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Agronomic Performance and Chemical Composition of Wheat Td-1 As Affected By Planting Methods

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Abstract: Wheat planting on beds is an alternative, to traditional wheat planting where by the nutrients and irrigation water can be efficiently and economically utilized to achieve yield targets fulfilling the increasing demand of the country. The field experiment evaluated the effect of different planting methods (i.e. ridge, raised and flat bed) on growth, yield and nutrient uptake of wheat TD-1. The ridges were 22.86 cm high, 45.72 cm wide with 25.60 cm furrow spacing. Similarly, the raised beds were 14.35 cm high, 60.96 cm wide with 25.12 cm furrow spacing. The field experiment was set in a completely randomized block design with 3 replications. The NPK (180-110-65 kg N, P_2O_5 and K_2O kg ha^{-1}) was applied in the form of urea, di-ammonium phosphate and sulfate of potash. The wheat grown under different planting methods significantly enhanced the growth, wheat yield and nutrient (NPK) uptake by plant and were in the order raised bed>ridge>flat bed. The raised beds produced 12% more yield, 19 and 20 % more N and K uptake over flat beds, which further reduced to half for yield (5%), N (10%) and K (9%) uptake under ridge sowing over flat bed. In case of P uptake, there was 35% increase by raised beds and 22% by ridges over flat beds. However, these differences were too small to be significant. There was positive and significant ($p<0.01$) relationship between grain yield and NPK uptake (R^2 = 0.984, 0.86 and 0.985) by wheat. Future studies on bed planting, including the flow of irrigation water will complete the essence of this study.

Keywords: Ridge, raised bed, flat bed, nitrogen, phosphorus, potassium

1. INTRODUCTION

The crop sector plays the most important role and is second largest contributor to agricultural value added in Pakistan after livestock. Major crops i.e. wheat, rice, maize, cotton and sugarcane contributed 25.6% to agriculture sector and 5.4% to GDP. Among these crops, wheat contributes 10% to agriculture sector and 2.1% to the country's GDP (GOP, 2015). Among wheat producing countries, Pakistan is listed as 8th, having wheat area of 9.18 m ha^{-1}. On the other hand, the country stands 59th with regard to yield (2775 kg ha^{-1}) which is quite low compared to wheat yields of other countries (Sarwar *et al*., 2010; GOP, 2015).

Wheat is an essential part of everyday meals of Pakistani people, and 60% (125 kg per capita) of daily diet per person is that from wheat (Zulfiqar and Hussain, 2014). Its demand is progressively growing with the population pace. In the light of wheat production (25.478m tons) during 2014-15, consumption (120 kg per person), population rate (1.8% per year), 10% feed and seed and 1.0 m t of food reserves, the country would necessarily need something like 34.25 million tons of wheat production with yield of 3785 kg ha^{-1}. This would mean about 10 m t of wheat with yield targets from 2.80 to 3.80 t ha^{-1} in the following 20 years. Low yields can be attributed to number of factors including poor land preparation, irrigation and nutrient (Memon *et al*., 2012; Amir *et al*., 2013), late sowing, lack of potential varieties (Hammed *et al*., 2003) and yet the self-reliable and conservative methods with special reference to planting methods (Majeed *et al*., 2015).

Traditionally, the wheat plants sown on flat-leveled beds having inter-row soil surface cause greater lodging and frequency of crop diseases (Fahong *et al*., 2004). The other two methods i.e. ridge and raised bed planting methods although are more advanced and effective but are not practiced by local farmer. Wave formation with equal furrow spacing gives rise to ridges. In raised bed, the ridge (a heap) is replaced by flat shape with definite height and width. In both methods of planting, the irrigation water moves freely between furrows with no flooding. Beds provide improved soil structure, surface drainage, weed control, nutrient placement through fertilizer (Singh *et al*., 2002) and diversification to crops which are sensitive to water logging (Singh *et al*., 2005). These techniques therefore, offer enormous potential for better irrigated wheat-based cropping system with low input resource and enhanced sustainability. Planting wheat under beds boost the carbon and nitrogen (Memon *et al*., 2012) dynamics in soil and cut down on greenhouse gases (Verachtert *et al*., 2009). Enhanced root proliferation, enhances the utilization of carbon from root hair, resulting in better

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respiration and ultimately, better nutrient utilization in the form of uptake (Paez-Garcia, 2015).

