Pak. J. Bot., 56(2): 657-666, 2024. DOI: http://dx.doi.org/10.30848/PJB2024-2(4)

PERFORMANCE OF WHEAT CULTIVARS UNDER DIFFERENT PHOSPHORUS LEVELS AND SOWING METHODS

HAKOOMAT ALI[1], SHABIR HUSSAIN[1*] AND HAFIZ SHAKEEL AHMAD[1]

[1]*Department of Agronomy, Bahauddin Zakariya University, Multan-Pakistan 38040.*
**Corresponding author's email: shabirhussain@bzu.edu.pk*

Abstract

Wheat (*Triticum aestivum* L) is an important grain crop cultivated worldwide. Phosphorous is an essential macronutrient element that greatly contributed to the growth and yield of wheat crops. Proper phosphorous concentration and suitable sowing methods are involved in increased growth, yield, and nutrient profiling of the wheat crop. An experiment was performed at Central Cotton Research Institute, Multan, to evaluate the application of phosphorous and different sowing methods on three different wheat cultivars i.e. Gandum- 1, Sehar-2006 and Faisalabad- 2008. The experiment was performed to study the impact of four different phosphorous levels (control, 60kg ha^{-1}, 120 kg ha^{-1}, 180kg ha^{-1}) on three different wheat cultivars by using three different sowing methods i.e. flat, drill and bed sowing. A randomized complete block design was used to perform the experiment. Present results indicated that leaf area index, leaf area duration, crop growth rate, net assimilation rate; plant height, spike length, number of spikelets, fertile tillers, number of grains per spike, 1000 grain weight, grain yield, biological yield, harvest index, phosphorous content, protein content, oil content and chlorophyll content were significantly increased in cultivar Faisalabad-2008, phosphorous 180 kg ha^{-1} and bed sowing method. From present results, it has been concluded that Faisalabad-2008 is a higher yielding cultivar grown on bed sowing method with the application of phosphorous 180 kg ha^{-1} and this combination is more suitable to attain higher yield in the future.

Key words: Bed sowing, Growth, Mineral nutrition, Yield.

Introduction

Wheat (*Triticum aestivum* L.) is a grain crop that is widely cultivated in tropical and subtropical areas of the world. Grain production is the key purpose of wheat cultivation (Ali *et al*., 2005). The share of wheat in agriculture is about 25% and 4.50% of GDP (Elahi *et al*., 2020). The main focus of cultivating the wheat crop is to obtain straw and grain (Godden & Brennan, 2019). To overcome the needs of 40% of Pakistan, approximately 1000 flour mills are working to produce different products (Chenu, 2015). In Barani and irrigated areas, the wheat seems to be successfully cultivated (Ali *et al*., 2017). The maximum yield of the crop is observed in irrigated areas (Li *et al*., 2011). Environment, cultivars, soil type, weed control, nutrition, and irrigation are major factors affecting agronomic crop yield, especially wheat crops (Ali *et al*., 2012).

In Pakistan, the average wheat yield is low as compared to the other developed countries due to different biotic and abiotic factors (Kacar & Katkat, 2007). Phosphorous deficiency is a common and major issue found in Pakistan's soil (Ali *et al*., 2020). It is not found in the free state in nature and is found as inorganic phosphate or in the ester form (Ryan *et al*., 2008). Phosphorus becomes the second nutrient after nitrogen for better development (von Tucher *et al*., 2018) and the growth of wheat crops (Rasul, 2016). The deficiency of phosphorous causes poor plant growth and yield (Sisie & Mirshekari, 2011).

The deficiency of phosphorous in wheat also caused stunted growth, reduced root system, leaves turning purple and poor tillering (Wang *et al*., 2016). Furthermore, for grain formation and flowering, phosphorous is the prime need for the wheat crop (Ali *et al*., 2016). During harsh environments like temperature extremities, phosphorous is required for better seed formation, uniform heading, and maturity (Bashir *et al*., 2015). The application of phosphorous is necessary before and after planting of the wheat crop to overcome many stress issues such as winter kill, disease pressure, and plant health (Doolette *et al*., 2019). Phosphorous is involved in the regulation of photosynthesis, cell division, and energy storage. Moreover, a short maturation period of wheat has been observed in different countries i.e. Pakistan, China, and India due to high temperatures. Therefore, sowing time is very critical within the country. Timely sowing and suitable phosphorous levels can enhance the maturation period of wheat crops (El-Metwally & Arafa, 2019).

The broadcast technique is used to apply phosphorous during sowing time (Sacristán *et al*., 2019). Different techniques such as soil analysis, application methods, sowing dates, and crop cycles are used to decide the dose of phosphorous (Dhaliwal & Mandal, 2019). An optimum level of phosphorous is applied while a low or excessive amount will minimize the yield (Shaoxia *et al*., 2019).

Sowing methods and techniques can also significantly affect the yield production and development of the wheat crop. Many sowing methods are used for the wheat crop's highest yield. These are flat sowing, drill sowing, and bed sowing, respectively. According to different soil types and climate conditions of the region, farmers used different sowing methods. So, the main focus is to adopt the best sowing technique for that specific area (Soomro *et al*., 2009). The use of drill sowing can reduce all input costs, such as the rate of seed per hectare. Wheat production was enhanced by 15% with drill sowing and bed sowing as compared to the flat sowing method (Gillani *et al*., 2014). The maximum number of wheat plants germinate with drill sowing on beds and flat sowing and plant height, grains per spike, grain weight, and grain yield is more in the bed planting system (Ali *et al*., 2016). Wheat crops on bed sowing with proper seed rates compared to others can enhance wheat yield (Chauhdary *et al*., 2016). Wheat with good quality and maximum yield can be achieved with a manageable sowing method and sowing time (Farooq *et al*., 2015).

The flat sowing method is the earliest and most outdated method used for wheat cultivation. Flooding irrigation is used in flat sowing, suitable with flat beds (Monsefi *et al*., 2016). Some disadvantages of flat sowing include leaching of nitrogen, bad aeration, vitalization, water lodging, and disturbance of upper soil as compared to bed sowing (Rawal *et al*., 2015). Poor information is available about higher-yielding sowing methods within the country (Teng *et al*., 2017). We can improve wheat crop yield by advancing the sowing method and phosphorous application. Hence the current study was designed to improve growth and yield using the appropriate sowing methods and suitable phosphorous levels. Phosphorus application n cotton is neglected and limited research is available on phosphorus. Bed sowing methods and 180 kg ha $^{-1}$ phosphorous level were purposed to be best for all the growth and yield parameters of the studied wheat cultivars. Phosphors and sowing methods can enhance growth and yield of cotton.

Material and Methods

The experiment was carried out in the research fields of Central Cotton Research Institute, Multan. The experimental site is placed at a latitude of 30°, a longitude of 71° and an altitude is 125. Gandum 1, Sehar 2006, and Faisalabad 2008 were three cultivars used to study the effect of phosphorous on growth and yield by applying three different techniques of sowing methods such as flat sowing, drill sowing, and bed sowing. The whole experiment was completed in two different years 2017 and 2018. Pre-soil testing was carried out before setting up the experiment. Four different levels of phosphorous i.e. 60kg ha^{-1},120kg ha^{-1}, 180.kg ha^{-1} were applied. Each treatment was comprised of three replications. Whereas the source of these nutrients was urea and triple super phosphate. Seed sowing was performed by hand drill method, keeping a distance of 20cm between two adjacent rows. After irrigation, almost three times plowing was done to prepare the fine seed bed. During the study, other agronomic activities were kept standard and uniform. Phosphorus applications were done during sowing time and the first irrigation. The first irrigation was made after four weeks of sowing.

