Int.J.Curr.Microbiol.App.Sci (2017) *6*(9): 2794-2803

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 9 (2017) pp. 2794-2803**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.609.344

Variation in Productivity and Energy Use in Rice-Wheat System under Different Establishment Methods

Shweta*, Manu Malik, S.K. Saini and A.K. Bhardwaj

Department of Agronomy, CCS Haryana Agriculture University, Hisar
**Corresponding author*

Keywords

Direct seeded rice, Establishment methods, Mechanical transplanting, Rice, Wheat.

Article Info

Accepted:
26 August 2017
Available Online:
10 September 2017

A B S T R A C T

Conventional crop establishment methods such as puddled transplanting in rice-wheat system in the Indo-Gangetic plains (IGP) require a large amount of water and labor, both of which are increasingly becoming scarce and expensive. Efforts have been made to evaluate alternate crops establishment methods, which are more efficient in. A field experiment was conducted for two years to evaluate various crop planting methods in rice-wheat system for their efficiency in labor, water and energy use and economic profitability. The result revealed that rice were recorded statistically equal yields of in conventional puddle, hand transplanting, machine transplanting, direct seeding of sprouted rice and dry seed methods. The difference between wheat establishments methods were significant, puddle transplanting requires 35-40 % more irrigation water than no tillage direct seeded rice. In first year, mechanical transplanting (MT) rice had a higher net return than the direct seeded rice, where as in second year, direct seeded rice had a higher net return as compared to other treatments. The study showed that the conventional practice of puddle transplanting could be replaced with direct seeded methods to save inputs. However, the occurrence and distribution of rainfall during the cropping season had considerable influence on the savings in irrigation water.

Introduction

The rice-wheat rotation is one of the major agricultural production cropping patterns in Asia. The Indo-Gangetic Plain (IGP) occupying 13.5 million ha area under rice-wheat systems (Ladha *et al.,* 2000; Dawe *et al.,* 2004). The intensively cultivated irrigated rice-wheat system is elementary to employment, revenue and occupation for hundreds of millions of people of South Asia. The annual increase in growth rates for food grain production (wheat 3%, rice 2.3%) in the IGP have kept pace with population growth, but proof is now come into view that rice-wheat cropping system productivity is plate awing because of a fatigued natural resource base (Ladha *et al.,* 2003). Thus, the region's food safety is vulnerable by the up-and-coming challenges of Post Green Revolution farming, and the expanding population.

Farmers in this region frequently cultivate rice in the *kharif* (rainy) season, pursued wheat in the *rabi* season. Rice and wheat crops have complementary edaphic requirements and differing tillage and agronomic practices. For rice, intensive wet tillage (Puddling) is practiced whereas wheat is grown as an irrigated crops. The drastically different seedbed requirements for rice and wheat build troubles in tillage, suitability of wheat seeding, upholding of soil structure, and organization of irrigation, weeds and other pests, fertilizers, and crop residue. A little revolve time among rice and wheat is required to prevent delayed wheat planting that can result in yield losses of 35 kg day^{-1} ha^{-1} (eastern IGP) (Pathak *et al.,* 2003) however, delays do occur because farmers insist on excessive tillage prior to wheat planting and the growing of a medium – duration (140 days) basmati rice variety. Timely planting affected by more labour demand in the season. But there is migratory behavior of labour during peak season.

In the IGP, and other parts of Asia, water is progressively more becoming scarce. Per capita availability of water has declined in many Asian countries by 40-60% between 1955 and 1990 (Cleik, 1993). Agriculture's share of freshwater supplies is likely to decline by 8-10 % because of increasing competition from the urban and industrial sectors (Toung and Bhuiyan, 1994; Sechler *et al.,* 1998). Poor–quality irrigation systems and greater reliance on ground water have led to water table decline of 0.1-1.0 myr^{-1} in parts of the IGP, resulting is a scarcity and higher cost of pumping water (Gill, 1994; Harrington *et al.,* 1993; Sharma *et al.,* 1994; Sondhi *et al.,* 1994).

