Indian Journal of Weed Science **48**(2): 158–163, 2016
DOI: 10.5958/0974-8164.2016.00040.X

Long-term impact of crop establishment methods on weed dynamics, water use and productivity in rice-wheat cropping system

S.S.Punia*, Sher Singh[1], Ashok Yadav[2], Dharam Bir Yadav and R.K.Malik[3]
Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana 125 004

Received: 24 April 2016; Revised: 30 May 2016

ABSTRACT

An experiment consisting of five establishment techniques in rice-wheat cropping sequence with different combinations of conventional tillage (CT), zero-tillage (ZT) and minimum tillage (MT) *viz*. CT-CT, ZT-CT, CT-ZT, ZT-ZT and MT-ZT) was conducted during 2003-2007 at the farm of a farmer in Haryana on a larger plot size of 0.4 ha under each treatment. During first year, grain yield of wheat did not differ significantly among different treatments but during 2004-05 to 2007-08, grain yield of wheat in ZT method of planting was either higher or at par with conventional ploughed method of planting but CT transplanting of rice was significantly more than ZT transplanted treatments except during first year when rains were very good at transplanting time. Weed dynamics after 4 years revealed that in rice crop, weed density of *Echinochloa colona, E. crusgalli, Leptochloa chinensis,Cyperus* spp. and broad-leaf weeds such as *Ammania baccifera* and *Eclipta alba* was more when rice was transplanted under ZT or MT conditions but in wheat, weed density of grassy weed *Phalaris minor* was less under ZT-ZT or MT-ZT treatments. After 4 years of continuous ZT in both rice and wheat crops, weed flora changed in favour of broad-leaf weeds. Bulk density of soil did not vary after 5 years of ZT-ZT conditions. Soil temperature of root zone in wheat crop planted under ZT conditions was more (0.7-1.7 ^{O}C) in first week of February and less (2.1-.3.8 ^{O}C) in first week of April as compared to conventional CT-CT practice of rice and wheat crops resulting in more grain yield of wheat due to temperature moderation and also due to a bit addition of organic matter in ZT conditions. Grain yield of rice planted under ZT or MT conditions was less mostly due to more weed infestation and it also consumed 4.8-184% more water as compared to CT method of puddle transplanted rice.

Key words: Crop establishment**,** Conventional tillage, Minimum tillage, Soil properties, System productivity, Weed dynamics, Water requirement, Zero tillage

Rice-wheat is the most important cropping system practised in an area of 13.5 million hectare in the Indo-Gangetic Plains of South Asia (Gupta and Seth 2007). Planting of wheat crop by zero-drill machine after harvest of rice is well documented and has been largely accepted by farmers of Haryana, Punjab, Uttar Pradesh, Uttaranchal and Bihar. The multifold benefits of this resource conservation technology realized during experimentation at farmers' fields is well documented (Malik *et al.* 2002). Similarly implications and benefits of long term trials under ZT wheat have been outlined earlier also (Yadav *et al.* 2002). In irrigated low land rice cultivation commonly practiced by farmers, puddling is done that makes transplanting of rice easy, checks weeds and leads to incorporation of organic matter (De Datta 1981). Puddling not only consumes much energy and time from the tillage point of view but also consumes a large quantity of the total water requirement in rice (Sharma *et al.* 1995). So, an alternative method of planting is needed which may provide effective weed control, prepare a good seed bed for rice seedling and also helps to conserve water. Therefore, no tillage system was presumed most convenient in such conditions. Puddling condition on certain type of low land soil could be achieved by irrigation water without intensive tillage (Hakim 1986). Shallow tillage with herbicide application has been found to reduce the impact of weed to crop in 2-3 years, 50% of irrigation water and increased crop yield compared to that of zero-tillage system (Xin *et al.* 2001). Application of glyphosate herbicide before transplanting may take care of weeds and ratoon decay or decomposition without any residual effects on rice crop (Lamid *et al.*1995). Results of experiments conducted by Reddy *et al.* (2005) in

