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Effect of tillage and sowing methods on productivity, economics and energetics of rice (*Oryza sativa*)-wheat (*Triticum aestivam*) cropping system

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ABSTRACT

Field experiments were carried out from 2004-05 to 2008-09 at Jabalpur, Madhya Pradesh to evaluate the four tillage practices (direct seeding in dry fields, direct seeding of sprouted seeds in puddled field by drum seeder, manual transplanting, and mechanical transplanting) in rice and four sowing methods (conventional till sowing, zero till sowing, strip till sowing and bed planting) in wheat on productivity, economics and energetics of rice (*Oryza sativa* L.) - wheat (*Triticum aestivam* L. emend. Fiori & Paol.) cropping system. Direct seeding of sprouted seeds in puddled field by drum seeder gave significantly higher grain yield of rice (5.70 t/ha), followed by direct seeding under dry field (5.32 t/ha) and mechanical transplanting (5.21 t/ha), whereas the lowest yield was recorded in manual transplanted rice (5.11 t/ha). The wheat sown after dry seeding of rice in dry field produced significantly higher grain yield (4.26 t/ha) than other sowing methods of rice. In wheat, strip till drilling recorded the highest values of yield attributing characters and grain yield (4.56 t/ha) than other methods of sowing. Consequently, strip till sown wheat after preceding rice grown under direct seeding of sprouted seeds in puddled field by drum seeder produced higher combined grain yields for entire cropping system in rice equivalent yield (11.88 t/ha), net monetary returns (₹49,116/ha) and B: C ratio (3.2), when compared with other methods of sowing . Moreover, direct seeding of sprouted seeds of rice followed by strip till sowing of wheat gave higher water productivity and energetics than that of other combinations of tillage and sowing methods by ensuring timely and cheep sowing without sacrificing the crop yields.

***Key words**:* Economics, Energetics, Productivity, Rice-wheat system, Sowing methods, Tillage

Rice–wheat cropping system is mainly distributed in Indo-Gangetic Plains (IGP) by covering nearly 10.5 mha area in north-west, north-east and central India adjoning to Indo-Gangetic Plains (Gopal *et al.,* 2010). Both crop components of this cropping system are fertility exhaustive and need more water, labour, time, non-renewable energy, heavy farm machineries and costs for their successful cultivation. Rice is grown by transplanting method to realize good yields and manage weed. But weed management is most serious constraint in direct seed rice (DSR). The land preparation to grow transplanted rice is not only tedious, costly and time consuming, but it also deteriorates the soil-properties due to formation of compacted hard soil surface. Continued puddling over decades has led to deterioration of soil physical properties through structural breakdown of soil aggregates and capillary pores; and clay dispersion (Giri et *al.,* 1993). Puddling forms the compacted layers in plough pan zone of soil that restrict the percolation of water-causing water logging and also restrict the root penetration and growth of succeeding crop after rice. Therefore, it is imperative that alternate method of growing crops that are more water efficient and less labour intensive to be developed to enable farmers to produce more with less cost of production. Huge labours are needed to accomplish transplanting of rice seedlings and mostly it is delayed to a greater extent due to unavailability of adequate labours during transplanting peak. Thus, the late planted rice takes more time to reach maturity, which not only reduces the rice yield, but also delays the sowing of succeeding crop particularly wheat. Simultaneously, intensive tillage operations are required with the use of heavy tillage farm machineries to obtain the desirable seed bed for growing succeeding wheat and many times frequent breakdown in farm machineries also poses serious problem in land preparation for timely sowing of succeeding crops (Gopal *et al.,* 2010). Conventional methods of wheat sowing, which requires excessive tillage delays sowing and reduce the yield, but the same can be accomplished efficiently with use of improved machines *viz.,* zero till seed drill, rotary seed drill and bed planter etc. to save the

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time, diesel, energy and cost (Jha *et al*., 2007). It is therefore, imperative to identify and quantify the suitable tillage and planting management for both the crop components under widely spreaded rice-wheat cropping system, which can minimize the consumption of time, energy, money and labour with sustainable productivity of entire cropping system in vertisols of Kymore Plateau and Satpura Hills zone of Madhya Pradesh on a long-term basis. Keeping these points in view, the present investigations were undertaken.