Data collection: Some growth parameters were observed during our course of study. These growth parameters are leaf area index (LAI) which is determined from the formula LAI = total leaf area/total ground cover as described by Fang and Xiong (2015).

Leaf area duration (LAD): It is estimated using the formula LAD= $LAI_1+LAD_2/2 \times T_2 - T_1$, whereas LAI_1 and LAD_2 are two different indices between two different time intervals T_1 and T_2 as described earlier (Farooq *et al*., 2008). Crop growth rate as a described method of Fang & Xiong (2015) and the Net assimilation rate through an earlier method by Fahad *et al*., (2016).

Some yield parameters were plant height (cm), spike length (cm), number of spikelets per spike, fertile tillers (m^2), 1000 grain weight (g), grains per spike, grain yield (t ha^{-1}), biological yield (kg ha^{-1}) and harvest index.

Biological yield = Grain yield + Straw yield

Harvest index = (Grain yield)/(Biological yield)

At the same time, quality parameters such as phosphorous content in grain (%) are determined by the spectrometer at a wavelength of 500 nm, protein content (%) is estimated by digestion followed by spectrometer technique at wavelength 517nm, by using Soxtec 12050 solvent extractor and oil content (%) and chlorophyll content of a sample of different wheat cultivars are calculated by SPAD meter. Also, some weed parameters [total weed density (m^{-2}), weed crop competition (days), individual weed present, weed biomass (g/plant), weed fresh weight (g/plant), weed dry weight (g/plant)] and stress parameters [catalase peroxidase (U/mg), superoxide dismutase (U/mg) and proline content (U/mg)] were analyzed to maintain the better yield and growth of the wheat crop.

Statistical analysis

Microsoft Excel program, 2019 was used to organize the data for research work. All the data were statistically evaluated by using statistix 8.1 software. LSD was used to separate the means of different treatments, and the probability level for this experiment was 5%.

Result

Growth and development parameters: Table 1 provides a comprehensive summary of the results obtained for leaf area index (LAI, cm²/cm²), leaf area duration (LAD, days), crop growth rate (CGR, g/m²/day), and net assimilation rate (NAR, g/cm²/day) during the years 2017 and 2018. In terms of cultivars, the findings indicate distinct variations in performance. Gandum-1 exhibited LAI values of 4.70 and 4.71, LAD values of 185.0 and 185.39, CGR values of 14.71 and 14.72, and NAR values of 6.24 and 6.25 for 2017 and 2018, respectively. Sehar-2006 demonstrated slightly higher values with LAI of 4.76 and 4.77, LAD of 193.54 and 193.58, CGR of 14.77 and 14.75, and NAR of 6.29 and 6.28. Notably, Faisalabad-2008 exhibited the highest performance, with LAI values of 4.84 and 4.85, LAD values of 192.00 and 192.18, CGR values of 14.82 and 14.84, and NAR values of 5.96 and 5.97. The choice of sowing method also influenced the growth and development parameters.

Flat sowing resulted in LAI values of 4.73 and 4.74, LAD values of 195.13 and 190.50, CGR values of 14.72 and 14.71, and NAR values of 6.02 and 6.05. Drill sowing showed LAI values of 4.74 and 4.75, LAD values of 209.78 and 209.79, CGR values of 14.73 and 14.72, and NAR values of 6.02 and 6.05. In contrast, bed sowing demonstrated the most favorable outcomes, with LAI values of 4.82 and 4.83, LAD values of 215.67 and 215.70, CGR values of 14.82 and 14.81, and NAR values of 6.20 and 6.22. The application of varying phosphorus levels also influenced the growth and development parameters. The control group exhibited LAI values of 4.73 and 4.74, LAD values of 210.00 and 210.37, CGR values of 14.72 and 14.71, and NAR values of 6.05 and 6.03.

Table 1. Influence of sowing methods and phosphorous levels on wheat growth and development parameters.

Treatments	2017	2018	2017	2018	2017	2018	2017	2018
	LAI		LAD (days)		CGR (gm^2 day^{-1})		NAR (g cm^{-2} $days^{-1}$)	
Cultivars								
Gandum-1	4.70c	4.71c	185.0b	185.39b	14.71c	14.72c	6.24a	6.25a
Sehar-2006	4.76b	4.77b	193.54a	193.58a	14.77b	14.75b	6.29b	6.28b
Faisalabad-2008	4.84a	4.85a	192.00c	192.18c	14.82a	14.84a	5.96c	5.97c
LSD value	0.11	0.17	2.25	2.09	0.93	0.81	1.03	0.97
Sowing methods								
flat sowing	4.73c	4.74c	195.13a	190.50a	14.72c	14.71c	6.02c	6.05c
drill sowing	4.74b	4.75b	209.78b	209.79b	14.73b	14.72b	6.02b	6.05b
Bed sowing	4.82a	4.83a	215.67a	215.70a	14.82c	14.81c	6.20a	6.22a
LSD value	0.09	0.07	2.00	2.11	0.62	0.94	0.43	0.71
Phosphorous levels								
Control	4.73c	4.74d	210.00c	210.37c	14.72c	14.71d	6.05c	6.03c
60$kgha^{-1}$	4.77d	4.78b	215.33b	215.35b	14.74d	14.75b	6.08d	6.09b
120$kgha^{-1}$	4.80a	4.81a	222.22d	222.28a	14.79a	14.80a	6.14a	6.16d
180$kgha^{-1}$	4.83b	4.84c	225.12a	225.14d	14.85b	14.86c	6.15b	6.17a
LSD value	0.33	0.48	0.61	1.04	0.79	0.67	1.00	0.09

LAI= Leaf area index; LAD= Leaf area duration; CGR= Crop growth rate; NAR= Net assimilation rate

Notably, the treatment with 60 kg/ha showed LAI values of 4.77 and 4.78, LAD values of 215.33 and 215.35, CGR values of 14.74 and 14.75, and NAR values of 6.08 and 6.09. The 120 kg/ha treatment yielded LAI values of 4.80 and 4.81, LAD values of 222.22 and 222.28, CGR values of 14.79 and 14.80, and NAR values of 6.14 and 6.16. Likewise, the 180 kg/ha treatment exhibited LAI values of 4.83 and 4.84, LAD values of 225.12 and 225.14, CGR values of 14.85 and 14.86, and NAR values of 6.15 and 6.17 (Table 1; Figs. 1 & 2).

Yield parameters: Among the cultivars, Faisalabad-2008 exhibited the highest values for plant height, with measurements of 77.48 cm in 2017 and 75.08 cm in 2018. It also had the longest spikes, measuring 16.08 cm in 2017 and 17.08 cm in 2018. Furthermore, it displayed a greater number of spikelets with 21.20 spikelets in 2017 and 21.22 spikelets in 2018. In terms of fertile tillers per square meter, Faisalabad-2008 achieved 225.74 tillers in 2017 and 227.74 tillers in 2018, making it the best-performing cultivar in this study.

Regarding sowing methods, bed sowing resulted in the highest plant height, with measurements of 78.43 cm in 2017 and 76.41 cm in 2018. It also produced spikes measuring 14.06 cm in both years. Additionally, bed sowing exhibited the largest number of spikelets, with 22.09 spikelets in 2017 and 22.10 spikelets in 2018. In terms of fertile tillers per square meter, bed sowing achieved 270.41 tillers in both years. Based on these results, bed sowing demonstrated superior performance compared to flat sowing and drill sowing (Table 2).

