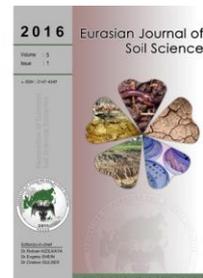




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## Growth and yield response of wheat (*Triticum aestivum* L.) to tillage and row spacing in maize-wheat cropping system in semi-arid region

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### Abstract

Tillage practices and row spacing can be manipulated to optimize spatial distribution and plant growth, therefore maximizing sunlight, soil water use efficiency, nutrients and grain yield on sustainable basis. A field study was conducted to determine the effect of tillage and row spacing on growth and yield of wheat (*Triticum aestivum* L.) at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during wheat season. The treatments were comprised of two tillage practices viz. zero tillage and conventional tillage and four row spacing viz. 15 cm, 20 cm, 25 cm and 30 cm. The experimental results revealed that zero tillage significantly enhanced the plant height, tillers m<sup>-2</sup>, spike length, 1000 kernel weight and yield and yield components of wheat plants as compared to conventional tillage. Wheat plants resulted in a significant increase in tillers m<sup>-2</sup> and accumulated higher biomass and grain yield under 15-cm row spacing than all three other row spacing. The grain yield increase was mainly attributed to more tillers m<sup>-2</sup> at 15-cm than the other row spacing. So, zero tillage and narrow row spacing (15 cm) proved to be involved in higher wheat yield for the wheat-maize cropping system in semi-arid regions.

**Keywords:** Grain, growth, maize, tillage, wheat, yield

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### Introduction

Wheat (*Triticum aestivum* L.), "King of the cereals" is an important staple food crop of Pakistan and is grown under different climatic conditions (Mirbahar et al. 2009). It is used as staple food by about 35% of the world population and its demand is growing faster than other major food crops. It contributes 13.1 percent to the value added in agriculture and 2.8 percent to GDP of Pakistan. It was grown in around 9,062 thousand hectares of area having annual production of 23,421 thousand tones during 2008-09 (GOP, 2009). However, the wheat yield in Pakistan is still quite low when compared with the world average. There are several factors responsible for low yield of wheat in Pakistan. The prime reasons being poor soil fertility, late planting, traditional sowing methods, irrigation water deficiency, weed infestation and poor crop husbandry.

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Managerial practices help to sustain the crop production at higher level without deteriorating natural resources. In the conventional tillage system crop residues and weeds are burned, used as feed or incorporated with soil. But, in conservation tillage more importance is given to conserving the soil properties. Here the plant cover is used to provide organic matter and higher infiltration of irrigation and rain water (Ortega, 1991) into soil. The concept of zero tillage has become a very common practice in many countries of the world, because it is ecologically, agronomically, economically and environmentally beneficial. Maintaining crop residues on the soil surface improved soil properties (Franchini et al. 2007; Sidiras et al. 1982). Zero tillage increases soil moisture retention capacity, minimizes soil temperature fluctuations, and decreases soil erosion by wind and water, enhances organic matter content in soil with time, improves soil micro-organisms activity, resulting in increased crop growth and yield (Malhi et al. 2006; Carter, 1992; Franzluebbers et al. 1999; Franchini et al. 2007; Derpsch, 1999; Warren, 1983). Zero tillage also reduces the cost of production and contributes to early sowing of wheat by 10-15 days (Erenstein and Laxmi, 2008; Sayre and Ramose, 1997) as compared to conventional tillage. Late wheat sowing can decrease wheat yield due to reduction in tillering period and enhances the risk of high temperature during grain filling stage (Razzaq et al. 1986; Bahera et al. 1994). Hussain et al. (1998) reported that with every single day delay in sowing of wheat from 20th November onward in Punjab (Pakistan) can decrease grain yields at 36 kg ha<sup>-1</sup> d<sup>-1</sup>.

