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RESEARCH ARTICLE

Irrigated Wheat Response to Different Tillage Systems, Crop Residue Management Practices and Sowing Dates in Rice-Wheat Cropping System

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ABSTRACT

The rice-wheat cropping system (RWCS) has been practiced by farmers in South-Asia for more than 1000 years. To find out the significance of RWCS, field experiments were carried out on silty clay soil at Government seed farm, Ratta Kulachi, Dera Ismail Khan, Pakistan during the crop season 2010-11 and 2011-12, to study the effect of three sowing dates (early; 20^{th} October, optimum; 15^{th} November and late; 10^{th} December) and six tillage systems on wheat yield in rice wheat cropping system. The tillage methods consisted of zero tillage (ZT) straw retained (ZTsr), ZT straw burnt (ZTsb), reduced tillage (RT) straw incorporated (RTsi), RT straw burnt (RTsb), conventional tillage (CT) straw incorporated (CTsi) and CT straw burnt (CTsb). Sowing dates, tillage systems and their interaction significantly influenced all the tested attributes. Mean values for sowing dates revealed that plant height (97.91 and98.80cm), 1000-grain weight (40.29 and 39.82 g), biological yield (17.47 and19.17 t ha^{-1}) and grain yield (5.39 and5.44t ha^{-1}) were significantly higher at early sowing in both the crop seasons. Mean values for tillage systems showed that either ZTsr or RTsi produced maximum grain (5.24 and 5.25 t ha^{-1}) and biological yields (16.91 and16.20 t ha^{-1}) with more 1000-grain weight (38.07 and 38.27 g) and plant height (92.74 and 94.07 cm), in both of the crop seasons. In interaction effects, early sowing with RTsi and optimum sowing with ZTsr produced maximum grain yield in both years. The results suggested that early sowing with RTsi and optimum sowing with ZTsr might be an optimum and sustainable approach to increase wheat yield in rice-wheat cropping system.

INTRODUCTION

The rice-wheat cropping system (RWCS) has been practiced by farmers in South-Asia for more than 1000 years. RWCS constitutes a major crop production system of Pakistan (Farooq et al., 2007; Krishna et al., 2012). In Pakistan wheat is cultivated over an area of 8.662 million hectares with total production of 23.00 million tons with average yield of 2.66 t ha^{-1} (GOP, 2013).

Average per unit wheat yield in Pakistan is lower than other developing and developed countries due to several biotic and abiotic factors such as rain showers at the time of harvest, imbalance fertilizer application, non-availability of certified seed, lack of resistant varieties, late sowing due to cropping patterns and improper cultural practices. Among these, sowing dates and selection of tillage practices is of prime importance. Optimum sowing date selection for different localities depends on temperature, rainfall pattern and the maturity duration of the particular wheat variety (Qasim et al., 2008). Early sowing is one of the favorable factors affecting crop growth, development and economic yield. Early sowing increases germination, plant height, spikelets per spike, grains per spike and 1000-grain weight compared to late sowing (Shafiq, 2004). Maximum grain yield can be obtained by early and optimum sowing dates (Baloch et al., 2010). Optimum sowing increases number of grains $spike^{-1}$, 1000-grain weight, biological yield and grain yield (Said et al., 2012). Yan et al. (2008) reported that optimum sowing date resulted in the highest grain protein content and yield in wheat.

Delay in sowing generally decreases individual plant growth and tiller production (Nazir et al., 2004). Late planting not only affects germination, growth, grain development (Haq and Khan, 2002) but also produces poor tillering due to winter injury in low temperature (Tahir et al., 2009). The late sown crop receiving higher temperature at grain filling stage may be one of the yield-reducing factors (Rehman et al., 2007). Delayed planting decreases wheat yield upto 37% compared to optimal sowing date (Anwar et al., 2011).