Adequate supply of essential plant nutrients is necessary for enhancing plant growth and getting promising wheat yield (Malghani *et al*., 2010). Nitrogen is part of chlorophyll, nucleic acid and proteins (Balikai, 2001; Ibrahim *et al*., 2009). It contains 1.5 to 5.0 % of the dry weight by higher plants (Nova *et al*., 1981). Under clay loam soils, 40% of the available NO_3-N leaches down and this percentage increases as the texture becomes lighter (Artiola, 1991). Accordingly, the bed sowing methods improve the irrigation efficiency and reduce N losses and ultimately the ground water contamination (Bar-Yosef, 1999). Phosphorus is required for nucleic acids, phospholipids synthesis, energy transfer and for enzyme activation (Lambers *et al*., 2006; Reich *et al*., 2009). Bed planting methods develop a loose fertile soil layer, whereby a well-developed root system and consequently higher phosphorus nutrient and water uptake (Bucher, 2007; Ao *et al*., 2010; Khan *et al*., 2012). Potassium facilitates the translocation of manufactured food, and stimulates growth and development (Sahai, 1991). Potassium deficient soils will not only have reduced yields, but at the same the function of N and P is also affected (Balasubramaniyan and Palaniappan, 2001).

Wheat sowing by bed planting methods may be a common topic of research in the world (Jat *et al*., 2011; Pahlavan-Rad *et al*., 2011; Hui *et al*., 2013). However, local studies have mainly covered growth and yield parameters (Ahmad *et al*., 2010; Nasrullah *et al*., 2010; Waraich *et al*., 2010; Mahmood *et al*., 2013; Shah *et al*., 2013) in some cases N uptake and use efficiency (Majeed *et al*., 2015) under ridges or beds of different height. Total area under wheat cultivation during 2014-15 has been reported as 1150 thousand ha (GOP, 2015) and 60-70% of that is TD-1 variety. Published research with regard to nutrient contents and relevant uptake of this variety using planting methods is scanty. This study was planned with the assumption that there will be improvement in growth, yield and nutrient uptake using bed planting method of sowing.

2. MATERIALS AND METHODS

The field experiment carried out at Wheat Research Institute, Sakrand, Pakistan ($68^0$16' E and $26^0$8' N) followed a randomized complete block design involving three planting methods viz. flat bed, ridge and raised bed grown in 4x4 m sub-plot size replicated thrice. The soil of experimental area was silt loam and sandy loam having electrical conductivity of 1.32 and 1.30 dS m^{-1}, pH 7.61 and 7.66, organic matter content of 0.71 and 0.59 %, respectively at surface and subsurface. The NH_4-N of soil was 7.0 mg kg^{-1} each, NO_3-N 12.25 and 10.5 mg kg^{-1}, ABDTPA extractable P 8.50 and 8.76 mg kg^{-1} and K 120 and 98 mg kg^{-1}, correspondingly at 0-15 and 15-30 cm depth. In flat beds, row to row distance was maintained at 20 cm, while the ridges were 22.86 cm high, 45.72 cm wide with 25.60 cm furrow spacing. Raised beds were prepared using bed planter and were 14.35 cm high, 60.96 cm wide with 25.12 cm furrow spacing.