In terms of phosphorus levels, the treatment with 180 kg/ha showed the highest plant height, with measurements of 77.15 cm in 2017 and 74.14 cm in 2018. It also exhibited spike lengths of 15.08 cm in 2017 and 15.10 cm in 2018. Moreover, this treatment had the largest number of spikelets, with 21.95 spikelets in 2017 and 21.97 spikelets in 2018. Fertile tillers per square meter reached 280.12 tillers in 2017 and 281.22 tillers in 2018 for the 180 kg/ha treatment. These findings suggest that a phosphorus level of 180 kg/ha led to the highest wheat yield parameters in this study.

Based on the results, Faisalabad-2008 was identified as the best-performing wheat cultivar, while bed sowing and a phosphorus level of 180 kg/ha were the most effective sowing method and phosphorus level, respectively, for optimizing yield parameters in wheat cultivation (Figs. 3 & 4).

Among the cultivars, Faisalabad-2008 demonstrated superior performance in terms of yield parameters. It produced the highest number of grains per spike, with 45 grains in 2017 and 44 grains in 2018. Furthermore, Faisalabad-2008 exhibited the highest 1000 grain weight, measuring 54 g in 2017 and 56 g in 2018. The grain yield of Faisalabad-2008 was also remarkable, reaching 4390 kg/ha in 2017 and 4460 kg/ha in 2018. In terms of biological yield, Faisalabad-2008 achieved 12278 kg/ha in 2017 and 12292 kg/ha in 2018. Additionally, Faisalabad-2008 had the highest harvest index, indicating efficient resource allocation, with 35.76% in 2017 and 36.28% in 2018.

Regarding sowing methods, bed sowing proved to be the most effective technique. It resulted in higher grain yield, biological yield, and harvest index compared to flat sowing and drill sowing. Bed sowing produced the highest number of grains per spike, with 41 grains in 2017 and 42 grains in 2018. Additionally, bed sowing achieved 1000 grain weights of 55 g in 2017 and 54 g in 2018. The grain yield for bed sowing was 3340 kg/ha in 2017 and 3330 kg/ha in 2018, while the biological yield reached 12112 kg/ha in both years. The harvest index for bed sowing was 27.58% in 2017 and 27.34% in 2018.

Regarding phosphorus levels, the treatment with 180 kg/ha exhibited notable results. It displayed a higher number of grains per spike, with 40 grains in 2017 and 42 grains in 2018. The 1000 grain weight for the 180 kg/ha treatment was 53 g in 2017 and 54 g in 2018. Furthermore, this treatment demonstrated grain yields of 3300 kg/ha in 2017 and 3350 kg/ha in 2018, along with biological yields of 12080 kg/ha in 2017 and 12096 kg/ha in 2018. The harvest index for the 180 kg/ha treatment was 27.32% in 2017 and 27.69% in 2018 (Table 3).

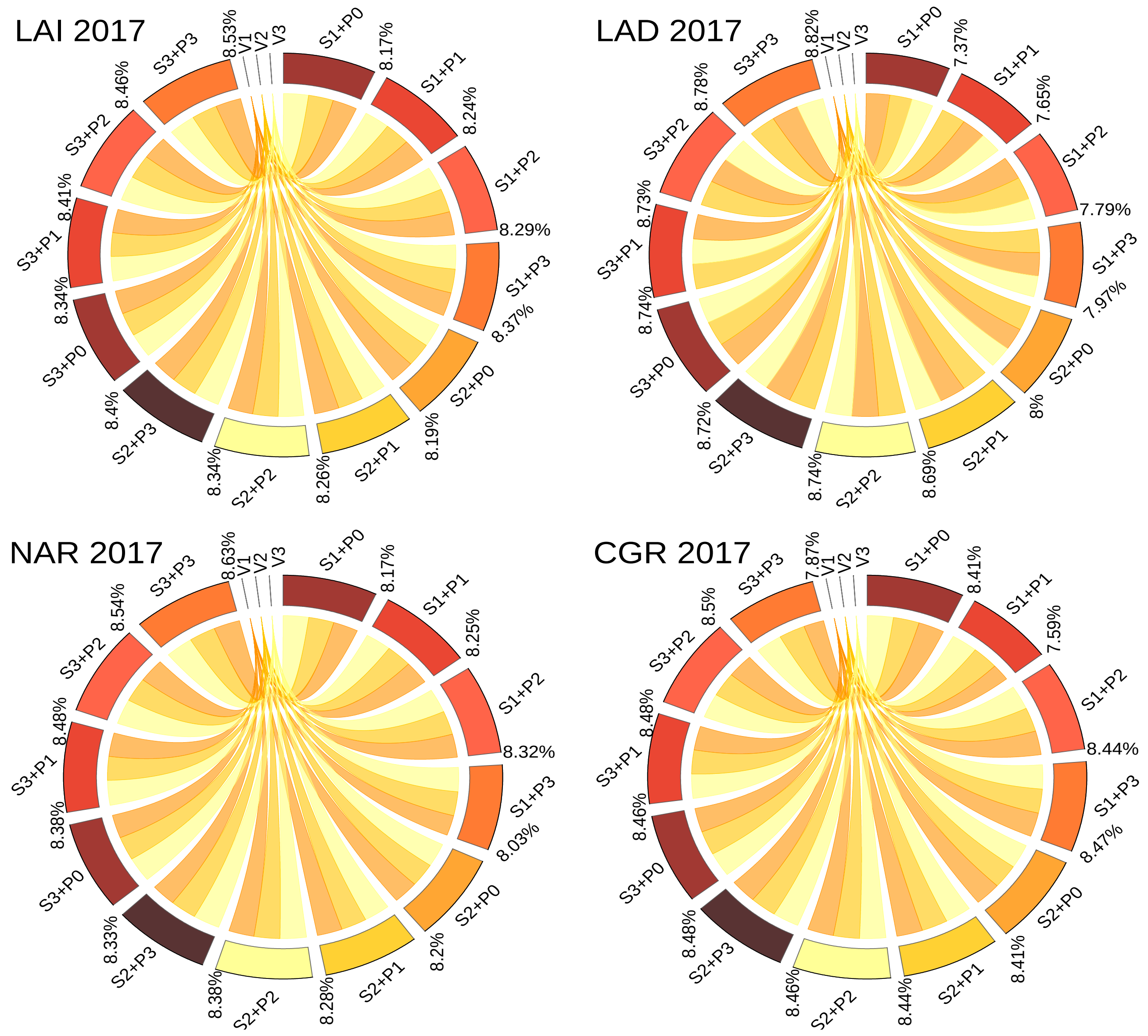

Fig. 1. Chord diagram showing the percentage contribution of each treatment for change in LAI, LAD, NAR and CGR for the year 2017 in Gandum- 1, Sehar-2006 and Faisalabad- 2008. Phosphorus applications were done during sowing time and the first irrigation. The first irrigation was made after four weeks of sowing.

Table 2. Influence of sowing methods and phosphorous level on wheat yield parameters.