Tillage practice is also an important yield contributing factor. Tillage practices and residue management often change soil micro-environment which ultimately affect wheat yield. This may be one of the reasons for drastic difference in wheat yield in different parts of the world (Stone and Savin, 2000). Most of the farmers use excessive tillage to rice field in addition to burning the stubbles, while some incorporate the residues into the soil to prepare suitable land for next season crop. Both excessive tillage and rice residues burning damage soil quality as well as pose adverse effects to environment. Burning produces greenhouse gases which are harmful to environment and human health (Mandal et al., 2004; Brar et al., 2010). Conventional tillage (CT) which includes several passes (8-16) of a tractor to complete sowing process results in delayed wheat sowing (Chauhan et al., 2003). Soil compaction is one of the reasons of low yield and is a severe environmental problem caused by CT (Ahmad et al., 2009).Enormous amount of nutrients may be lost from residues burning (Brar et al., 2010) which destroy valuable natural resources (organic matter) and as a result soil physical, chemical and biological properties are adversely affected (Taa et al., 2004; Gangwar et al.,2006; Brar et al., 2010).The retention or incorporation of rice residues in soil may affect soil fertility, physical and chemical properties and crop yield (Eagle et al., 2000; Witt et al., 2000; Wang et al., 2001).Reduced tillage (RT) also mitigates greenhouse gas emission through carbon sequestration (McConkey et al., 2003).

Wheat is a major staple food crop of half of the global population and follow rice in RWCS. Residue management in RWCS through different tillage system has gained enormous importance since last decades due to rising atmospheric CO_2 concentration around the globe. Keeping in view the importance of residue management in RWCS; the current study was conducted to evaluate the response of wheat crop to sowing dates, tillage systems and reside management practices in rice-wheat cropping system.

MATERIALS AND METHODS

Experimental site

The current study was conducted at Government Seed Farm Ratta Kulachi, District Dera Ismail Khan (31º49´N, 70°55´E, 166 m a.s.l.) Pakistan for two consecutive years 2010-11 and 2011-12. The soil of the area is Hyperthermic, and Typic Torrifluvents, a little saline, less fertile and needs irrigation for growing crops (Soil Survey Staff, 2009). The area is arid and Indus river water is the major source of irrigation. Climate is hot and dry in summer with small rainfall in monsoon season. Rainfall generally occurs in February-May. The weather data of the cropping season is shown in Figure 1.

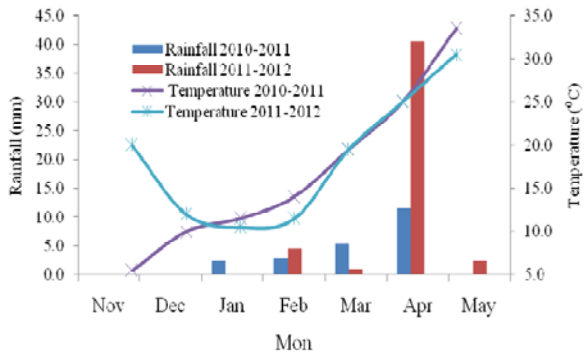

Fig. 1: Rain fall data of Dera Ismail Khan

Soil analysis

Soil samples were taken to a depth of 30 cm prior to crop sowing and analyzed for physico-chemical properties as mentioned in table.

Organic matter was determined by Walkley and Black method (Nelson and Sommers, 1982) while total soil N was analyzed by Kjeldhal method (Bremner and Mulvaney, 1982). Phosphorus and Potassium were calculated through spectrophotometer and flame photometer, respectively. The extractable P and K in soil samples were measured by the AB-DTPA extractable method (Soltanpour, 1985).

