INTERACTIVE EFFECT OF RICE PRODUCITON SYSTEMS AND TILLAGE SYSTEMS IN RICE-WHEAT CROPPING SYSTEM

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ABSTRACT: Wheat yield is fined to be stagnant in rice-wheat cropping system. Zero tilled wheat followed by direct seeding of rice with alternate wetting and drying irrigation (AWD) technique requires less water and labor and seem to be a promising option to increase the productivity and net returns of rice-wheat cropping system. A field experiment was carried out to compare the zero and conventional tilled wheat after three different rice establishment methods *i.e.* flooded, alternate wetting and drying (AWD) and direct seeded conditions during the years 2008-09 and 2009-10. The wheat crop was cultivated soon after the harvesting of rice crop sown under three different conditions; *i.e.* flooded rice, the direct seeded rice sown with AWD and the aerobic direct seeded rice (DSR). Wheat (Seher-2006) was sown using zone disk tiller machine in zero tillage (ZT) and using farmers practices in conventional tillage (CT). The results revealed that the fertile tillers per unit area and grains spike^{-1} were affected substantially in 2008-09 showing maximum number of fertile tillers 311.25 in ZT wheat after AWD Rice and 379.73 CT wheat after DSR, but it was non-significant in 2009-10. In case of grain per spike in 2008-09, maximum number of grains spike^{-1} (53.93) was recorded in Zero Tilled ZT wheat after Flooded Rice and non-significant in rice - CT wheat. In year 2009-10, higher number of grains spike^{-1} 58.47 and 55.00 were recorded in ZT wheat after AWD Rice and CT Wheat after AWD Rice, respectively. Wheat grain yield 4.07 and 4.11 t ha^{-1} was harvested in 2008-09 while, 2.72 and 2.62 t ha^{-1} for zero and conventional tillage technology, respectively. Economic analysis revealed that during both years ZT wheat after rice gave feasible net returns (NR) as well as benefit cost ratio (BCR), when followed any rice cultivation system but maximum NR and BCR was achieved in AWD rice - ZT wheat system.

Key words: Alternate wetting and drying, Direct seeded rice, Zero till wheat and Yield.

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INTRODUCTION

Both rice (*Oryza sativa* L,) and wheat (*Triticum aestivum* L.) are the staple food crops and provides 80% of the total cereal crop production (Ali *et al.,* 2017). Wheat, a synonymous to staple food by the people and is one of the largest grain crop as compared to other cereals (Zain *et al.,* 2017). It contributes approximately 1.9% in the total GDP and 9.6% value addition in agriculture (Government of Pakistan, 2017). Area under wheat cultivation in irrigated and rain-fed areas of Pakistan consist of 9.052 Mha, providing 2.845 t ha^{-1} average yield (Ali *et al.,* 2008). Mostly, wheat crop is planted after transplanted flooded rice and rice-wheat (R-W) system occupies approximately 24 Mha in South-East-Asian subtropics, while especially in South-Asia, R-W system covers approximately 13.5 Mha area (Harmeet *et al.,* 2017).

Mostly rice is sown by transplanting (TPR) method and transplanting is done by manual labor. Conventional method of sowing (TPR) is quite laborious, time consuming and costly practice and the labor for this purpose is hired on area basis which is not familiar to the importance of plant population. Problem of transplanting in rice can be lessened through direct seeding which is being practiced in Pakistan on small scale (Farooq *et al.,* 2006a; Farooq *et al.,* 2009c; Joshi *et al*., 2013). Shortage of water is another problem which is limiting the yield of rice in Pakistan. (Briscoe and Qamar, 2009). Direct seeded rice saves 30% of irrigation water over the traditional method (Pepsico International, 2011).

Transplanted rice necessitates puddled compact soils to create standing water of depth 3-5 cm during the most of growing period of rice, while wheat demands well-drained and porous soils to grow vigorously (Weerakoon *et al.,* 2011). The puddled-flooded practice creates hardpan which is imperative to provide standing water condition but beside breaking this hardpan upcoming wheat root proliferation hindered due to problem of suffocation (Sharma *et al.,* 2003). So, for the breaking of this hardpan a lot of energy and time is required in conventional way of planting wheat (Bhatt *et* *al.*, 2016). The practices of conventional tillage (CT) for wheat after rice harvest involves drudgery with cultivator or sub soiling/deep tillage implements to provide fine porous seedbed for wheat cultivation which is tedious job in term of economics and labor (Iqbal *et al.*, 2002).