Similarly, row spacing also plays a vital role in wheat production. In Pakistan wheat is normally sown by broadcasting or at 25 cm row to row distance, whereas in leading wheat producing countries it is much lower (10-15 cm) (Wibberley, 1989). Narrow row spacing in wheat caused suppression of weeds by increasing ground cover, leaf area, light interception, and even spatial plant distribution (Weiner et al. 2001; Drews et al. 2009). It also reduced soil evaporation and increased nutrient use efficiency by deploying nutrients (Johri et al. 1992; Chen et al. 2010). It has been shown by many studies, carried out in different climates, that narrow row spacing increased yield as compared to wider row spacing (Johnson et al., 1988; Marshall and Ohm, 1987; Chen et al. 2008). However, in contrast some reports have also found that wider row spacing in wheat produced higher yield or was same as compared to narrow spacing (Lafond, 1994; Lafond and Gan, 1999; Hiltbrunner et al. 2005). This indicated that the response of wheat yield to row spacing varied with environment and genotype (Marshall and Ohm, 1987).

Wheat is grown in Pakistan in a diverse cropping system following rice, maize, cotton, sugarcane, vegetables and fodders. Maize was planted on an area of 1,118 thousand hectares during 2008-2009 in Pakistan (GOP, 2009). To date, zero tillage wheat after rice has been most widely adopted resource conserving technology in the south Asian Indo-Gangatic Plains (Erenstein and Laxmi, 2008). Zero tillage technology is being rapidly adopted by the farmers in India but comparatively very slow progress has been seen in Pakistan (Malik et al. 2005; Erenstein and Laxmi, 2008; Erenstein et al. 2007). Mostly researchers are focused on sowing of wheat by zero tillage after rice harvesting in rice-wheat cropping system in India and Pakistan (Erenstein and Laxmi, 2008, Gupta et al. 2004; Iqbal et al. 2002; Sarwar and Goheer, 2007). However, wheat grown by zero tillage after maize harvesting in maize-wheat cropping system in Pakistan has rarely been reported. Thus, it is very imperative to study the feasibility of zero tillage in wheat-maize cropping system and the effect of row spacing on wheat plants. Hence, a field experiment was conducted to investigate effects of tillage and row spacing on growth and yield of wheat plants in a semiarid region wheat-maize copping system in Pakistan.

## Material and Methods

### Experimental site and treatments

Studies pertaining to investigate the effect of tillage and row spacing on the growth and yield of wheat cultivars "Auqab 2000" was carried out at the at the Agronomic Research Area, University of Agriculture, Faisalabad during wheat season. After maize harvesting (latitude = 31°30'/N, longitude = 73°10'/E and altitude = 184.4 m). The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement (tillage practices in main plots and row spacing in subplots, respectively) having three replications. Net plot size was 3m × 6m. Soil under study belonged to Lyallpur Soil Series (Aridisol fine-silty, hyperthermic ustallic, haplargid, mixed in USDA classification and Haplic Yermosols in FAO classification scheme). The soil pH and electrical conductivity (EC) were observed 7.7 and 1.2 dS m<sup>-1</sup>, respectively. The treatments were comprised of two tillage practices (T<sub>1</sub>= conventional tillage and T<sub>2</sub>= zero tillage) and four row spacings (S<sub>1</sub> = 15 cm, S<sub>2</sub> = 20 cm, S<sub>3</sub> = 25 cm and S<sub>4</sub> = 30 cm). Conventional tillage was comprised of three cultivations, each followed by planking).

## Crop husbandry

The crop was sown with the help of single row hand drill maintaining variable row spacing as per treatment 15, 20, 25 and 30 cm after maize harvesting. Seed rate was maintained and accomplished manually at a rate of 130 kg ha<sup>-1</sup> for all the treatments. Urea and ammonium phosphate were used as source of Nitrogen and Phosphorus, respectively. Half of nitrogen and full dose of phosphorus was applied at the time of sowing. The remaining half of the nitrogen was applied along with fist irrigation. No water stress in plants happened in the whole growing season, and all essential nutrients were not considered to limit growth. All other agronomic practices were kept normal and uniform for all the treatments during the entire course of study. Harvesting of crop was done on its physiological maturity. Observations on growth and yield parameters of the crop were recorded using standard procedures.

## Measurements

Plant height, spike length, number of spikelets per spike, number of grains per spike was recorded from twenty randomly selected plants from each plot. Total number of tillers taken at random from each plot, measuring 1 m<sup>2</sup> were counted, averaged and recorded. Crop harvest was completed by using a plot combine and air dried. Biological, straw and grain yield of wheat plants were measured from each plot and then converted into t ha<sup>-1</sup>. 1000-grain weight was measured at random from the produce of each plot. Harvest index was calculated by using the following formula.