Experimental procedure

The experiments were conducted at the same site for two consecutive years using a 2 year rice-wheat rotation in a randomized complete block (RCB)design with split-plot arrangement. The experimental field was divided into main and sub-plots. The stubbles of the previous rice crop were burnt in selected plots. Field was given light irrigation before land preparation to have better and soften field condition, it was given 3ploughings (including operation with disc-plough, cultivator and rotavator) followed by planking for land preparation and sowing of wheat crop after the harvest of rice (conventional method of sowing). A shallow rotavator was used after cultivator in reduced tillage, while in case of zero tillage no ploughing was done. Sowing dates viz; (i)20 October, (ii) 15 November and (iii) 10 December were assigned to main plots while tillage plus residue management viz;(i)Zero Tillage (ZT) + Rice straw retained on surface (ZTsr), (ii) ZT + Rice straw burnt (ZTsb), (iii) Reduced Tillage (RT) + Rice straw incorporated (RTsi), (iv) RT + Rice straw burnt (RTsb), (v) Conventional Tillage (CT) + Rice straw incorporated (CTsi), and (vi) CT + Rice straw burnt (CTsb) were assigned to sub-plots. There were four replications with sub plot size of 5 × 2.4 m during both years. Wheat variety Hashim-08 was used as test material. Recommended dozes of fertilizers @150-120-90 NPK kg ha^{-1} was applied. All P, K and half N was applied at the time of sowing and the remaining half dose of N was further divided into two splits and was applied with 1st and 2nd irrigation. All other agronomic practices were kept optimum to keep crop free from diseases and pests.

Data recording and statistical analysis

The data regarding Plant Height (cm), 1000-grain weight (g), biological yield (t ha^{-1}), economic yield (t ha^{-1}) and harvest index (%) was collected at harvest and subjected to analysis of variance technique (ANOVA) appropriate for RCBD with split-plot arrangement as suggested by Steel and Torrie (1980). Least significance difference (LSD) test was applied when ANOVA showed significant differences.

RESULTS

Plant height (cm)

Plant height was significantly (P≤0.01) influenced by sowing date, till age practices and interaction among sowing dates and tillage practice during both the crop season (Table1). Maximum plant height of 97.91 and 98.04 cm was recorded in early sown wheat crop during both the crop seasons, whereas late sowing depicted minimum plant height (Table2). ZTsr produced taller wheat plants (92.74 and 94.07cm in 2010-11 and 2011-12 respectively) while minimum plant height was recorded in CTsb during both the years. In the interactions (D×T), maximum plant height of 98.58and 98.40 cm was observed in RTsi and ZTsr with early sown wheat cropduring 2010-11 and 2011-12 respectively. Minimum plant height 79.93and 82.10cm was recorded in late sown crop with RTsb and CTsb in both season respectively (Table2).

1000-grain weight (g)

Thousand grain weight was significantly (P≤0.01) affected by sowing date, tillage and interactions among sowing dates and tillage systems in both the growing season (Table1). Maximum 1000- grain weight of (40.29 and 39.82 g) was noted in early sown crop during both years, whereas, minimum 1000-grain weight (31.60 and32.80 g) was observed in late sowing during both years of study (Table-3). Among different tillage and residue management practices; ZTsr produced maximum 1000-grain weight during both crop seasons. Minimum 1000-grain weight was noted in ZTsb and CTsb during 2010-11 and 2011-12 respectively. In D × T, maximum 1000-grain weight was obtained in early sowing with RTsi and ZTsr during 2010-11 and 2011-12 respectively. Minimum 1000-grain weight was noted in late sown crop with ZTsb and CTsb in both years.

Table 1: Physico-chemical properties of experimental site

S. No.	Physico-chemical properties	Values
1	Texture	Silty clay, calcareous
2	Sand	147 g kg^{-1}
3	Silt	451 g kg^{-1}
4	Clay	402 g kg^{-1}
5	Ph	7.8
6	Organic Matter	6.4 g kg^{-1}
7	Total N	0.3 g kg^{-1}
8	AB-DTPA extractable P	7.7 mg kg^{-1}soil
9	Available K	195 mg kg^{-1}soil

Biological yield (t ha^{-1})

Biological yield was significantly (P≤0.01) affected by sowing date, tillage practices and interactions among sowing date and tillage practices in both years (Table-1). Maximum biological yield was noted in early sown crop during in each year of trial. Optimum sowing also produced comparable biological yield in both years. Minimum biological yield was recorded in late sowing during both years (Table-4). ZTsr produced maximum biological yield in both years while, minimum biological yield was recorded in CTsb. Regarding interactions, optimum sowing with ZTsr produced maximum biological yield during 2010-11 and early sown crop with RTsi depicted maximum biological yield of 20.92 t ha^{-1} in 2011-12. Minimum biological yield was observed in late sown wheat crop with ZTsb and CTsb in both years.

