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Improvement in Wheat Crop Growth and Grain Yield under Different Planting Techniques in Faisalabad zone

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Abstract: Planting methods being one of the most important agronomic factors play an essential role in seed placement at appropriate depth, ensures enhanced seed emergence and succeeding crop growth. The selection of appropriate planting method for wheat rely on available soil water at planting, planting time, amount of residues in the field as well as the accessibility of planting machines. A study was conducted during 2005-06 growing season at Agronomic Research Area, University of Agriculture Faisalabad using six planting methods to evaluate the effect of different planting methods on wheat (*Triticum aestivum* L.) grain yield and yield components, to find out the most appropriate and cost-effective planting method for wheat grown under agro-climatological conditions of Faisalabad zone. The wheat cultivar Uqab-2000 was used as experimental material, the planting methods include broadcast on flat, raised bed, line sowing 22 cm apart, line sowing 11 cm apart, ridging planting and 45 cm spaced double row strip planting. The data concerning grain yield and yield components were recorded at maturity. The results showed that the plant height (cm) at maturity and grains per spike were maximum in case of raised bed planting as compared to the rest of the sowing methods. The line sowing 11 cm apart showed maximum number of total and productive tillers. The planting methods showed non-significant effects on grain weight per spike (g). The biological yield was significantly higher in 45 cm double row strip planting, while the broadcast on flat showed significantly higher harvest index. The highest 1000-grain weight (g) and grain yield (t ha^{-1}) as well as the highest net income of Rs. 51810.00 ha^{-1} with a benefit cost ratio of 4.16 revealed that line sowing 22 cm apart is most appropriate and cost-effective method for wheat grown in Faisalabad zone.

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1. Introduction

Wheat (*Triticum aestivum* L.) is the most imperative global grain crop. The area under wheat cultivation and global production was approximately 240 million ha and 655 million metric tons, respectively, in 2012-13. In Pakistan, wheat occupies the largest area under cultivation and being staple food, it constitutes 60% of the daily diet of common man in Pakistan. It contributes 10.1% to the value added in agriculture and 2.2% in total GDP of Pakistan (Government of Pakistan, 2013). Due to its national significance, wheat occupies a central position in agricultural policies of the government. Pakistan falls in ten major wheat-producing countries of the world in terms of acreages, total production and yield per hectare.

Wheat was cultivated on an area of 8.693 million hectares in Pakistan during 2012-13 with an average yield of 24.3 million tonnes. This average yield is very low as compared to many other wheat growing countries and farmers are getting only 30-35% of total yield capability. Lower average wheat yield in the country is associated to many factors such as, late sowing, suboptimal plant population, cultivars with lower yield potential, poor weed control practices, ineffective water use as well as inappropriate planting methods (Rehmani, et al., 2016). Among the aforementioned factors planting method is of prime importance.

The selection of appropriate planting method plays a vital role in seed placement at proper depth to ensure better emergence, improved crop stand establishment, balancing plant competition for better resource utilization and ultimately improving the subsequent crop growth and yield (Tanveer et al., 2003; Khan et al., 2007; Ali and Ali, 2012). Wheat is planted using different planting methods depending upon the accessible soil water, planting time, quantity of residues in field and accessibility of planting machines. Due to better crop stand establishment, wheat grain yield and yield components are significantly affected by the different planting methods.

Wheat in Pakistan is generally planted by manual broadcasting in field after harvesting rice and cotton. Broadcasting not only involves higher seed rate but also results in lower plant population due to improper seed placement. In contrast, line sowing by drill method is usually recommended by the national and provincial agriculture departments due to uniform distribution of seeds, seed placement at appropriate depth, which in turn ensures higher germination and uniform crop stand but it requires level field for even water distribution. Raised bed planting has been widely practiced in several wheat growing countries, especially in Sonora State of Mexico since decades (Sayre and Moreno Ramos, 1997; Hobbs et al., 1998).