The growing labor and water shortages are likely to adversely affect the productivity of the rice-wheat system (Ladha *et al.,* 2003) One way to reduce water demand is to grow direct seeded rice instead of the conventional puddled transplanted rice (Bhuiyan *et al.,* 1995; Caban gon *et al.,* 2002). With consequent aerobic soil conditions, dry seeding of rice avoids water application for puddling and maintaining submerged soil conditions and thus reduces the coverall water demand (Bouman, 2001; Sharma *et al.,* 2002). Another way to save water is to grow rice in raised beds as Borrel *et al.,* (1971) observed that the raised bed system saved 16-43% water compared with puddled transplanted rice, though at the expense of yield. Similarly, a yield reduction of more than 15% was reported when rice was grown on raised beds vis-à-vis the puddled transplanted system (Sharma *et al.,* 2003; Vories *et al.,* 2002). Intermittent irrigation and mid-season drying of soil instead of continuous submergence as used in the conventional puddled-transplanted system could be another option for saving water.

Compared with rice, wheat has a much lower water demand. Rice consumes about 80% of the total water applied in the rice-wheat system. Therefore, much water could be saved if tillage and crop establishment practices of water were adopted in rice. However, the extension of tillage and crop establishment practices followed in wheat to rice without a yield penalty has always been a major challenge for researchers. Minimum tillage or no tillage is becoming an increasingly accepted management technology is parts of the IGP (Hobbs and Gupta, 2002; Singh and Ladha, 2004). Tillage operations performed and establishment methods followed for growing rice should complement those practiced for growing wheat and vice-versa. It is the overall system productivity that should be considered while judging the suitability of a practice and not just the individual crop productivity. The reduced tillage operations with diverse crop establishment methods such as direct seeding on flat land and raised beds can result in significant water savings (Gupta *et al.,* 2003), These practice's effect on yield, soil fertility and water use in the rice- wheat system are not reviewed in a systematic way. The objectives of our study was to evaluate the crop establishment methods and sowing methods on productivity, irrigation requirement and water use efficiency, and net return of the rice-wheat system of the IGP.

Materials and Methods

The experiment was conducted at the Research Farm (29^0 N, 79^0 E altitude and 243.84 m above mean sea level) of G.B.P.U.A. & T. Pantnagar, Uttarakhand, India, during 2005-2007. The climate of the area is sub-humid, with an average annual rainfall 1364 mm (75-80% of which is received during July to September), minimum temperature of 0-3.7 ^{0}C in January, maximum temperature of 37.5 to 38.3 ^{0}C in June and relative humidity of 20 to 62% throughout the year. The experimental soil (0-15 cm) was sandy loam in texture, with pH 7.8, organic carbon 0.68 % available nitrogen 263.4 kg Nha^{-1}, Olsen P 37.8 kg ha^{-1} and 1N NH_4 OAC extractable K 264.3 kg ha^{-1}. Sixteen treatments (involving four establishment methods of each for rice and wheat were evaluated in rice-wheat rotation during 2005-06 and 2006-07 using a strip-strip plot design with 3 replications. In all, there were 12 main plots of 3.6 m x 42.5 m and 64 sub plots of 3.6 m x 10 m size each. The rice establishment methods were as direct seeding of dry seed, wet sprouted rice, hand transplanting and machine transplanting. The wheat tillage methods were as conventional sowing of wheat, raised bed planting of wheat strip till drill wheat and zero tillage wheat. Rice (cv. NDR-359) was seeded on June 7 and 3 in direct-seeded plots, whereas transplanting was done on June 28 and 24 in 2005 and 2006, respectively. Rice was seeded in flat beds as well as in raised beds after seed priming (soaking seeds in water for 12 hr followed by air drying). A seeding rate of 40 and 30 kg ha^{-1} was used for direct – seeded rice on flat and raised beds, respectively. The wheat variety PBW-343 was sown on 20 and 22 November as per the treatments in 2005 and 2006, respectively.