***Corresponding author:** puniasatbir@gmail.com
[1]ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
[2]IRRI CSISA-Hub Coordinator, ATIC Building, OUAT, Bhubaneswar, Odisha
[3]CIMMYT, New Delhi, India

rice-wheat cropping zone of Haryana and Lamid *et al.* (2001) in Indonesia showed feasibility of successful cultivation of Zero-tilled transplanted rice with slight yield gain and water saving. No-till rice technique in rice-wheat cropping system has been largely accepted by farmers of sichuan province of China (Au 2001). Encouraged with success of ZT sowing of wheat, experiments on feasibility of ZT or MT rice were initiated. In order to be ready to tackle expected implications in future related to impact of different establishment techniques (ZT-ZT/MT-ZT/ZT-CT) in both rice-wheat cropping systems on soil compactness, crop productivity, weed dynamics, water requirement and grain yield of both rice and wheat crops, long-term tillage trials were considered appropriate. Keeping aforesaid facts in view, the present investigation was planned to study the feasibility of double zero or minimum till - zero tillage options in rice-wheat cropping system and also to study the effects of various tillage practices on weed dynamics, soil physical properties and grain yield of rice and wheat.

MATERIALS AND METHODS

To investigate the long-term effect of different tillage treatments on crop productivity, soil health and weed dynamics, an experimental trial consisting of five combinations tillage (conventional tillage-CT, zero tillage-ZT and minimum tillage-MT) treatments *i.e.* CT-CT, ZT-CT, CT-ZT, ZT-ZT and MT-ZT in rice-wheat cropping system was conducted consistently for five years during 2003-04 to 2007-08. Experiment was initiated during *Rabi* season of 2003-04 on a large plot size of one acre for each treatment in village Pirthala of district Fatehabad (Haryana) and continued until up to *Rabi* season of 2007-08. Every year wheat crop var. '*PBW 343*' was grown after harvesting of rice by following all recommended package of practices except tillage practices (as per treatment). During all the years, rice and wheat crops were raised as per recommended practices of CCS HAU Hisar.

Data on density of different weeds in weedy check were recorded at 35 DAS in wheat and 30 DAT in rice. After harvest of wheat crop by combine harvester, loose straw left was burnt and fields were left as such but in case of rice, it was retained up to 30-40% on soil surface under ZT. Prescribed tillage practices (as per treatment) were adopted before *Kharif* season crop. In treatments of ZT (zero till transplanted rice), weeds emerged if any due to rains in month of May were controlled by spraying non-selective herbicide glyphosate (1.5% on product basis). In MT treatment, one slight disking was given to control the weeds and then field was irrigated and planked. In CT (conventional tillage treatment), field was prepared after harrowing twice and then puddling and removal of weeds with cultivator. Every year, rice crop was transplanted in last week of June and wheat in first week of November in all the fields under treatment. Pre-emergence application of pretilachlor at 1000 g/ha common to all treatments was made to control weeds. To control grassy weeds emerged in later stages, post-emergence use of fenoxaprop 9 EC (Whip Super) at 56.25 g/ha was incorporated in treatments where rice was transplanted by ZT method. Tubewell water with flow of 0.623 Cu sec was used for irrigating the crop and number of hours taken to irrigate under a particular treatment were counted and considered for calculating water consumption. Data on grain yield and bulk density of soil after harvesting were recorded from all the treatments. After harvest of rice in *Kharif* 2004, soil samples from different soil depths *i.e.* 0-5, 5-10 and 10-15 cm were collected from all treatments to study weed seed dynamics as influenced by tillage practices.

RESULTS AND DISCUSSION

Weed studies

Weed density studies conducted at 30 DAT in rice revealed significantly higher density of grassy weeds as well as broad-leaf weeds in treatments of ZT and MT methods of rice transplanting as compared to CT (conventional puddled method of rice transplanting). *Echinochloa crusgalli*, *E. colona* and *Leptochloa chinensis* were major grassy weeds, while broad-leaf weed *Ammania baccifera* and sedges *Cyperusiria* and *C. rotundus* were other prominent weeds (Table 1). During *Kharif*, 2007 (7^{th} crop in sequence) total number of weeds were more when rice was transplanted by ZT and MT methods. Higher density of broad-leaf weeds in zero till rice was also reported by Lamid *et al.* (2001). Density of *P. minor* was more in wheat planted by CT method but broad-leaf weeds such as *Chenopodium album, Melilotus indica* and *Rumex dentatus* dominated the weed flora planted by ZT method. Density of *R. dentatus* was significantly higher in plots of ZT-ZT and CT-ZT (data not given). After five years of continuous zero till wheat, weed flora changed in favour of broad-leaf weeds particularly *R. dentatus* and *C. album* during *Rabi* 2007 (Table 3). During first year, density of *P. minor* in field at 35 DAS was almost same in all tillage treatments and decreased in next two seasons but density of broad-leaf weeds particularly *C. album* increased every year and was more in wheat planted by ZT method.