H.I. = grain yield/ biological yield x 100.

Crop harvest was completed by using a plot combine. After harvesting, grains were air-dried, and plot yield and 1000 seed weight were determined.

## Statistical analysis

Data collected on different parameters were analyzed statistically by using a statistical package, SPSS version 16.0 (SPSS, Chicago, IL) and differences among the treatments means were compared by using the least significant difference (LSD) test at 5% probability level. Pearson correlation coefficients were calculated to determine the relationship among quantitative and qualitative growth and yield traits in wheat plants.

## Results

### Plant height and tillers m<sup>-2</sup>

The effects of tillage practices on plant height and tillers m<sup>-2</sup> of wheat plants are presented in Fig. 1A and B, respectively. Zero tillage led to significant increase in plant height at all levels of row spacing as compared to conventional tillage. But in case of tillers m<sup>-2</sup> zero tillage showed significantly higher value at 15 cm row spacing and slightly higher values at all other three row spacing levels than conventional tillage but no significant difference was detected. Plant height and tillers m<sup>-2</sup> were significantly affected by row spacing. In case of plant height the treatments 15 cm and 30 cm were statistically at par but significantly higher than the treatments 20 cm and 25 cm in both tillage levels. As regarding tillers m<sup>-2</sup>, the treatment 15 cm had significantly higher value as compared to other three treatments; those were found statistically at par among each other. The interaction between tillage practices and row spacing on plant height and tillers m<sup>-2</sup> was observed non-significant.

### Spike length, number of kernels spike<sup>-1</sup> and 1000 kernel weight

The data regarding spike length, number of kernel spike<sup>-1</sup> and 1000 kernel weight of wheat plant as affected by different tillage practices and row spacings are shown in Fig 2A, B and C. Zero tillage had significantly higher spike length at 30 cm row spacing than conventional tillage but at other row spacings no significant difference was found. It is evident from the figure 2B and C that zero tillage had significantly higher number of kernel spike<sup>-1</sup> and 1000 kernel weight than conventional tillage on all row spacing treatments. While the row spacing the treatment 30 cm gave significantly more spike length over the rest of treatments in both tillage treatments, but the other treatments were statistically at par among each other. Row spacing at 30 cm had significantly higher values number of kernel spike<sup>-1</sup> than the other three row spacing levels in conventional tillage, while these treatments statistically at par among each other. But in case of zero tillage 30 cm row spacing had significantly higher values followed by 15 cm and 25 cm and 20 cm. While the 25 cm and 20 cm statistically had no difference with each other. As regarding 1000 kernel weight, slight increase was observed with increasing row spacing, though not statistically significant. . The interaction between tillage practices and row spacing on spike length, number of kernel spike<sup>-1</sup> and 1000 kernel weight was found non-significant.