At maturity, rice and wheat were harvested manually at 15 cm above ground level. Grain and straw yields were determined from an area of 2 x 5 m^2 in flat beds and 69.7 m^2 in center of each plot. The grains were threshed using a plot thresher, dried in a batch grain dryer, and weighed. Grain moisture was determined immediately after weighing. Straw weight was determined after oven-drying at 70 ^{0}C to constant weight and expressed on an over dry-weight basis.

The cost of cultivation was calculated by taking into account costs of seed, fertilizers, and the wages (Rs.73 day^{-1}) and machines for land preparation, irrigation, fertilizer application, plant protection, harvesting, and threshing, and the time required per ha to complete an individual field operation. Cost of irrigation was calculated by multiplying time (hr) required to irrigate a particular plot, consumption of diesel by the pump (1hr^{-1}) and cost of diesel. The prices of human and machine labor, and diesel were the prices in north India collected by market survey. Gross income was the minimum support price offered by the Government India for rice and wheat. Net income of the farmers was calculated as the difference between gross income and total cost. System productivity was calculated by adding the grain yield of rice and wheat in each year.

All the data on yield and yield parameters of rice and wheat, water use efficiency, economics, and nutrient uptake were analyzed with IRRISTAT for Windows for one-way analysis of variance (ANOVA) with partitioning of treatments by linear contrast (IRRI, 2005).

Results and Discussion

Yields

Rice

The various rice establishment methods had a non-significant effect on rice yield in both years. During first year due to wheat tillage methods had a significant effect on rice yield, but during second year non-significant effect observed. Yields were similar when rice was conventionally transplanted (P_3), machine transplanted (P_4), sprouted seeding (P_2), and direct dry seeding (P_1) (Table 2). This indicated that puddling of soil, for which normally a large amount of water and labor are required, can be avoided without dry yield penalty in rice. Hand transplanting (P_3) had a lower yield in 2005 than machine transplanting (P_4), sprouted rice (P_2), and direct seeded rice (P_1). Reducing the number of irrigations in 2006 did not affect the rice yield negatively because adequate precipitation was received. As a result P_3 had a yield similar to that of P_1, P_2 and P_4. Rice direct dry seeded (P1), sprouted seed (P2) or machine transplanting (P4) in 2006 yield 10.27 % to 23.07 % lower than hand transplanting (P3). Partitioning of treatments using linear contrast showed that conventional tillage treatment (T1) gave higher rice yields than the raised bed (T_2), strip till drill wheat (T_3) and zero tillage (T_4) in 2006, whereas zero tillage treatments (T_4) gave higher yields than the raised bed (T_2) regardless of seeding method in both the years (Table 2). Transplanted rice on beds apparently suffered form more water stress compared to plot and resulting in lower yields lower grains panicle^{-1} (Table 3) and poor tillering (data not shown or something else) were also recorded in this treatment.

Several researchers have shown that moisture stress at panicle initiation and flowering stages could lead to yield loss because of reduction in number of grains per panicle and spike let sterility (Lu *et al.*, 2001; Nieuwenhuis *et al.*, 2002; Belder *et al.*, 2002). However, despite the higher grains panicle^{-1} (Table 3) in the direct seeded rice (P1) than that of puddle- transplanted conditions (P2, P3 and P4), rice yield were equal in both the year (Table 2). This was due to higher sterility nullifying the advantage of higher grains per panicle in P1. Comparison of transplanting (P3, P4) and direct seeding (P1, P2) showed that rice yield was higher in the former in 2005.

Wheat

Rice establishment methods had no effect on wheat yield in 2005 (Table 2). In 2006, however, wheat grown on raised bed (T2) yielded less than in the strip till drill and zero tillage treatment (T3, T4), (Table -2). More over partitioning of treatments using linear contrast showed that in 2006, zero tillage (T4) and strip till drill (T3) gave higher yields than the raised bed (T2) and conventional (T1) treatment. A lower number of effective tillers caused by poor crop establishment as a result of the presence of rice residue caused lower wheat after either puddle-transplanted or direct seeded rice gave equal yields. These findings are in agreement with Ladha *et al.*, (2003) who found that the performance of wheat was not much affected by the way the previous rice crop was grown.