Weed seed bank and its dynamics in soil

Grow out tests of soil samples collected from different soil depths in permanent tillage trial before *Kharif* 2007 (after 4 years of completion of trial) showed that in rice *E. colona, L. chinensis, E. crus-galli, C. difformis, A. baccifera* and *Dactyloctenium aegyptium* were the major weeds emerged from soil at different soil depths. Number of weed seeds emerged were more in ZT-ZT and MT-ZT treatments as compared to CT-CT. Weed density was maximum in upper 0-5 cm soil layer in all treatments(Fig. 1). Grow out test of soil samples collected during *Rabi* 2007-08 (after 5 years of trial) from different soil depths under different treatments before wheat sowing, revealed pre-dominance of *P. minor, C. album* and *M. indica* in all treatments. Density of weeds was maximum in CT-CT treatment and it was distributed in all soil depths being more in 0-5 and 5-10 cm soil depths. In ZT-ZT and CT-ZT (rice-wheat) treatments, density of weeds was minimum and that was mainly concentrated in 0-5 and 5-10 cm soil depth. *P. minor* population was very low in ZT-ZT or CT-ZT treatments as compared to CT-CT in 0-5 cm and 5-10 cm soil depth. Density of broad-leaf weeds particularly *C. album* was more in CT-ZT treatment followed by ZT-ZT and MT-ZT treatments at both soil depths (Table 3 and Fig. 2).

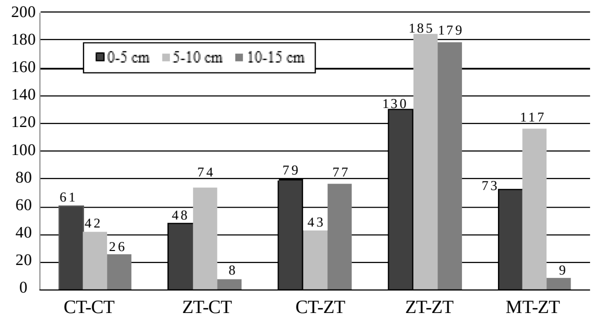

Fig. 1. Weed seeds emergence at different depths as affected by tillage methods (*Kharif* 2007)

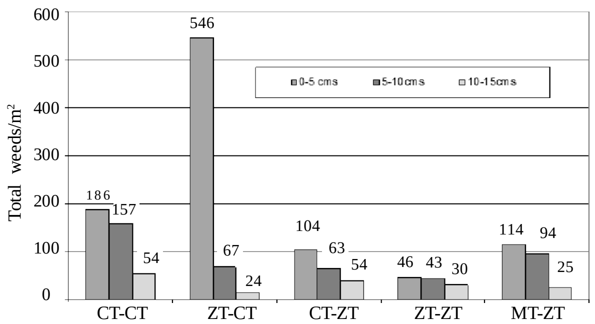

Fig. 2. Weed dynamics in different soil layers as affected by tillage practices (*Rabi* 2007-08)

Grain yield

Grain yield of rice and wheat varied significantly among treatments every year except *Rabi* 2003-04. During 2004-05, 2005-06 and 2007-08, maximum grain yield (4.98, 4.87 and 5.45 t/ha) of wheat was obtained under MT-ZT treatment which was significantly higher over CT-CT method during second and third years (Table 4). More grain yield of wheat under ZT-ZT planting method as compared to other tillage treatments in long term trial in pearl millet – wheat cropping system has been reported by Yadav *et al*. (2005). Grain yield of rice also differed significantly due to different tillage practices. During first year, grain yield of rice was maximum in MT-ZT and ZT-ZT but during 2nd, 3rd and 4th years, maximum grain yield (7.52, 7.71 and 7.20 t/ha) was recorded in CT-CT practices which was significantly higher than ZT-ZT and MT-ZT tillage practices. Higher grain yield of rice under MT and ZT during *Kharif* 2004 could be due to quick growth of seedling transplanted in shallow position in ZT and MT due to good rains occurred at transplanting time. Adhikari *et al* (2003) also reported grain yield of ZT rice at par with conventional transplanted rice.

