Research Article

Response of Zero Tillage Wheat to Row Spacing and Nitrogen Application Methods

Sikandar Hayat, Khalid Usman* and Muhammad Tahir Amin

Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan.

Abstract | Zero tillage is a cost effective and resource conserving technique, however, drill clogging and immobilization of nitrogen are problems in the standing stubbles of the previous crop. Row adjustment and an appropriate N fertilizer application method may be a possible solution. Field trials were carried out to explore suitable row spacing and N fertilizer application method for zero tillage wheat at Agronomic Research Area, Faculty of Agriculture, Gomal University, Dera Ismail Khan (D.I. Khan), Pakistan in 2015-2016 wheat growing season. The experimental design was randomized complete block with split plot arrangement replicated thrice. Four row-spacing i.e., 10, 20, 30, and 40cm were assigned to main-plots while N fertilizer application methods (broadcast and placement) were kept in subplots. Results revealed that row spacing of 30 cm had higher yield and yield components besides higher benefit cost ratio (3.50). Nitrogen placement method proved to be superior to broadcast method of application regarding wheat yield and yield contributing traits. Row spacing and N application methods interaction showed that zero tillage wheat had the optimum wheat yield (5352 kg ha^{-1}) when grown at 30 cm row spacing and fertilized with N placement method. The overall results indicated that N placement method along with 30 cm row spacing is quite feasible in zero tillage wheat having no clogging problem to wheat seeder besides higher yield (5352 kg ha^{-1}) and economic return as evident from the BCR data (3.80).

Received | October 02, 2016; **Accepted** | August 10, 2017; **Published** | November 19, 2017
***Correspondence** | Khalid Usman, Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan; **Email:** drusmangu@gmail.com
Citation | Hayat. S., K. Usman., M.T. Amin. 2017. Response of Zero Tillage Wheat to Row Spacing and Nitrogen Application Methods. *Sarhad Journal of Agriculture,* 33(4): 680-687.
DOI | http://dx.doi.org/10.17582/journal.sja/2017/33.4.680.687
Keywords | Zero tillage, row spacing, N application methods, yield, BCR

Introduction

The existing cultivable land is not sufficient for growing population of the world (World Fact Book 2012). Thus there is dire need of increasing food production (vertically) on the existing area rather than expanding it horizontally (Pimentel and Pimentel, 2000; Smil, 2000). Since 45 percent of the world cultivable lands are degraded (Lal, 2007), the FAO (Food and Agriculture Organization) considers resource conserving technology as an important footstep to meet long term world food demand (Mackenzie, 2009). Land under irrigation may not extend to compensate the deficits in production of food due to high demand of potable water by ever rising population. The only option to enhance productivity is the efficient use of water. Zero tillage system is well recognized for its positive impacts on crop productivity, economic viability and efficient use of soil and water resources (Zentner et al., 2002; Zentner et al., 2004; Holm et al., 2006). Recent research have shown further yield increments in wheat (*Triticum aestivum* L.) when zero tillage was practiced in previous crop residues (Lafond et al., 2011). Cutforth et al. (2002) and Cutforth et al. (2006) reported increased grain yield and water use efficiency (WUE) in spring wheat when grown into more than 30cm tall stubbles. Seeding crops into previous crop residues with zero tillage system for a longer period characterize a significant strategy to enhance crop productivity. Despite known benefits of zero tillage, there have been challenges such as drill plugging when planting in to standing stubbles and into intact surface residues. Row adjustment i.e. widening of the row spacing is a possible solution to either avoid or reduce seeder plugging. Some researchers such as Chen et al. (2008) have reported the common accepted knowledge that narrow row-spacings give higher yield in small grain cereal crops. There were no significant differences in grain yields between zero tillage and conventional tillage spring wheat, when row configurations were tested at 10, 20, and 30cm (Lafond, 1994). Similarly, zero tillage wheat had identical yield at 23 and 30cm row spacing under sub-humid conditions (Johnston and Stevenson, 2001). There were no differences in grain yield in barley when row spacing of 10, 20, and 30cm were compared under zero tillage and conventional tillage (Bailey et al., 1998). Zero tillage durum wheat also gave similar yields in 10, 20, and 30cm row spacings in similar growing conditions. Xie et al. (1998) reported similar grain yield in spring wheat between 25 and 38cm row spacing. They also reported lowest grain yields in canola and spring wheat at 51cm. Thus, there is enough proof to hold up the concept of wider-row spacing in spring wheat in arid and semiarid area. This gives an opportunity to exploit the benefits of tall stubbles, particularly in the arid to semi-arid area of D. I. Khan, Pakistan, by facilitating sowing between the stubble rows. By doing so one can deal with problems related to management of surface residues and standing stubbles. Applying half of the crop N fertilizer at sowing and the other half nitrogen fertilizer at early vegetative growth stage of crop is the most common practice using either a broadcast method or placement method in zero tillage wheat on the silty clay soil of D.I. Khan. However, as row spacing decreases the fertilizer placement practically becomes difficult unlike broadcast method which is easier in narrow row spacing. An effort to apply seed-placed fertilizer may also be harmful because inorganic fertilizer may have severe salt and toxic effects on seed germination and subsequent young sensitive seedlings. No studies were conducted to evaluate the effects of side dressing inorganic nitrogen fertilizer at various row-spacing in zero tillage spring wheat. Aim of this study was to explore interaction effects between row-spacing and different N fertilizer application methods on yield and yield related traits of wheat using zero tillage production system.