Treatments	2017	2018	2017	2018	2017	2018	2017	2018
	Plant height (cm)		Spike length (cm)		No. of spikelets		Fertile tillers (m^2)	
Cultivars								
Gandum-1	72.14c	69.72c	13.93c	14.93c	15.90c	15.94c	247.07b	248.07b
Sehar-2006	75.21b	71.81b	14.00b	15.00b	18.10b	18.12b	280.56a	282.56a
Faisalabad-2008	77.48a	75.08a	16.08a	17.08a	21.20a	21.22a	225.74c	227.74c
LSD value	1.34	1.43	2.67	1.95	0.89	0.73	0.90	0.89
Sowing methods								
Flat sowing	72.53c	70.15c	13.97c	13.97c	16.35c	16.39c	172.30c	174.30c
Drill sowing	72.84b	70.42b	13.98b	13.98b	16.68b	16.69b	267.67b	266.67b
Bed sowing	78.43a	76.41a	14.06a	14.06a	22.09a	22.10a	270.41a	270.41a
LSD value	0.23	0.31	0.19	0.34	1.52	0.94	1.56	1.25
Phosphorous levels								
Control	72.82c	70.47d	11.97c	13.97d	16.35c	16.39c	224.07c	226.07c
60kgha^{-1}	74.86b	72.84b	14.01d	13.01b	18.94b	18.95b	256.70d	255.70b
120kgha^{-1}	76.09a	73.69a	14.04a	15.04a	19.83d	19.85a	275.59a	276.59d
180kgha^{-1}	77.15d	74.14c	15.08b	15.10c	21.95a	21.97d	280.12b	281.22a
LSD value	1.00	0.34	1.17	1.20	1.03	0.80	0.35	0.69

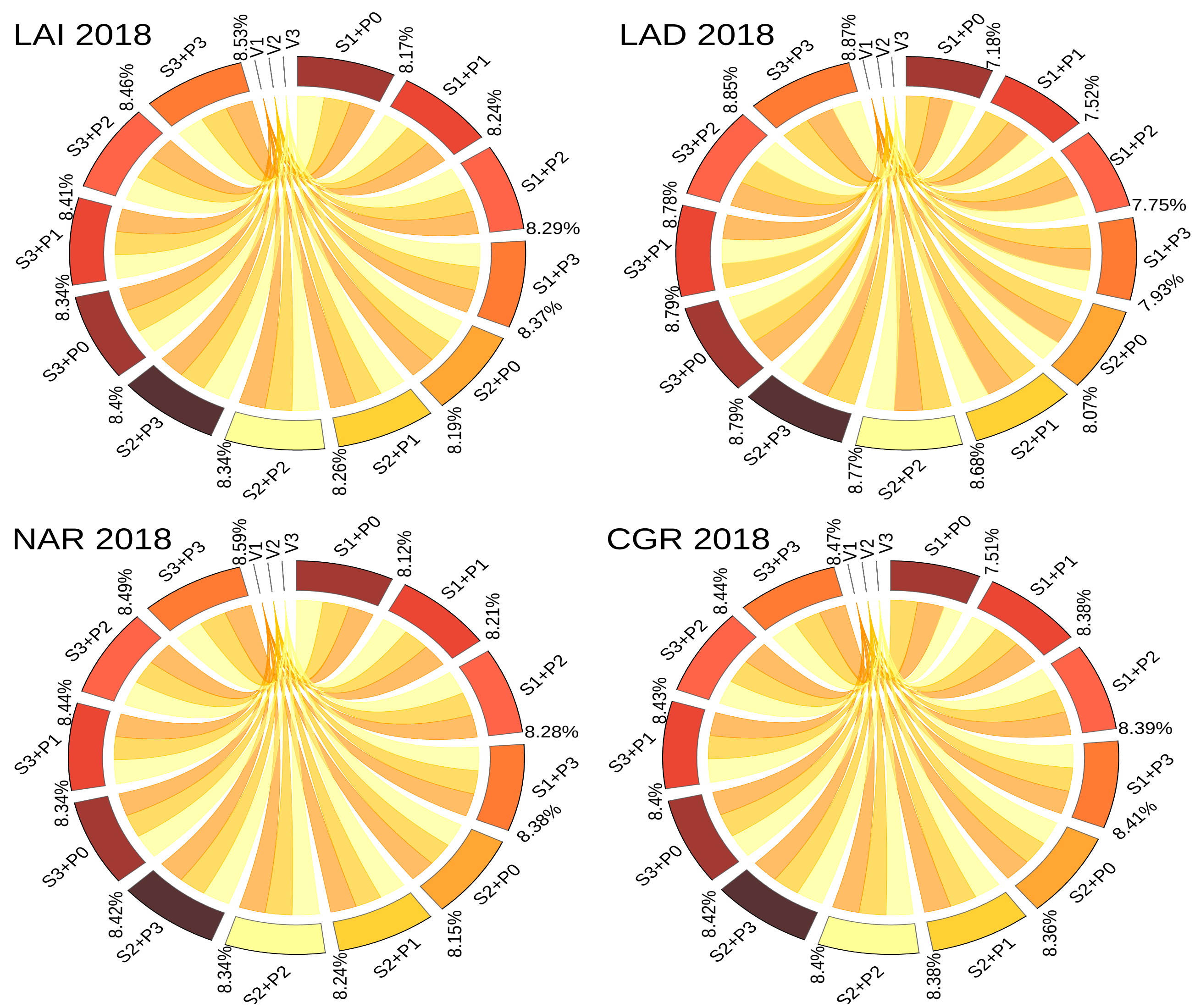

Fig. 2. Chord diagram showing the percentage contribution of each treatment for change in LAI, LAD, NAR and CGR for the year 2018 in Gandum- 1, Sehar-2006 and Faisalabad- 2008. Phosphorus applications were done during sowing time and the first irrigation. The first irrigation was made after four weeks of sowing.

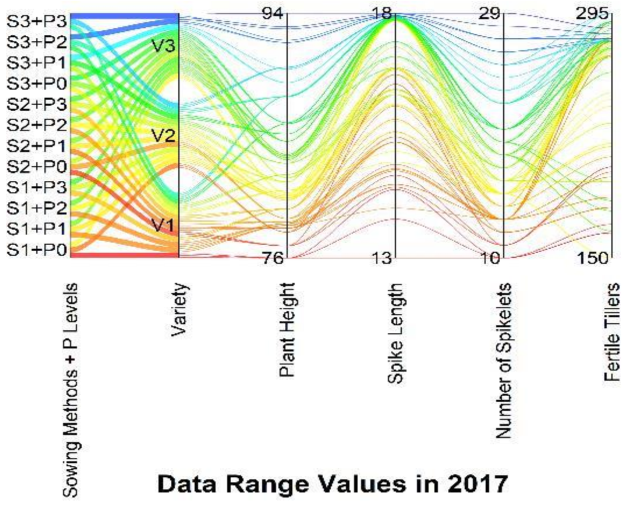

Fig. 3. Parallel plot showing the data range of plant height, spike length, number of spikelets and fertile tillers for the year 2017 in Gandum- 1, Sehar-2006 and Faisalabad- 2008 under influence of sowing methods and P levels. Phosphorus applications were done during sowing time and the first irrigation. The first irrigation was made after four weeks of sowing.