Bulk density

Bulk density of the soil did not vary much even after five years of experimentation. Bulk density of soil increased with soil depth but did not vary much even after ninthcropharvest. In CT-CT, bulk density in 0-5 cm was around 1.37-1.39 g cm^3, whereas corresponding values for ZT-ZT were 1.38-1.42 g cm^3 (Table 5).

Soil temperature

The data on soil temperature (0-10 cm soil layer) recorded during first week of February and April (2004-08) in wheat have been given Table 6. It indicates that soil temperature in early February was 0.7-1.7 ^{O}C higher under ZT/MT method compared to CT. This increase in temperature under ZT might have facilitated better crop growth by better uptake and utilization of nutrients and also by avoiding crop from possible cold injury. Whereas lower temperature (2.1-3.8 ^{O}C) under ZT or MT compared to CT in first week of April might be helpful in uniform crop maturity by avoiding crop from terminal heat which usually results in forced maturity leading to shriveled grains and lower yields. Similar findings have been reported earlier also in wheat under ZT method in rice-wheat cropping system (Yadav *et al.* 2002).

Table 1. Effect of tillage practices on the density of different weeds in rice at 30 DAT

Tillage (Rice- wheat)	Weed density (no./m^2)							
	Echinochloa spp.				BLW			
	2004	2005	2006	2007	2004	2005	2006	2007
CT-CT	2.04(3.7)	2.04(2.9)	2.44(5)	1.73(2)	2.17(3.7)	1(0)	1.71(2.6)	1.91(2.7)
ZT-CT	4.67(22)	4.67(19)	4.54(19.8)	4.39(18.3)	2.94(7.6)	2.15(3.6)	2.62(6)	2.70(6.3)
CT-ZT	1(0)	1(0)	2(3)	1.71(2)	1.51(1.3)	1(0	1(0)	1(0)
ZT-ZT	5.06(28)	5.06(27)	5.25(26.7)	4.72(21.3)	3.46(11)	2.30(4.3)	3.49(15)	3.94(14.7)
MT-ZT	3.21 (9)	3.21(10)	2.47(5)	5.19(26)	1.92(2.7)	2.30(4.3)	2.62(6)	4.68(21)
LSD (P=0.05)	0.35	0.35	0.24	0.34	0.17	0.18	0.42	0.35

Figures in the parentheses indicate $(\sqrt{x+1})$ transformed data

Table 2. Density of different weeds in wheat as influenced by tillage practices at 35 DAS

Tillage (Rice-wheat)	Weed density (no./m^2)									
	P. minor					BLW				
	2003-04	2004-05	2005-06	2006-07	2007-08	2003-04	2004-05	2005-06	2006-07	2007-08
CT-CT	4.2(16.7)	2.1(3.3)	1(0)	2.2(44)	3.6(12.5)	3.3(9.6)	3.2(9.3)	1.6(1.7)	1.8(1.2)	1.9(3.7)
ZT-CT	4.5(19.0)	2.5(5.4)	1.7(2.2)	7.3(52.3)	4(15)	3.7(13.0)	3.2(9.1)	1.5(1.3)	2.1(3.3)	2.1(3.4)
CT-ZT	4.3(17.6)	2.4(5.0)	1.8(2.4)	6.6(42.6)	3(8.3)	4.3(17.9)	4.1(16.2)	8.9(79)	5.5(29)	5.3(28)
ZT-ZT	4.1(16.3)	2.4(4.7)	1(0)	4.5(19.3)	2.5(5.4)	4.1(16)	5.3(27.2)	8.4(70.4)	7(48.3)	6.3(38.4)
MT-ZT	4.2(17.5)	2.6(6.0)	1.7(1)	6.6(43)	1.9(2.7)	3.7(12.9)	4.1(15.7)	2.6(5.7)	4.9(22.7)	4.7(21.3)
LSD (P=0.05)	NS	NS	0.13	0.32	0.52	0.34	0.31	0.83	0.63	0.46

Figures in the parentheses indicate $(\sqrt{x+1})$ transformed data

Table 3. Weed dynamics in wheat as affected by planting methods (*Rabi* 2007-08)

