

Influence of tillage, cultivar, seed rate and planting geometry on wheat yield

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Abstract

Field experiments were conducted to improve the wheat yield through adjustments in seed rate, spacing and sowing method at Indian Institute of Wheat and Barley Research, Karnal, Haryana during *Rabi* seasons of 2008-09 to 2012-13. The results showed that by using the precision seed drilling, seed rate from present recommendations of 100 kg/ha can be reduced to 75 kg/ha, however further reduction in seed rate caused yield reductions. If we translate 25% saving across the wheat growing area of India (30 mha) then we can have a huge saving of about 7.5×10^5 ton per year of wheat seed. The yield improved as row spacing was reduced from 22.5 to 15 cm, although yield was not significantly different among 15, 17.5 and 20 cm row spacing. Among three varieties (PBW 550, PBW 502 and DBW 17) maximum yield was produced by PBW 550. Among three crop establishment methods viz. no till (NT), conventional till (CT) and bed planted wheat, the lowest yield was obtained in bed planted system, whereas NT and CT had similar yield levels. In 2 and 3 rows bed planted system, 3 rows yielded more compared to 2 row system. Yield improved with bidirectional (criss-cross) sowing ($\frac{1}{2} + \frac{1}{2}$ seed) compared to uni-directional sowing. The results of the present studies clearly indicate that wheat yield can be improved through right choice of cultivar, seed rate, spacing and crop establishment methods (Criss- cross sowing).

Key words: Bed planting, broadcast sowing, criss-cross sowing, no-till and wheat

1. Introduction

Crop yield depends on genotypes (genetic potential of a variety), environment (soil and climatic conditions) and management practices. Crop genotypes may vary in their growth and yield contributing factors (tillers/m², spike/m², grains/spike, grain weight). The appropriate combination of these yield attributes is needed for harvesting maximum productivity. Generally, among wheat yield attributes, the most significant contributor is spikes/m². Depending on the effective tillering of a cultivar, optimum earhead density can be achieved through seed rate adjustments. The varieties having high tillering can contribute higher yield at low seed rate and vice-versa.

Optimum planting geometry (plant population and their distribution) is a pre-requisite to realize the full genetic potential of a variety, which can be achieved through seed rate and spacing adjustments. Planting geometry affects light penetration in plant canopies, plants per unit area and micro environment in and around plant canopies. It should be in such a manner that it minimizes the intra-plant competition and maximizes resource utilization (space, solar radiation, nutrient and moisture) for higher yield. So, ideally, the plants should be arranged equidistantly from each other in the field, thereby equally sharing growth resources (Berry, 1967). Duncan (1971) also reported that crop

productivity can be enhanced by varying the planting geometry for better light and CO₂ utilization. Also, with altered plant geometry the decline in per plant yield is compensated by cumulative plant yields through adjustment in yield attributes (mainly the effective tillering) leading to maximum per unit area yield. The general recommendation for wheat in India is 20-22.5 cm row spacing with seed rate of 100 kg/ha (considering 1000 grains weight as 38 g).

There are contradictory reports regarding the role of row spacing and seed rate in wheat production. Numerous research workers from different regions have reported the benefits of narrow row spacing (Holliday, 1963; Sroskopf, 1967; Auld *et al.*, 1983; Kemp *et al.*, 1983; Roth *et al.*, 1984; Frederick and Marshall, 1985; Joseph *et al.*, 1985; Winter and Welch, 1987; Marshall and Ohm, 1987; Johnson *et al.*, 1988; Freeze and Bacon, 1990; Tompkins *et al.*, 1991; Solie *et al.*, 1991; Marko, 1994; Sial *et al.*, 2001; Arian *et al.*, 2002; Chen *et al.*, 2008) and increased seed rate (Teich *et al.*, 1993; Arian *et al.*, 2002). Some of the workers reported the benefit of narrow row spacing of as low as 9 cm (Tompkins *et al.* 1991) in wheat. Contrary to it, some workers (Lafond, 1994; Lafond and Derksen, 1996; Lafond and Gan, 1999; McLeod *et al.* 1996; Raj *et al.* 1992; Roy *et al.* 1991; Sharma and Thakur (1990) observed no significant differences among row spacing and reported wider spacing (25-30 cm) as beneficial because it facilitate intercultivation for weed management and feasibility of inter cropping.

