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Research Article

CROP ESTABLISHMENT, TILLAGE AND WATER MANAGEMENT TECHNOLOGIES ON CROP AND WATER PRODUCTIVITY OF RICE CULTIVARS IN WESTERN UTTAR PRADESH

***Sanjeev Kumar[1], Om Pal Singh[1], R.K. Naresh[2], Sarita[1] and Sheeshpal Singh[2]**
[1]*JV College, Baraut, CCS University, Meerut*
[2]*SVPUniversity of Agriculture & Technology, Meerut, Uttar Pradesh*
**Author for Correspondence*

ABSTRACT
Rice receives a large amount of water during land preparation and the growing period, causing poor crop water productivity and lower net benefits. Over exploitation of ground and surface water resources is a major threat to the sustainability of rice production in western Uttar Pradesh. The rice system in this region is critical for food security of the ever increasing population in India. However, yields are stagnating or declining in association with degradation of the soil and ecological imbalance as a result of sub-optimal cropping practices, which also create considerable air pollution (particulates, greenhouse gases) and water pollution. Many resource conserving technologies have been developed for system with many potential benefits including improved soil fertility, more efficient use of inputs, reduced environmental pollution, and greater profitability for farmers. Many of these technologies also lead to substantially reduced irrigation applications at the field level, and there is much belief that widespread adoption of such technologies "saves" water and will help halt the decline in groundwater tables.
This paper reviews the irrigation water savings associated with a range of technologies, the partitioning of the irrigation water savings across components of the water balance, and the potential of these technologies to reduce net water depletion from the system and thus provide "real" water savings. Dry seeding of rice can be expected to reduce water inputs and tillage costs compared with the conventional system of rice cultivation. The yields of rice in conventional puddled transplanting were higher as compared to, unpuddled transplanting, reduced-till transplanting, and direct-seeding systems. Rice varieties PusaSugendha-4 and PusaSugendha-5 performed better under alternative tillage and crop establishment methods. The dry-direct seeding of rice crop had a savings in labor and machine use. Zero-tillage transplanted and reduced till dry-direct-seeded rice had a higher net return than the conventional and unpuddled system. Our study showed that the conventional practice of puddled transplanting could be replaced by unpuddled and reduced tillage–based crop establishment methods to save water and labor and achieve higher income.

Key Words: *Resource-Conserving Technologies, Crop Establishment Methods, Tillage, Water Productivity*

INTRODUCTION
The rice-wheat (RW) system is one of the largest and most important agricultural production systems in Asia, occupying about 18 million ha, of which 13.5 million ha are in the Indo-Gangetic Plains (IGP) of India, Pakistan, Bangladesh, and Nepal (Ladha *et al.*, 2000).This system provides livelihoods for 1.8 billion people (FAO1999).The South Asian population still increases around 2% annually, land and water resources available for rice and wheat cultivation are declining rapidly, and farmers are losing interest in RW farming because of decreasing profits. Increasing the yield per unit of inputs used, especially land, water, fertilizer, and labor, is a must to produce more food (Bhushan *et al.*,2007).Improvement of water-use efficiency in rice production is becoming very important with the increasing demand for irrigation water and increasing costs of the development of new water resources for irrigation (Tabbal *et al.*,