Wheat planting on raised beds could improve water management, plant stands, weed and root diseases control as well as improved fertilizer use efficiencies. The strip planting enables intercultural practices, ease in working of inter-tillage devices as well as permits convenient intercropping in wheat during its vegetative growth period (Nazir et al., 1987). Moreover, raised bed and ridge methods of planting provide ease in water and fertilizer application, provide better drainage and result in less water logging damage to wheat, however, these methods are expensive due to increasing labor and fuel costs.

Despite the pros and cons of aforementioned planting methods, an integrated investigation of these methods could give useful insight into their effects on wheat crop growth and yield, Although several attempts have been made to evaluate effects of planting methods on grain yield and yield components of wheat, there remains controversy regarding the most appropriate planting method. Therefore, the present study was conducted to evaluate the performance of different planting methods to find out the most appropriate and cost-effective planting method for wheat grown under agro-climatological conditions of Faisalabad zone. The projected results would help to develop an appropriate and cost-effective planting method in wheat.

2. Materials and Methods

2.1 Experimental Design

The study pertaining to six planting methods of wheat was conducted at Agronomic Research Area, University of Agriculture, Faisalabad, during Rabi season of 2005-06 to evaluate the effect of different planting methods on wheat grain yield and yield components as well as to find out the most appropriate planting method for wheat grown under agro-climatological conditions of Faisalabad zone. The experiment was laid out in a randomized complete block design (RCBD) with four replications. The size of each plot was 6m x 10 m. One of the most widely cultivated wheat cultivar in the zone, Uqab-2000 was used in the experiment. Planting methods include manual broadcasting on flat, raised bed (4 rows on each bed), flat sowing with a rabi drill 22 cm apart, flat sowing with a rabi drill 11 cm apart, broadcast followed by ridge making and 45 cm spaced double row strip planting (45/15 cm). In raised bed sowing, seed was drilled on already formed beds while in ridge sowing, ridges were formed after broadcasting the seed and seed was also drilled between the ridges with a rabi drill. A summary of soil physio-chemical properties is presented in Table 1.

2.2 Crop Management

The wheat crop was planted on November 23, 2005 using a seed rate of 100 kg ha^{-1}. At the time of planting, 66 kg nitrogen ha^{-1}, 110 kg phosphorus ha^{-1} and 60 kg potassium ha^{-1} was applied as urea, diammonium phosphate and sulphate of potash, respectively. The remaining nitrogen was added with first irrigation. Pre-emergence weedicides were applied to control the weeds at early growth stages of wheat crop. Each experimental plot was regularly hand-weeded until plant canopy was closed to prevent the damage caused by weeds. Pesticides were used to avoid insect and disease damage. Four irrigations were applied during crop growth period.

Table 1 Soil physio-chemical properties of the experimental site

Soil Properties	
Electrical conductivity (d Sm^{-1})	0.96
pH	7.8
Organic matter (%)	0.69
Available-P (ppm)	18
Available-K (ppm)	80
Saturation (%)	40
Texture	Loam
Remarks	Normal soil

Table 2 Meteorological data during the wheat growing season

	Temperature (°C)		Relative Humidity (%)	Rainfall (mm)	Wind Speed (kmh^{-1})
	Daily Maximum	**Daily Minimum**			
November (2005)	29.1	12.6	12.6	12.6	12.6
December	23.9	5.3	5.3	5.3	5.3
January (2006)	20.8	6.3	6.3	6.3	6.3
February	27.6	13	13	13	13
March	28.1	14.6	14.6	14.6	14.6
April	37.6	20.7	20.7	20.7	20.7

All other agronomic practices were used according to the local recommendations to avoid the yield losses. Wheat crop was harvested on April 23, 2006.The meteorological data of growing season 2005-06 were collected from local weather station of Agronomic Research Area, University of Agriculture Faisalabad (Table 2).