The crop row spacing also depends on the cultivars and growing conditions. Narrow spacing and higher seed rates are generally preferred under high productive environment to achieve maximum yield. Narrow spaced rows favor dwarf low tillering cultivars, whereas cultivars with high tillering rate performs better in wider rows. Wheat grown at 10 cm row spacing produced 0.4-0.8 t/ha more grain than 20 cm rows spacing (Joseph *et al.* 1985; Johnson *et al.* 1988). When row spacing of soft red winter wheat was decreased from 17.8 cm to 12.7 cm in Pennsylvania, yield increased by 7.5% (Roth *et al.* 1984) and by 8.2% (Frederick and Marshall 1985). Solie *et al.*(1991) observed improved wheat yields in weed (Cheat) free and weedy conditions when row spacing was reduced from 23 to 7.5 cm. A predicted 14.2% yield

increase was observed as row spacing reduced to 7.5 cm. They further stated that optimum row spacing for hard red winter wheat seeded at recommended seeding rates is projected to be 6.6 cm.

Seeding rates alone did not influence grain yield much but suitable combination of seed rate and row spacing could increase grain yield of wheat (Marshall and Ohm, 1987). Roth *et al.* (1984) also recommended a cumulative response of narrow row spacing and increased plant density. Row spacing (10 and 20 cm) at a constant (1.6, 3.2, and 6.4 million seed/ha seed rates) did not affect yield. With increasing seed rate there was an increase in yield mainly through more ear heads per unit area, which compensated for a decrease in seeds per head. Narrow rows also reduced the number of lamb'squarters and the overall weed count (Teich *et al.*, 1993).

Method of sowing also affects crop productivity. Compared to broadcast sowing, line and cross sowings yield better (Arif *et al.*, 1997; Dhiman *et al.*, 1984). However, Ahuja *et al.*, (1996) recorded 5.08 t/ha grain yield with broadcasting, while 4.75 t/ha with sowing in 23 cm apart rows. Many workers have reported the wheat yield gain 4 to 18% with cross sowing as compared to unidirectional line sowing (Dhiman *et al.*, 1984; Jadho and Nalamwar, 1993). Further, closer or cross sowings were also found effective in reducing the weed problem (Jadho and Nalamwar, 1993; Solie *et al.*, 1991; Teich *et al.*, 1993).

Keeping in view the importance of row spacing, seed rate and sowing method in realizing higher productivity, the present study was designed to the suitable crop geometry (seed rate and spacing), variety and sowing method for higher wheat grain yield under irrigated conditions of North Indian plains.

2. Material and methods

Field experiments were conducted to optimize wheat productivity through identification of suitable varieties, row spacing, seed rate, plant geometry and tillage options during winter seasons of 2008-09 to 2012-13 at ICAR-Indian Institute of Wheat and Barley Research (IIWBR), Karnal, Haryana, India. The soil was sandy loam in texture, alkaline, low to medium in organic carbon and phosphorus and high

in available potash. The details of the experiments conducted are as under.

2.1 Effect of row spacing and varieties: An experiment involving four row spacing with three varieties was sown in two consecutive winter seasons of 2010-11 and 2011-12 in split plot design. The main plot consisted of 4 row spacing (15, 17.5, 20 and 22.5 cm) with three wheat varieties (PBW 550, PBW 502 and DBW 17) as sub-plots and the treatment combinations were replicated thrice. The sowing was done using a standard 8-tyne precision seeder (Bhopal drill) with row to row spacing as per treatment using a seed rate of 100 kg/ha (1000 grain weight as 38 g). Each plot had two swath of drill (16 lines) with a plot length of 8 meters. Based on the area and grain weight of a variety, the adjusted weighed quality of seed was drilled using the Bhopal drill. The sowing was done on 17th November, 2010 and 08th November, 2011, during first and second crop season, respectively. The other package of practices were followed as per the recommendations.