2002).Traditionally in this region, farmers grow rice in the wet (monsoon) season after intensive dry and wet tillage (puddling). But the traditional tillage and crop establishment methods create problems in maintenance of soil structure, and management of irrigation, weeds, and other pests, fertilizers and crop residues (Rao *et al.,* 2007). Puddling reduces weed competition and water losses but destroys soil structure and creates a hard pan at shallow depth and consumes a large quantity of water (Sharma *et al.*, 2002). Conventional practices have further led to (1) a decline in soil carbon to as low as 0.2, (2) an increase in soil compaction, and (3) creation of a hard pan (Sharma *et al.*, 2002). Rice is the largest user of fresh surface water bodies and has led to an increase in tube wells of 480% in the past four decades in the region (Central Groundwater Board, Northwestern Region,). Poor-quality irrigation systems and a greater reliance on ground water have led to problems of waterlogging, salinity, sodicity, hydraulic imbalance and water-table decline of 0.1 to 1.0 m y^{-1} in the western IGP, resulting in a scarcity and higher cost of pumping water (Harrington *et al.,* 1993, Sondhi *et al.,* 1994). Moreover, timely labor availability and increasing labor costs are becoming a serious concern for the timely planting of crops (Ladha *et al.*, 2003). In the changing climatic conditions, increased night temperature at the flowering stage causes spikelet sterility in rice and a reduction in yield of about 5% per degree Celsius rise above 32^0C (Peng *et al.*,1999). The luxurious environment of excessive nitrogen and moist conditions provides a paradise for insect pests and diseases in the region and also decreases input-use efficiency. Evaluation and promotion of integrated crop and resource management in the rice crop in western Uttar Pradesh. Total factor productivity (TFP) has declined by 50% in the region and a shift in weed flora and herbicide-resistant weeds are some of the major causes of the decline in TFP (Naresh *et al.,* 2011). Problems in the rice crop have been further intensified by planners and policymakers who have provided high subsidies for power, fertilizer and irrigation. This has not only led to an overuse of these resources, but has also discouraged voluntary crop diversification. Despite the ecological damage, farmers continue to grow rice due to government support in terms of an assured minimum price for crops, ever-increasing demand, mechanization of the system, and assured irrigation. But concerns are growing about the sustainability of the rice yields are either stagnant or declining.

The North West India, which serves as India's food basket, may become food-insecure in the near future. Therefore,the need is urgent to develop innovative alternative strategies for the future transformation of the irrigated rice system toward improved practices, ones that (1) are more resource-use-efficient, (2) lead to food security, (3) are economically sustainable and (4) help in adaptation to climate change. Conservation agriculture CA)–based resource-conserving technologies (RCTs) include any new technologies (cultivars; more efficient implements; reduced or minimal tillage; soil, water, and crop management practices) that are more efficient, use less inputs, improve production and income and attempt to overcome emerging problems (Gupta and Seth 2007). RCTs involving no or minimum tillage with direct seeding, and bed planting; innovations in residue management to avoid straw burning; and crop diversification need to be advocated as alternatives to the conventional rice system for improving productivity and sustainability (Gupta *et al.,* 2003). Alternative methods have been proven effective to sustain soil health and reduce water demand in the rice crop in on-station trials in different agro ecological regions by many scientists (Ladha *et al.*, 2003; Naresh *et al.*, 2010).But the application of these new tillage and crop establishment methods needs to be tested on a wider scale for water, labor and energy efficiency in farmer-managed trials. Therefore, systematic studies were conducted with a wider approach of on-station trials to develop and accelerate productivity-enhancing, input (water, labor, and energy)-efficient, soil- and environment-friendly, and profitable RCTs in the western Uttar Pradesh.

MATERIALS AND METHODS

The field experiment was conducted on different crop establishment techniques i.e. transplanted rice on flat bed, raised bed (Table 1) at farmer field in Ramraj, under Chaudhary Charan Singh University, Meerut, (Uttar Pradesh), India (29°4'N, 77°46'E, 237 m above sea level), during kharif, 2009 & 2010. The water table depth of the experimental sites is 07 m with very good quality of water. The climate of the region is broadly classified as semi-arid subtropical, characterized by very hot summers and cold winters.