MATERIALS AND METHODS

The field experiments were carried out at Krishi Nagar Research Farm, J.N. Krishi Vishwa Vidayalya, Jabalpur, (M.P.) continuing 5 years, from 2004-05 to 2008-09. The soil of the experimental field was sandy clay loam in texture and neutral in reaction (7.4) and low in organic carbon contents (0.68%) and analyzing medium in available N (250 kg/ha), P (12.5 kg/ha) and high in available K (308 kg/ha) contents. Sixteen treatments consisted with 4 tillage and planting management for both crop components under rice-wheat system were tested in strip plot design with 3 replications. Tillage and sowing methods were P_1- direct drilling in dry field, P_2-direct seeding of sprouted seeds through drum seeder in puddled field, P_3-manual transplanting and P_4-transplanting through self propelled transplanter (SPT) for rice 'Kranti' and T_1-conventional tillage sowing, T_2-zero till sowing, T_3 -strip till sowing and T_4-bed planting for wheat 'GW-273'. Sowing of rice, *viz.* direct drilling in dry field before onset monsoon (P_1), sowing in nursery to get seedlings for transplanting (P_3 and P_4) and soaking of seeds to obtain sprouted seeds (P_2) was done on the same day. The seed rate 100 kg /ha for direct seeding in dry field and 50 kg /ha for direct seeding of sprouted seeds through drum seeder in puddled field where as 30 kg seeds/ha was use only for both manual transplanting and transplanting through self propelled transplanter. Tillage operation in direct seeding in dry field were once with cultivator, twice harrow followed by planking and for transplanting methods and direct seeding of sprouted seeds through drum seeder in puddle soil consisted of one cultivator, 2 puddling and 1 planking. Twenty one-days-old seedlings were used for manual transplanting and transplanting through SPT. The seedlings were raised on mat type nursery for transplanting through SPT. Butachlor @1.5 kg/ha was applied as pre-emergence for weed control in rice. This was supplemented with hand weeding twice at 20 and 40 days in direct seeding in dry field plots, whereas one hand weeding was done at 40 days after in puddled condition field. All the direct seeded plots received frequent irrigation to keep the soil wet. After harvesting of rice, a pre–sowing irrigation was given to the all the plots to ensure optimum moisture for sowing of wheat. Wheat was sown by different methods immediately after harvesting preceding rice. The conventional sowing and bed planting in wheat involved 1 cultivator, 2 harrows and 1planking. Under zero till and strip till sowing of wheat was done directly without land preparation. For weed control in wheat, Isoproturon 1 kg ai+ 2,4-D 0.5 kg/ha was sprayed after 35 days of sowing. A uniform dose (120 kg N+ 60kg P_2O_5+40 kg K_2O/ha) of fertilizers was applied to both crops along with other agronomic practices. The consumptive use of water calculated by Dastane, (1972) and water productivity was calculated by Y/CU where Y- Yield CU- Consumptive uses of water. The economics and energy requirements for all the treatments were calculated for the growing periods. For calculating the energy input and output through different power sources, *viz.,* labour, fuel, machinery, fertilizer, seeds, pesticides, irrigation and crop yield were calculated by standard energy coefficient given by Mittal and Dhawan (1988). Then sustainable yield index was determined by using the formula as suggested by Wanjari *et al.,* (2004).

RESULTS AND DISCUSSION

Rice

Yield attributes and grain yield of unhusked rice were differed significantly by various rice-establishment methods (Table 1). The highest pooled yield (5.70 t/ha) was recorded with drum seeding (puddled), followed by direct seeding under dry field and mechanical transplanting than manual transplanting. Higher grain yield under drum/direct seeding rice was mainly due to higher plant population, more number of effective tillers/m^2 and good weed management practices adopted under direct seeding rice in dry field (Gopal *et al.,* 2010). The data showed that effective tillers/m^2 significantly differed among different seeding/planting method of rice, but other parameters were at par among them. Direct seeding of sprouted seeds by drum seeder led to record maximum number of effective tillers/m^2 (324) followed direct seeded rice (312), transplanting by SPT (300) and manual transplanting (294). The overall performance of rice grown by drum seeding/ direct seeding in dry bed was better than transplanted rice either mechanical or manual. The residual effect of the various sowing methods of wheat during the previous years on the grain yield of rice in every year was not significant (Table 3).