Grain yield (t ha^{-1})

Grain yield was significantly (P≤0.01) influenced by sowing date, tillage and interaction of sowing date to tillage practices (Table-1). Maximum grain was recorded in early sown wheat crop during each year while minimum grain yield was noted in late sown crop (Table-5).The grain yield of optimum sowing date was comparable and intermediate between early and late sown crop. RTsi and ZTsr produced maximum grain yield during 2010-2011and 2011-2012 respectively. Moreover, regarding interactions, early sown crop with RTsi observed maximum grain yield which was statistically at par with grain yield produced in optimum sown crop with ZTsr in 2010-11. In 2011-12, maximum grain yield was obtained in optimum sowing with ZTsr where as minimum grain yield was found in late sown wheat crop with ZTsb and RTsb during both the seasons.

Harvest index (%)

Harvest index (HI) remained significant (P≤0.01) for sowing date, tillage practices and interaction of sowing date to tillage in both the growing season(Table-1). Maximum HI was recorded in late sown wheat crop during both years while minimum was calculated in early planted crop during each year (Table-6). ZTsb and CTsb observed higher HI during both years of experiment while minimum was noted in CTsi in 2010-11 and ZTsr in 2011-12. In D × T, maximum HI was

Table 2: Mean square of yield and related attributes of wheat as affected by sowing dates and tillage plus crop residue management during growing season 2010-11 and 2011-12

S.V	D.F	Plant height	1000-grain weight	Biological yield	Grain yield	Harvest Index
2010-2011						
Replication	3	12.54	0.174	0.034	0.08960	1.99
Sowing date(D)	2	1710.83**	491.617**	417.001**	9.25232**	1172.91**
Tillage (T)	5	14.67**	13.622**	8.272**	0.52945**	21.35**
D × T	10	7.04*	4.507**	4.601**	0.66759**	7.65**
Error	45	3.41	0.011	0.004	0.00672	0.18
2011-2012						
Replication	3	1.25	0.659	0.144	0.0876	1.58
Sowing date(D)	2	1464.24.77**	324.103**	592.882**	13.2260**	1208.18**
Tillage (T)	5	12.70**	8.935**	12.192**	0.7082**	12.69**
D x T	10	2.57**	2.561**	6.526**	0.2766**	8.58**
Error	45	0.27	0.019	0.015	0.0064	0.34

***,**=** Significant at 5% and 1% level of probability respectively.

Table 3: Plant height (cm) of wheat as affected by sowing date and tillage plus crop residue management during growing season2010-2011 and2011-2012

Sowing Dates	Tillage plus residue management						Mean
	ZTsr	ZTsb	RTsi	RTsb	CTsi	CTsb	
2010-2011							
Oct.20	98.36a	97.05ab	98.58a	98.23a	98.53a	96.70ab	97.91a
Nov.15	97.23ab	96.44ab	93.43cd	93.38cd	94.75bc	91.70d	94.49b
Dec.10	82.63ef	80.88fg	92.90ef	79.93g	83.88e	81.05fg	81.88c
Mean	92.74a	91.45ab	91.63ab	90.51bc	92.38a	89.82c	
$LSD_{0.05}$ for D=1.81, T=1.52, D ×T=2.63							
2011-2012							
Oct.20	98.40a	97.71ab	98.34ab	98.05ab	98.13ab	97.63b	98.04a
Nov.15	98.30ab	97.78ab	97.95ab	94.53d	95.93c	94.95d	96.57b
Dec.10	85.50 e	84.34fg	84.75f	82.69h	83.65g	82.10h	83.84c
Mean	94.07a	93.28b	93.68ab	91.75d	92.57c	9156d	
$LSD_{0.05}$ for D=0.57, T=0.42, D ×T =0.73							

Table 4: 1000-grain weight (g) of wheat as affected by sowing date and tillage plus crop residue management during growingseason 2010-2011 and2011-2012