2.3 Plant Sampling and Measurements

A quadrate of one m^2 made of iron rod was positioned at three randomly designated locations in each plot and the data concerning plant height at maturity (cm), total number of tillers m^{-2}, number of productive tillers m^{-2}, grains spike^{-1}, grain weight spike^{-1} (g), 1000-grain weight (g), biological yield (t ha^{-1}), grain yield (t ha^{-1}) and harvest index (%) was measured. The harvest index was calculated as Eq. 1.

$$HI = \frac{EY}{BY} \times 100 \qquad [1]$$

Where HI is harvest index, EY is economic yield and BY is biological yield.

2.4 Economic Analysis

Cost of labor, seed bed preparation, inputs and irrigation were noted for simple economic analysis including total variable cost (TVC), net field benefit and cost benefit ratio (CBC) were determined for each planting methods.

Net field benefit was calculated by using Eq. 2.

$$NI = \mathrm{GI} - \mathrm{CP} \qquad [2]$$

Where NI is net income (Rs. ha^{-1}), GI is Gross income and CP is Cost of production.

The benefit cost ratios (BCR) were determined by using Eq. 3.

$$BCR = \frac{GI}{TE} \qquad [3]$$

Where BCR is benefit cost ratio, GI is gross income and TE is total expenditure.

Gross income and cost of production were calculated on the basis of the market prices of the commodities in 2005-06.

2.5 Statistical Analysis

The data of grain yield and grain yield components were subjected to analysis of variance (ANOVA) using MSTAT C. The differences between treatment means were assessed using least significant difference (LSD) test at 95% level of significance.

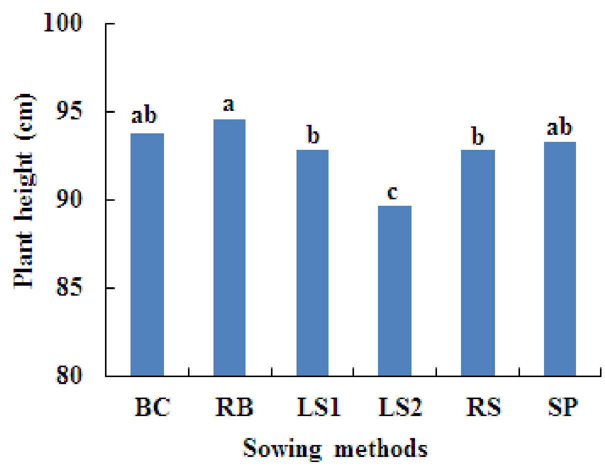

Fig.1 Effect of different planting methods on plant height of wheat at harvest (cm). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

3. Results and discussion

3.1 Plant height (cm)

Plant height is a function of both the genetic as well as the environmental factors, and is crucial constituent of straw yield. It is evident from the result that plant height was significantly influenced by different planting methods (Fig.1). The maximum plant height of 94.51 cm was recorded in raised bed + drill sowing against the lowest of 89.67 cm in line sowing 4.5 inches apart.

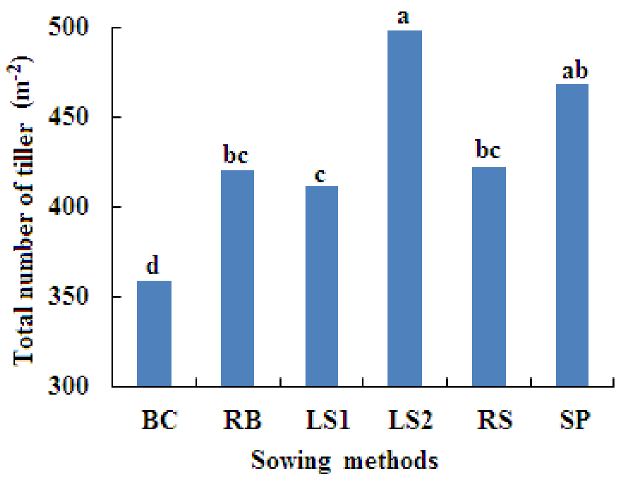

Fig.2 Effect of different planting methods on total number of tillers (m^{-2}). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