Table 1: Description of technological options during crop season

Name	Abbreviation	Brief Description	Benefits	Limitations
Conventional till (puddled) transplanted rice	CTTPR	Land is plowed, puddled and leveled; 21- 30dold seedlings are transplanted at random or in rows.	Good water retention due to plow pan; fewer weeds; sustainable.	Time Consuming; labor intensive; delays wheat seeding in RW system; destroys soil structure.
Reduced till (nonpuddled) dry drill seeded rice	RTDSR	Dry seeds are drilled in rows by a zero till fertiseed drill at 2–3cm depth in a well prepared moist soil and leveled, followed by one light irrigation applied for good germination.	Reduced tillage; faster crop establishment; allows timely planting; less labor; easy to weed between rows; good soil structure due to no puddling.	Heavy weed infestation Requiring chemical weed control.
Reduced till (nonpuddled slit opened) transplanted rice	RTTPR	2–3 dry tillages followed by planking/ leveling and ponding water but without puddling; 21–30dold seedlings are transplanted at random or in rows.	Reduced tillage; good soil structure due to no puddling.	Time consuming; labor-intensive; difficult to plant manually; weed pressure.
Raised bed transplanted rice	Bed TPR	A bed former cum drill seeder is used to form 37cmwide raised beds and 30cmwide furrows in well prepared, pulverized soil. Then, 21 d old seedlings are planted on both sides of moist beds. Furrows are kept flooded for up to 21 DAT.	Good crop stand; good drainage; saving in water; facilitates mechanical weeding.	More weeds micronutrient deficiency; termite problems; labor intensive.

The hottest months are May and June when the maximum temperature reaches 41–45°C, while in December and January, the coldest months of the year, the minimum temperature often goes 4°C and relative humidity of 67-83% during the year. Average annual rainfall is 805 mm, 80% of which is received through the north-western monsoon during June–September. The mean relative humidity varied from 21.57 to 91.57 per cent in 2009 and from 18 to 92 per cent in 2010.The soils are generally sandy loam to loam in texture and low to medium in organic matter content, low in available nitrogen, medium in available phosphorus and low in available potassium.120 kg N, 60 kg P_2O_5, 40 kg K_2O, and 20 kg $ZnSO_4$ ha^{-1} was applied. Half dose of N and full doses of P, K, and Zn was applied as basal and remaining N was applied in two equal splits.

Economic Analysis

The cost of cultivation was calculated by taking into account costs of seed, fertilizers, biocide, and the hiring charges of labor and machines for land preparation, irrigation, fertilizer application, plant protection, harvesting, and threshing, and the time required per hectare to complete an individual field operation. Cost of irrigation was calculated by multiplying time (h) required to irrigate a particular plot, consumption of diesel by the pump (L h^{-1}) and cost of diesel The prices of human and machine labor, and diesel are their current prices in north India collected by market survey. Gross income was the minimum support price offered by the Government of India for rice. Net income was calculated as the difference between gross income and total cost.

RESULTS AND DISCUSSION

Yield Attributes

The panicle length increased with the improvement in moisture supply (i.e. RCT's technologies) the crop planting in various geometry mode (Table 2), accordingly irrigation applied and the crop receiving irrigations at T_1 and T_3 treatments performed greater panicle length as compared to T_2 and T_4 treatments. However, most of the treatments were significant. The differences in the panicle length per plant treatments T_1 perform significantly longer panicle length as compared to T_2 , T_3 and T_4 treatments which was statistically at par with various sowing techniques. However, the differences among the treatments T_1 and T_3 were non-significant, respectively during both the years. Among the varieties Sugandha-4 (V_3) and Sugandha-5 (V_4) were recorded longer panicle length than rest of the cultivars during both the years.

The number of grains per panicle due to sowing techniques treatments was found to be significant (Table 2).In general; number of grains per panicle in treatments T_1 was significantly more as compared to other treatments. However, the differences among T_1, T2, andT_3 treatments were significant in both the years. More number of grains was recorded during the second year as compared to the first year. Varietal differences were significant for grains panicle^{-1} during both the years. Varieties Sugandha-4(V_3) Sugandha-5 (V_4) recorded 164 and 170 grains panicle^{-1} each during 2009 as against 168 and 174 during 2010.