Wheat

Yield attributes and grain yield of wheat were influenced significantly due to different conservation establishment methods was applied in preceding rice (Table 2). Effective tillers /m^2 and grains yield were recorded to be significantly higher when wheat was grown in unpuddled rice field than after direct seeding of sprouted rice and both transplanted rice under puddled condition. This was mainly attributable to relatively greater compaction of soil under direct seeding of sprouted rice, manual and mechanical transplanted rice (Gangwar *et al.,* 2010). The better growth parameters and yield attributes of wheat under direct seeded rice on dry field were attributed its effect on providing ideal seed bed for wheat sowing which resulted in higher growth and yield of wheat (Gangwar *et al.,* 2008). Irrespective of the various methods in rice, sowing of wheat by strip till drill significantly increased number of effective tillers /m^2, grains/spike and grain yield as well as straw yield over other methods. The germination of seeds was not uniform under other methods of sowing which resulted into lesser tillers counts /m^2. The variation between conventional till sowing and zero till sowing of wheat was not significant because of similarity in yield attributing characters. Bed planting significantly produced the lowest grain yields due to less plant population.

Rice – wheat system

Total productivity of rice-wheat system as a whole was determined in rice equivalent yields (REYs) for all treatments. Direct seeding of sprouted rice gave the highest system productivity (11.26 t/ha/yr) and proved significantly better than other two methods of establishment (Table 4). The next best treatment was direct seeding in dry field (11.25 t/ha/yr). The latter two crop establishment methods manual and mechanical transplanted rice statically at par with each other, resulted in the lowest rice equivalent yield due to lower grain yield of rice and wheat than former two. These observations were in agreement with finding of Gangwar *et al.,* (2010). In wheat, strip till sowing produced significantly maximum REYs (11.88 t/ha/yr) among all sowing methods, while bed planting – T_4 led to record minimum REYs (10.65 t/ha/yr). The REYs were comparable with conventional till sowing -T_1 (11.20 t/ha/yr) and zero till sowing-T_2 (11.02 t/ha/yr). Similar findings were reported by several workers from their studies in different rice – wheat growing areas of the country (Jha *et al*., 2007).

Table 1. Yield and yield attributes of rice as affected by different tillage and sowing management.

Tillage and sowing methods	Effective tillers/ m^2	Panicle length (cm)	Grains/ panicle	Test weight (g)	Days taken to maturity (days)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
Direct drilling in dry field	302	20.9	90	25.6	115	5.32	7.22	41.0
Direct seeding of sprouted seeds in puddled field	322	21.8	98	25.9	118	5.70	7.58	42.2
Manual Transplanting	294	21.6	85	24.2	130	5.11	6.94	40.7
Mechanical transplanting	300	20.6	86	25.2	130	5.21	7.03	42.5
SEm±	2.8	0.8	1.0	0.7	-	0.02	0.02	0.9
CD (P=0.05)	8.4	NS	3.2	NS	-	0.04	0.05	NS

Table 2. Yield and yield attributes of wheat as affected by different tillage and sowing management.

Tillage and sowing methods	Effective tillers/ m^2	Spike length (cm)	Grains/ spike	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
Rice							
Direct drilling in dry field	230	9.8	47.5	42.1	4.26	6.28	40.41
Direct seeding of sprouted seeds in puddled field	215	9.6	46.0	41.5	4.10	6.18	39.41
Manual transplanting	210	9.2	46.2	41.7	4.02	6.20	39.92
Mechanical transplanting	214	9.6	46.9	41.4	4.08	6.12	39.70
SEm±	2.4	0.4	0.6	0.4	0.01	0.04	0.9
CD (P=0.05)	7.3	NS	NS	NS	0.02	NS	NS
Wheat							
Conventional till sowing	224	10.2	42.4	41.4	4.13	6.14	40.79
Zero till sowing	222	10.4	41.6	41.2	4.08	6.02	40.08
Strip till sowing	238	10.6	46.8	41.2	4.56	6.64	40.71
Bed planting	214	10.7	40.2	41.3	3.82	5.69	40.16
SEm±	2.1	0.4	0.34	0.4	0.03	0.02	0.5
CD (P=0.05)	6.4	NS	1.8	NS	0.07	0.04	NS