Rice-wheat system

Treatment effects on rice-wheat (System) yield were observed in both years. (Table 2). The yields of the rice-wheat system were similar in the puddled (P2, P3 and P4) and non-puddled (P1) systems but were lower in direct drill seeded in 2006. Partitioning of treatments by linear contrast showed that system yields under zero tillage (T4), were higher than the strip till drill (T3), bed planting (T2) and conventional planting of wheat (T1) regardless of seeding method moreover, hand transplanting (P3) gave higher system yields than direct drill-seeding (T1) during 2006. The data indicated that there is still a need to improve the direct drill-seeded and zero tillage systems to improve productivity.

Table.1 Description of the treatments

Treatments	Rice	Treatments	Wheat
P1	Direct seeded rice	**T1**	Conventional wheat
P2	Wet Sprouted rice	**T2**	Bed planting
P3	Hand transplanting	**T3**	Strip-till drill
P4	Machine transplanting	**T4**	Zero-till drill

Table.2 Effect of crop establishment methods on yields of rice and wheat

Treatment	Grain Yield (Mg ha^{-1})					
	Rice		Wheat		System	
	2005	2006	2005	2006	2005	2006
P1	4.3	3.0	3.5	5.2	7.8	8.2
P2	4.1	3.2	3.6	5.2	7.7	8.4
P3	3.7	3.9	3.5	4.9	7.2	8.8
P4	3.9	3.5	3.5	4.4	7.4	7.9
CD	NS	NS	NS	0.5	-	-
T1	4.0	3.7	3.2	4.3	7.2	8.0
T2	3.6	3.3	3.0	4.8	6.6	7.1
T3	4.1	3.2	3.4	4.9	7.5	8.1
T4	4.4	3.4	4.6	5.7	9.0	9.1
CD	0.4	NS	0.5	0.2	-	-

Table.3 Effect of crop establishment methods on yield attributes of rice crop

Treatments	Tiller m^{-2}		Panicle length (cm)		Grains/panicle		1000-grain wt.(g)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Rice								
P1	245	270	26.2	24.4	135.5	103.9	28.1	27.5
P2	231	213	25.3	24.1	132.2	103.4	27.9	27.3
P3	225	212	24.7	23.9	131.6	98.5	26.5	27.1
P4	206	200	24.0	23.2	119.4	91.0	26.4	26.9
S.Em±	11	15.4	0.4	1.1	5.0	6.3	0.3	0.5
C.D. (5%)	NS	NS	1.3	NS	NS	NS	1.1	NS
Wheat								
T1	219	217	24.7	23.8	128.8	97.8	27.0	26.9
T2	212	213	24.4	23.7	125.9	86.1	26.5	26.8
T3	234	226	24.9	24.1	130.2	105.6	27.6	27.3
T4	243	229	26.1	24.3	133.5	107.3	28.0	27.7
S.Em±	8.7	18.6	0.52	1.1	4.3	4.2	0.4	0.3
C.D. (5%)	NS	NS	NS	NS	NS	14.5	NS	NS

Table.4 Effect of crop establishment methods on yield attributes of wheat crop

Treatments	Tiller m^{-2}		Spike length (cm)		grains/spike		1000-grain wt.(g)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Rice								
P^1	432	426	8.6	9.8	49.9	52.2	43.0	43.6
P^2	417	416	8.5	9.6	49.3	51.1	40.5	42.5
P^3	412	407	8.4	9.6	47.3	50.2	39.9	41.6
P^4	385	400	8.3	9.2	45.6	49.6	38.8	41.2
S.Em±	41	24	0.26	0.04	1.32	0.40	1.8	0.3
C.D. (5%)	NS	NS	NS	0.15	NS	1.4	NS	0.9
Wheat								
T^1	401	397	8.67	9.3	47.3	50.4	40.5	39.8
T^2	393	389	8.28	9.0	45.9	49.3	39.4	41.6
T^3	402	418	8.71	9.6	49.4	51.5	40.6	42.7
T^4	450	445	8.73	10.1	49.9	51.9	41.6	45.0
S.Em±	18	29	0.20	0.13	1.40	0.84	1.3	0.5
C.D. (5%)	NS	NS	NS	0.45	NS	NS	NS	1.6