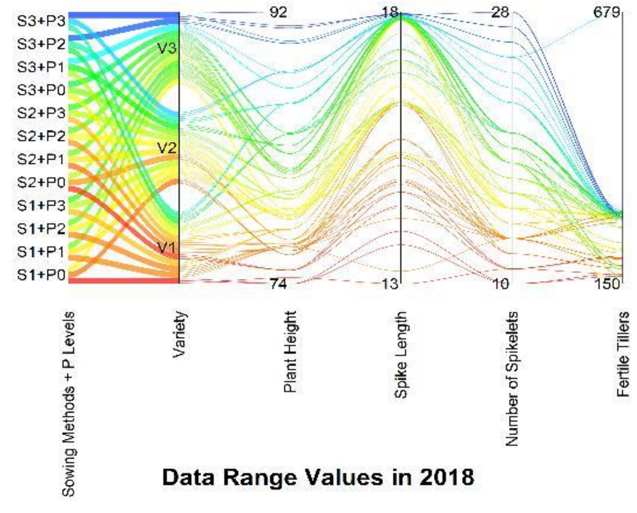

Fig. 4. Parallel plot showing the data range of plant height, spike length, number of spikelets and fertile tillers for year 2018 in Gandum- 1, Sehar-2006 and Faisalabad- 2008 under influence of sowing methods and P levels. Phosphorus applications were done during sowing time and during first irrigation. First irrigation was made after four week of sowing.

Based on these results, Faisalabad-2008 emerged as the best-performing wheat cultivar, exhibiting higher grain yield, biological yield, and harvest index. Bed sowing proved to be the most effective sowing method, resulting in higher yield parameters compared to flat sowing and drill sowing. Moreover, a phosphorus level of 180 kg/ha led to improved yield parameters in wheat cultivation (Figs. 5 & 6).

Quality parameters: Among the cultivars, Faisalabad-2008 exhibited the highest phosphorus contents in grains, measuring 10.54% in 2017 and 9.67% in 2018. It also showed the highest protein contents in grains, with 15.08% in 2017 and 14.08% in 2018. Additionally, Faisalabad-2008 had the highest oil contents, measuring 3.16% in 2017 and 3.39% in 2018. Moreover, Faisalabad-2008 displayed the highest chlorophyll contents, with 42.08% in 2017 and 43.04% in 2018.

Regarding sowing methods, bed sowing resulted in higher phosphorus contents in grains, with 10.04% in 2017 and 9.65% in 2018. Bed sowing also exhibited higher protein contents in grains, measuring 16.01% in 2017 and 15.01% in 2018. Furthermore, bed sowing showed higher oil contents, measuring 3.14% in 2017 and 3.37% in 2018. The chlorophyll contents for bed sowing were 43.07% in 2017 and 44.03% in 2018 (Table 4).

For phosphorus levels, the treatment with 180 kg/ha exhibited higher phosphorus contents in grains, with 10.20% in 2017 and 10.01% in 2018. The protein contents for the 180 kg/ha treatment were 14.00% in 2017 and 13.01% in 2018. Moreover, this treatment showed higher oil contents, measuring 3.15% in 2017 and 3.40% in 2018. The chlorophyll contents for the 180 kg/ha treatment were 41.13% in 2017 and 41.70% in 2018 (Figs. 7 & 8).

Table 3. Influence of sowing methods and phosphorous levels on wheat yield parameters.

Treatments	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
	Grains per spike		1000 grain weight (g)		Grain yield (kg ha^{-1})		Biological yield (kg ha^{-1})		Harvest index (%)	
Cultivars										
Gandum-1	28c	30c	41c	42c	3200c	4200c	12022c	12114b	26.62	34.67c
Sehar-2006	35b	36b	49b	48b	3570b	3590b	12043b	12048a	29.64b	29.80b
Faisalabad-2008	45a	44a	54a	56a	4390a	4460a	12278a	12292c	35.76a	36.28a
LSD value	2.33	2.14	3.20	1.88	1.32	4.03	5.15	7.73	2.17	3.19
Sowing methods										
Flat sowing	32c	33c	47c	45c	3250c	3256c	11969c	11540c	27.15c	28.21c
Drill sowing	33b	34b	46b	46b	3260b	3240b	12062b	12132b	27.03b	26.70b
Bed sowing	41a	42a	55a	54a	3340a	3330a	12112a	12182a	27.58a	27.34a
LSD value	1.27	2.19	3.53	2.00	9.06	10.01	11.63	9.95	1.83	2.78
Phosphorous levels										
Control	32c	33d	44c	45c	3230c	3220c	12021d	12092c	26.87c	26.63c
60kgha^{-1}	35d	37b	49b	49b	3270b	3250d	12000b	12120b	27.25d	26.81b
120kgha^{-1}	38a	40a	52a	53d	3200a	3320a	12071a	12141d	26.50a	27.35a
180kgha^{-1}	40b	42c	53d	54a	3300d	3350b	12080c	12096a	27.32b	27.69d
LSD value	2.81	2.93	2.06	0.97	11.06	11.55	13.22	10.64	4.00	0.92

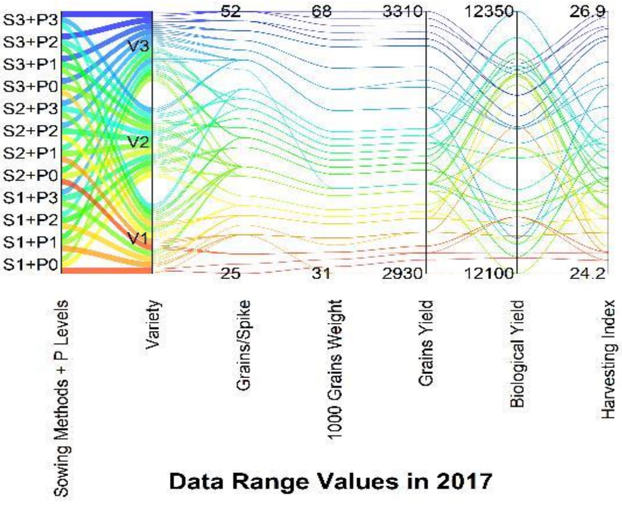

Fig. 5. Parallel plot showing the data range of grains/spike, 1000 grains weight, grains yield, biological yield and harvesting index for year 2017 in Gandum- 1, Sehar-2006 and Faisalabad- 2008 under influence of sowing methods and P levels. Phosphorus applications were done during sowing time and during first irrigation. First irrigation was made after four week of sowing.

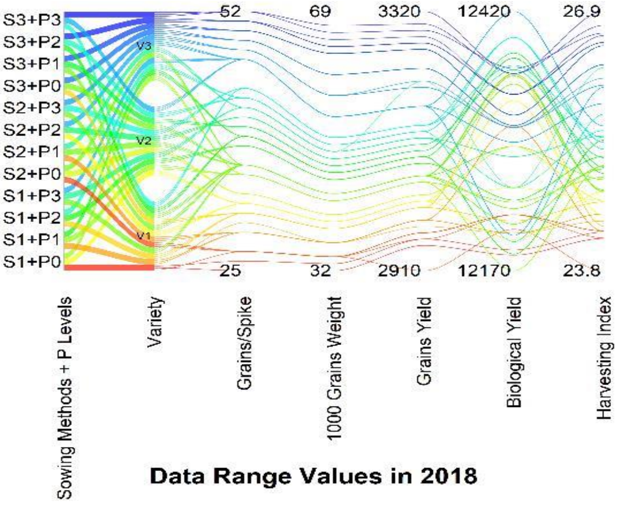

Fig. 6. Parallel plot showing the data range of grains/spike, 1000 grains weight, grains yield, biological yield and harvesting index for year 2018 in Gandum-1, Sehar-2006 and Faisalabad- 2008 under influence of sowing methods and P levels. Phosphorus applications were done during sowing time and during first irrigation. First irrigation was made after four week of sowing.