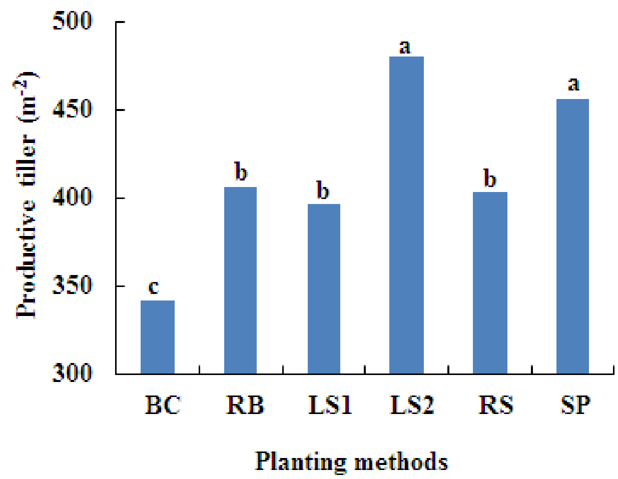

Fig.3 Effect of different planting methods on productive tillers (m^{-2}). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

However, raised bed + drill sowing showed non-significant differences with broadcast and 45 cm spaced double row strips planting, which in turn were statistically at par with line sowing 9 inches apart and ridge sowing. The results of lower plant height in line sowing 4.5 inches apart was attributed to comparatively lesser availability of water to the plants due to the inter-plant competition and was in agreement with the previous reports on wheat (Satya et al., 2002).

3.2 Total tillers per m^2

Tillering in wheat is a key yield determining parameter and is influenced noticeably by planting techniques. The results revealed that there were highly significant differences among different planting methods in present study (Fig. 2). Significantly higher number of tillers m^{-2} (498) was observed in case of line sowing 4.5 inches apart while the tillers m^{-2} was lowest (359) in broadcast method.

There were no significant difference between the tillers of 45 cm spaced double row strip planting and raised bed + drill sowing and ridge planting which in turn was statistically at par with line sowing 9 inches apart. Higher number of tillers in line sowing 4.5 inches apart and 45 cm double row strip planting might be attributed to lower weed competition and better micro environment as compared to other planting methods. Our results were in accordance with the previous findings that narrow row spacing of 10 cm resulted in significantly higher number of tillers m^{-2} (Joseph et al., 1985; Hussain et al., 2013).

3.3 Productive tillers per Unit Area

The number of productive tillers is the key component of yield in wheat. The results revealed that line sowing 4.5 inches apart (480) and 45 cm spaced double row strips planting (456) produced significantly higher number of productive tillers as compared to other planting methods and were at par with each other (Fig. 3). The lowest number of productive tillers was produced under broadcast method. Better crop stand in line sowing 4.5 inches apart and 45 cm double row strip planting might be credited to lower weed competition and better micro environment as compared to other planting methods. Our results were in accordance with the previous findings that narrow row spacing of 10 cm resulted in significantly higher number of tillers m^{-2} (Joseph et al., 1985; Hussain et al., 2013).

3.4 Number of grains per spike

The magnitude of the sink capacity of wheat spike is determined by the number of grains per spike produced. The number of grains per spike produced is generally influenced by the planting conditions. The results showed that there were highly significant differences between different planting methods of wheat (Fig. 4). The maximum number of grains per spike was recorded in raised bed planting (53.55) and 45 cm spaced double row strip planting (52.83), however, the grains per spike were showed non-significant differences with the grain per spike produced in broadcast (48.50) and ridge planting (49.65).