Zero tillage in wheat is the direct placing of seed by a suitable zero tillage drill into a narrow slot with only a minimal soil disturbance by using the residual moisture (Phillips and Young, 1973). Timely sown wheat gives more grain yield in R-W system of Pakistan and India especially because of ZT technology (Kahloon *et al.*, 2012; Singh *et al.*, 2012). Presently, the ZT drill is used for Cultivation of upcoming wheat crop in the paddy fields (Iqbal *et al.*, 2002; Tripathi *et al.*, 2013). Zero tillage technology is proving to be conducive in increasing the crop production and net income. ZT is an economical, labor saving, enhancing efficiency of fertilizers as well as water use and time saving cultivation practice, which ensure all sowing operations instantaneously (Iqbal *et al.*, 2002). Zero tillage also has great potential to improve the soil structure, aeration by returning the crop residues to the soil and also reducing the soil pollution by minimal use of chemical fertilizers (Sarwar and Goheer, 2017). Zero tillage also reduces tractor operations in the farmer's zero tillage wheat field to a single pass, implying a saving of 6-7 tractor hours and 35 L diesel with no significant yield difference compared with traditional method, in R-W system of Pakistan's Punjab but in Haryana state of India it also gave significantly increase in yield (Farooq et al., 2007; Mileusnic *et al*., 2010). In Pakistan area under zero tilled wheat was about one Mha during 2003-04 and currently more than 5,000 ZT drills are under use of farmer community for wheat cultivation (Keil *et al*., 2006; Akhtar, 2006).

Keeping in view the above discussed problems like scarcity of labor, fuel cost, moisture saving and delayed sowing of wheat in our prevailing R-W cropping system, an field based experiment was conducted to assess the feasibility of wheat at zero tillage in various rice planted conditions with zero tiller machine under the agro-climatic conditions of district Faisalabad.

MATERIALS AND METHODS

An experiment to investigate the performance of zero-tilled wheat after various rice planted conditions was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad during Rabi season of years 2008-09 and 2009-10. Weather conditions during the growing season of both years are provided in **Table I**. Composite sample of soil was taken for analysis from the area under experimentation and results of soil analysis are depicted in **Table II.**

Attributes	Value	Units	Status
Physical			
Sand	56	%	
Silt	28	%	
Clay	16	%	
Class			Sandy loam
Chemical			
Nitrogen	0.08	%	Low
Phosphorus	7	mg kg^{-1}	Low
Potassium	160	mg kg^{-1}	Medium
EC	0.6	dS m^{-1}	Non-saline
pH	7.9		Medium alkaline
Organic matter	0.47	%	Low

Table II. physical and chemical attributes of experimental area soil.

Replicated thrice experimental set of treatment was laid out under randomized complete block design with split-plot arrangement. Rice planting conditions were kept in the main plots while tillage intensities for wheat were placed in sub-plots. Wheat crop was cultivated soon after the harvesting of rice crop sown under three different conditions of previous crop *i.e.* flooded rice, the rice sown with alternate wetting and drying (AWD) and the direct seeded rice (DSR). Wheat variety (Seher-2006 procured from Ayub Agriculture research institute, Faisalabad) was cultivated using seed rate @ 125 Kg ha^{-1}. In first year crop was sown on December 4, 2008 while in 2nd year it was sown on November 23, 2009. In zero tillage (ZT) zone disk tiller machine was used to sow the crop utilizing the residual moisture of previous rice crop, while, in conventional tillage (CT), conventional wheat drill was used to sow the seed after conventional practices of tillage. Wheat was planted at distance of 22.5 cm apart rows.

Fertilizers were applied @ 105-85-60 Kg NPK ha^{-1} using sources urea, SSP and SOP fertilizers to provide nitrogen, phosphorus and potassium respectively. Complete dose of P, K and half dose of N was applied before sowing. While, remaining dose of N was top-dressed at tillering stage and before panicle initiation stage.