The thousand grain weight varied from 24.58 and 27.29 gm in treatment (T_1) to 24.48 and 27.17 in the treatment (T_3). Most of the treatments (T2 and T_3) recorded thousand grain weights at par with T_1. Treatment T_1 was slightly superior over T2, and T_4. Treatments T_1 and T_3 were at par with each other, but superior over T_4 with respect to 1000 grain weight during both the years (Table 2). Among the varieties Sugandha-2 (V_1) and Sugandha-3 (V_2) were recorded higher grain weight than rest of the cultivars during both the years.

Yield

Sowing techniques had significant effect on grain yield (Table 2) and treatment T_1 was found significantly superior to all the treatments and recorded maximum grain yield (46.33 and 48.33 q/ha). T_3 was significantly superior to remaining treatments.T_2, however, recorded significantly higher grain yield over T_4 treatment which recorded minimum grain yield (40.35 and 41.80 q/ha) during 2009 and 2010, respectively.

Varietal differences with respect to the grain yield per hectare also found to be significant in both the years. Sughanda -5 V_4 produced significantly higher grain yield (49.31 and 51.64 q/ha) as compared to rest of the varieties. Increase in per plant yield can be attributed to increase in vegetative growth in different sowing techniques i.e Resource conservation technologies with increasing moisture supply. Similar trend was observed by Bhushan *et al.*, 2007, Sharma *et al.*, 2002, Ladha *et al.*, 2003, Naresh *et al.*, 2010. Thus the differences in soil conditions i.e. unpuddled and differences in moisture condition was responsible for differential response of rice to irrigation and sowing techniques (Resource Conservation technologies) treatments.

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Sowing techniques had significant effect on strover yield and treatment T_1 was found to be significantly superior to all the treatments, and recorded maximum strover yield (70.23 and 72.63 q/ha) in both the years (Table 2)

Table 2: Effect of different treatments on panicle length (cm), grains panicle^{-1}, test weight (gm) and yield (q/ha) of rice crop

Treatments	Panicle Length (cm)		No. of Grains Panicle^{-1}		Test Weight (gm)		Grain Yield		Strover Yield	
(A)Sowing techniques	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	21.05	23.65	165	175	24.58	27.29	46.33	48.33	70.23	72.63
T_2	19.52	21.52	159	169	24.24	26.91	44.08	46.08	61.51	62.49
T_3	20.40	22.40	161	171	24.48	27.17	45.05	47.32	63.50	66.08
T_4	19.86	21.86	160	171	24.16	26.82	40.35	41.80	59.97	60.76
SEm ±	0.0533	0.3047	0.1333	0.1487	0.0074	0.0075	0.0140	0.0595	0.0164	0.0588
C.D. 5%	0.1841	1.0516	0.4602	0.4926	0.0256	0.0260	0.0482	0.2052	0.0566	0.203
A) (B) Varieties										
V_1	19.98	21.98	156	166	26.58	29.50	40.56	42.56	53.97	56.44
V_2	20.08	22.08	158	168	25.50	28.30	41.30	43.30	56.67	59.24
V_3	20.48	23.23	164	174	24.68	27.39	47.48	49.48	69.62	72.07
V_4	20.81	22.81	170	180	23.45	26.03	49.31	51.64	74.90	77.41
V_5	19.68	21.68	161	171	21.63	24.00	46.69	48.69	65.98	68.53
SEm ±	0.4827	0.5835	0.1467	0.1581	0.7490	0.8313	0.5541	0.5592	0.7991	0.8034
C.D. 5%	0.1841	N.S.	0.4228	0.4556	2.1582	2.3954	1.5966	1.6114	2.3025	2.3150

Interaction	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%	SEm ±	C.D. 5%
Compare varieties means within the same sowing techniques	0.1193	N.S.	0.1193	N.S.	0.2981	N.S.	0.3191	N.S.	0.0166	N.S.	0.0169	N.S.	0.1193	N.S.	0.1193	N.S.	0.2981	N.S.	0.3191	N.S.
Compare sowing techniques mean at the same or different level of varieties	0.8651	N.S.	0.8651	N.S.	0.2944	N.S.	0.3168	N.S.	1.3399	N.S.	1.4871	N.S.	0.8651	N.S.	0.8651	N.S.	0.2944	N.S.	0.3168	N.S.