2.2 Effect of row spacing and seed rate (crop geometry): In this experiment, row spacings (15, 17.5, 20 and 22.5 cm) and seed rates (50, 75, 100, 125, 150 kg/ha) were evaluated in an experiment conducted thrice in split plot design during two crop seasons of 2010-11 and 2011-12. The sowing of wheat cultivars PBW 550 and DPW 621-50 was done on 30th November and 9th December 2010 during first year and on 9th December, 2011 during second crop season. The spacing was kept in main plot and sub plots were assigned with seed rate. During first experimentation, main plot had three row spacing (15, 17.5 and 20 cm) and subsequent repetition of experiments had four row spacings (15, 17.5, 20 and 22.5 cm). The five seed rates were finally adjusted considering 1000 grain weight as 38 g. The plot size consisted of two swath of a standard 8-tyne precision seeder (Bhopal drill) and sowing was done using desired seed quantity calculated based on area per swath in a plot depending on row spacing, seed rate and 1000 seed weight.

2.3 Effect of tillage crop establishment: Experiments were conducted to compare the different crop establishment options (no tillage, bed planting, conventional tillage having unidirectional line sowing and cross sowing) during 2008-09 to 2012-2013 crop seasons. In bed

planting option (FIRBS-Furrow Irrigated Raised Bed System), the geometry consisted of 2 or 3 rows per bed in line sowing. To know the contribution of various rows in 3 row bed planted wheat, the individual rows were harvested and yield recorded. In another option of broadcast sowing, seeds were broadcasted after field preparation and beds were formed using bed planter. Bed planter machine prepares two beds at a time with top width of about 40 cm and furrows of about 30 cm. In no tillage (NT), except no field preparation other agronomic management options were similar and sowing was done using zero till seed cum fertilizer drill. The sowing of Conventional Tillage (CT) and cross sowing (CS) was done using precision seed drill (Bhopal drill). In cross sowing, seeding was done with half seed in one direction and the other half as cross sowing over the first sowing.

The recommended dose of fertilizer in different experiments consisted of 150 kg N, 60 kg P₂O₅ and 30 kg K₂O/ha. To meet PK requirements, NPK mixture (12:32:16) was used as basal application. The balance N was applied in the form of urea as top dressing in two splits just before first and second irrigation at around 20 and 40 days after sowing, respectively. Irrigations were applied using the check basin method in flat bed and in furrows for bed planting system. Recommended herbicides were used as per requirement in different experiments against broadleaf and grass weeds in wheat.

The observations were recorded on various yield and yield attributes. The effective tillers were counted about a fortnight before harvesting in one running meter at two places in each plot and converted to per meter square. The crop was manually harvested and threshing was done by small plot thresher and after recording the yield, a random sample was taken from each treatment to calculate 1000 grain weight (TGW). The grains/earhead were worked out using the formula (yield, q/ha x 10000)/(earhead/m² x TGW, g).

The data were subjected to analysis of variance (ANOVA) for determining the differences among the treatment means and when the F test was significant, means were compared with Fisher's protected least significant difference (LSD) test at 5% level of significance. Based on the data of different field observations, average and \pm SEM were also worked out. Two tail "Paired

t-test" was used for comparing the significance of two treatment means. The data were pooled where the results were similar in experimentation over the years.

3. Results and discussion

3.1 Effect of row spacing and varieties: During both the years of study, the varietal differences were significant for yield and yield attributes (Table 1). However, the effect of row spacing was significant for earhead density and grains/ earhead and non-significant for yield and 1000 grains weight. The row spacing effect was significant for yield on pooled analysis basis. The interaction effects were non-significant for yield and yield attributes. The narrow row spacing of 15 and 17.5 cm recorded numerically higher grain yield than the 20 and 22.5 cm row spacing during both the years. On pooled basis, narrow row spacing had significantly higher yield than the widest row spacing of 22.5 cm. The mean yield recorded in 15 and 17.5 cm row spacing was 62.60 and 62.75 q/ha during 2010-11 and 64.16 and 62.43 q/ha during 2011-12, respectively. Whereas, the yield recorded with wider spacing of 20 and 22.5 cm was 61.88 and 59.44 q/ha during first year and 61.73 and 61.32 q/ha during second year of study, respectively. The better yield in narrow row spacing was mainly due to more tillers/m² in narrow row spacing as compared to wider row spacing. Based on pooled analysis, narrow spacing of 15.0 cm recorded significantly higher number of tillers/m² (491/m²) than spacing of 20 cm (464/m²) and 22.5 cm (443/m²). The more effective tillers under narrow row spacing at the same seeding rate are likely due to more uniform spatial distribution causing less in-row-plant-to-plant competition as compared with the wide row spacing (Auld *et al.*, 1983), where plants are more concentrated in narrow bands with lesser space per plant. The mean wheat yield recorded with three varieties namely DBW 17, PBW 550 and PBW 502 was 60.96, 63.60 and 60.44 q/ha during first year and 57.91, 66.24 and 63.08 q/ha during second year of experimentation, respectively. On pooled basis, the significantly highest yield was of PBW 550 (64.92 q/ha). The better yield of cultivar PBW 550 was due to more grains/earhead although its tillers/m² were the lowest. This variety also had shorter vegetative span than other two varieties.

