatment recorded least bulk density (1.51 g/ cm³) and it was at par with CT-CT (1.52 g/cm³ and CT-ZT (1.54 g/ cm³). In the lower layer (15-30 cm) the differences among the treatments in bulk density values was reduced. All the treatments showed higher bulk density values in comparison to upper layer. The highest bulk density value (1.62 g/cm³) was recorded in CT-CT treated plot. Further in lower layer (30-45 cm), among the treatments no difference in bulk density values was observed (Table 1).The ZT practice had the highest bulk density at 0-15 cm depth, which could be attributed primarily to the lack of seasonal loosening from tillage machinery coupled with no residues on the soil surface, contrary to lower bulk density found in CT as also reported by others (Singh and Malhi, 2006; Alletto and Coquet, 2009; Alvarez and Steinbach, 2009). Residue incorporation or retention in respective tillage treatments viz. Turbo Happy Seeder in wheat significantly affected bulk density at 0-15cm depth. For rest of the depths, no effect was observed. A low bulk density in ZT-HS treatments in comparison to ZT-ZT was due to significant amount of residue incorporation resulting to improvement in organic matter content and physical health of soil. Consistent levels of compaction was noticed in 15-30 cm layer irrespective of tillage or residue management practices, indicating influence of residue limited to only top few cm layer.

Table 1: Bulk density (BD) as affected by different tillage scenario in g/cm^3

Tillage Practices	ZT-ZT	ZT-HS	CT-ZT	MT-CT	CT-CT
0-15 cm	1.59	1.57	1.54	1.51	1.52
15-30 cm	1.60	1.60	1.61	1.61	1.62
30-45 cm	1.70	1.70	1.70	1.70	1.70

Irrespective of tillage practices, a hard pan with cone index (CI) values of 1.71-1.75 MPa was clearly observed at 15-30 cm soil layer. In the upper layer (0-15 cm) the ZT-ZT treated plots recorded highest CI values (1.76 MPa) followed by ZT-HS (1.73 MPa) and CT-ZT (1.72MPa) whereas, the two treatments (MT-CT and CT-CT) with conventional tillage recorded lower CI values of 1.70MPa and 1.69 MPa, respectively. In the lower layer(15-30cm) highest CI value was recorded by CT-CT treated plots (1.75 MPa). In 30-45 cm soil layer no difference in CI values was observed among the treatments (Table 2). The higher CI value under CT-CT plots obstructed deep penetration of roots into the deeper layer resulting into more energy consumption.

Table 2: Penetration Resistance as affected by different tillage scenario as cone index (CI) in MPa

Tillage Practices	ZT-ZT	ZT-HS	CT-ZT	MT-CT	CT-CT
0-15 cm	1.76	1.73	1.72	1.70	1.69
15-30 cm	1.71	1.71	1.71	1.71	1.75
30-45 cm	1.70	1.70	1.70	1.70	1.70

Effect of Sowing/transplanting Methods in Rice

Yield and yield attributes

Transplanting by self-propelledtransplanter*i.e.* mechanical transplanting (MT) though statistically at par with the manual transplanting, produced significantly higher number of effective tillers/m^2 (212.4) over Zero tilled (ZT) rice and other methods of seeding (Table 2) which have been attributed towards higher number of seedlings per hill planted through mechanical transplanter. Manual transplanted and mechanical transplanted rice had performed equally better in respect of yield/ha over zero tilled and direct wet sown rice. Manjunatha *et al.*(2009) also derived similar type of findings from their experiment on zero tilled rice.Filled grains/panicle and test weight (1000 grains) were also found higher in transplanted rice by both methods (manual and mechanically transplanted rice) over direct seeded rice. Similar trend was also observed for grain and straw yields. Direct seeding resulted in lowest grain and straw yields, probably because of adverse soil condition for rice seed germination and growth. Moreover, inspite of use of herbicides, weed infestation was also more pronounced in direct seeded rice over other methods of transplanting at active tillering and primordial emergence stages which leads to poor grain yield. The results are in conformity with the findings of Kumar *et al.* (2012).