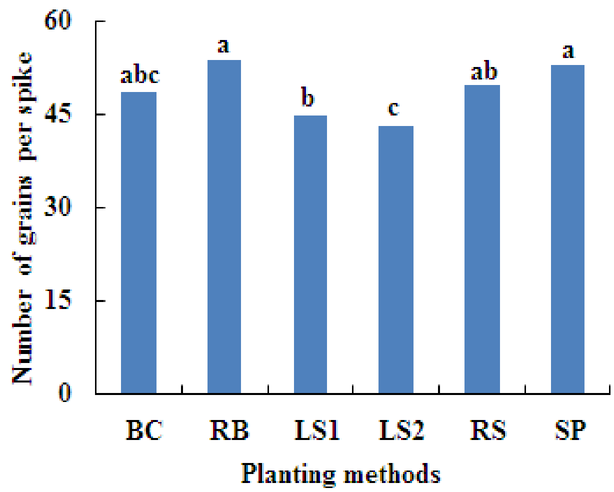

Fig.4 Effect of different planting methods on number of grains per spike. BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

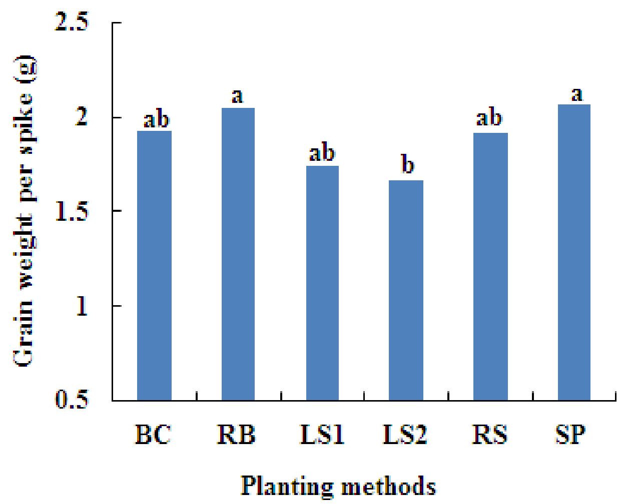

Fig.5 Effect of different planting methods on grains weight per spike (g). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

The minimum numbers of grains per spike (43.02) were recorded in line sowing 11 cm apart. The results of higher number of grains might be attributed to relatively healthy spikes in raised bed planting and 45 cm spaced double row strip planting in present study were in agreement with previous reports on wheat that wheat grown on raised bed produced significantly greater number of grains per spike and grains per spike were higher under bed furrow than under other conventional planting system (Satya et al., 2002; Tripathi et al., 2002).

3.5 Grains weight per spike (g)

Grain weight per spike has a direct bearing on the final grain yield of wheat. The data regarding grains weight per spike showed non - significant differences among different planting methods (Fig. 5). The highest grain weight of 2.063 g was recorded for 45 cm spaced double row strip planting, followed by 2.048 g, 1.928 g and 1.913 g in raised bed, broadcast and ridge planting, respectively. The minimum grain weight per spike of 1.668 g was recorded in line sowing 11 cm apart followed by 1.740 g in line sowing 22 cm apart. The results of lower grain weight per spike were in consensus with the previous reports on wheat that narrow row spacing produced lower grains weight per spike (Rafique et al., 1997; Ali et al., 2010).

3.6 1000-Grain weight (g)

1000-grain weight plays an essential role in determining the yield component and makes a major contribution towards final grain yield of wheat. The results showed that the highest 1000-grain weight (42.91 g) was recorded in line sowing 22 cm apart followed by broadcast method (42.04 g) (Fig. 6).

However, the 1000-grain weight obtained under these methods was statistically at par with each other (Fig. 6). Ridge planting (40.15 g), 45 cm double row strips (40.14 g) and raised bed planting (39.11 g) showed non-significant difference with one another. Lower 1000-grain weight (38.48 g) was recorded in case of line sowing 11 cm apart and was statistically at par with raised bed planting. The higher 1000-grain weight in line sowing 22 cm apart and in broadcast methods was attributed to healthy plant stand, which resulted in bold grains. Our results of 1000-grain weight were in accordance with the previous reports on wheat (Tripathi et al., 2002; Tanveer et al., 2003). Moreover, the results of lower 1000-grain weight in 11 cm apart line sowing were attributed to the narrow row spacing and were in consensus with previous reports (Rafique et al., 1997; Ali et al., 2010).