The differences in the strover yield due to sowing techniques proved significant. The strover yield increased significantly with every successive improvement in resource conserving technologies i.e. reduced till etc. Treatment T_3 was significantly superior to the remaining treatments. T_2 and T_4 were at par with each other, however, they recorded significantly higher strover yield over V_1 which recorded minimum strover yield (59.97 and 60.76 q/ha) during 2009 and 2010, respectively Varietal differences with respect to the strover yield per hectare also proved significant in both the years. Sughanda -4 (V_3) and Sughanda- 5 (V_4) produced significantly higher strover yield (69.62, 74.90 and72.07, 77.41q/ha) as compared to Pusa Basmati-1(V5), Sughanda-3 (V_2) and Sughanda-2 (V_1). This could be attributed to proper moisture supply and better soil environment at this critical stage, leading to more number of tillers per plant, more number of panicle lengths and more number of grains per panicle under these treatments.

Water Application and Water Productivity:

The input water application includes the irrigation water applied and the rain water during the rice season (179.6 and 125.7mm) during 2009 and 2010. The total water application in rice varied markedly due to varieties and crop establishment techniques (Table 3).The conventional puddled transplanted rice consumed more water (2795 and 2680 mm ha^{-1}) compared to Reduced till (non-puddled slit opened) transplanted rice (T_3),Reduced till (non puddled) dry drill seeded rice (T_2) and raised bed transplanted rice (T_4),(2450 and 2375, 2365 and 2285 with RT-TPR and RT - DSR, and 2215 and 2120 with Beds-TPR) during both the years.The savings in water use with beds was 20.75 and 20.90% compared to conventional puddled transplanted rice during 2009 and 2010.The water productivity under raised beds was higher compared to other crop establishment techniques and lowest system water productivity was recorded with CT-TPR.

Profitability

The net income from the rice crop received various sowing techniques and verities and was higher in Treatment T_3 Reduced till (non puddled slit opened) transplanted rice followed by T_2 Reduced till (nonpuddled) dry drill seeded rice and T_1 Conventional till (puddled) transplanted rice. The lowest net income was being recorded with T_4 Raised bed transplanted rice (Table 3). The lower net income with the raised beds transplanted rice was due to the cost on preparing the beds in first season. Further, the profitability of rice was remarkably higher with transplanted rice in reduced till non-puddled practice compared to bed and other practices during both the years. Among the varieties Sughanda-4 (V_3) was observed higher returns during both the years as compared to rest of the varieties. Variety Sughanda-2 (V_1) was observed lowest net returns in 2009 and 2010. Variety Pusa Basmati-1 (V_5) also observed close profitability as V_3 during both the years.

Table 3: Water application, water productivity, net income and B: C ratio in different sowing techniques and varieties

Treatment	Irrigation Water Applied (mm ha^{-1})		Water Productivity (kg Grain m^{-3})		Net Income (Rs ha^{-1})		B:C Ratio	
A) Sowing Techniques	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	2795	2680	0.17	0.18	17200	17945	1.68	1.65
T_2	2365	2285	0.19	0.21	18725	19575	1.47	1.45
T_3	2450	2375	0.18	0.20	19665	20656	1.43	1.41
T_4	2215	2120	0.18	0.20	14750	15280	1.63	1.61
Av.	**2456**	**2365**	-	-	**17585**	**18364**	-	-
B) Varieties								
V_1	2625	2560	0.15	0.17	17850	18725	1.52	1.50
V_2	2675	2515	0.15	0.17	18175	19052	1.49	1.46
V_3	2420	2380	0.20	0.21	20895	21775	1.56	1.54
V_4	2395	2335	0.21	0.22	19725	20656	1.45	1.43
V_5	2385	2275	0.20	0.21	20545	21426	1.57	1.55
Av.	**2500**	**2413**	-	-	**19438**	**20327**	-	-