Table 4. Influence of sowing methods and phosphorous levels on wheat quality parameters.

Treatments	2017	2018	2017	2018	2017	2018	2017	2018
	P contents in grains (%)		Protein contents in grains (%)		Oil contents (%)		Chlorophyll contents (%)	
Cultivars								
Gandum-1	9.81c	9.52c	9.86c	9.00c	3.02c	3.24c	36.67c	37.64c
Sehar-2006	9.88b	9.59b	12.00b	11.00b	3.08b	3.31b	39.00b	40.00b
Faisalabad-2008	10.54a	9.67a	15.08a	14.08a	3.16a	3.39a	42.08a	43.04a
LSD value	0.96	0.97	0.29	0.03	0.83	1.06	2.03	1.83
Sowing methods								
Flat sowing	9.85c	9.56c	10.23c	9.27c	3.05c	3.28c	37.12c	38.08c
Drill sowing	9.86b	9.57b	10.60b	9.69b	3.06b	3.29b	37.56b	38.56b
Bed sowing	10.04a	9.65a	16.01a	15.01a	3.14a	3.37a	43.07a	44.03a
LSD value	3.44	4.10	5.27	4.00	1.51	0.09	6.09	4.50
Phosphorous levels								
Control	9.85c	9.56c	10.34d	9.38c	3.05c	3.35c	37.19d	39.15c
$60kgha^{-1}$	9.89b	9.60b	12.78b	11.78d	3.09b	3.31d	39.75b	40.75b
$120kgha^{-1}$	10.02a	9.63d	13.71a	12.71a	3.12a	3.28a	40.71a	41.67d
$180kgha^{-1}$	10.20d	10.01a	14.00c	13.01b	3.15d	3.40b	41.13c	41.70a
LSD value	0.07	0.04	1.23	2.16	0.02	0.06	2.39	3.89

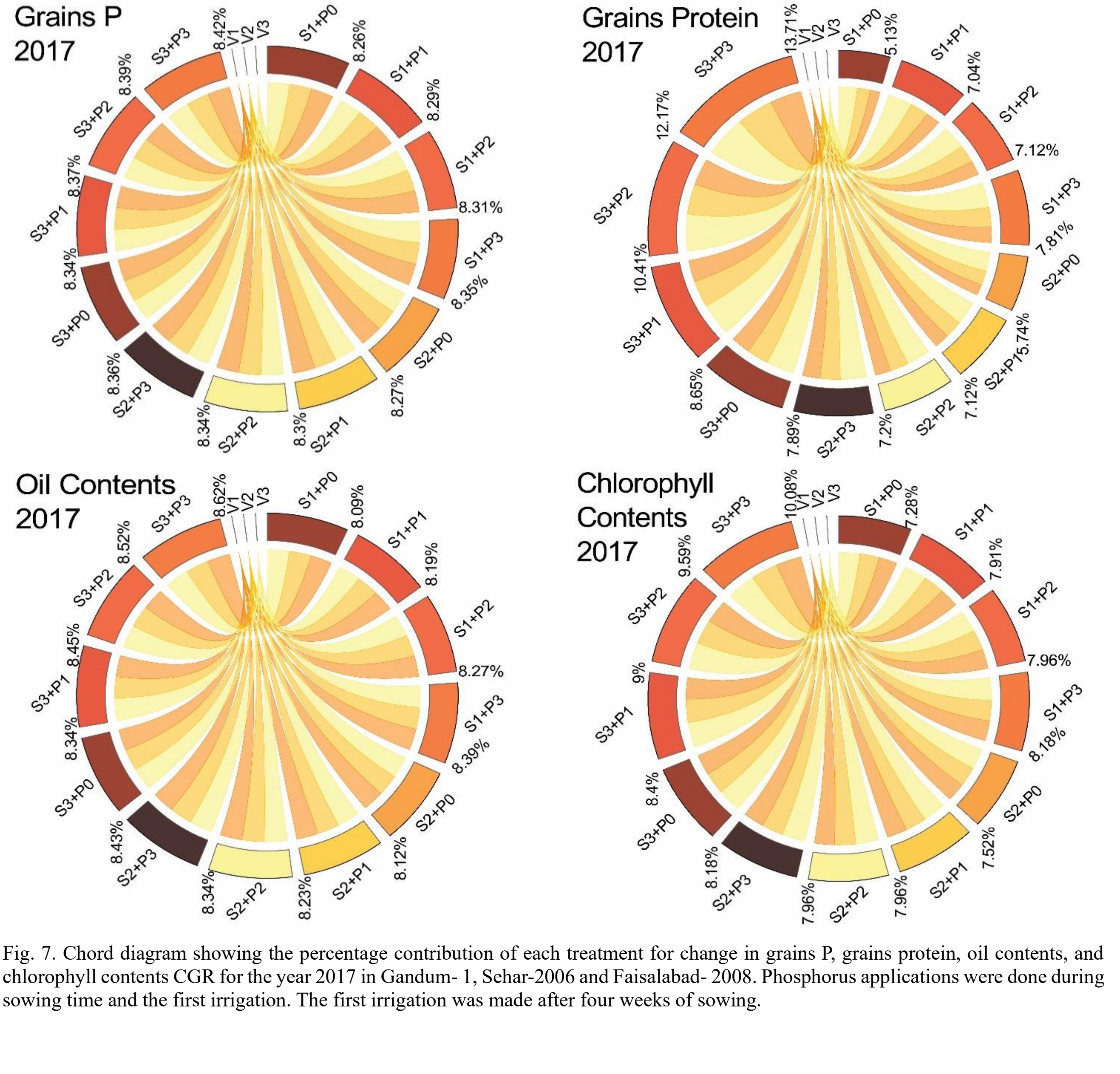

Fig. 7. Chord diagram showing the percentage contribution of each treatment for change in grains P, grains protein, oil contents, and chlorophyll contents CGR for the year 2017 in Gandum- 1, Sehar-2006 and Faisalabad- 2008. Phosphorus applications were done during sowing time and the first irrigation. The first irrigation was made after four weeks of sowing.