At harvest maturity, square meter area from each plot was harvested with sickle at 29th April and 21st April in 2008 and 2009 respectively. The yield and attributes related to yield like number of grains $spike^{-1}$, number of fertile tillers, test weight, grain yield, harvest index and biological yield were documented by following standard methods. Total tillers and fertile tillers of each square meter area from treatment were counted. Ten tillers from each treatment was taken randomly and thrashed separately to count the grain per spike and averaged. Digital grain counter was used to count three sample of 1000 grains and then weighed using digital electronic weighing balance and averaged. Adjusting 14% moisture content grain yield was calculated in Kg plot^{-1} and then converted into mound acre^{-1}. Collected data of all parameter was examined by using Fisher's ANOVA techniques and treatments mean were compared by using the LSD test at 5% probability level (Montogomery, 2013).

RESULTS AND DISCUSSION

The analysis of two years result data exhibited that yield and yield components of wheat were affected significantly by various rice field conditions and tillage intensities. Mostly the year's effect was found significant hence separate analysis for both the years was carried out.

Results revealed that wheat planted in various field conditions after rice harvest, had significant effect on number of fertile tillers m^{-2} in zero and conventional tillage system during 2008-09, while non-significant difference in 2009-10. In conventional tillage during 2008-09, wheat after flooded rice conditions and direct seeded rice produced higher number of fertile tillers (371 & 380 tillers m^{-2} respectively) than wheat after AWD rice conditions (**Table 1**). Wheat planted under zero tillage after all rice planted conditions performed in similar way in case of fertile tillers, so it suited well to all rice planted conditions. Conventional tillage also showed the similar trend during 2009-10 but it produced the fertile tillers least in wheat after AWD rice conditions and difference could not reach to the level of significance. Maximum number of wheat fertile tillers in the fields under DRS conditions may be attributed to normal and well aerated conditions beneath soil with ample aeration which promoted tillering, resulting in more number of fertile tillers than transplanted. These results are in accordance with Ehsanullah *et al.,* (2013) who stated that zero tillage produced higher number of seed fertile tillers as compared with conventional method of planting.

Interactive effect of sowing conditions of rice and tillage intensities on number of grains per spike was significant during both years 2008-09; the ZT wheat after flooded rice conditions and direct seeded rice conditions produced higher grains per spike, while conventional tillage gave similar response to all the rice conditions which was statistically at par with direct seeded rice conditions. Minimum number of grains per spike (49.83) was produced with zero tillage wheat after alternative wetting and drying conditions in 2008-09 while 50.87 grains per spike of wheat were observed in zero tillage wheat after flooded rice conditions during 2009-10 (Table 2). The wheat sown with conventional tillage system produced more number of grains per spike (58.53) after flooded rice conditions as against after direct seeded conditions. Number of grains per spike might be attributed due to better soil conditions which promoted number of fertile tillers ultimately increases the number of spikes, spikelet per spike and number of grains per spike. Subhan *et al*. (2017) concluded from their studies that tillage methods did not affect the number of grains per spike, these findings of are contrary to our study.

Data regarding 1000-grain weight indicated that both conventional and zero tillage did not show any difference in 1000-grain weight at all the rice field conditions for planting wheat during 2008-09. Next year the interactions were again non-significant, but data of means showed that zero tillage significantly produced higher 1000-grain weight (38.42 g) over the conventional tillage which was 36.95 g (Table 3). In our study, for first year 1000-grain weight was higher which might be due to better moisture availability due to plenty of rainfall throughout the growing season whereas lesser grain weight during 2009-10 was due to drought conditions at critical stages of wheat crop due to less rain fall and reserved soil moisture. So, it was concluded that environment had direct influence on the test weight that eventually influenced the total yield of a crop yield (Pavan *et al.,* 2011).

Wheat sowing methods *i.e.* conventional as well as zero tillage could not create significant differences in the grain yield during both the years. However, means of data in 2008-09 showed that conventional tillage produced 4.11 t ha^{-1} and zero tillage produced 4.07 t ha^{-1} while in 2009-10 zero tillage gave 3.72 and conventional 3.62 t ha^{-1} (Table 3). It is clear that grain yield was more during 2008-09 than second year which was due to climatic conditions such as rain fall. It might be due to more number of fertile tillers and 1000-grain weight during 2008-09 than 2009-10.