Tillage	*P. minor*	*C. album*	*R. dentatus*	*M. indica*	*Total*
0-5 cm soil depth					
CT-CT	166	4	0	16	186
ZT-CT	546	0	0	0	546
CT-ZT	8	80	0	16	104
ZT-ZT	33	12	0	1	46
MT-ZT	85	22	0	7	114
5-10 cm soil depth					
CT-CT	133	3	0	21	157
ZT-CT	54	0	0	13	67
CT-ZT	31	33	0	0	64
ZT-ZT	9	28	2	4	43
MT-ZT	69	16	8	2	95
10-15 cm soil depth					
CT-CT	40	4	0	12	54
ZT-CT	5	1	0	8	14
CT-ZT	3	57	1	8	39
ZT-ZT	2	13	7	8	30
MT-ZT	11	7	4	3	25

Soil carbon

Data on soil carbon recorded after 7thcrop of wheat harvest in May, 2007 from different soil layers (0-5, 5-10, 10-15 and 15-20 cm) varied significantly in different soil layers. In general, it was maximum in treatments of ZT-ZT and MT-ZT method of planting and significantly more than CT- CT method at all soil depths (Table 7). In 0-5 cm soil layer, soil organic carbon was maximum(1.01-1.03%) in ZT-ZT and MT-ZT method of planting as compared to 0.85% in CT-CT method. Similarly, the soil organic carbon content was reported more in soil that had been more under zero tillage/reduced tillage for longer periods (Doran 1987, Havlin *et al.* 1990, Franzluebebbers *et al.* 1995).

Microbial population

Microbial population after harvest of 6th crop (rice) in sequence as shown in (Table 8), ranged from 219-242 mg/kg soil in treatments of zero tillage (MT-ZT and ZT-ZT) which was more than CT-CT treatment (168 mg/kg soil). Dehydrogenase activity

Table 4. Effect of tillage practices on grain yield (t/ha) of wheat and rice

Tillage (Rice-wheat)	Wheat					Rice			
	2003-04	2004-05	2005-06	2006-07	2007-08	2004	2005	2006	2007
CT-CT	5.50	4.80	4.81	5.25	5.42	7.52	7.98	7.71	7.20
ZT-CT	5.55	4.82	4.80	5.16	5.20	7.53	6.96	7.60	7.16
CT-ZT	5.60	4.90	4.70	5.02	5.38	7.45	7.11	7.65	7.18
ZT-ZT	5.54	4.92	4.81	5.20	5.40	7.97	6.72	6.70	6.60
MT-ZT	5.55	4.98	4.87	5.18	5.45	8.13	6.88	6.94	6.30
LSD (P=0.05)	NS	0.07	0.06	0.06	0.03	0. 24	0.24	0.31	0.24

Table 5. Bulk density of soil as influenced by various tillage practices in rice-wheat cropping system (2005-2008)

Tillage (Rice-wheat)	Bulk density (g/cm^3) Kharif				Rabi			
	2005	2006	2007	2008	2004-05	2005-06	2006-07	2007-08
Soil depth 0-5 cm								
CT-CT	1.37	1.39	1.38	1.38	1.39	1.38	1.38	1.39
ZT-CT	1.37	1.37	1.38	1.39	1.39	1.37	1.38	1.39
CT-ZT	1.40	1.39	1.40	1.40	1.41	1.40	1.39	1.40
ZT-ZT	1.42	1.38	1.41	1.41	1.42	1.39	1.40	1.40
MT-ZT	1.43	1.39	1.42	1.42	1.41	1.41	1.41	1.41
LSD(P=0.05)	0.02	NS	0.02	0.02	NS	0.021	NS	NS
Soil depth 5-10 cm								
CT-CT	1.46	1. 47	1. 50	1.48	1.47	1.47	1.48	1.47
ZT-CT	1.51	1.48	1.54	1.50	1.51	1.48	1.48	1.48
CT-ZT	1.50	1.49	1.51	1.51	1.50	1.49	1.49	1.49
ZT-ZT	1.50	1.50	1.49	1.49	1.50	1.50	1.50	1.51
MT-ZT	1.47	1.49	1.51	1.50	1.47	1.50	1.50	1.50
LSD(P=0.05)	0.03	NS	0.02	NS	0.023	NS	NS	0.027
Soil depth 10-15 cm								
CT-CT	1.66	1.66	1.66	1.67	1.66	1.66	1.67	1.67
ZT-CT	1.66	1.68	1.66	1.68	1.68	1.68	1.69	1.66
CT-ZT	1.65	1.65	1.63	1.63	1.63	1.63	1.63	1.65
ZT-ZT	1.63	1.63	1.61	1.64	1.63	1.63	1.63	1.65
MT-ZT	1.64	1.63	1.64	1.63	1.64	1.64	1.64	1.67
LSD(P=0.05)	NS	0.03	0.03	0.03	0.04	0.03	0.04	NS