Materials and Methods

Site description

A field study was carried out at Agronomic Research Area, Faculty of Agriculture- Gomal University- D.I. Khan- Pakistan during 2015–2016 wheat growing seasons. D.I. Khan (31°49´N, 70°55´E, 166 m a.s.l.) is the southern district, Khyber Pukhtunkhwa Province, Pakistan. The texture of the soil being silty clay showed 400 gram per kg clay, 450 gram per kg silt, and 150 gram per kg sand. There is limited rainfall with less than 200mm per annum. The climate of the area is hot. Soil is hard, calcareous and requires irrigation for raising crops.

Experimental procedure

Wheat was seeded into rice stubbles using a zero tillage drill. The seeder consists of zero tillage shank openers connected on ranks. The openers moved physically on the ranks to get the desirable row-spacing. The seeding depth was 7 cm. The treatments comprised of 4 row-spacing's (10, 20, 30 and 40cm) and two nitrogen fertilizer application methods viz. broadcast (a. broadcasting half N at planting-basal application, b. top dressing of remaining half N in standing crop with 2nd irrigation) and localized placement (a. drilling half N at sowing, b. remaining half N by side dressing with 2^{nd} irrigation). Plots were 10 m long with 10, 20, 30 and 40-cm row spacing's. There were six rows in each subplot. Fertilizer nitrogen (Urea), phosphorus (TSP), and Potassium (Potassium sulphate were given at the rates of 150, 90, and 50 kg per hectare, respectively. All amounts of P and K and about half N (70 kg N per hectare) were supplied with sowing, whilst rest of the nitrogen (80 kg N per hectare) was given with second irrigation. The nitrogen fertilizer source was urea with fertilizer grade of 46–0–0. All plots were seeded at the rate of 120 kg per hectare. All other field and crop management practices like irrigation (6 Nos.) and weeding (broad-spectrum herbicide, affinity sprayed) were equally adopted. Trial was laid out using a RCBD (Randomized Complete Block Design) with split plot arrangement having three replications. The main-plots were row spacing and the subplots were N fertilizer application methods.

Procedure for data recording

Plant height data were recorded at crop maturity (physiological maturity). Ten plants were randomly chosen from each subplot for measuring plant height with measuring tape from ground to the tip of plant. Average plant height was then calculated. Productive tillers or spike bearing tillers were counted along 1m row length at three sites selected at random in each subplot and mean spikes per m^2 were then calculated. Spike length was recorded in centimeter from 10 spikes selected at random in each subplot and mean spike length was calculated. Ten spikes selected at random were subjected to threshing and grains obtained were counted. The mean numbers of grains per spike were then calculated from ten threshed spikes in each plot. One thousand grains were collected from seed lot of each subplot and weighed by electronic balance. Biological yield was recorded at crop harvest (harvest maturity) by cutting all sub plots at the ground level and bundles obtained were dried in sun light. Biological yield recorded in each plot was then changed into kg per hectare.