Table.5 Effect of crop establishment methods on energy use ($GJha^{-1}$) in rice, wheat and rice-wheat cropping system (total)

Treatments		2005-06			2006-07		
Rice	Wheat	Rice	Wheat	Total	Rice	Wheat	Total
DSR	CW	11.15	10.52	21.67	10.16	11.14	21.3
	BPW		10.27	21.42		11.29	21.45
	STW		8.19	19.34		8.38	18.54
	ZTW		8.25	19.40		8.59	18.75
	Mean	11.15	9.31	20.46	10.16	9.85	20.01
SR	CW	11.59	10.38	21.97	10.59	10.91	21.50
	BPW		10.21	21.80		10.77	21.36
	STW		8.11	19.70		8.50	19.09
	ZTW		8.25	19.81		8.77	19.36
	Mean	11.59	9.24	20.83	10.59	9.74	20.33
HT	CW	13.22	11.13	24.35	11.86	11.81	23.67
	BPW		10.99	24.21		11.54	23.40
	STW		7.99	21.21		8.19	20.05
	ZTW		8.09	21.31		8.30	20.16
	Mean	13.22	9.55	22.77	11.86	9.96	21.82
MT	CW	12.49	10.92	23.41	11.68	11.76	23.44
	BPW		10.94	23.43		10.83	22.51
	STW		8.03	20.52		8.34	20.02
	ZTW		8.05	20.54		8.36	20.04
	Mean	12.49	9.49	21.98	11.68	9.82	21.50

Table.6 Effect of establishment methods on net returns (Rs) from rice-wheat system

Treatments		2005	2006
Rice	Wheat		
DSR	CW	41173	45147
	BPW	40497	48085
	STW	45712	51377
	ZTW	55720	57345
	Mean	**45775.5**	**50488.5**
SR	CW	35744	39166
	BPW	34985	44559
	STW	46100	46105
	ZTW	52474	57060
	Mean	**42325.75**	**46722.5**
HT	CW	31420	39238
	BPW	28607	42800
	STW	35145	35504
	ZTW	55189	57376
	Mean	**37590.25**	**43729.5**
MT	CW	45346	34554
	BPW	41021	37587
	STW	48341	42553
	ZTW	56818	48799
	Mean	**47881.5**	**40873.25**

Energy input

Hand transplanting rice had the highest energy input requirement (13.22 $GJha^{-1}$) followed by machine transplanting rice (12.49 GJh^{-1}) (Table-6). Direct seeded rice had the lowest energy input requirements. Conventionally tilled wheat had the highest energy requirement, whereas all other treatments had a lower energy input requirement. Direct seeded rice-strip till drill wheat had lower energy input requirement (19.34 and 18.54 GJha-1, respectively) compared to the other treatment combination, because of the larger human labor requirement for transplanting rice (Table 5).

Economic analysis

The net returns of rice were higher in first year than in second year largely because of more rainfall resulting in a lower cost of irrigation. The largest financial benefit was for hand transplanting rice (P4) followed by direct seeding. In wheat returns were higher in second year than in first year largely because of the differences in the amount of water applied. On a system basis, the returns were higher in direct seeded rice-zero tillage wheat in first year and in hand transplanting-zero tillage wheat in second year (Table 6).

Conventional practices of puddle transplanting in rice and conventional tillage in wheat require a large amount of energy input. The emerging shortages and increasing costs of water and labor will therefore force and changes in the way farmers grow these crops.