Input Use and Saving:
There were considerable savings in diesel, total cost of inputs, energy and irrigation water with raised beds and reduced till flat beds in comparison with CT-TPR. In PRB the savings in time, labour, diesel, cost, energy and water compared with CT-TPR were 81%, 78%, 86%, 80%, 85% and 38% respectively (Figure 1).

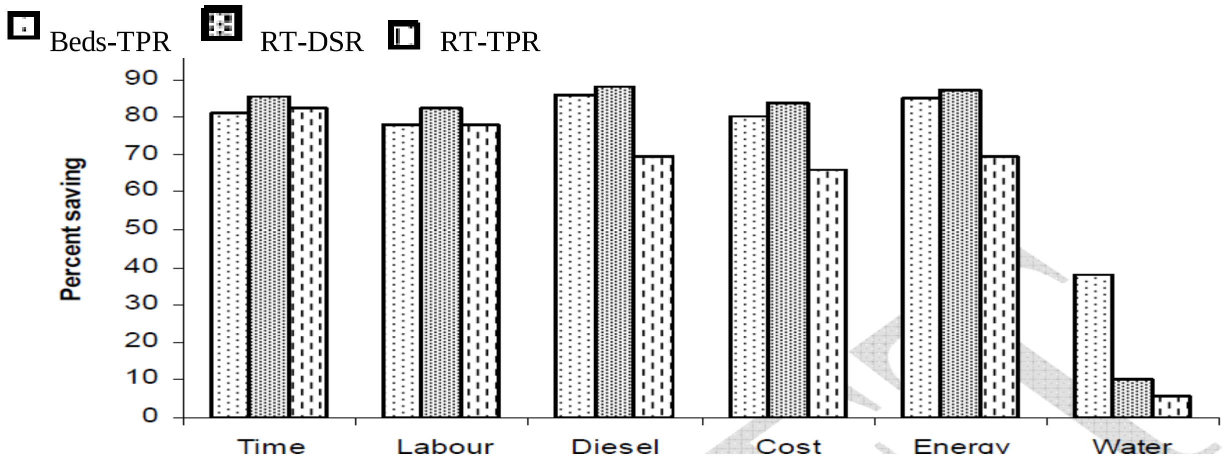

Figure 1: Relative saving of input use (%) over conventional practice of rice (CT-TPR)

CONCLUSIONS

Conventional practices of puddled transplanting in rice require a large amount of water and labor. The emerging shortages and increasing costs of water and labor will therefore force a change in the way farmers grow these crops. In addition, many farmers tend to transplant rice during the hot, high water evaporative demand months of May and June. This would also enable farmers to delay rice seeding until end of June when the monsoon season starts, thereby reducing the irrigation application in rice planting. But there is grower apprehension that planting of rice in May will result in more yields compared to planting in July. Therefore, delaying rice planting up to 20 July may not affect yield potential.
The water-saving feature of reduced till (non-puddled slit opened) transplanted rice (RT-TPR), is largely attributed to the avoidance of puddling used in transplanted rice. However, savings in irrigation largely depended on the occurrence and distribution of rainfall during the crop growing period. Therefore, more efforts will be needed to evaluate and improve the technologies on a site- and season-specific basis. Shifting from conventional tillage practice to reduce till transplanted rice system may cause changes in soil properties, micro flora, micro fauna, and weed flora affecting long-term crop productivity and input use efficiency. Therefore, long-term changes in the crop performance, input efficiencies, and weed flora should be monitored to achieve a paradigm shift in farmers' practices.

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