There are differential views of the researchers about row spacing as some are in favour of narrow row spacing to harness more yield (Johnson *et al.*, 1988, Marshall and Ohm, 1987; Roth *et al.*, 1984; Fredrick and Marshall, 1985; Holliday, 1963) and others in favour of wider rows because of ease in mechanical inter-culture and no yield penalty (Nazir *et al.*, 1987; Roy *et al.*, 1991; Ayaz *et al.*, 1999; Lafond, 1994; Lafond and Derksen, 1996; Lafond and Gan, 1999; McLeod *et al.*, 1996). Some studies in Saskatchewan, Canada, demonstrated no yield differences of spring and winter wheat at 10-cm vs 30-cm row spacing comparison (Lafond, 1994; Lafond and Derksen, 1996; Lafond and Gan, 1999) and 18 cm vs 36 cm comparison (McLeod *et al.*, 1996).

However, Roth *et al.* (1984) reported consistent yield increase in Pennsylvania with a narrow row spacing of 12.7 cm than recommended 17.8 cm. Also, Fredrick and Marshall (1985) observed a significant yield increase of 6.0 to 13.2 % with decreasing row spacing. Similarly, Holliday (1963) estimated increased wheat grain yield by 5-7% with narrower row spacing than the conventional (18-23 cm) spacing. Joseph *et al.* (1985) recorded 0.6 to 0.8 t/ha higher grain yield in 10 cm over 20 cm row spacing and Marko (1994) reported 0.3t/ha more grain yield at a spacing of 6 cm over 15 cm. Ercoli and Masoni (1995) reported that grain yield decreased progressively with increase in row spacing, however yield was not affected by row orientations.

3.2 Effect of row spacing and seed rate: The field experiments were conducted to evaluate the effect of row spacing and seed rate on productivity of wheat cultivars (PBW 550 and DPW 621-50). The effect of row spacing was non-significant in both the varieties but the effect of seed rate was found significant (Table 2). The yield was significantly less at seed rate of 50 kg/ha but seed rate of 75 kg/ha and more had more or less similar grain yield in all the three experimentations during two consecutive years of study. Similarly, Samra and Dhillon (1993) observed non significant effect of seed rate varying from 75 to 125 kg/ha in their studies involving wheat cultivars, seed rates (75, 90, 105 and 125 kg/ha) and N levels. Ciha (1993) also reported optimum grain yield at a seed rate of 75 kg/ha. While, Salazar *et al.*, (1996) reported that seed rate can be reduced up to 5 kg/ha without reduction in grain yield

as compared to seed rate of 150-200 kg/ha. In India, generally, a seed rate of 100 kg/ha have been widely used (Singh and Singh, 1984).

Based on these results, the seed rate can be reduced by 25% for optimum wheat production. Extending the seed rate savings, by using precision seed drilling mechanism, across the wheat growing area of our country (30 mha), an enormous saving of about 750 x 10⁶ kg seed /year can be made, if recommended seed rate of 100 kg/ha is considered. However, the seed rate being used is still higher, especially broadcast sowing (125 kg/ha). For seed production with limited breeder seed availability, the seed rate can be reduced to 50% to cover more area so as to harvest higher quantity of seed.

The earlier findings (Chen *et al.*, 2008; Sial *et al.*, 2001; Nanaenko and Loktionor, 1993; Kumar *et al.*, 1991; Tompkins *et al.*, 1991; Arian *et al.*, 2002) have shown improved wheat grain yield with combinations of narrow row spacing and higher seed rates. Sial *et al.* (2001) observed improved wheat grain yield with combination of 15 cm narrow row spacing and higher seed rate of 150 kg/ha. Similarly, Nanaenko and