Biological yield (kg per hectare) = {Biomass in kg/ plot size (m^2)} x 10,000

Economic yields (Grain yields) were determined by manually harvested all the experimental plots which were threshed, cleaned and grains obtained were weighed. Yield was converted to kg per hectare.
Grain yield (kg per hectare) = {Grain yield (in kg)/ plot size (m^2)} x 10,000
The harvest index was calculated by the formula given below:
Harvest index (H.I.) = (Economic yield / Biomass yield) x 100
BCR was calculated by the following formula:
Benefit cost ratio (BCR) = (Total income/Total expenses)

The data recorded were subjected to statistical analysis by ANOVA (Analysis of Variance techniques) (Steel and Torrie, 1980) and then least significant difference test was determined using MSTATC software (MSTATC, 1991).

Results and Discussion

Plant height (cm)

Data regarding plant height were significantly affected by nitrogen application methods (NAM) however; main effect of row spacing and its interaction with NAM was not significant (Table 1). Mean values for nitrogen application methods revealed that N placement method had higher plant height (85.6 cm) than broadcast method of N application (80.1 cm). The probable reason might be more efficient utilization of nutrients in case of placement method than in broadcast method of N application. In broadcast method of N application there is higher nutrients losses and lower uniformity as compared to placement method of fertilizer application. Xie et al. (1998) reported analogous results that plant height was higher for 20-30 cm row spacing under placement method of N application. Lafond et al. (2013) reported feasibility of wide row spacing up to 35 cm combined with placement method of N fertilization.

Table 1: *Plant height (cm) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast	81.7NS	80.4	80.1	78.3	80.1b
Placement	86.3	86.9	87.0	82.2	85.6a
Mean	84.0NS	83.6	83.5	80.2	
$LSD_{0.05}$ for N application methods (N) = 2.5839					

Means having similar letter (s) in each category do not differ significantly at 5% level of probability.
NS: Non-significant

Spikes m^{-2}

Data regarding spikes m^{-2} were significantly affected by nitrogen application methods and row spacing, however, nitrogen application methods × row spacing interaction was not significant. Mean values for nitrogen application methods revealed that N placement method had higher spikes m^{-2} (430.1) than broadcast method of N application (335.5) (Table 2). The highest numbers of spikes m^{-2} (627.5) were observed in plots having 10 cm row spacing followed by 20 cm row spacing. The wider row spacing (40 cm) had the lowest number of spikes m^{-2}. Since plant to plant spacing was much narrower in wider row spacing and there was tough interplant competition that probably resulted in lower fertile tillers. Lafond et al. (2013) communicated similar results who reported ikthat number of tillers decreased with increase in row spacing because of increased interplant competition.

Spike length

Data regarding wheat spike length were affected significantly by NAM and row spacing, though, N application method x row spacing interactions were not significant. Mean values for nitrogen application methods revealed that N placement method had longer spikes (10.4 cm) than broadcast method of N application (10.1cm) (Table 3). Mean values for row spacing revealed that 30-40 cm row spacing produced longer spikes than spikes length obtained from 10-20 cm row spacing. Too narrow or too wide spacing caused inter-row and intra-row plant competition, respectively that probably resulted in lower spike length (Kirkland, 1993; Ali et al., 1999). These results are analogous to that of Ali et al. (2016) who reported that zero tillage wheat with 30 cm row spacing produced higher spike length compared to all other spacing whether narrower or wider than 30 cm spacing.

Table 2: *Spikes (m^2) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast	595	318	255	174	336b
Placement	660	471	328	263	430a
Mean	628a	394b	291c	218c	
$LSD_{0.05}$ for spacing (S) =101.8, N application methods (N) = 42.8					

Means having similar letter (s) in each category do not differ significantly at 5 % level of probability.