Biological yield during 2008-09 was higher in conventional tillage than zero tillage. Both the tillage practices *i.e.* conventional and zero after three rice planted conditions could not show any interactive significant difference on the biological yield of wheat crop during both the years. However, the mean data showed that in 2008-09 the conventional tillage produced significantly higher biological yield 12.22 t ha^{-1} under zero tillage 11.57 t ha^{-1} while in second year the conventional and zero tillage did not differ in biological yield (Table 3). It is evident from results that during 2008-9 the weather conditions were supportive for growth of wheat very well which ultimately accumulated maximum assimilates which transferred to sink (grains) and resultantly increased the grain yield. Furthermore, over all lower biological yields for second year might be due to unfavorable conditions (no rain fall). These results are contradictory to Ahmad *et al.,* (2013) as they indicated that over all biological yield obtained from ZT was higher than CT system.

The harvest index was not significantly affected by both the wheat sowing methods *i.e.* zero and conventional ones after all the rice planting conditions. Similarly, interaction among the wheat sowing methods and rice planting conditions was also found non-significant. However, in 2008-09 the value of harvest index varied from 31.21 to 38.08 % and 32. 27 to 34.77 during 2009-10 (Table 3). The results obtained pertaining to harvest index is contradictory to Imran *et al.,* (2013) and Erenstein *et al.,* (2008) who concluded that zero tillage gave the maximum harvest index in the favorable environmental conditions. So, it is clear from this study that the zero-tilled wheat in all rice system produced statistically similar values of harvest index but somewhat higher than conventional method.

Wheat crop planted with zone disk tiller at zero tillage produced the highest net return of Rs. 50759/- with benefit cost ratio (BCR) of 1.68 which was higher than the conventional sowing method. However, among the different rice planted conditions, the maximum net return of Rs. 54049/- with BCR of 1.72 was achieved from the field where previously rice was planted using intermittent wetting and dry at zero tillage. In ZT, the cost of production was low as compared to CT system that's why ZT gave the higher net return not only in intermittent irrigated rice field conditions but also in the flooded rice conditions. The conventional tillage wheat sown in direct seeded rice conditions gave higher net return than zero tillage in the same field (Rs. 53211/- with 1.65 BCR). The conventional tillage wheat sown after AWD rice field conditions gave the minimum net return during both years (Table 4). No doubt, in all combinations yield produced was statistically at par but net return was reduced in ZT wheat because of least cost of production in conservational tillage (ZT) as equated with CT. These results were well supported by Coventrya *et al.,* (2011) who reported from their long-term research, that ZT is primarily an economical technology which gave higher return over the CT in R-W system. During the year 2009-10, the weather remained mostly dry and total rain fall was low during the whole season. Due to this reason, the yield was lower than the previous year and response was different to various treatments. No doubt, during this year the crop accumulated enough dry matter but at the time of transferring these assimilates into sink, the temperature was abruptly increased, and crop sharply moved to its maturity due to which the grains shrunk and lead to the lower yield. Anyhow, the zero tillage for wheat also performed well in similar harsh weather (Table 8). Here, it is cleared that the overall performance of zero tillage for wheat in rice-wheat system was better than the conventional method during both years experiment. Erenstein and Laxmi, (2008) reported that zero tillage was a resource conservation technology which produced the maximum net return not only in terms of money but also kept the nutrients status balanced in the rice-wheat system of Indo-Gangetic plains. Tabatabaeefar *et al.* (2009) reported the similar results that zero tillage was cost saving technology in terms of fuel and labor charges and ultimately gave a maximum net return in the rice-wheat cropping system.

Table: 1. Effect of sowing methods of wheat planted after various rice conditions on number of fertile tillers m^{-2}.

Treatments	2008-09		2009-10	
	ZT	CT	ZT	CT
Wheat after Flooded Rice	293.64 c	370.72 a	271.12 NS	268.08 NS
Wheat after AWD Rice	311.25 a	295.38 b	298.85	258.20
Wheat after DSR	305.76 b	379.73 a	288.02	307.09
Mean	303.55 B	348.61 A	286.00	277.79

Values sharing the different letters differ significantly at $p \leq 0.05$, LSD value for tillage densities (2008-09) = 30.39 while for interactions (2008-09) = 52.64, ZT = Zero tillage,
CT = Conventional tillage

Table: 2. Effect of sowing methods of wheat planted after various rice conditions on number of grains per spike.