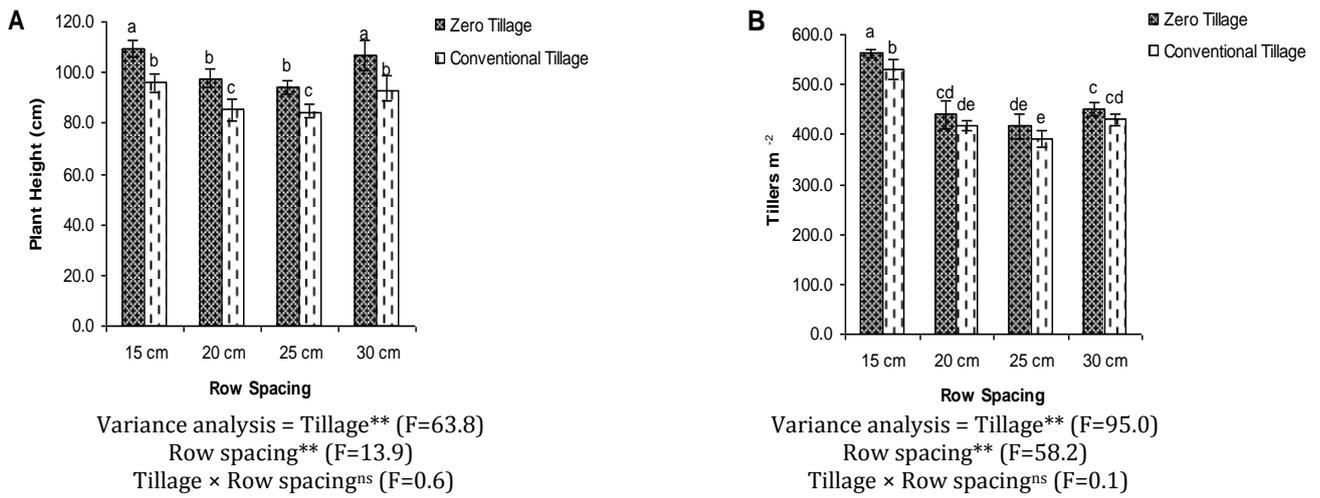


Figure 1. Effect of tillage practices and row spacing on plant height (A) and tillers m<sup>-2</sup> (B). Data are means ± S.D. (n=3). F-value indicates significance level based on two-way ANOVA. ns= non significant, \* significant at P<0.05, \*\* significant at P<0.01