Table 6. Impact of tillage practices on soil temperature in the root zone of wheat

Tillage (Rice-wheat)	Soil temperature (^0C) January					April				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
CT-CT	8.72	8.64	8.32	8.42	8.46	26.5	27.2	27.6	27.6	27.3
ZT-CT	8.70	8.70	8.69	8.50	8.65	26.5	26.9	27.8	28.0	26.8
CT-ZT	8.72	8.76	9.48	9.45	9.46	26.2	24.3	25.0	25.3	24.5
ZT-ZT	8.98	9.48	9.56	9.56	9.52	25.9	23.5	24.6	23.0	23.4
MT-ZT	9.16	9.46	9.54	9.55	9.54	25.7	23.3	24.0	23.8	23.8
LSD (P=0.05)	0.04	0.03	0.06	0.2	0.03	NS	1.2	2.2	1.8	2.3

Table 7. Soil organic carbon (%) at various soil depths in different tillage treatments after 4 years (before 7th crop of rice *i.e.* after wheat harvest, 2006)

Planting (Rice-wheat)	Soil depth (cm) 0-5	5-10	10-15	15-20
CT-CT	0.85	0.68	0.35	0.35
ZT-CT	0.81	0.64	0.32	0.31
CT-ZT	0.87	0.68	0.43	0.38
ZT-ZT	1.01	0.86	0.54	0.46
MT-ZT	1.03	0.82	0.62	0.45
LSD(P=0.05)	0.11	0.12	0.14	0.6

Table 8. Microbial population as affected by tillage practices in rice and wheat after wheat harvest (2006)

Tillage (Rice-wheat)	MBC (mg/kg soil)	Dehydrogenase activity (µg TPF/µg soil/24 hrs	Phosphate activity (µg PNP/g dry soil/hr
CT-CT	168	77	80
ZT-CT	212	115	90
CT-ZT	223	114	98
ZT-ZT	242	117	104
MT-ZT	219	87	90

in ZT-ZT treatment was 117 µg TPF/µg soil/24 as compared to CT-CT treatment whereas phosphate population in ZT-ZT method was 104 µg PNP/g dry soil/hr as compared to 80 µg PNP /g dry soil/hr in CT-CT method. Results of experiments conducted at CCS HAU Hisar by Kumar *et al*. (2003) also have clearly reflected that microbial count, soil organic carbon and DHA were higher in ZT field followed by mould board plough and CT soil. The greater number of microorganisms and their activity closure to soil surface under zero till system could be associated primarily with some residues retained.

Water consumption

During *Kharif* 2004 and 2005, rains were very good but even then water requirement of ZT transplanted rice was more (4.9-27.9%) as compared to conventional transplanted rice. During 2006, due to poor rains rice crop consumed more water and in ZT-ZT method of planting, Tube well had to run for 685 hours which was 184% more than CT-CT method due to higher percolation of water in unpuddled conditions (Table 9).

Conclusion

Transplanted zero till rice would provide lowland farmers with some flexibility in the timeline of the rice planting and its establishment in accordance to the onset of monsoon rains as does the normal farmer practice. Non-puddled rice transplanting method could be a viable technology

Table 9. Water requirement of rice under different tillage systems in *Kharif*

Tillage (Rice-wheat)	2004 Total time consumed for irrigations (h)	2004 Percent increase /decrease over conventional method	2005 Total time consumed for irrigations (h)	2005 Percent Increase /decrease over conventional method	2006 Total time consumed for irrigations (h)	2006 Percent increase over conventional method
CT-CT	143	-	91.6	-	241	-
ZT-CT	167	+16.6	100.7	+10.3	526	118
CT-ZT	112	-21.7	77.4	-15.5	244	1.2
ZT-ZT	184	+27.9	96.0	+4.8	685	184
MT-ZT	152	+5.8	90.0	-1.75	562	133

and an alternative to puddled transplanted rice particularly in the years of heavy rainfall. Therefore, puddled transplanting of rice followed by zero till sowing of wheat was the most promising option for improving productivity and profitability while sustaining the natural resources and addressing the emerging challenges in rice-wheat cropping system of north-west India.