An extended turnaround time between rice and wheat, delays wheat planting that can result in yield losses. No tillage can allow timely seeding of wheat immediately after rice harvest. This would also enable farmers to delay rice seeding until end of June when the monsoon season starts, therefore reducing the irrigation applications in rice planting. But there in grower apprehension that planting of rice in May will results in more yield compared to planting in July.

The second year results showed that zero tillage and direct seeding methods require the less energy and gave the higher net return than the conventional method of planting. The water saving feature of direct seeding is largely attributed to the avoidance of puddling used in transplanted rice. However, saving in irrigation largely depend 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 zero tillage system may cause change 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. Appropriate integration of crop residues in zero tillage rice-wheat system is another crucial issue, which needs to be addressed. Therefore, there is need to develop cost effective and profitable residue management practices, which will attract the farmers for adoption. It is also important that small-scale farmers trained and have access to these technologies.

References

Belder, P., B.A.M. Bouman, L. Spiertz, Guoan Lu, and E.J.P. Quilang. 2002. Water use of alternately submerged and non-submerged irrigated lowland rice. 51-61. In B.A.M. Bouman *et al.*, (eds.) Water-wise rice production. International Rice Research Institute, Los Banos, Philippines.

Bhuiyan, S.I., M.A. Sattar, and M.A.K. Khan. 1995. Improving water use efficiency in rice irrigation through wet seeding. *Irrigation Sci*. 16:1-8.

Borrel, A.K., A.L. Garside, and S. Fukai. 1997. Improving efficiency of water for irrigated rice in semi-arid tropical environment. *Field Crops Res*. 52:231-248

Bouman, B.A.M., 2001. Coping with the water crisis: water management strategies in rice produion. Paper presented at the International Symposium on Sustainable soil and Water Resources Management, 30-31 May 001, Diliman, Ouezon City, Philippines.

Cabangon, R.J., T.P. Tuong and N.B. Abdullah. 2002. Comparing water input and water use efficiency of transplanted and direct-seeded rice production systems. *Agric. Water Manage* 57: 11-3.

Dawe, D., S. Frolking, and C. Li, 2004. Trends in rice-wheat area in China. *Field Crops Res*. 87: 89-95.

Gill, K.S., 1994. Sustainability issues related to rice-wheat production system. P, 30-61 In R.S. Paroda *et al.,* (eds.) Sustainability of rice-wheat production system in Asia. FAO, Bangkok (Thailand).

Gleik, P.H., (ed.) 1993. Water crisis: a guide to the world fresh water resources. 473 p Pacific Institute for Studies in Development, Environment and Security Stockholm Environment Institute. Oxford University Press, New York.

Gupta, R.K., P.R. Hobbs, J. Jiaguo, and J.K. Ladha. 2003. Sustainability of post-Green revolution agriculture. 1-25. In J.K. Ladha *et al.*, (eds.) Improving the productivity and sustainability of rice-wheat systems: issues and impacts. ASA special Publication No. 65. Madison, Wis., USA.

Harrington, L.W., S. Fujisaka, M.L. Morris, P.R. Hobbs, H.C. Sharma, R.P. Singh, M.K. Choudhary, and S.D. Dhiman. 1993. Wheat and rice in karnal and Kurukshetra districts, Haryana, India: farmers' practices, problems and an agenda for action. ICAR, HAU, CIMMYT, Mexico, and IRRI, Los Banos, Philippines.

Hobbs, P.R., and R.K. Gupta. 2002. Rice-wheat cropping systems in the Indo-Gengetic plains: issues of water productivity in resource-conserving technologies. Water Productivity Workshop, 12-14 November 2001, International Water Management Institute, Sri Lanka.

Ladha, J.K., H. Pathak, A.T. Padre, D. Dawe, and R.K. Gupta. 2003. Productivity trends in intensive rice-wheat cropping system in Asia. 45-76. In J.K. Ladha *et al.*, (eds.) Improving the productivity and sustainability of rice-wheat system: issues and impacts. ASA Special Publication No. 65. Madison. Wis. USA.