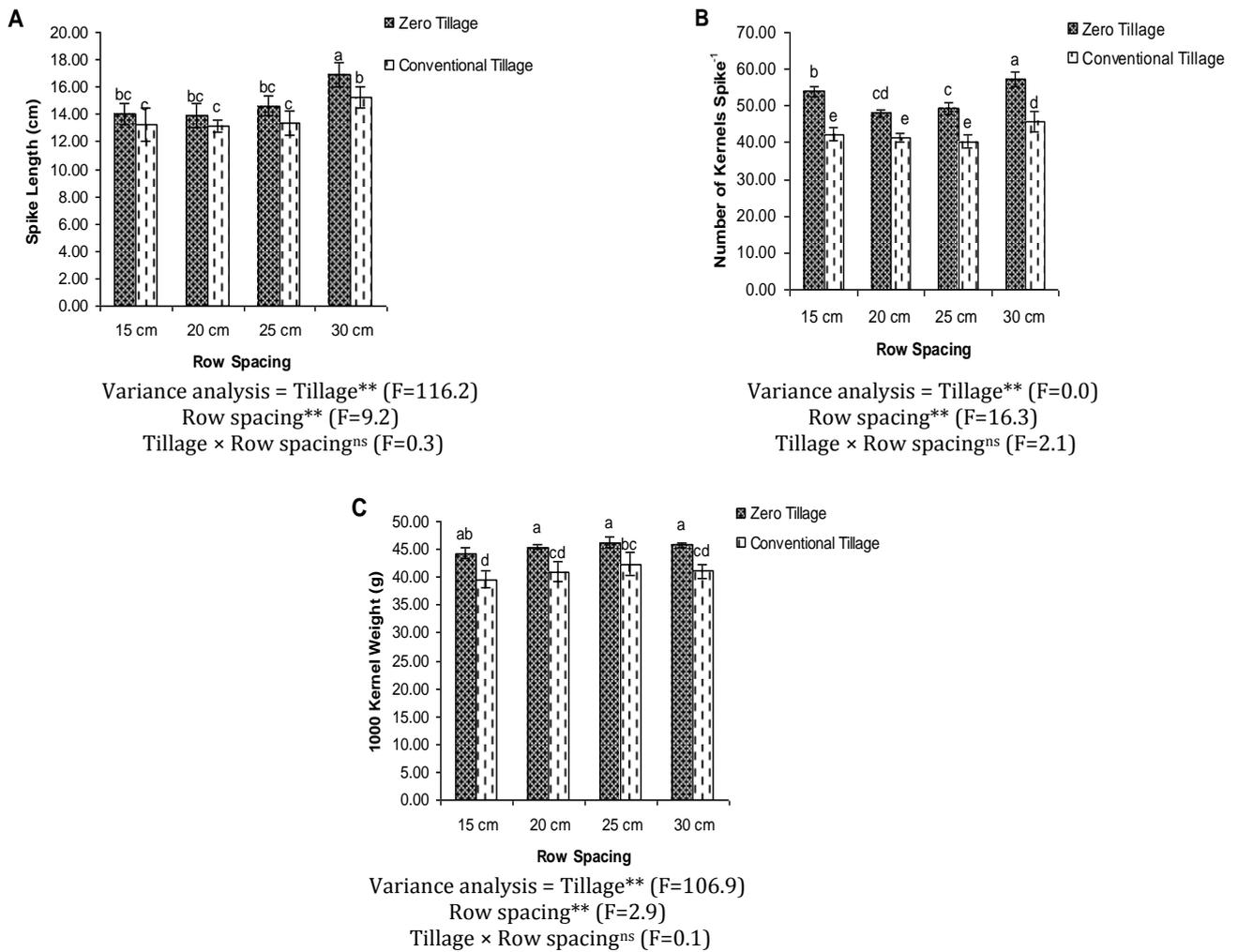


Figure 2. Effect of tillage practices and row spacing on spike length (A), number of kernels spike<sup>-1</sup> (B) and 1000 kernel weight (C). Data are means ± S.D. (n=3). F-value indicates significance level based on two-way ANOVA. ns= non significant, \* significant at P<0.05, \*\* significant at P<0.01

### Biological yield, grain yield, straw yield and harvest index

Data shown in Fig.3A, B and C revealed that sowing of wheat by zero tillage significantly increased biological yield, grain yield and straw yield at all row spacings than wheat sown by conventional tillage. But, in case of harvest index the results were just opposite (Fig.3D), mainly due to higher biomass production for zero tillage than for conventional tillage. Row spacing significantly affected the biological yield, grain yield, straw yield and harvest index. 15 cm row spacing had significantly higher biological yield, grain yield and straw yield in both tillage practices. While in the other three row spacing, no significant difference could be detected. But, in case of harvest index 15 cm had significantly lower value than other treatments. 20 cm, 25 cm and 30 cm treatments are statistically at par among each other. The interaction between tillage practices and row spacing on biological yield, grain yield, straw yield and harvest index was found to be non-significant.