REFERENCES

Adhikari U, Justice S, Tripathi J and Bhatta MR. 2007. Performance evaluation of non-puddled rice transplanting methods. In: *25th National Summer Crops Workshop* June 21-23, 2007 at National Agriculture Research Institute, NARC, Khumaltar,Lalitpur, Nepal.

Au J. 2001. The no tillage technique with grammaxone in rice and wheat production in the water saving and conservation agriculture, pp. 836-842. In: *Proceedings of 18th Asian-Pacific Weed Science Society Conference,* May 28-June 2 2001, Beijing, China.

De Datta SK. 1981. *Principles and Practices of Rice Production.* A Wiley Inter Science Publication, John Wiley& Sons, Inc, 605 Third Avenue, New York. 618 p.

Doran JW. 1987. Microbial biomass and mineralizable nitrogen distributionin no tillage and plowed soils. *Biology and Fertility of Soils* **5**: 68-75.

Franzluebbers AJ, Hons FM and Zuberer. 1995. Soil organic carbon, microbial biomass and mineralizable carbon and nitrogen in sorghum. *Soil Science Society of America Journal* **59**: 460-466.

Gupta RK and Seth A. 2007. A review of resource conserving technologies for sustainable management of the rice–wheat cropping systems of the Indo-Gangetic plains (IGP), *Crop Protection* **26:** 436-447.

Hakim N. 1986. *Fundamentals of Soil Science.* Univ. Lampung, Bander Lampung. (Indonesia). 480 p.

Havlin JL, Kissel DE, Maddux LD, Claassen MM and Lang JH. 1990. Crop rotation and tillage effects on soil organic carbon and nitrogen. *Soil Science Society of America Journal* **59:** 467-470.

Hobbs P. and Morris M. 1996. Meeting South Asia's future food requirement from rice-wheat cropping systems: Issues facing researchers in the post-green revolution era. *NRG Paper 96-01 Mexico,* DF: CIMMYT.

Kumar S. 2003. *Influence of tillage in wheat (*Triticum aestivum*) on soil microbial population and its activities.* MSc Thesis, CCS HAU Hisar.

Lamid, Z, Saraigih ES and Tambijo AD. 2001. Effect of continuous no-tillage applied glyphosate herbicide on weed community of irrigated low land rice, pp. 43-48. In: *Proceedings of 18th Asian-Pacific Weed Science Society Conference*. 28 May - 2 June, 2001, Beijing,China.

Sharma SK, Tomar RK and Gangwar KS. 1995. Effect of crop establishment and tillage practices on yield and economic of irrigated rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Sciences* **65**(9): 636-638.

Reddy CV, Malik RK and Yadav Ashok. 2005. Evaluation of double zero tillage in rice-wheat cropping system. pp. 118-121. In: *Accelerating the adoption of Resource Conservation Technologies in Rice-Wheat Systems of the Indo-Gangetic plains,* Proceedings of Project Workshop, June 1-2, 2005 at Hisar (Haryana), India.

Xin CY, Guo QY and Qin XL. 2001. Effect of shallow tillage on weed seed, soil moisture and crop yield,pp 324-327. In: *Proceedings of 18th Asian-Pacific Weed Science Society Conference.* 28 May - 2 June, 2001. Beijing, China.

Yadav Ashok, Malik RK, Balyan RS, Singh S. Chauhan BS, Yadav Dharambir, Murti Ram and Malik RS. 2002. Long term effects of zero tillage in rice-wheat cropping system, pp 158-161. In: *Herbicide Resistance Management and Zero Tillage in rice-wheat Cropping System*. Proceedings of International Workshop March 4-6, 2002, CCS Haryana Agricultural University, Hisar-125004(Haryana), India.

Yadav Ashok, Malik RK, Punia SS, Malik RS and Singh Sher. 2005. Studies on the impact of long term zero tillage in pearl millet-wheat cropping sequence, pp. 23-31. In: *Accelerating the adoption of Resource Conservation Technologies in Rice-wheat cropping systems of Indo-Gangetic Plains.* Proceedings of the Project Workshop, June 1-2, 2005, Directorate of Extension Education, CCS HAU Hisar (Haryana), India.