Ladha, J.K., K.S. Fischer, M. Hossain, P.R. Hobbs, and B. Hardy. 2000. Improving the productivity of rice-wheat systems of the Indo Gangetic Plains: a synthesis of NARS-IRRI partnership research. IRRI Discussion Paper No. 40. International Rice Research Institute, Los Banos, Philippines.

Lu-Jun, Hirasawa-T, and Lu-J. 2001. Study on intermittent irrigation for paddy rice: I. Water use efficiency. *Pedosphere* 11:49-56

Nieuwenhuis, J., B.A.M. Bouman, and A. Castaneda. 2002. Crop-water responses of aerobically grown rice: preliminary results of pot experiments. P. 177-185. In B.A.M. Bouman *et al.*, (eds.) Water-wise rice production. International Rice Research Institute, Los Banos, Philippines.

Pathak, H., J.K. Ladha, P.K. Aggarwal, S. Peng, S. Das, Y. Singh, Bijay-Singh, S.K. Kamra, B. Mishra, A.S.R.A.S. Sastri, H.P. Aggarwal, D.K. Das, and R.K. Gupta. 2003. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Res*. 80:223-234.

Seckler, D., U. Amarasinghe, D. Molden, R. De Silva, and R. Barker. 1998. World water demand and supply, 1990 to 2025: scenarios and issues. Research Report 19. International Water Management Institute. Colombo, Sri Lanka.

Sharma, H.C., S.D. Dhiman, and V.P. Singh. 1994. Reice-wheat cropping system in Haryana: potential, possibilities and limitations. P. 27-39. In S.D. Dhiman *et al.*, (eds.) Proceedings of the symposium on sustainability of rice-wheat system in India. CCS Haryana Agricultural University, Regional Research Station, Karnal, India.

Sharma, P.K., J.K. Ladha, and Lav Bhushan. 2003. Soil physical effects of pudding in rice-wheat cropping system. P. 97-114. In J.K. Ladha *et al.*, (eds.) Improving the productivity and sustainability of rice-wheat system: issues and impact. ASA Special Publication no. 65. ASA Madison, Wis.

Sharma, P.K., L. Bhushan, J.K. Landha, R.K. Naresh, R.K. Gupta, V. Balasubramanian, and B.A.M. Bouman. 2002. Crop-water relations in rice-wheat cropping systems and water management practices in a marginally sodic, medium-textured soil. p. 223-235. In B.A.M. Bouman *et al.*, (eds.) Water-wise rice production. International Rice Research Institute, Los Banos, Philippines.

Singh, Y., and J.K. Ladha. 2004. Principles and practices of no-tillage systems in rice-wheat systems of Indo-Gangetic plains. p. 167-207. In R. Lal *et al.*, (eds.) Sustainable Agriculture and the rice-wheat systems. Mercel Dekker Inc., New York, USA.

Sondhi, S.K., M.P. Kaushal, and P.Singh. 1994. Irrigation management strategies for rice-wheat cropping system. p. 95-104. In S.D. Dhiman *et al.*, (eds.) Proceedings of the symposium on sustainability of rice-what system in India. CCS Haryana Agricultural University, Regional Research Station, Karnal, India.

Toung, T.P., and S.I. Bhuiyan. 1994. Innovations toward improving water-use efficiency in rice. Paper presented at the Word Bank's 1994 Water Resource Seminar, 13-15 December 1994. Virginia, USA.

Vories, E.D., P.A. Counce, and T.C. Keilsling. 2002. Comparison of flooded and furrow irrigated rice on clay. *Irrig. Sci*. 21: 139-144.

How to cite this article:

Shweta, Manu Malik, S.K. Saini and Bhardwaj, A.K. 2017. Variation in Productivity and Energy Use in Rice-Wheat System under Different Establishment Methods. *Int.J.Curr.Microbiol.App.Sci.* 6(9): 2794-2803. doi: https://doi.org/10.20546/ijcmas.2017.609.344