Production efficiency and sustainable index

Production efficiency refers to per day productivity of entire cropping system under a particular treatment. Thus, production depend on the quantum of total production as well as duration of total crop period under a particular treatment. Direct seeding of sprouted seeds through drum seeder had the highest production efficiency (46.23 kg/ha/day) closely followed by direct seeding in dry field (45.77 kg/ha/day) and these two sowing methods of rice had significantly higher production efficiency than transplanting of seedlings by SPT (42.45 kg/ha/day) and manual transplanting (42.13 kg/ha/day). Similarly, strip till sowing of wheat had significantly maximum production efficiency, which reduced as 44.87, 43.26, 41.24 kg/ha/day due to conventional till sowing, zero till sowing and bed planting, respectively. The variations in production efficiency between conventional till sowing and zero till sowing of wheat following to all sowing methods of rice were also not significant. The wheat crop grown under different sowing methods required almost similar time with increased production under strip till sowing methods; therefore rice- wheat system associated with strip till sowing of wheat resulted in to higher production efficiency. Similarly DSR and direct seeding of spouted rice seeds produced numerically higher grain yield than transplanted rice and former two sowing methods of rice needed about a week lesser duration to complete the life-cycle of rice (Gill *et al.,* 2008). The sustainable yield index (SYI) values were determined on the basis of total productivity of entire rice-wheat system for 5 years under each treatment. The DSR and direct seeding of sprouted rice seeds by drum seeder being at par had maximum SYI (0.75), which reduced as 0.74 and 0.73 under transplanting by SPT and manual transplanting , respectively (Table 4). Thus, the yields of that direct seeded rice in dry fields as well as direct seeding of sprouted rice seeds were proved to be more sustainable for the productivity of rice – wheat system than growing of rice by transplanting methods. The SYI was maximum with strip till sowing of wheat among all sowing methods, which remarkably reduced as 0.73, 0.73 and 0.70 owing to conventional till sowing, zero till sowing and bed planting , respectively.

Water productivity

Water is natural resources and its scarcity is being seriously felt in agricultural sector. Both rice and wheat require high quantity of water for their successful cultivation. The consumptive use of water (CUW) to grow these crops could be minimized to a considerable extent by adopting adequate tillage operation with proper sowing methods of these crops. The CUW was minimum (171.12 cm) with direct seeding in dry field but water productivity

Table 3. Yearly rice and wheat grain yield under different treatments (2004-05 and 2008-09)

Tillage and sowing methods	Rice grain yield (t/ha)						Wheat grain yield (t/ha)					
	2004-05	2005-06	2006-07	2007-08	2008-09	Mean	2004-05	2005-06	2006-07	2007-08	2008-09	Mean
Rice												
Direct drilling in dry field	5.15	5.37	5.42	5.22	5.42	5.32	4.31	4.02	4.41	4.34	4.24	4.26
Direct seeding of sprouted seeds in puddled field	5.65	5.58	5.75	5.81	5.70	5.70	4.08	4.12	4.11	4.05	4.15	4.10
Manual transplanting	5.03	5.21	5.02	5.20	5.11	5.11	3.94	4.11	3.98	4.00	4.05	4.02
Mechanical transplanting	5.03	5.08	5.34	5.27	5.31	5.21	4.06	4.09	4.12	4.07	4.08	4.08
SEm±	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.02	0.01
CD (P=0.05)	0.05	0.04	0.06	0.05	0.06	0.04	0.03	0.04	0.04	0.03	0.04	0.02
Wheat												
Convention till sowing	5.28	5.29	5.34	5.36	5.31	5.32	4.08	4.15	4.18	4.05	4.20	4.13
Zero till sowing	5.30	5.28	5.32	5.30	5.33	5.31	3.98	4.11	4.12	4.02	4.16	4.08
Strip till sowing	5.36	5.39	5.40	5.42	5.38	5.39	4.42	4.54	4.60	4.63	4.59	4.56
Bed planting	5.27	5.31	5.32	5.35	5.34	5.32	3.90	3.72	4.05	3.14	3.70	3.82
SEm±	0.03	0.04	0.04	0.03	0.04	0.04	0.02	0.03	0.03	0.02	0.04	0.03

was quite higher under direct seeding of sprouted rice (Table 4). Direct seeding of sprouted rice had greater total productivity of cropping system as a whole in REYs with almost similar quantity of the CUW. Strip till wheat sowing following to rice grown under different methods had significantly higher water productivity than other sowing methods of wheat except to conventional till sowing. The maximum grain yields of wheat under strip till among all sowing methods may be the probable reason for such maximum water productivity with it. Though the CUW was minimum with bed planting, its lowest grain yields might have resulted into minimum water productivity. Several research workers have emphasized similar opinions with regard to conservation on water (Maurya and Singh, 2008).