Wheat seeds of TD-1 variety were sown in rows at the rate of 80 kg ha^{-1} for all planting methods. Single row planting was done on flat beds and ridges using Rabi drill and ridge planter, respectively. In case of raised bed, four rows of plants per bed were sown with bed planter. The crop received 180 kg N, 110 kg P_2O_5 and 65 kg K_2O ha^{-1}, respectively in the form of urea, diammonium phosphate and sulfate of potash. Full dose of P, K and half dose of N was given at the time of planting, and the leftover N after three weeks at the tillering stage. For workable soil moisture level, all the plots were irrigated before sowing of wheat. Second irrigation was applied after 21 days and remaining irrigations between the intervals of 21 days depending on the soil moisture content. An area of one square meter was randomly marked at three points in each sub plot, followed by random tagging of 10 plants, which were later averaged for each replication and planting method. The crop was harvested at maturity. The data for plant height, number of tillers, spikelets $spike^{-1}$, spike length, seed index (1000 grain weight) and grain yield were recorded. Plant dry matter was tested for total N, P and K (Cottenie, 1980; Knudsen *et al*., 1982; Jones, 1991), which was further utilized in calculating the N, P and K uptake separately using the formula: [Nutrient content in plant (%) x yield (kg ha^{-1})/100]. One way analysis of variance was carried out by using Statistix 8.1 and the means were compared using least significant difference (LSD) test at alpha 0.05. Further, the grain yield was regressed separately with N, P and K uptake in wheat plants.

3. RESULTS

Growth parameters:

Planting methods i.e. flat, ridge and raised bed generally had significant ($p<0.05$) effect on plant height and number of tillers at 60 and 120 but 90 days of planting **(Table-1)**. Under raised bed planting, wheat plants grew well and the height increased from 61.40 in flat beds to 67.20 cm at 60 days and 80.43 (flat bed) to 83.00 cm at maturity (120 days). Considering the 60 days growth stage after wheat planting, plant height increased by 8.63% in raised beds and 2.38% in ridges over flat beds. While at maturity (120 days of planting), there was 3.09% increase in plant height under raised bed compared to flat bed planting and the differences between plant height under ridge (81.13 cm) and raised beds (83.00 cm) were non-significant.

Wheat grown on raised beds showed more tillers compared to two other methods **(Table-1)**. In view of growth stages, the values increased from 7.13 at 60 days to 7.83 tillers plant^{-1} at maturity. Planting methods showed a significant increase from 6.30, 6.70 and 7.00 under flat beds to 7.13, 7.40 and 7.83 tillers plant^{-1}, respectively under raised bed grown wheat. The tillers at 60 days of planting were significantly similar under ridge and raised bed planting. The same was true at 90 days of planting for flat and ridge sowing.

Table-1 Plant height and number of tillers at different growth stages of wheat (TD-1) as influenced by planting methods

Planting patterns	Plant height (cm)			Number of tillers (plant^{-1})		
	60 days	90 days	120 days	60 days	90 days	120 days
Flat bed	61.40 b	78.60	80.43b	6.30 b	6.70 b	7.00 c
Ridge	62.90 b	80.33	81.13 ab	6.80 a	7.00 b	7.46 b
Raised bed	67.20 a	81.53	83.00 a	7.13 a	7.40 a	7.83 a
LSD (5%)	4.13	-	2.87	0.43	0.35	0.18
Standard error	1.48	-	0.67	1.15	0.12	0.06
F value	8.18*	4.81^{NS}	7.73*	14.62*	14.80*	78.50**

NS - non significant; * and ** - significant at 0.05 and 0.01probability level

Wheat yield and yield related components:

The yield contributing parameters, although were not significantly affected by planting methods, nonetheless, highest spikelets spike^{-1} (16.13), spike length (9.00 cm) and 1000 grain weight (44.73 g) was observed under raised bed planting **(Table-2)**. The lowest values were 13.66 spikelets spike^{-1}, 8.40 cm spike length and 42.93 g of 1000 grain weight under flat bed sowing. In contrast, wheat yield showed clear differences among various planting methods. Raised beds enhanced the wheat yield up to 11.92% against the yield under flat bed sowing **(Table-2)**. Wheat grown on ridges also yielded more than that under flat beds with percent increase of 4.68% over flat bed.