3.7 Biological yield (t ha^{-1})

Biological yield represents the overall performance and growth evidence and is an indispensable tool concerning the crop production. Biological yield is also an important yield parameter. There were significant differences in biological yield of different planting methods under study (Fig.7). Wheat planting using 45 cm spaced double row strips produced significantly higher (9.69 tha^{-1}) biological yield as compared to other planting methods.

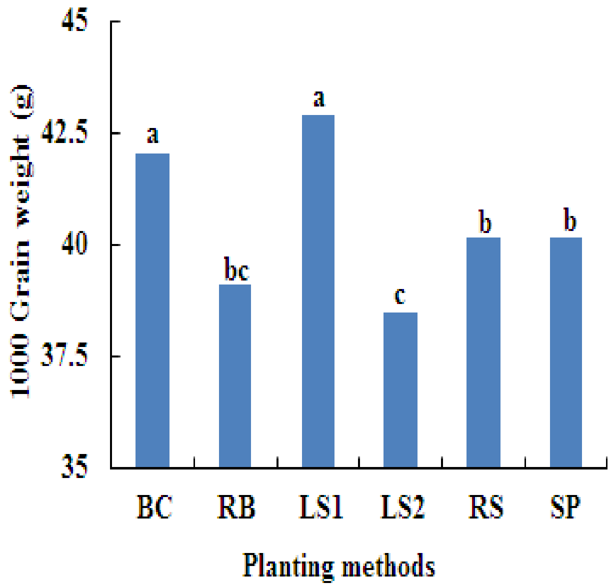

Fig.6 Effect of different planting methods on 1000-grains weight (g). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

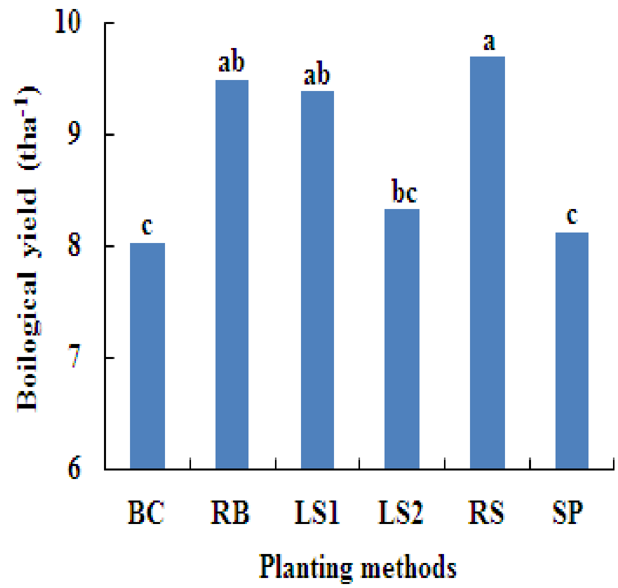

Fig.7 Effect of different planting methods on biological yield (t ha^{-1}). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

Raised bed and line sowing 22 cm apart produced 9.48 and 9.38 t ha^{-1}, respectively, which was statistically at par with 45 cm spaced double row strip planting and line sowing 4.5 inches apart. The lowest biological yield of 8.023 t ha^{-1} was obtained when wheat was broadcasted on flat followed by 8.13 t ha^{-1} and 8.34 t ha^{-1} in ridge planting and line sowing 11 cm apart but was at par with each other. The lowest biological yield in broadcast on flat and in line sowing 11 cm was attributed to lesser number of tillers m^{-2} and shorter plants, respectively.