Output: Input ratio

Mechanical transplanted rice had produced highest output: input ratio (2.43) and proved its utility in terms of remunerativeness than the other methods of transplanting/sowing (Table 3) followed by drum seeder (1.9). However, sowing by conventional method resulted in lowest output: input ratio (1.7) whereas, in terms of yield it superseded all direct sown methods. The higher profits from mechanical transplanter, drum seeder and zero tilled rice was ascribed to their low cost of transplanting or sowing along with irrigation water requirement (35-40 percent). These results are in conformity with those of Manjunatha *et al.*(2009).

Economic analysis of different field operations

Zero tilled rice sown by zero till drill covered maximum area (2000m^2) followed by mechanical transplanter (1250m^2) on hourly basis. Labour utilization was very poor under manual transplanting i.e. consumed largest number of man-hours (610 man-hours/ha) in performing transplanting activity (Table 4). In comparison to manual transplanting, zero-till drill sown rice saved 96 percent time and 81 percent cost of transplanting. Gathala *et al.* (2011) also reported similar type of economics in case of ZT rice and Mechanical transplanted rice. Likewise, mechanical rice transplanter also saved 94 percent time and 72.06 percent of cost which was followed by direct wet seeding (88 percent time and 64.6 percent of cost) over manual transplanting.

Table 3: Yield attributes, yield and output: input ratio of rice as influenced by various sowing/transplanting methods (Pooled data of 2011-14)

Treatments	Effective tillers/m^2	Filled grains/ panicle	Test weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Output: input ratio*
ZT rice	172.8	116.2	14.9	35.1	53.6	1.9
Direct wet sowing	168.5	115.6	15.1	34.2	52.2	2.1
Manual transplanting	215.3	136.1	17.5	45.6	63.2	1.7
Mechanical Transplanting	212.4	140.2	17.2	44.2	62.8	2.4
CD (P= 0.05)	11.3	12.2	0.81	4.9	5.3	-

*output: input ratio= gross return/cost of cultivation

Table 4: Comparison of different sowing/transplanting methods of rice for various field operations (pooled data of 2011-14)

Particulars	ZT rice	Direct wet sowing	Manual transplanting	Mechanical transplanting
Labour for raising nursery (hours/ha)	-	-	86	72
Labour for sowing/T/P (hour/ha)	15	70	610	24
Saving (%) in time by use of different transplanter / seeder over manual T/P	96.0	88.0	-	94.0
Cost of sowing/T/P including cost of nursery raising (Rs/ha)*	2250	4360	12350	3450
Saving (%) in cost by use ofZT, drum seeder, MT over manual T/P	81	64.6	-	72.06
*Based upon fuel consumption and man-hours required ZT- Zero tillage, MT- mechanical transplanter/ing, T/P- transplanting				

Effect of Sowing Methods in Wheat

Yield and yield attributes

Sowing of wheat by Turbo Happy seeder produced significantly higher effective tillers/m^2, number of grains/ear than zero tilled wheat of manual line sowing wheat (Table 5). However, different sowing methods remained statistically at par with regard to test weight (100 grains). Further, wheat crop sown through Turbo Happy seeder produced maximum grain yield (43.8q/ ha) and straw yield (567.8q/ha) over other methods of wheat sowing. Zero tilled wheat and manual line sowing of wheat had been found statistically at par in respect of all yield attributes and grain as well as straw yields. The higher yield in case of Turbo Happy seeder sown wheat may be due to incorporation of straw of previous crop (rice) in the field which acted as mulch and provided better soil moisture and optimum temperature to the crop throughout whole crop cycle (Sidhu *et al.*, 2007). Unpuddled mechanical transplanted rice and zero-tilled rice plots resulted in the maximum grain (45.6q/ ha) and straw yields (56.0 q/ha) of wheat. The better performance of wheat on plots followed by unpuddled mechanical transplanting of rice and zero-tilled rice can be attributed to its effect on providing ideal seedbed and soil environments for wheat which resulted in better growth and yield of wheat crop (Erenstein *et al.*, 2008).