Table-2 Yield and yield related components of wheat (TD-1) as influenced by planting methods

Planting method	Spikelet's (spike^{-1})	Spike length (cm)	1000- grain weight (g)	Grain yield (kg ha^{-1})
Flat bed	13.66	8.40	42.93	3473.7 c
Ridge	14.66	8.53	43.83	3644.3 b
Raised bed	16.13	9.00	44.73	3944.0 a
LSD (5%)	-	-	-	158.37
Standard error	-	-	-	57.04
F value	5.38^{NS}	6.23^{NS}	3.93^{NS}	34.85**

NS - non significant; * and ** - significant at 0.05 and 0.01probability level

Nutrient content, uptake and yield:

The nutrient content for N, P and K related to straw (after 60, 90 and 120 days of planting) and grain (at maturity) in addition to straw and grain uptake along with its statistics is presented in Table 3. Planting methods had a significant ($p<0.05$) effect on N, P and K content and uptake in straw and grain except P content and uptake in straw. The mean nutrient contents i.e. N and P in the dry matter of straw gradually increased from 1.84 and 0.28 % at 60 days planting stage to 2.20 and 0.38 at 90 days and further reduced to 1.30 and 0.14 % at maturity in all three sowing methods. This shows the increase in N and P contents with growth stage and their utilization at maturity. As for K, there was increase in nutrient contents from 1.64% at 60 days to 2.33% at 90 days planting, which shows the availability of K in dry matter, however, minor increase in K contents (2.45%) at maturity does not show its utilization by wheat plant. The N content increased from 1.78 to 1.91% at 60 days, 2.10 to 2.29 % at 90 days and 1.22 to 1.39 % at maturity in raised beds over flat bed planting. Similarly, P content increased from 0.23 to 0.34 % at 60 days, followed by 0.33 to 0.43 % at 90 days and 0.13 to 0.17 % at maturity under raised bed planting over flat beds. Likewise, the values for K followed the same order as 1.55 to 1.72 %, 2.24 to 2.43 % and 2.34 to 2.54 % respectively at 60, 90 and 120 days of planting in raised beds over flat beds. The N, P and K contents in grain at wheat maturity were highest under raised bed and lowest under flat bed. The values improved from 2.19 to 2.38 % for N, 0.34 to 0.46 % for P and 1.22 to 1.35 % for K in raised beds over flat beds. In view of P contents, there were no differences among the P contents in dry matter of grain under raised bed (0.46%) and ridge (0.42%). The uptake in grain and straw followed the similar trend. Highest straw and grain uptake of 79.82 and 94.14 kg ha^{-1}for N, 9.94 and 18.41 kg ha^{-1} for P and 146.00 and 53.51 kg ha^{-1} for K was observed in raised beds. The lowest values of 54.45 and 76.31 kg ha^{-1} for N, 5.77 and 11.91 kg ha^{-1} for P and 103.80 and 42.62 kg ha^{-1} for K were observed in flats bed planting.

Table-3 Nutrient content and uptake in straw and grain of wheat (TD-1) as influenced by planting methods