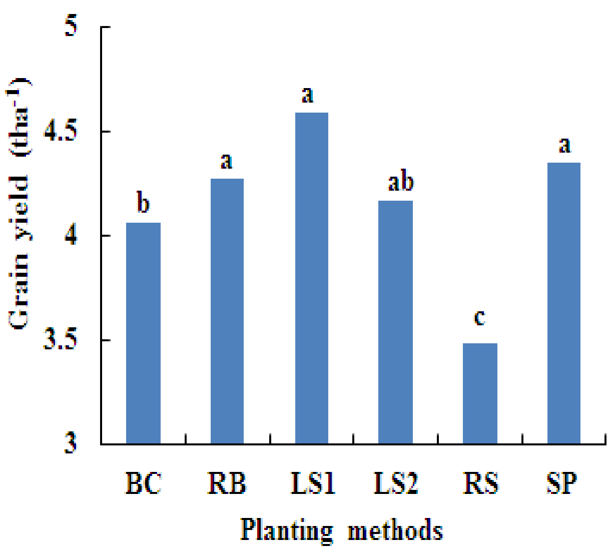

Fig.8 Effect of different planting methods on grain yield (t ha^{-1}). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

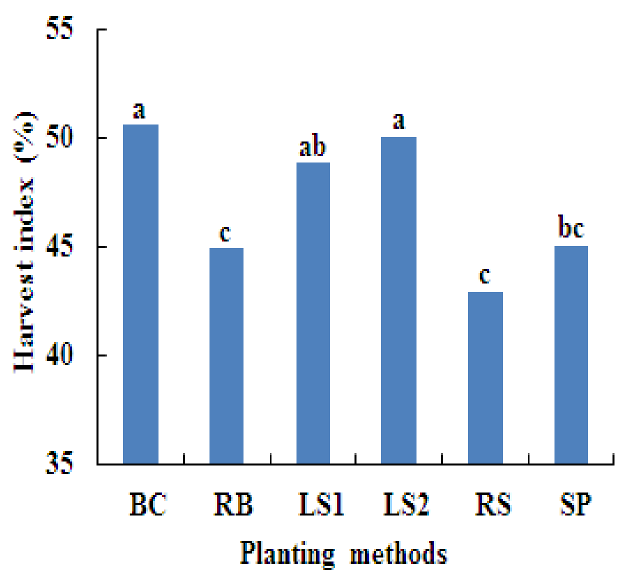

Fig.9 Effect of different planting methods on harvest index (%). BC, RB, LS1, LS2, RS and SP represents broadcasting, raised bed, line sowing (22 cm), line sowing (11 cm), ridge sowing, and double row strip planting, respectively.

Table 3 Economic analysis of different planting methods in wheat growing season

Planting method	Total variable cost (Rs. ha^{-1})	Total expenditure (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	Benefit cost ratio
Broad cast	2780	12553.6	47624	44844	3.79
Raised bed	4270	13993.6	53408	49138	3.82
Line planting (22 cm)	3520	13293.6	55330	51810	4.16
Line planting (11 cm)	3520	13293.6	49824.5	46304.5	3.75
Ridge Planting	5145	14868.6	44801	39656	3.02
Strip planting	3520	13293.6	54417.5	50897.5	4.09

The results were in agreement with previous report on wheat, which reported that biological yield is interrelated with the plant height and planting density (Ghaffar et al., 2013).

3.8 Grain yield (t ha^{-1})

Grain yield is of key importance of any agronomic study and a common objective of all the research experiments is to improve agronomic management practices which can ensure optimum grain yield production. The efficiency of a planting method is ultimately determined by the level of grain yield ha^{-1} which in turn is a function of the interaction of the numerous yield components. Grain yield is an imperative parameter with reverence to its economic value. It is determined by the cumulative impact of different yield traits. The data concerning to grain yield tha^{-1} was presented in Fig. 8. It is evident that among the various planting methods there were significant differences in grain yield t ha^{-1}. Line sowing 22 cm apart gave significantly highest grain yield (4.59 t ha^{-1}) as compared to the rest of planting methods and was statistically at par with all other sowing methods except broadcast and ridge planting.