Sowing Dates	Tillage plus residue management						Mean
	ZTsr	ZTsb	RTsi	RTsb	CTsi	CTsb	
2010-2011							
Oct.20	41.59b	39.18e	42.66a	39.80c	39.40d	39.10e	40.29a
Nov.15	38.35f	38.25fg	38.15gh	38.08h	38.10h	38.05h	38.16b
Dec.10	34.26 i	29.12n	32.79j	37.46 l	31.95k	30.05m	31.60c
Mean	38.07a	35.51e	37.87b	36.45c	36.48c	35.73d	
LSD0.05 for D=0.12,T=0.09,D x T=0.15							
2011-2012							
Oct.20	41.82a	38.34f	41.57b	38.48f	39.60c	39.15d	39.82a
Nov.15	38.74e	38.05g	38.46f	38.32f	37.73h	37.75h	38.17b
Dec.10	34.24i	33.16j	33.15j	32.78k	32.25l	31.20m	32.80c
Mean	38.27a	36.52c	37.73b	36.53c	36.53c	36.03d	
LSD0.05 for D=0.07, T=0.11, D×T=0.20							

recorded in late sown crop with tillage practices RTsb, CTsb, RTsi and ZTsbin growing season 2010-2011 while in 2011-12, maximum HI (44.80%) was noted in late sown wheat crop with CTsb.

DISCUSSION

Sowing date had a significant effect on wheat yield and yield components. Wheat production is also highly dependent on optimum availability of nutrients and soil moisture. As reduced tillage has minimum soil manipulation, it economized the soil water loss through evaporation (Litch and Al-Kaisi, 2005). Optimum nutrients and well developed soil conditions due to carbon based source might extend the growth as a result of vigorous crop growth (Li, 2003). Early sowing date produced highest grain and biological yields due to heavier1000-grains and more plant height which might

Table 5: Biological yield (t ha^{-1}) of wheat as affected by sowing date and tillage plus crop residue management during growing season 2010-2011 & 2011-2012

Sowing Dates	Tillage plus residue management						Mean
	ZTsr	ZTsb	RTsi	RTsb	CTsi	CTsb	
2010-2011							
Oct.20	18.13b	16.88e	18.19b	17.02d	17.86c	16.75f	17.47a
Nov.15	19.06a	16.59g	16.72f	15.14i	16.41h	13.56j	16.24b
Dec.10	9.66m	8.42o	10.20l	9.31n	10.50k	10.20l	9.72c
Mean	15.61a	13.96d	15.03b	13.82e	14.92c	13.50 f	
LSD0.05 for D=0.03, T=0.05, D x T=0.09							
2011-2012							
Oct.20	19.53c	18.12e	20.92a	18.11e	19.21d	19.10d	19.17a
Nov.15	20.41b	19.51c	17.88f	16.43h	16.85g	14.30i	17.56b
Dec.10	10.77j	9.97k	9.79l	9.57m	10.08k	9.03n	9.87 c
Mean	16.91a	15.87c	16.20b	14.70e	15.38d	14.14f	
LSD0.05 for D=0.11, T=0.10, D x T=0.18							

Table 6: Grain yield (t ha^{-1}) of wheat as affected by sowing date and tillage plus crop residue management during growing season 2010-2011 and2011-2012

Sowing Dates	Tillage plus residue management						Mean
	ZTsr	ZTsb	RTsi	RTsb	CTsi	CTsb	
2010-2011							
Oct.20	5.54bc	5.52bc	5.85a	5.11de	5.23d	5.08e	5.39a
Nov.15	5.69ab	5.67b	5.42c	5.26d	4.60f	4.52f	5.19b
Dec.10	4.10g	3.68h	4.47f	4.11g	4.52f	4.50f	4.23c
Mean	5.11b	4.96c	5.25a	4.82d	4.78d	4.70e	
$LSD_{0.05}$ for D=0.13, T=0.07, D x T=0.12							
2011-2012							
Oct.20	5.67b	5.25d	5.70b	5.33cd	5.38c	5.30cd	5.44a
Nov.15	5.85a	5.71b	5.73b	5.02e	4.87f	4.65g	5.30b
Dec.10	4.20h	4.05ij	4.18h	3.95j	4.11hi	4.05ij	4.09c
Mean	5.24a	5.00b	5.20a	4.76c	4.79c	4.66d	
LSD0.05 for D=0.78, T=0.07, D x T=0.11							