Planting method	Nutrient contents (%)				Uptake (kg ha^{-1})	
	Straw at (days)			Grain at maturity	Straw	Grain
	60	90	120			
Nitrogen						
Flat bed	1.78 c	2.10 b	1.22 c	2.19 c	54.45 c	76.31 c
Ridge	1.84b	2.23 a	1.29 b	2.31 b	68 .85 b	84.44 b
Raised bed	1.91 a	2.29 a	1.39 a	2.38 a	79.82 a	94.14 a
LSD (5%)	0.01	0.09	0.01	0.03	2.07	4.78
Standard error	4.71	0.03	4.71	0.01	0.74	1.72
F value	381.0**	16.4*	607.0**	138.5**	582.2**	53.7*
	Phosphorus					
Flat bed	0.23 b	0.33 c	0.13	0.34 b	5.77	11.91 b
Ridge	0.27 b	0.39 b	0.14	0.42 a	7.80	15.44 a
Raised bed	0.34 a	0.43 a	0.17	0.46 a	9.94	18.41 a
LSD (5%)	0.04	0.04	-	0.06	-	2.77
Standard error	0.01	0.01	-	0.02	-	0.05
F value	22.36**	24.90**	1.87^{NS}	13.91*	6.41^{NS}	17.2*
	Potassium					
Flat bed	1.55 c	2.24 c	2.34 c	1.22 c	103.8 c	42.62 c
Ridge	1.65 b	2.33 b	2.47 b	1.29 b	131.9 b	47.02 b
Raised bed	1.72 a	2.43 a	2.54 a	1.35 a	146.0 a	53.51 a
LSD (5%)	0.03	0.04	0.02	0.01	4.42	2.77
Standard error	0.01	0.01	9.42	4.30	1.59	0.05
F value	71.7**	87.0**	241.7**	456.4**	363.7**	85.6**

NS – non significant; * and * - significant at 0.05, 0.01 probability level Relationship between wheat yield and N, P and K uptake in grain was separately developed to come up with the nature of relationship. Fig. 1 shows increase in grain yield with the increase in N, P and K uptake in grain under different planting methods. This is illustrated by significant ($p<0.01$) relationship with corresponding coefficient of determination (R^2) for N (0.984), P (0.860) and K (0.985).**

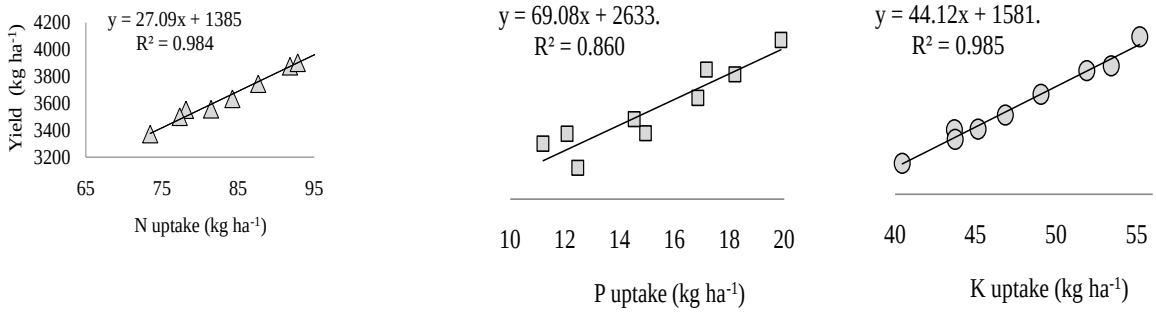

Fig-1 Relationship between yield and nutrient uptake of wheat TD-1

4. DISCUSSIONS

Wheat is the main food of local people. The ever-increasing population, enhanced input cost with special reference to fertilizer, unavailability of promising cultivars, climate change, etc. reinforces the wheat growers to make use of advanced planting technologies to utilize the applied nutrients in an efficient and economic conduct. The nutrients N, P and K have been regarded as essential nutrients for growth and yield of wheat (Balasubramaniyan and Palaniappan, 2001; Malghani *et al*., 2010). In Pakistan, particularly in Sindh, wheat is customarily planted on flat beds (Laghari *et al*., 2010). The advanced methods i.e. ridge and raised beds have been widely used in China, Bangladesh, Mexico and other countries (Fahong *et al*., 2004; Khalique *et al*., 2008; Lichter *et al*., 2008). It is evident from research records that bed planting techniques have benefit over flat bed ones and offer improved fertilizer and water through high nutrient use efficiency. Therefore, increase yields and reduce the input cost (Pahlavan-Rad *et al*., 2011; Majeed *et al*., 2015). Very few studies have highlighted the uptake for major plant nutrients i.e. N, P and K using advanced planting techniques.