Treatments	2008-09		2009-10	
	ZT	CT	ZT	CT
Wheat after Flooded Rice	53.93 a	52.78 NS	50.87b	58.53 a
Wheat after AWD Rice	49.83 b	53.60	58.47a	55.00 a
Wheat after DSR	53.15 a	51.80	53.67a	52.13 b
Mean	52.31	52.73	54.33	55.22

Values sharing the different letters differ significantly at $p \leq 0.05$, LSD value for interaction (2008-9) = 3.14 while for interactions (2009-10) = 5.32, ZT = Zero tillage, CT = Conventional tillage

Table: 3. Effect of different rice field conditions and rice systems on yield components of wheat.

Treatments	TGW		BY		HI		GY	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Rice field conditions								
Flooded rice	44.77	39.40	11.6	9.76	35.82	34.04	4.15	3.67
AWD rice	44.81	35.84	12.19	9.45	32.46	34.49	3.96	3.69
DSR	47.02	37.79	11.89	9.53	35.04	33.87	4.16	3.64
LSD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS
Tillage systems								
ZT	45.01	38.42 A	11.57 B	9.44	35.22	32.81	4.07	3.72
CT	46.06	36.95 B	12.22 A	9.06	33.66	34.45	4.11	3.62
LSD ($p \leq 0.05$)	NS	1.16	0.58	NS	NS	NS	NS	NS
Interaction	**Non-significant**							

Means with different letters differ significantly at $p \leq 0.05$; TGW= 1000-grain weight (g); BY= Biological yield (t ha^{-1}); HI= Harvest index; GY= Grain yield (t ha^{-1}); AWD= Alternate wetting and drying; DSR= Direct seeded rice; ZT= Zero tillage; CT= Conventional tillage

Table: 4. Effect of sowing methods of wheat planted after various rice conditions on economic analysis.

Treatment	GrainYield t ha^{-1}	Value Rs. ha^{-1}	Straw yield t ha^{-1}	Value Rs. ha^{-1}	Gross Income Rs. ha^{-1}	Variable cost Rs. ha^{-1}	Total cost Rs. ha^{-1}	Net Return Rs. ha^{-1}	Benefit cost ratio
2008-09									
P_1S_1	4.20	99750	6.81	25550	125300	24340	74541	50759	1.68
P_1S_2	4.10	97295	8.10	30362	127658	30453	80654	47004	1.58
P_2S_1	4.13	98087	8.07	30275	128362	24112	74313	54049	1.72
P_2S_2	3.80	90170	8.39	31475	121645	29473	79674	41971	1.52
P_3S_1	3.88	92070	7.62	28562	120633	23284	73485	47148	1.64
P_3S_2	4.45	105608	7.84	29400	135008	31596	81797	53211	1.65
2009-10									
P_1S_1	3.75	89063	5.79	23160	112223	19620	69821	42402	1.60
P_1S_2	3.59	85263	5.40	21600	106863	25527	75728	31135	1.41
P_2S_1	3.79	90013	6.10	24400	114413	19737	69938	44475	1.63
P_2S_2	3.59	85263	5.43	21720	106983	25527	75728	31255	1.41
P_3S_1	3.61	85738	5.27	21080	106818	19160	69361	37457	1.54
P_3S_2	3.68	87400	5.49	21960	109360	25841	76042	33319	1.43

P_1 = Wheat after flooded rice, P_2 = Wheat after AWD rice, P_3 = Wheat after DSR, S_1 = Zero tillage, S_2 = Conventional tillage, Wheat @ Rs. 950/40 kg, Wheat straw @ Rs. 160/40 kg, Permanent cost = Rs. 50201/-

Conclusion: Wheat sowing under zero tillage and conventional tillage after various rice cultivation practices, it is concluded that zero tillage of wheat after direct seeded rice or conventional rice cultivation is a resource conservation technology which facilitates timely sowing of wheat crop, reduces edaphic conflicts, labor and energy saving practice and gave maximum net return as well as higher BCR.

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