Table 3: *Spike Length (cm) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast	9.8	9.9	10.5	10.3	10.1b
Placement	10.0	10.2	10.7	10.6	10.4a
Mean	9.9b	10.1b	10.6a	10.4a	
$LSD_{0.05}$ for spacing (S) = 0.3301, N application methods (N) =0.1553					

Means having alike letter (s) in each category are not significant at 0.05 level of probability.

Grains per spike

Analysis of variance results revealed that grains spike^{-1} were significantly affected by nitrogen application methods (NAM), and row spacing, however, nitrogen application methods x row spacing interaction was not significant. Mean values for nitrogen application methods revealed that N placement method had more grains spike^{-1} (50.0) than broadcast method of N application (46.0) (Table 4). Highest number of grains spike^{-1} (51.2) was recorded with row spacing of 30 cm among all other spacing. These results indicated that N placement method is quite efficient for proper utilization of applied nutrients compared to broadcast method. On the other hand row spacing of 30 cm is probably optimum under zero tillage wheat that resulted in more grains spike^{-1}. Ali et al. (2016) reported that zero tillage wheat had more grains spike^{-1} with 30 cm row spacing compared to other tillage systems. Muñoz-Romero et al. (2010) also communicated similar findings who reported that grains spike^{-1}were more with 30 cm row spacing under zero tillage wheat than other tillage systems.

Table 4: *Grains spike^{-1} of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast	44	45	49	46	46b
Placement	47	48	53	52	50a
Mean	46c	46c	51a	49b	
$LSD_{0.05}$ for spacing (S) =2.1001, N application methods (N) =1.7773					

Means having similar letter (s) in each category do not differ significantly at 5% level of probability.

Thousand grains-weight

Statistical analysis of the data revealed that 1000-grains weight had significant response to N application methods (NAM) and row spacing while N application methods x row spacing interaction was not significant. Mean values for nitrogen application methods revealed that N placement method had higher 1000-grains weight (38.8 g) than broadcast method of N application (35.0 g) (Table 5). Highest 1000-grains weight (40.3-43.9g) was recorded in 30-40 cm row spacing compared to narrow row spacing having lowest 1000-grains weight (28.9g). Mehla et al. (2000) reported that 1000-grains weight was higher with zero tillage wheat having 30 cm row spacing provided with placement method of N fertilization.

Biological yield

Analysis of variance results revealed that biological yield had significant response to row spacing while NAM and NAM x S interactions had no significant response. Mean values for row spacing revealed that biological yield was higher with row spacing ranging from 30-40 cm (11516-11523 kg ha^{-1}) compared to row spacing ranging from 10-20 cm (8219-8517 kg ha^{-1}) (Table 6). These results indicate that zero tillage wheat with placement method of N application in combination with 30 cm row spacing is more feasible and productive because spacing narrower than 30 cm may cause clogging of zero tillage drill due to the previous crop residues and hence may adversely affect stand establishment. Sen et al. (2002) reported higher biological yield for zero tillage wheat with 30 cm row spacing and placement method of N fertilization.

Table 5: *1000- grains weight (g) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	**20**	**30**	**40**	
Broadcast	27.7	31.7	43.2	37.4	35.0b
Placement	30.0	37.3	44.6	43.1	38.8a
Mean	28.9 d	34.5 c	43.9 a	40.3 ab	
$LSD_{0.05}$ for spacing (S) =4.1538, N application methods =3.4438					

Means having similar letter (s) in each category do not differ significantly at 5% level of probability.

Table 6: *Biological yield (kg ha^{-1}) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	**20**	**30**	**40**	
Broadcast	8167	8667	11472	10273	9645
Placement	8270	8367	11574	12759	10243
Mean	8219b	8517b	11523a	11516a	
$LSD_{0.05}$ for spacing (S) =2831.2					

Means having similar letter (s) in each category do not differ significantly at 5% level of probability.