Loktionor (1993) also reported significantly higher grain yield at 7.5 cm row spacing with 150 kg/ha seed rate than 15 cm row spacing and 100 kg/ha seed rate. Kumar *et al.* (1991) reported increased grain yield particularly of long spike cultivars with higher seeding rates coupled with narrow row spacing while comparing the varietal performance having variable tillering and spike length at different seeding rates (100, 125 and 150 kg/ha) and row spacing (15, 18 and 22.5 cm). Xhomo (1989) obtained highest yield at a density of 600 plants/m². The greater grain yield with higher densities is due to greater number of spikes per unit area as the spike number is the main factor controlling wheat grain yield. However, sometimes lodging may be a problem particularly at high plant densities. Optimum plant density is of immense importance for higher yield as it helps in maximum utilization of the resources. However, it may vary depending upon the on genotypes and growing conditions. For late sown wheat, we have to increase the seed rate by 25% so as to compensate for yield decline due to lower tiller formation.

Table 1. Effect of row spacing and varieties on yield and yield attributes of wheat

Treatment	Earhead/m ²			1000 grain weight (g)			Grains/earhead			Grain Yield (q/ha)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing (cm)												
15.0	527	456	491	40.7	44.8	42.8	29.6	31.7	30.7	62.60	64.16	63.38
17.5	513	431	472	40.8	44.8	42.8	30.7	32.5	31.6	62.75	62.43	62.59
20.0	503	424	464	40.1	44.7	42.4	31.5	32.9	32.2	61.88	61.73	61.80
22.5	465	421	443	40.2	44.5	42.4	32.5	33.1	32.8	59.44	61.32	60.38
LSD (p=0.05)	34.8	N.S.	26.4	NS	NS	NS	0.96	1.08	NS	NS	NS	1.95
Varieties												
DBW17	586	459	522	39.6	43.2	41.4	26.4	29.4	27.9	60.96	57.91	59.43
PBW 550	434	411	422	39.3	44.1	41.7	37.5	36.7	37.1	63.60	66.24	64.92
PBW 502	487	429	458	42.5	46.9	44.7	29.4	31.6	30.5	60.44	63.08	61.76
LSD (p=0.05)	30.3	24.2	16.7	0.61	0.64	0.54	1.70	1.85	1.15	1.67	1.52	0.99

Table 2. Effect of row spacing and seed rate on wheat yield during 2010-11 and 2011-12

Treatments	Grain Yield (q/ha)			Pooled
	2010-11		2011-12	
	Set 1 (PBW 550 sown on 30th Nov.)	Set 2 (DPW 621-50 Sown on 9th Dec)	PBW 550 (Sown on 9th Dec)	
Spacing (cm)				
15.0	56.03	49.62	57.52	54.39
17.5	55.67	48.35	57.56	53.86
20.0	55.28	47.71	56.00	53.00
22.5	-	47.52	55.18	51.35
LSD (p=0.05)	NS	NS	NS	
Seed rate (kg/ha)				
50	54.32	45.53	54.88	51.58
75	55.97	48.11	57.01	53.70
100	56.07	49.35	56.77	54.06
125	55.81	49.17	57.32	54.10
150	56.13	49.35	56.85	54.11
LSD (p=0.05)	1.28	1.67	1.52	-

3.3 Effect of tillage crop establishment (TCE): Different TCE were evaluated for 3-4 years with different wheat varieties and as the varietal performance was similar so, tillage wise data across varieties were pooled and presented in Figures 1-4. The perusal of data revealed no significant difference between CT (52.3 q/ha) and NT (51.7 q/ha) wheat yield (Fig. 1). However, NT has an advantage of reduced cost of cultivation/production due to reduction in tillage cost. So, wheat can be grown successfully under NT as cost effective technology. In comparison to CT (52.3 q/ha) and NT (51.7 q/ha), FIRBS (47.1 q/ha) recorded 4.6-5.2 q/ha lower yield. Although, FIRBS yielded lesser, yet, it has an advantage of water saving and system's diversification (Jat *et al.*, 2006). Some of the researchers have reported similar or better yield under bed planting system (Jat *et al.*, 2006). This difference might be due to differences in varietal performance and agro climatic conditions. So there is a need to breed high tillering suitable genotypes for bed planting system.