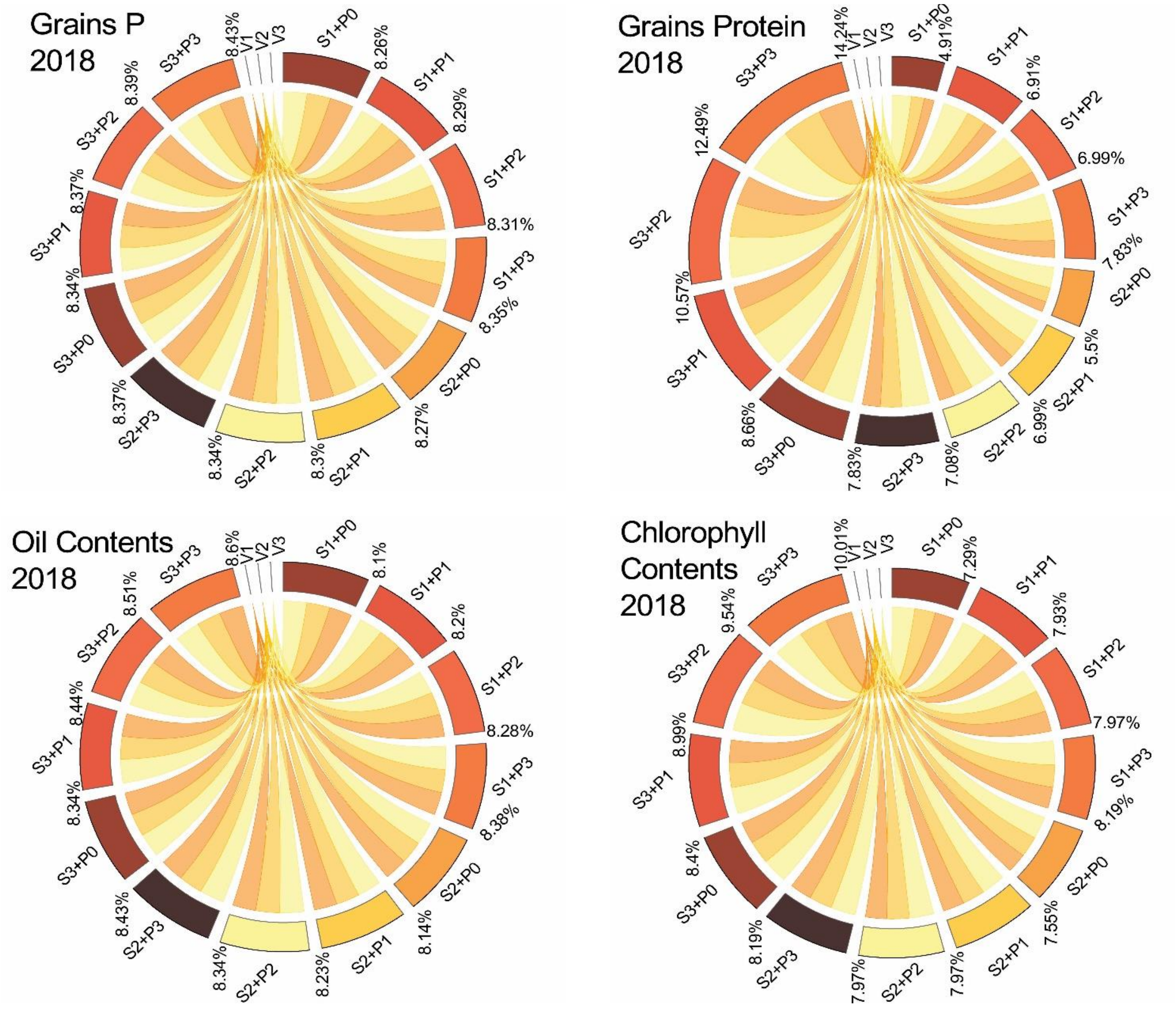

Fig. 8. Chord diagram showing the percentage contribution of each treatment for change in grains P, grains protein, oil contents and chlorophyll contents CGR for year 2017 in Gandum-1, Sehar-2006 and Faisalabad- 2008. Phosphorus applications were done during sowing time and the first irrigation. First irrigation was made after four weeks of sowing.

Discussion

To enhance crop production and yield, phosphorus-based fertilization plays a key role in grain production (van de Wiel *et al*., 2016). Estimation of optimum fertilizer for wheat crops is necessary for good growth and higher yields (Fioreze *et al*., 2012). Previous studies revealed that a 20% yield could be increased by using phosphorous fertilizers as it helps in maturation, more tillers, and help to absorb maximum nutrition (Li *et al*., 2011). The bed sowing method gives a better yield than drill and flat sowing as it helps to balance plant-to-plant competition and absorb maximum light energy (Ali *et al*., 2016). In this experiment, we study the effect of different levels of phosphorous and sowing methods on the growth and yield of different wheat cultivars.

Agronomic practices are more suitable for increase of crop productivity. The balanced inputs are also necessary for sustainable crop production. Mineral nutrition also contributed inn increase of nutritional value of the respective crop. The process of bio-fortification of minerals is very necessary and greatly contributed in nutritional status of wheat crop. As regards phosphorus levels, boron application increased the LAI, LAD, CGR and NAR. From the present findings, it has been observed that LAI, LAD, CGR and NAR were improved and found to be more effective and contributed to improved growth and yield. Phosphorus application is a rapid way of nutrients that can be utilized for good yield (Alam *et al*., 2003). Phosphorus application via leaves and roots on growth, yield, and grain quality is imperative for higher yields. Numerous plant researchers were dedicated to boron use in leaves, soil, and seed treatment. Though, the use of boron is more insignificant in numerous developed countries, particularly in Pakistan. Hence, phosphorus application is effective to fetch higher yields of wheat.

Balanced fertilization and appropriate sowing methods are more necessary for increase of crop performance. Phosphorus fertilization is neglected from a long time due to higher input costs. So, it has been recommended that fertilization is necessary for increase of crop yield. Sowing on raised beds is more suitable because it has potential to conserve moisture for longer time.

Regarding sowing methods, bed sowing is more efficient as compared to flat and drill sowing methods. Bed sowing had different advantages, especially moisture conservation. Huge input losses can be controlled by the development of raised beds to protect from excessive rains and moisture. The increased growth, yield, and quality parameters were recorded from the bed sowing as compared to drill and flatbed sowing methods. Current findings are in accordance with earlier results because bed swing is an imperative method to attain higher yields. Flat sowing is commonly used in developing countries and therefore this type of sowing should be prohibited.

Conclusion

This experiment was performed to determine the effect of phosphorous on the growth and yield of wheat cultivars. Different phosphorous levels were applied to evaluate phosphorous use efficiency and different sowing methods were used to select the most suitable method for wheat cultivation. The results showed that all growth, yield, and quality parameters were significantly increased in cultivar Faisalabad 2008 with bed sowing method by using 180 kg ha $^{-1}$ phosphorous level. More investigations are suggested for the declaration of bed sowing method with 180 kg ha $^{-1}$ phosphorous level as best combination for cultivar Faisalabad 2008 under different agroclimatic.

Acknowledgment

The author of this research paper is grateful to the Supervisory Committee and the supporting staff at the Department of Agronomy, Bahauddin Zakaria University, Multan for the provision of their support to conduct the present research work. The author is also highly gratified to the IT Department, Library Department, Bahauddin Zakaria University, Multan and HEC for access to journals, books and valuable databases.

References

Adnan, M., M. Hussain, M.Z. Anjum, F. Rehman, H. Bilal, M.D. Toor and R. Ahmad. 2020. Role of phosphorous in wheat production: A review. *Int. J. Agric. Sci.*, 8: 10-15.

Ali, A., M. Asif, M. Adnan, A. Aziz, M.S. Hayyat, M. Saleem, M. Hanif, M.A. Javed, W. Hassa and S. Ali. 2020. Effect of different levels of phosphorus on growth, yield and quality of wheat (*Triticum aestivum* L.). *Int. J. Bot. Stud.*, 5: 64-68.

Ali, H., S. Ahmad, H. Ali and F.S. Hassan. 2005. Impact of nitrogen application on growth and productivity of wheat (*Triticum aestivum* L.). *J. Agri. Soc. Sci.*, 1: 216-218.

Ali, H., N. Tariq, S. Ahmad, T.H. Chattha and A. Hussain. 2012. Effect of irrigation at different growth stages and phosphorus application methods on agronomic traits of wheat (*Triticum aestivum* L.). *J. Food, Agri. Environ.*, 10: 1371-1375.