Output: Input ratio

Different sowing and transplanting methods of rice had also influenced the output: input ratio of succeeding wheat crop (Table 5). Unpuddled mechanical transplanting of rice produced significantly maximum output: Input ratio (2.1) and was closely followed by zero tilled rice plots (2.1) which were found statistically at par with each other. Manjunatha *et al.*(2009) also made similar observations. Straw yields obtained from manual transplanted plots were found as most uneconomical (Singh and Rao, 2012). Turbo Happy seeder resulted in the maximum output: input ratio (2.1) over zero-till-drill wheat (1.8) and manual line sowing (1.4). This may be due to the fact that in case of sowing through Turbo Happy seeder straw of previous crop acted as mulch and created favorable condition for wheat crop throughout the crop cycle by providing optimum soil

Table 5: Effect of sowing method and tillage on yield attributes, yield and output: input ratio of rice and wheat (pooled data of 2011-14)

Treatments	Effective tillers/m^2	Filled grains/ panicle	Test wt. (g)	Grain yield (q/ha)	Straw yield (q/ha)	Output: input ratio
Sowing/Transplanting (rice)						
ZT rice	231.0	35.2	40.9	35.1	53.7	1.6
Direct wet sowing	213.6	29.8	40.2	34.1	53.4	1.4
Manual transplanting	241.2	30.6	41.2	45.6	56.0	2.1
Mechanical Transplanting	240.6	29.9	41.2	44.2	54.8	2.0
CD (P= 0.05)	8.9	3.23	NS	1.2	NS	0.35
Sowing of wheat						
Manual line sowing	218.2	28.2	40.6	38.2	52.5	1.4
Turbo Happy Seeder	243.5	34.5	41.2	43.8	57.8	2.1
Zero -till -drill	230.8	31.3	40.8	39.4	54.1	1.8
CD (P= 0.05)	11.8	2.8	NS	2.8	3.0	-

moisture and temperature resulting higher grain and straw yieldbesides lesseningthe cost of cultivation by Rs. 8,800/ha.

Comparison between different Methods of Sowing

Zero tillage covered the maximum area (2500 m^2/labour/hour) followed by Turbo Happy Seeder (1690 m^2/labour/hour), while manual line sowing of wheat resulted in least efficient method (32 m^2/labour/hour) as indicated in Table 6. In comparison to line sowing by manual, zero seed drill and Turbo Happy Seeder saved about 99.2 and 98.8% time as well as 66.6% and 56.2% cost of cultivation, respectively. Conventional tillage (manual line sowing), as it involved repeated ploughing and also resulted in delayed sowing by two weeks as compared to zero seed drill and Turbo Happy Seeder, resulted in least efficient and uneconomical method of wheat sowing due to lesser returns and more cost of cultivation.Similar observation was also made by Sidhu *et al.*,(2007).

CONCLUSION

On the basis of findings, it is imperative to conclude that zero tillage/reduced tillage- conventional tillage scenario (ZT-CT) or vice- versa provides better soil physical condition in terms of bulk density and penetration resistance etc.under rice- wheat cropping system. Further, the same scenario also provides better crop yields and maximum returns. Mechanical sowing of wheat either by Turbo Happy seeder or Zero- till –drill proved its utility by providing better returns and reduced cost of cultivation by Rs. 8,000- 10,000/ha. Unpuddled mechanical transplanting of rice and ZT rice has also emerged as better option to solve the issue of labourcrisis in agriculture and water requirement under rice- wheat cropping system.

Table 6: Saving in time and cost of sowing in wheat under different tillage practices

Treatments	**Manual line sowing**	**Turbo Happy Seeder**	**Zero- till- drill**
No. of labours for sowing	32	4	4
Capacity (m^2/hour/ha)	35	1690	2500
Earliness in sowing through THS and ZTD over MLS	-	14	14
Saving (%) in time by THS	-	98.8	99.2
Cost of sowing (Rs/ha)	4,800	3000	2000
Saving (%) in cost of sowing over MLS	-	56.2	66.6
Overall cost of cultivation including all other expenses	22,300	13,500	12,500

Note: MLS- manual line sowing, THS- Turbo Happy Seeder, ZTD- Zero- till- drill; Rate: labour/day (8 hours): Rs. 150

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Correct Citation: Kumar S, Shivani, Kumar U and Manibhushan.2014. Productivity and Economics of Rice-Wheat Cropping System as Affected by Methods of Sowing and Tillage Practices in the Eastern Plains.*Journal of AgriSearch***1**(3) : 145-150