Economics

Economic analysis of the treatments showed relevance to consider the practical adoptability of a particular treatment from the farmers point of view. Direct seeding of sprouted rice gave maximum benefit: cost ratio and net income, hence proved more remunerative than the other methods of establishment (Table 4). The next best treatment was direct seeding in dry field .This was ascribed to higher grain yield and minimum cost of production. The manually transplanted rice fetched the minimum net monetary returns (NMRs) and B:C ratio of entire rice-wheat system mainly due to higher cost of cultivation involved with it mainly for the employment of huge man power (Jha *et al.,* 2007). Among different tillage and sowing methods of wheat, strip till sowing led to record significantly maximum NMRs (₹49,116/ha/yr) and B:C ratio (3:2) mainly by fetching maximum gross monetary returns with the considerably low cost of investment. The next sowing method of wheat was zero till sowing with NMRs of ₹45,695/ha/yr and B:C ratio (3.0) followed by conventional till sowing (₹44,509/ha/yr) and bed planting (₹ 42,037/ha/yr). Though conventional till sowing of wheat fetched higher GMRs than zero till sowing and bed planting but the position of NMRs and B: C ratio reversed for them because of more cost of investment required under conventional till sown wheat than zero till sown and bed plating wheat.

Energetic

The comparison of energy use pattern (Table 4) in different crop establishment methods of rice revealed that the highest input energy were (42,563 MJ/ha) consumed in manually transplanted and closely followed by mechanically transplanted rice (41,758 MJ/ha) and direct seeding of sprouted rice (41,758 MJ/ha). The lowest energy was consumed under direct seeding of rice in rice field (39,514

Table 4. Total productivity, water productivity, economics and energetics of rice-wheat system as affected by different tillage and sowing management.

Tillage and sowing methods	Rice equivalent yield (t/ha)	Consumptive use of water (cm/ha)	Water productivity (kg/ha/cm)	Production efficiency (kg/ha/day)	Sustainable index	Gross monetary returns (₹/ha)	Net monetary returns (₹/ha)	B:C ratio	Energy input (MJ/ha)	Energy out (MJ/ha)	Energy use efficiency
Rice											
Direct drilling in dry field	11.25	171.45	65.78	45.77	0.75	66,264	43,826	2.8	39,514	2,24,457	5.6
Direct seeding of sprouted seeds	11.46	175.47	65.32	46.23	0.75	68,703	47,373	3.2	41,634	2,29,869	5.5
Manual Transplanting	10.96	176.32	61.34	42.13	0.73	64,563	41,364	2.1	42,563	2,10,078	4.9
Mechanical transplanting	11.05	175.50	62.99	42.45	0.74	68,772	44,325	3.1	41,785	2,24,104	5.3
SEm±	0.03	0.9	0.6	0.4	-	628	509	-	-	-	-
CD (P=0.05)	0.06	2.7	1.8	1.3	-	1,884	1,529	-	-	-	-
Wheat											
Conventional till sowing	11.15	175.45	64.14	44.87	0.73	67,754	44,509	2.7	42,169	2,22,191	5.2
Zero till sowing	11.08	174.46	62.16	43.26	0.73	67,124	45,695	3.0	35,942	2,21,829	6.1
Strip till sowing	11.88	175.01	67.87	47.26	0.81	71,251	49,116	3.2	36,140	2,20,664	6.0
Bed planting	10.65	170.34	61.83	41.34	0.70	65,184	42,037	2.9	36,582	2,19,174	5.9
SEm±	0.01	0.8	0.7	0.8	-	741	623	-	-	-	-
CD (P=0.05)	0.05	2.4	2.1	2.5	-	2,223	1,871	-	-	-	-

MJ/ha). However, the output energy was highest in drum seeded rice (2,29,869 MJ/ha) closely followed by direct seeded rice (2,24,457 MJ/ha) and lowest was (2,10,078 MJ/ha) in manual transplanted rice. Similarly, conventional till sown wheat consumed the highest total energy (42,169 MJ/ha) among all tillage and sowing methods. Other tillage and sowing methods of wheat consumed almost equal energy ranging between 35,942 and 36,140 MJ/ha. The higher energy consumption under conventional till sowing when compare with zero till sowing and strip till sowing due to more tillage operation (Jain *et al.,* 2007). The energy use efficiency was maximum (5.6) by growing rice through direct seeding in dry fields closely followed by direct seeding of sprouted rice seeds through drum seeder (5.5), transplanting through SPT (5.3) and manual transplanting (4.9) in descending order (Table 4). Similarly, zero till sown wheat had maximum energy use efficiency (6.1) closely followed by strip till sowing was (6.0) and bed planting (5.9), but conventional till sowing had significantly minimum energy use efficiency (5.2). The higher energy use efficiency under a particular tillage and sowing method of a crop was mainly attributed to higher energy production with the use of relatively lesser energy utilization.

Thus it was concluded that direct seeding of rice in dry field and strip till for wheat are best tillage and sowing method for higher yield and profitability.

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