In bed planting system also, different geometries involving FIRBS line sowing in 2 rows (2R) and 3 rows (3R) and broadcast sowing were evaluated (Fig. 2 and 3). Between 2R and 3R, 3R had slight yield advantage than 2R and showed significance at P= 0.10 (Fig. 2). Whereas over 3R, broadcast sown wheat had shown numeric yield advantage (Fig. 3). The better yield in broadcast sowing was due to more uniform distribution

of seeds over large area because in line sowing only top of bed is covered but in broadcast sowing, sides of the beds are also covered with plant stand thus using more space. Although, the yield of 2R system was slightly lower to 3R but we can harness the added advantage of 2R system of having the possibility of mechanized interculture as well as fertilizer placement by selecting suitable narrow wheel tractors. Moreover, there is a need to integrate suitable genotypes along with proper sowing time for the system. Early and normal sowing can give better yield in bed planted system compared to late seeding as narrow spacing is required for late sown wheat and in bed planting only 2-3 rows are grown in 70 cm (Centre of furrow to centre of furrow). However, this system of seeding can help in advancing the seeding time by avoiding the pre seeding irrigation after harvest of previous crop. Since, just after seeding in dry soil, irrigation can be applied for proper germination and crop establishment. Thus, besides reducing the turnaround time it will also help in saving of water. Moreover, the bed planted system has an additional advantage of diversification as there is a possibility to grow additional crop in furrows as intercrop or relay crop thus making the system more profitable. Further, by converting the beds into permanent beds with suitable cropping system will make this crop establishment system more economical.

In three row sowing, the wheat grain yield of individual row was calculated (Fig.4) and based on that the contribution of the side rows and the middle row on the total wheat productivity of 3 rows per bed was estimated for two growing seasons. It was found that centre row had lower yield than side rows/border rows. The contribution of middle row was 27.6 % as compared to 72.4 (37.3 + 35.1) % by two side rows (Northern + Southern). This difference was due to the border effect as more space and other resources were available for side rows. As compared to unidirectional sowing, bidirectional or cross sowing (CS) *i.e.* 1/2 seed rate in one direction and rest 1/2 cross sown over the first had shown yield advantage (Fig. 5). About 2.4% higher yield was recorded with CS (51.6 q/ha) over CT unidirectional (50.4 q/ha) sowing. Dhiman *et al.* (1984) also reported advantage of cross sowing over unidirectional sowing.

As far as cross and narrow row space sowings are concerned, we have to improve the drilling mechanism by replacing the tyne drilling with double disc drilling. Such alteration will allow very less soil disturbance during drilling and will ensure proper crop stand and ultimately the yield advantage. Further experiments are needed with varying the spacing using the disc type drilling mechanism.

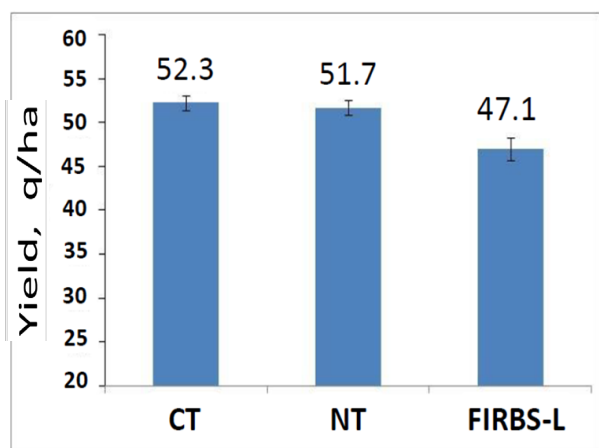


Fig. 1 Performance of wheat under different tillage systems (CT= conventional tillage, NT = no-tillage and FIRBS-L= Furrow irrigated raised bed system-line sowing). Vertical bars represent \pm SEM (average of 15 field observations).

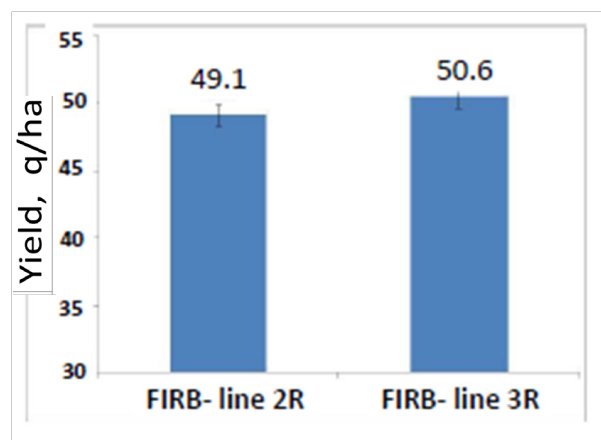


Fig. 2. Performance of wheat under 2 row and 3 row bed planted orientation geometry. (average of 7 field observations). Vertical bars represent \pm SEM. Means are significantly different at $P=0.10$ using two tailed "Paired t test".