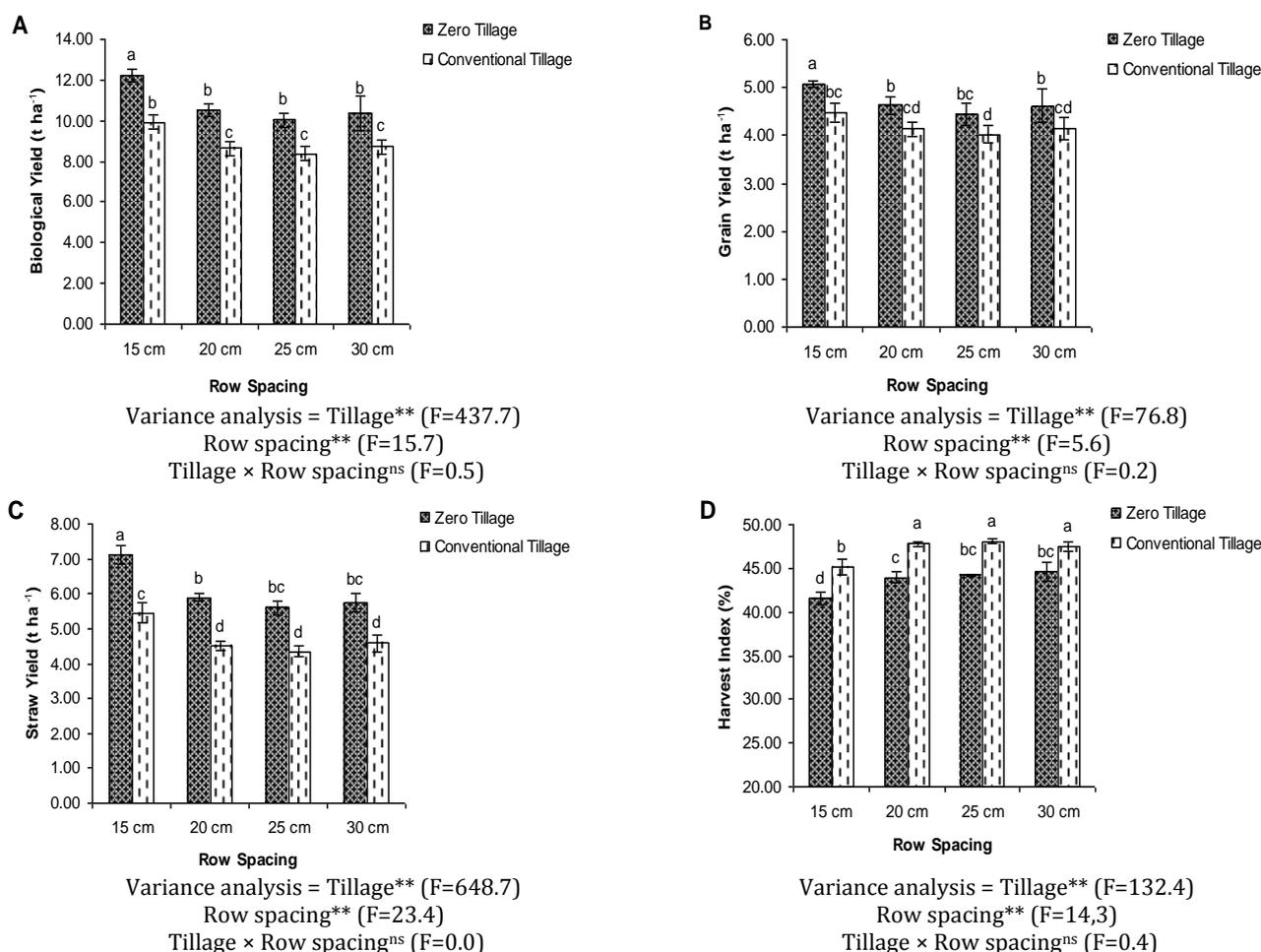


Figure 3. Effect of tillage practices and row spacing on biological yield (A), grain yield (B), straw yield (C) and harvest index (D). Data are means  $\pm$  S.D. (n=3). F-value indicates significance level based on two-way ANOVA.

ns= non significant, \* significant at  $P < 0.05$ , \*\* significant at  $P < 0.01$

### Pearson correlation coefficients among qualitative and quantitative traits

The relationships among qualitative and quantitative traits in wheat plants are presented in Table 1. The results showed that grain yield was very remarkably and positively correlated with the plant height, tillers m<sup>-2</sup>, number of kernel spike<sup>-1</sup>, straw yield and biological yield but significantly and negatively correlated with harvest index. But there was no significant relationship found between grain yield and Spike length or 1000 Kernel weight. There was observed a significant and positive correlation between tillers m<sup>-2</sup> and biological yield, grain yield or straw yield (Table 2). Plant height had significantly positive correlation with tillers m<sup>-2</sup>, number of kernel spike<sup>-1</sup>, straw yield, biological yield and harvest index.

Table 1. Weather data during the course of the study

Source: Agricultural Meteorology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan

Months	Mean monthly Temperature	Mean monthly relative humidity	Total monthly rainfall
	°C	%	mm
November	19.7	58.9	0.0
December	15.5	68.9	14.6
January	13.5	68.0	13.1
February	20.3	52.4	14.6
March	21.0	57.0	37.0
April	25.0	57.0	0.0
May	29.5	57.0	24.0

Table 2. Pearson correlation coefficients among qualitative and quantitative traits of wheat

	PH	TL	SL	NKPS	1000KW	BY	GY	SY
TL	0.716*							
SL	0.546	-0.081						
NKPS	0.900**	0.364	0.766*					
1000KW	0.497	-0.119	0.517	0.753*				
BY	0.898**	0.766*	0.189	0.754*	0.533			
GY	0.918**	0.782*	0.214	0.765*	0.508	0.997**		
SY	0.889**	0.758*	0.180	0.749*	0.542	1.000**	0.994**	
HI	0.861**	-0.707	-0.188	-0.743	-0.596	-0.986**	-0.973**	-0.989**

\*\*Significance at 1% probability level; \*Significance at 5% probability level; PH: Plant height, NT: Tillers m<sup>-2</sup>, SL: Spike length, NKPS: Number of kernel spike<sup>-1</sup>, 1000KW: 1000 Kernel weight, BY: Biological yield, GY: Grain yield, SY: Straw yield, HI: Harvest index.