Table 7: Harvest index (%) of wheat as affected by sowing date and tillage plus crop residue management during growing season 2010-2011 & 2011-2012

Sowing Dates	Tillage plus residue management						Mean
	ZTsr	ZTsb	RTsi	RTsb	CTsi	CTsb	
2010-2011							
Oct.20	30.57g	32.72ef	32.15f	29.99g	29.28h	30.32g	30.84c
Nov.15	29.85gh	34.17d	32.43f	34.72d	28.01i	33.37e	32.09b
Dec.10	42.38c	43.75a	43.87a	44.08a	43.00b	44.07a	43.52a
Mean	34.27c	36.88a	36.15b	36.26b	33.43d	35.92b	
Turkey HSD $_{0.05}$ for D=0.70, T=0.35, D x T=0.61							
2011-2012							
Oct.20	29.03g	28.98g	27.22i	29.41g	28.02hi	27.70i	28.39c
Nov.15	28.67gh	29.24g	32.03e	30.53f	28.92g	32.49e	30.31b
Dec.10	39.01d	40.58c	42.72b	41.32c	40.75c	44.80a	41.53a
Mean	32.24d	32.93c	34.00b	33.75b	32.56cd	35.00a	
Turkey HSD $_{0.05}$ for D=0.33, T=0.48, D x T=0.84							

be attributed to the accumulation of more heat units by having the better environmental conditions especially the temperature and solar radiations (Tahir *et al*., 2009). Baloch *et al.,* (2010) also obtained highest grain yield in early and optimum sown wheat crop which confirms the present findings. The late sown crop produced minimum grain and biological yield probably due to the reason that late sown crop matures in shorter time as compared with the normal sown crop because the hot summer approaches and crop takes less number of Growing Degree Days (GDD) which ultimately hampers yield components and as a result the yield of the crop is reduced **(**Lone et al., 1999).

Plots with rice straw retained/incorporated presented better yield than those with straw burned. Enhanced yield was possibly an advantage of the opportunity in straw retained/incorporated plots to exploit crop nutrients removal and reduce the risk of nutrient loss

(Usman et al., 2014). The greater availability of nutrients (Blair et al., 2006), maximum water holding capacity of soil (Wong et al., 1999) and less volatilization of N fertilizer to ammonium gas (Tran-Thuc-Son et al., 1995) might be possible explanation for better crop stand in rice straw incorporated into the soil treatment. Rice straw incorporation in soil might also reduce the soil evaporation (Ortega et al., 2002) ensuring maximum water availability for root development and better crop growth. Hossain et al., (2002) also observed similar results in plots having combined sources of organic (rice straw) and inorganic fertilizers. The higher availability of nutrients and better water holding capacity (Hossain et al., 2002; Matsi et al., 2003) in straw incorporated plots might have accelerated cell expansion, enlargement and division, and thus resulted into taller plants (Iqtidar et al., 2006). The increased wheat yield in straw incorporated plots can also be associated to increased productive tillers, number of grains per spike and 1000-grain weight (Hossain et al., 2002). The lesser wheat yield in straw burnt plots was probably due to massive losses of organic matter, N (up to 80%), P (25%) and K (21%) and the disturbance of soil microbial activities (Liu et al., 2003; Gangwar et al., 2006). In disparity to this, crop residues retention/incorporation might have improved soil nutritional status in addition to improvement in soil physical, chemical and biological properties (Xu et al., 2009).The increased growth and yield of wheat crop in zero and reduced till age than the conventional tillage could be attributed to the better utilization of soil moisture, water use efficiency, nutrients up take and less variation in the soil temperature (Chan et al., 2002; Bauer et al., 2002).

Conclusion

The results showed that early sowing with RTsi and optimum sowing with ZTsr significantly increased wheat yield. Therefore, RTsi and ZTsr tillage practices with early and optimum sowing might be adopted as a sustainable approach to increase wheat yield in rice-wheat cropping system.

Authors' contributions

All authors contributed equally in this manuscript.

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