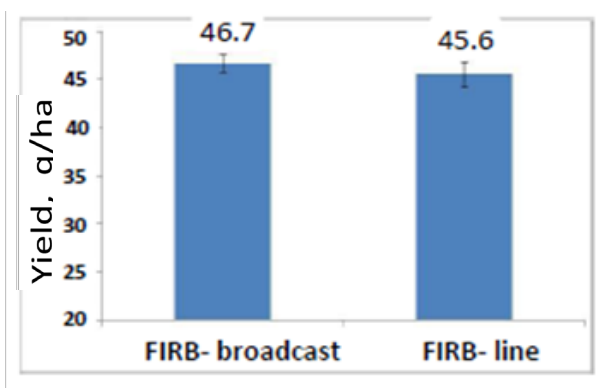


Fig 3. Performance of broadcast and line seeded bed planted systems. (average of 6 field observations). Vertical bars represent \pm SEM. Means are not significantly different at $P=0.10$ using two tailed "Paired t test"

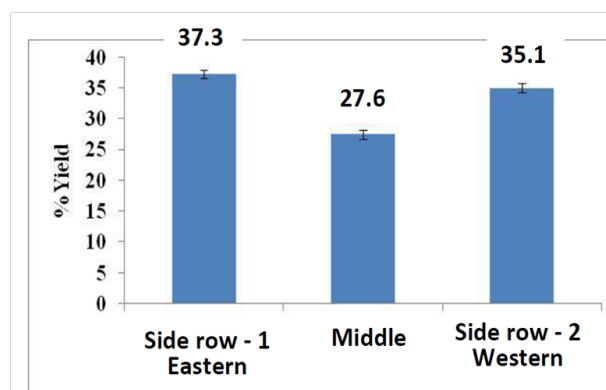


Fig. 4 Grain yield contribution (%) of individual row in 3-R bed planting systems sown in north-south direction (average of 15 field observations). Vertical bars represent \pm SEM

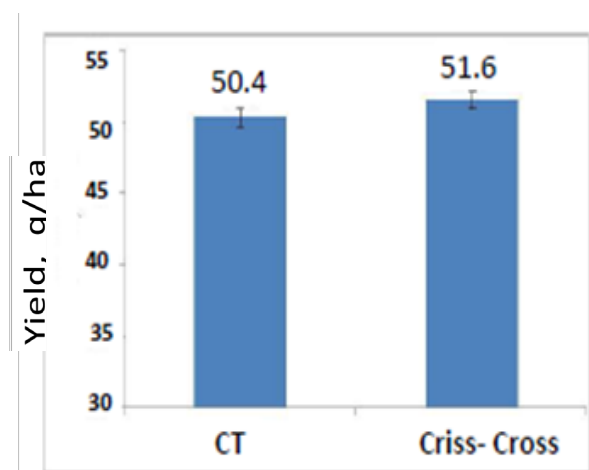


Fig. 5. Performance of wheat under conventional tillage (CT) and cross sowing methods. (average of 8 field observations). Vertical bars represent \pm SEM. Means are significantly different at $P=0.10$ using two tailed "Paired t test".

Agronomic practices must aim at maximizing the capturing and utilization of plant growth resources. Narrow row spacing or cross sowing configurations with optimum plant density can help in early ground coverage and better resource utilization such as increased light capture by canopy than wider rows and lesser plant density. Based on this study, for improving wheat yield a closer spacing (15-17.5cm) or cross sowing should be adopted. For cost saving NT wheat production should be adopted. We can also save (25%) on account of the seed by using 75 kg/ha seed rate by adopting precision drilling. For this, the fluted seed and fertilizer drilling mechanism should be replaced with the horizontal inclined plate drilling mechanism in seed-cum-fertilizer drills. Further, there is a need to

identify or breed cultivars having bolder grains and more grains per earhead and which are also capable of maintaining these characters at high plant density with narrow spacing so as to harness more wheat grain yield.

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