Grain yield

Statistical analysis of the numerical data revealed that grain yields had significant response to nitrogen application methods (NAM), row spacing and nitrogen application methods x row spacing interactions (Table 7). Interaction effects revealed that N placement method produced highest grain yield with row spacing of 30 cm (Figure 1). Wider row spacing than 30 cm resulted in lower grain yield probably due to more vulnerability of the crop to losses from weed competition for moisture, space, light as well as nutrients as reported by Amjad and Anderson (2006). It was also clear from the results that nitrogen placement method in combination with 30 cm row spacing had the potential to yield more compared to all other combinations probably due to favourable inter- and intra-plant spacing. Placement method of N fertilizer application was more effective compared to broadcast method for efficient use of nitrogen. Bonfil et al. (1999) reported that N could be efficiently utilized when applied with placement method and wheat yield was more with row spacing adjusted at 30 cm. The results indicate that surface applied N fertilizer with broadcast method may be subject to more losses of nitrogen compared to banding/placement method of N fertilizer which is easily available to the crop due to close proximity of the nutrients along the crop rows. That is why placement method of N resulted in more yield and yield components of spring wheat compared to broadcast method. However, placement method had the one demerit that it cannot be easily applied in narrow row spacing and hence for practical purpose, broadcast method in such condition will be more feasible and economical.

Table 7: *Grain yield of wheat as affected by row spacing and N application methods (NAM) during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	**20**	**30**	**40**	
Broadcast	3567	3833	4657	4167	4056b
Placement	3733	4100	5352	4319	4376a
Mean	3650c	3967bc	5005a	4243b	
$LSD_{0.05}$ for spacing (S) =479.04, N application methods (N) =139.20 , S x N =278.40					

Means having alike letter (s) in each category are not significant at 0.05 level of probability.

Harvest index

Analysis of variance results revealed that harvest index (%) had significant response to nitrogen application methods (NAM), row spacing and interactions of nitrogen application methods x row spacing (Table 8). Interaction effects revealed that H.I. obtained from placement method of N application was higher with row spacing ranging from 30-40 cm compared to narrow row spacing viz. 10 and 20 cm spacing (Figure 2). These results suggest that zero tillage wheat with placement method of N application in combination with 30 cm row spacing gives higher H.I. indicating more partitioning of dry matter to grains. Halvorson et al. (2000) reported higher harvest index when zero tillage wheat was sown at 30 cm row spacing and fertilized with placement method of N application.

Table 8: *Harvest index (%) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast	41.66	41.66	45.0	44.667	43.3 b
Placement	34.66	47.0	50.0	46.0	44.4 a
Mean	38.2 d	44.3 c	47.5 a	45.3 b	
$LSD_{0.05}$ for spacing (S) =0.4709, N application methods (N) =0.2718 , S x N =0.5435					

Means having alike letter (s) in each category are not significant at 0.05 level of probability.

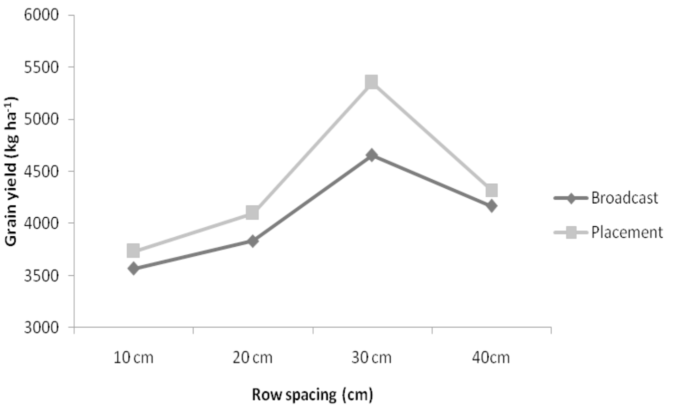

Figure 1: *Interactive effects of row spacing and N fertilizer application methods on wheat grain yield.*