The higher grain yield was due to higher 1000-grain weight. 45 cm spaced double row strip planting produced 4.35 t ha^{-1} followed by raised bed planting (4.27 t ha^{-1}), line sowing 11 cm apart (4.17 t ha^{-1}) and broadcast on flat (4.07 t ha^{-1}), respectively. The minimum grain yield (3.49 tha^{-1}) was recorded in ridge planting. The maximum grain yield under line sowing 22 cm apart in present study was in accordance with the previous studies on wheat which reported that higher wheat grain yields are obtained with drill sowing as compared to broadcast and drill is superior to broadcast if the seed bed is finely prepared. The maximum yields obtained with 22 cm row spacing and lower grain yield under ridge planting and line sowing 11 cm apart due to the narrow row spacing which in turn increased the competition for resources among plants were in agreement with previous reports on wheat (Negi and Mahajan, 2000). The lower grain yield in raised bed planting as compared to the line sowing has been widely reported in wheat (Rath et al., 2000; Walia et al., 2003). However, sometimes wheat produces higher yield m^{-2} on the beds, but when it was converted on per ha^{-1} bases, yields were often lower or not significantly different to that from flat conventional sowing due to 25-30 % loss of production area from the furrows (Riffkin et al., 2003; Walia et al., 2003).

On the contrary several studies reported that sowing of wheat on bed increased the grain yield by 19.46 % over flat planting (Tripathi et al., 2002). (Khatri et al., 2002) reported that sowing of three rows on bed gave significantly higher wheat grain yield than flat sowing and concluded that triple row bed planting of wheat was found to be appropriate and economical method under rice-wheat cropping system. (Asif et al., 2003) reported that bed furrow method consumed about 36.60 % less water as compared to flat border irrigation method and grain yield was 13.40 % higher in bed and furrow method than that in flat planting method.

3.9 Harvest index (%)

The harvest index reflects the physiological efficiency of a crop to convert the dry matter into grain yield. The data of harvest index as affected by various planting methods were shown in (Fig. 9). A perusal of the Fig. 9 showed highly significant differences among different planting methods. The highest harvest index (50.64 %) was recorded in broadcast on flat, followed by line sowing 11 cm a part (50.01 %) and line sowing 22 cm a part (48.87 %). However, these three planting methods were statistically at par with one another. 45 cm spaced double row strip planting gave harvest index of (45.05%) and was statistically at par with line sowing 22 cm apart. The lowest harvest index (42.94%) was recorded for ridge planting followed by raised bed planting (44.90 %). This indicates better resource use efficiency in term of grain production. These results are in line with the findings of Pratik et al. (2002) who reported that harvest index inhibited significant positive correlation with grain yield under the conventional system but under bed furrow irrigation system it had significant positive correlation.

3.10 Net field benefit

Data pertaining to the economic analysis revealed that the maximum net income of (Rs. 51810) was obtained in case of line sowing 22 cm apart, followed by 45 cm double row strip planting (Rs. 50988) and raised bed planting (Rs.49138) Table- 3. Among other sowing methods, line sowing 11 cm apart gave net income of (Rs. 46305); broadcast on flat gave net income of (Rs. 44844) while ridge planting gave the lowest net income of (Rs. 39656). The lowest net income in ridge planting was attributed to the lower grain and biological yields.

3.11 Benefit cost ratio

The benefit-cost ratio calculated for different planting methods are shown in Table 3. The maximum benefit-cost ratio of 4.16 was observed in case of line sowing 22 cm apart, followed by 45 cm spaced double row strips with a benefit-cost ratio of 4.09. The lowest benefit-cost ratio of 3.02 was obtained in case of ridge planting. Raised bed planting gave a benefit-cost ratio of 3.82 while broadcast on flat and line sowing 11 cm apart gave a benefit-cost ratio of 3.79 and 3.75, respectively. The lower benefit-cost ratio in ridge planting was associated to the higher cost of labor and machinery involved.

4. Conclusion

Highest 1000-grain weight and grain yield (t ha^{-1}) as well as the highest net income with a benefit cost ratio proved line sowing of wheat 22 cm apart as an appropriate and economical method of wheat sowing under agro-ecological conditions of Faisalabad. There was non-significant effect of planting methods on grain weight per spike (g). However, the detailed investigation using different wheat cultivars under various climatic conditions is required to confirm these findings.

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Competing Interests: The authors declare that there is no potential conflict of interest.

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