## Discussion

In this investigation, tillage practices had significant effect on plant growth and yield of wheat plants. Zero tillage had higher values of plant growth and yield parameters such as plant height, tillers m<sup>-2</sup>, spike length, number of kernel spike<sup>-1</sup>, 1000 kernel weight, biological yield, grain yield and straw yield as compared to conventional tillage. These results confirmed the findings of the previous studies who reported that zero tillage increased the growth and yield of plants (Munoz-Romero et al. 2010; Mehla et al. 2000; Sen et al. 2002; Bonfil et al. 1999; Halvorson et al. 2000). Increasing growth and yield of wheat plants under zero tillage than conventional tillage could be attributed to the following benefits of zero tillage over conventional tillage. Soil moisture and water use efficiency is affected significantly by the type of soil tillage (Moitra et al. 1996). Zero tillage enhances the rate of water stable aggregates and increases the size of soil aggregates. In the result, it improves the soil structure (Beare et al. 1994). Under conventional tillage aggregates formation process is disturbed regularly (Green et al. 2007). Heavy use of agricultural machinery in the soil causes soil compaction and increased soil bulk density (Miransari et al. 2007), which results in increased thermal conductivity of soil (Sarkar and Singh 2007). Tillage affects the structure of the soil porosity by disturbing shape, size and continuity of soil pores. Cassel et al. (1995) reported that zero tillage increased soil bulk density, resulting in decreased porosity of soil and soil resistance ultimately increased compared with conventional tillage methods viz. chisel plow and moldboard plow. Zero tillage also increases soil microbial biomass N and C as compared to other conventional methods (Franchini et al. 2007). Under conventional tillage, little amount of plant residues are changed into microbial biomass, because higher microbial respiration increased CO<sub>2</sub> emission from the soil (Lopez-Garrido et al. 2009). Zero tillage protect soil organic matter from microbial degradation. However, under disturbed soil conditions, mineralization rate increases and it becomes more exposed to microbial biomass (Balesdent et al. 2000). Moreover, there was very highly significant correlation found between soil moisture and soil microbial biomass (Torabi et al. 2008). So, it is worth mentioning that zero tillage has positive environmental impacts (reduced emissions of greenhouse, gas savings of fossil fuel, water savings) and ecologically, agronomically, economically and environmentally advantageous as compared with conventional tillage.

Row spacing affect on growth and yield of wheat plants. A number of researchers revealed that narrow row spacing gave better yield in wheat than wider row spacing (Johnson et al. 1988; Tompkins et al. 1991; Marshall and Ohm, 1987; Joseph et al. 1985). In this study, narrow row spacing (15 cm) increased tillers per

unit area and yield of wheat plants. Although 15-cm treatment had lower 1000 kernel weight than wider rows but the difference was observed slight and compensated by increased tiller per unit area. So, the higher grain yield at the 15-cm compared with other row spacings in this investigation was chiefly attributed to the increased spike density per unit area. Our results confirmed the earlier findings of [Frederick and Marshall \(1985\)](#) who reported that by decreasing row spacing to 12.7 cm, grain yield increased by 8.2%, and the main contributing factor was higher number of tillers per unit area. Narrow row spacing caused more even spatial plant distribution, increased leaf area index, crop ground cover, light interception and dry matter. Thus, narrow spacing also decreased weed population and reduced soil evaporation ([Drews et al. 2009](#); [Weiner et al. 2001](#); [Chen et al. 2010](#)). Our results also agreed with the findings of [Lafond \(1994\)](#), who revealed that by increased row spacings caused decreased number of spikes m<sup>-2</sup>. Similarly, it was reported that narrow row spacing had higher plant density than at wider row spacing ([McLeod et al. 1996](#)). The higher values of tiller m<sup>-2</sup> in 15-cm row spacing in this study was likely due to more uniform and accurate spatial distribution and less plant-to-plant competition ([Auld et al. 1983](#)). In our study, higher biomass was produced at the 15-cm row spacing indicating better resource utilization at this row spacing level.

## Conclusion

The investigation results indicate that sowing wheat by zero tillage is an efficient tillage system and resource conservation technology. The results obtained also confirmed the validity of innovative tillage system for energy conservation in broad sense with assurance of satisfactory yield production. The row spacings also significantly affected growth and yield of wheat plants. Row spacing 15-cm should be adopted for its contribution towards higher grain yield. Therefore, zero tillage with 15-cm row spacing may be recommended for the wheat-maize cropping system in semi-arid region of Pakistan.

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