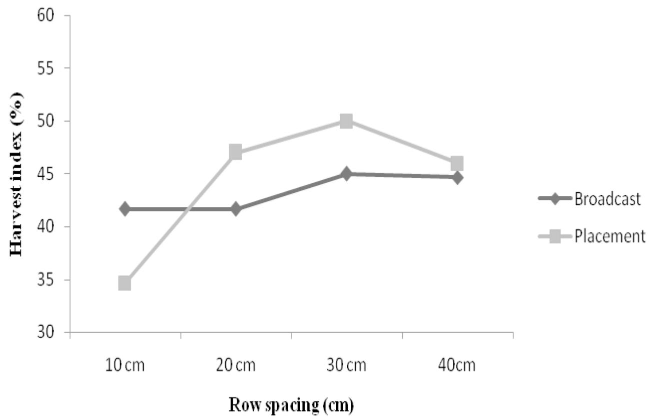

Figure 2: *Interactive effects of row spacing and N fertilizer application methods on wheat harvest index.*

Cost of production

Data recorded on cost of production included cost of seed, fertilizer, pesticides, sowing, irrigation, harvesting and threshing and presented in Table 9. The data revealed that cost of production was higher for placement method of N application compared to broadcast method. On the other hand closer row spacing had higher costs compared to wider row spacing. Placement method proved to be superior to broadcast method as the yield gained could offset the cost.

Table 9: *Cost of production (Rs. ha^{-1}) of wheat on the basis of inputs prices in the market during 2015.*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast method	140,000	87000	58000	47000	83,000
Placement method	145000	89000	59462	49000	85616
Mean	142,500	88000	58731	48000	

Cost of production included cost of seed, fertilizer, pesticides, sowing, irrigation, harvesting and threshing.

BCR (Benefit cost ratio)

Data pertaining to BCR (benefit cost ratio) revealed that row spacing and N application methods had influence on benefit cost ratio. Mean values for nitrogen application methods showed that placement method of nitrogen had higher benefit cost ratio (2.2) than broadcast method of N application (2.0) (Table 10). Mean values for row spacing revealed that highest benefit cost ratio was obtained from 30 cm row spacing. All other spacing produced lower benefit cost ratio probably due to unfavourable inter- and intra-plant competition that resulted in lower grain yield. The results suggested that placement method of N application with 30 cm row spacing is more economical compared to all other combinations. Although placement method had higher cost than broadcast method but the yield gained could offset the extra cost. Higher BCR in placement method with 30 cm row spacing may be due to higher grain yield than broadcast method of N application as communicated by Timmons et al. (1973) who reported that more nutrients were lost from broadcasting than from placement method. Singh et al. (2009) reported that zero tillage wheat with 30 cm row spacing had more economic return besides reduced cost of production. Lafond (1994) reported that zero tillage wheat with 30 cm row spacing had important implications regarding handling of previous crop residues besides more economic return. He further communicated that yield potential of spring wheat could be maintained with 30 cm row-spacing in zero tillage system. Lafond implies that inefficiency of resource utilization commonly attributed to wider rows might be countered by the gains in moisture use efficiency under direct seeding systems.

Table 10: *BCR (Benefit cost ratio) of wheat as affected by row spacing and N application methods during 2015-2016 wheat growing season*

N application methods	Row spacing (cm)				Mean
	10	20	30	40	
Broadcast	0.80	1.50	3.20	2.40	1.98
Placement	0.90	1.60	3.80	2.50	2.20
Mean	0.90	1.60	3.50	2.50	

Conclusions

The following conclusions can be drawn from the results:

1. Row spacing of 30 cm was quite feasible, productive, and economical regarding zero tillage wheat production.
2. Placement method was more productive and economical compared to broadcast method of N application.

Thus row spacing of 30 cm along with placement method of N application is recommended for growing zero or no-tillage spring wheat in rice based cropping.

Author's contribution

Sikandar Hayat carried out research and prepared the manuscript draft. Khalid Usman supervised him and assisted in giving final shape to the manuscript. Muhammad Tahir Amin helped in data collection and compilation.

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