The study reports significant development in growth, yield, and nutrient uptake in response to planting methods. The supremacy of raised bed over flat

bed planting was recorded with regard to plant height (3%), number of tillers (11%), wheat yield (12%), N, P and K contents in straw (12, 23 and 8 %) and grain (8, 26 and 10 %) and relevant uptake by wheat plants in straws (32, 42 and 29 %) and grain (19, 35 and 20 %). In case of P, in grain and its uptake by wheat under ridge and raised beds performed in a similar manner, and this was in line with the work by Pahlavan-Rad *et al.* (2011). Majority of the studies relating to different planting methods have worked on growth and yield traits (Ahmad *et al*., 2010; Shah *et al*., 2013). Our results with regard to growth and yield parameters were exactly in line with those published by Khalique *et al*. (2008) reporting 2.51 tillers plant^{-1} and 2555 kg ha^{-1} wheat yield under bed planting. The work by Hossain *et al.* (2006) also supported these results. Wheat planting on raised beds has recorded maximum growth and yield for many varieties. Ahmad *et al*. (2010) reported highest number of tillers and grain yield for Inqlab-91 and Mahmood *et al*. (2013) reported maximum tillers, highest seed index and grain yield for Sehar-2000. Similarly, Jat *et al*. (2011) reported tallest plants, maximum tillers and grain yield for wheat variety PBW-343. Further, the work by Mollah *et al.* (2009) for wheat variety Kanchan also gave similar results. They recorded 97.3 and 99.9 cm plant height with grain yield of 2585 and 3030 kg ha^{-1}.

Majority of the local research pertaining to bed planting (Khalique *et al*., 2008; Jat *et al*., 2011; Pahlavan- Rad *et al*., 2011; Alam, 2012; Hui *et al*., 2013; Majeed *et al*., 2015) have focused on nutrient content and relevant uptake, growth parameters and yield. These studies report improvement in nutrient uptake under beds and in some cases ridges. However, they all have reported low contents in case of flat bed. Jat *et al*. (2011) reported maximum P uptake in grain (13.3 kg ha^{-1}) and straw (6.02 kg ha^{-1}) of wheat variety PBW-343 under raised bed planting. The total uptake reported by them was although much lower (6.11 kg ha^{-1}) than the one achieved in this study (33.42 kg ha^{-1}), however, was still highest under raised bed planting. Pahlavan-Rad *et al.* (2011) reported that planting methods have significant effect on N, P and K uptake, with highest one under bed planting. Whereas, the highest grain nutrient uptake for N, P and K was observed in furrow planting and so were the growth and yield parameters. These results of the research work given by Majeed *et al*. (2015) supported bed planting. The bed planting produced higher grain yield (15.06%), N uptake (25.04%), N use (15.2%), and agronomic recovery (14.59%) and efficiency (29.83%) by applying 120 kg N ha^{-1}. Planting methods oriented studies with regard to nutrient content and uptake have focused more on N content and have reported similar results with maximum N content in straw (0.40 %) and grain (2.23 %) and uptake of 79.62 % (Khalique *et al.*, 2008), in addition to growth and yield of wheat. Later, the work by Alam (2012) supported these results by recording highest N content of 0.362 and 2.145 % in straw and grain of wheat under bed planting.

The study concludes that growth, yield and nutrient uptake of wheat TD-1 was significantly affected by planting methods. Wheat grown under raised bed planting produced 12% more yield and 19, 35 and 20 % more N, P and K uptake in grain. This was followed by ridges planting with 5% increase in yield and 10, 22 and 9 % N, P and K uptake in grain. Phosphorus uptake in wheat grain by ridge and raised bed was similar. There was positive relationship between yield of wheat and nutrient uptake under various planting methods. It is suggested that wheat growers should switch to bed planting either ridge or raised beds, however, future studies should include the irrigation water flow with the transport of nutrients utilized under different textured soils and varieties of wheat.

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