Ali, H.H., A.M. Peerzada, Z. Hanif, S. Hashim and B.S. Chauhan. 2017. Weed management using crop competition in Pakistan: A review. *Crop Protect.*, 95: 22-30.

Ali, M., L. Ali, M.Q. Waqar and M.A. Ali. 2016. Bed planting: A new crop establishment method for wheat (*Triticum aestivum* L.) in cotton-wheat cropping system of Southern Punjab. *Int. J. Agri. Appl. Sci.*, 3: 115-129.

Alam, S.M. S.A. Shah and M. Akhter. 2003. Varietal differences in wheat yield and phosphorus use efficiency as influenced by method of phosphorus application. *Songklanakarin J. Sci. Technol.*, 25(2): 175-181.

Bashir, S., S. Anwar, B. Ahmad, Q. Sarfraz, W. Khatk and M. Islam. 2015. Response of wheat crop to phosphorus levels and application methods. *J. Environ. Earth Sci.*, 5: 151-155.

Chauhdary, J., U. Khan, S. Shah, M. Shahid and M. Arsalan. 2016. Effect of sowing methods and seed rates on wheat yield and water productivity. *Qual. Assuran. Safety Crops Foods,* 8: 267-272.

Chenu, K. 2015. Characterizing the crop environment–nature, significance and applications. *Crop Physiol.*, 321-348.

Dhaliwal, S. and A. Mandal. 2019. Transformations and availability of iron to wheat as influenced by phosphorus and manganese fertilization in a Typic Haplustept soil. *Comm. Soil Sci. Plant Anal.*, 50: 1081-1092.

Doolette, A., R. Armstrong, C. Tang, C. Guppy, S. Mason and A. Mcneill. 2019. Phosphorus uptake benefit for wheat following legume break crops in semi-arid Australian farming systems. *Nut. Cyc. Agroecosys.*, 113: 247-266.

El-Metwally, I. and S. Arafa. 2019. Agronomic and anatomical performance of wheat genotypes in response to some weed control treatments under sandy soil conditions. *Gesunde Pflanzen,* 71: 9-18.

Elahi, E., Z. Khalid, C. Weijun and H. Zhang. 2020. The public policy of agricultural land allotment to agrarians and its impact on crop productivity in Punjab province of Pakistan. *Land Use Pol.,* 90: 104324.

Fahad, S., S. Hussain, S. Saud, F. Khan, S. Hassan, W. Nasim, M. Arif, F. Wang and J. Huang. 2016. Exogenously applied plant growth regulators affect heat-stressed rice pollens. *J. Agron. Crop Sci.*, 202(2): 139-150.

Fang, Y. and L. Xiong. 2015. General mechanisms of drought response and their application in drought resistance improvement in plants. *Cell. Mol. Life Sci*., 72: 673-689.

Farooq, O., M. Ali, M. Naeem, A. Sattar, M. Ijaz, A. Sher, T.A. Yasir and M.M. Iqbal. 2015. Impact of sowing time and planting method on the quality traits of wheat. *J. Global Innov. Agric. Soc.l Sci.*, 3: 8-11.

Fioreze, S.L., G. Castoldi, L.A. Pivetta, L.G. Pivetta, D.M. Fernandes and L.T. Büll. 2012. Perfilhamento de dois genótipos de trigo em função de doses de fósforo. *Acta Scientiarum. Agron.,* 34: 331-338.

Gillani, S.M.W., A. Ahmad, F. Khalid, M. Zamir, M. Anwar, W. Ikram and A. Jabbar. 2014. Impact of nutrient management on growth, yield and quality of forage maize (*Zea mays* L.) under agroclimatic conditions of Faisalabad. *J. Agric. Res.*, 52: 499-510.

Godden, D. and J. BrenNAN. 2019. Policy Influences on wheat genetic diversity in Australia. *Econ. Anal. Diver. Modern Wheat.* CRC Press.

Kacar, B. and A. KatkAT. 2007. Plant Nutrition. Nobel Publication No. 849. *Science and Biology Publication Series, Ankara*.

Li, H., G. Huang, Q. Meng, L. Ma, L. Yuan, F. Wang, W. Zhang, Z. Cui, J. Shen and X. Chen. 2011. Integrated soil and plant phosphorus management for crop and environment in China. A review. *Plant Soil,* 349: 157-167.

Monsefi, A., A. Sharma and N.R. Zan. 2016. Weed management and conservation tillage for improving productivity, nutrient uptake and profitability of wheat in soybean (Glycine max)-wheat (*Triticum aestivum*) cropping system. *Int. J. Plant Prod.,* 10: 1-12.

Rasul, G.A.M. 2016. Effect of phosphorus fertilizer application on some yield components of wheat and phosphorus use efficiency in calcareous soil. *J. Dynamic. Agric. Res.,* 3: 46-51.

Rawal, N., N., Bhandari, S., Subedi, D. Chalise and D. Khadka. 2015. Assessment of soil fertility management practices of wheat in western terai of Nepal. *J. Ins. Agric. Anim. Sci.*, 105-114.

Ryan, J., H., Ibrikci, M., Singh, A., Matar, S., Masri, A. Rashid and M. Pala. 2008. Response to residual and currently applied phosphorus in dryland cereal/legume rotations in three Syrian Mediterranean agroecosystems. *Eur. J. Agron.*, 28: 126-137.

Sacristán, D., A. González-Guzmán, V. Barrón, J. Torrent and M.C.D. Campillo. 2019. Phosphorus-induced zinc deficiency in wheat pot-grown on noncalcareous and calcareous soils of different properties. *Arch. Agron. Soil Sci.*, 65: 208-223.

Shaoxia, W., L. Meng, Z. Xiaoyuan, F. Peiwen, C. Yanlong, S. Jianglan and T. Xiaohong. 2019. Impact of foliar and root application of phosphorus on zinc concentration of winter wheat grown in China. *Crop Past. Sci.*, 70: 499-508.

Sisie, S.A. and B. Mirshekari. 2011. Effect of phosphorus fertilization and seed biofertilization on harvest index and phosphorus use efficiency of wheat cultivars. *J. Food Agric. Environ.*, 9: 388-391.

Soomro, U.A., M.U. Rahman, E.A. Odhano, S. Gul and A.Q. Tareen. 2009. Effects of sowing method and seed rate on growth and yield of wheat (*Triticum aestivum*). *World J. Agric. Sci*., 5: 159-162.

Teng, W., Y.Y. Zhao, X.Q. Zhao, X. He, W.Y. Ma, Y. Deng, X.P. Chen and Y.P. Tong. 2017. Genome-wide identification, characterization, and expression analysis of PHT1 phosphate transporters in wheat. *Front. Plant Sci.,* 8: 543.

Van De Wiel, C., C.G. Van Der Linden and O.E. Scholten. 2016. Improving phosphorus use efficiency in agriculture: opportunities for breeding. *Euphytica,* 207: 1-22.

Von Tucher, S., D. Hörndl and U. Schmidhalter. 2018. Interaction of soil pH and phosphorus efficacy: Long-term effects of P fertilizer and lime applications on wheat, barley, and sugar beet. *Ambio.*, 47: 41-49.

Wang, Z.B., H.L. Zhang, X.H. Lu, M. Wang, Q.Q. Chu, X.Y. Wen and F. Chen. 2016. Lowering carbon footprint of winter wheat by improving management practices in North China Plain. *J. Clean. Prod.*, 112: 149-157.

(Received for publication 12 September 2022)