Research Article

Association among Yield and Grain's Physical Attributes in Spring Wheat Genotypes

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Abstract | The physical properties of wheat grain strongly influence on yield and have direct or indirect impact on the wheat milling and baking quality. Association of yield and physical traits of grain in 33 spring wheat genotypes were examined under field experimental conditions during the wheat crop season of 2020-21. The experiment was set up in a three-replications through randomized complete block design (RCBD). Analysis of variances revealed that all the studied parameters, like spikelet per spike (SPS), number of grains per spike (NGS), grain yield per plant (GYP), grain length (GL), grain width (GWD), grain area (GA) and grain sphericity (GS) differed significantly among all genotypes, indicating the presences of genetic variability. Yield related traits like SPS, NGS, and GYP is positively and highly correlated with GL, GW, GA and GS which exhibited the importance of these indices in studied germplasm. It was therefore suggested that positively and significantly correlated traits can be used for future breeding programs. The genotypes G33 followed by G20 and G22 well performed while the genotypes lowest performed G19 followed by G15 and G13 in yield and grain's physical attributes in the current experiment. It will help the breeders for the selection of high yielding genotypes by only identifying plant yield and physical grain's attributes to develop the high yielding wheat varieties.

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Introduction

Wheat (*Triticum aestivum* L.) is a cereal crop of the Poaceae family. From historical point of view, it was cultivated for grain purpose. It is used as daily routine food (Ahmed *et al*., 2022a). Wheat is staple food of 2 billion people and contribute to the production of world grain (30%) and 50% to the global trade (Karki *et al*., 2021). While wheat yields in Pakistan are significantly better than in the past, consistent efforts are required to keep up with the country's continually growing population. It contributes for 9.2%of agricultural value added and 1.8% added tGDP. Wheat self-sufficiency has long been a top priority for governments. Over the previous year's planted area of 8,805 thousand hectares. The area under cultivation climbed by 4.2% to 9,178 thousand hectares in 2020-21. Wheat crop output reached an all-time high of 27.293 million tonnes, an increase of 8.1% above previous year's production of 25.248 million tonnes (Economic Survey of Pakistan, 2021).

Pakistan is among the world's top ten wheat producers (Li *et al.*, 2016). In Pakistan, wheat is the most important crop which is used in daily routine food. Wheat is important food for Pakistan population because it makes up 60% of daily diet for ordinary person (Ahmed *et al.*, 2021). Significant breeding efforts in the wheat enhancement area have been made with the remarkable result to fulfill the day by day increasing global demand for wheat (Khan *et al.*, 2018). The yield of wheat grain is a polygenic character and inherited quantitatively that effect on many traits that are contributing to the yield and yield related attribute indirectly and directly. It is also strongly affected by environmental conditions which demand to evaluate both environmental and genotypic effects on yield (Ahmed *et al.*, 2021).

Grain yield has low heritability and affected by many other traits (Zhao *et al.*, 2016). There are many other traits that can increase and decrease the wheat yield like spike length, spikelet per spike, peduncle length *etc*. These traits have positive impact on wheat yield. The plant height and spike length are interesting attribute for breeders form several years. The crop yield can be increased by increasing the spike length and spikelet per spike. The grain number per spike is maximum when plant has maximum spikelet per spike and spike length. Spike length has indirect relation with grain yield through fertile spikelet, so breeder must give importance to these attributes of wheat (Ahmed *et al.*, 2021). If the trait is complex and controlled by polygenes like grain yield and the enhancement is required for them than selection of parent become more complicated. One of the most important techniques in wheat breeding is indirect selection through attributes related to grain production (Ahmed *et al.*, 2018; Khan *et al.*, 2018). When comparing different spikelets the grain might differ in terms of grain developmental stages like grain weight, grain number, grain height, grain length, grain area, grain width and sphericity (Li *et al.*, 2016). The central spikelet in a spike have maximum and heavier grain than basal and top portion of spike.

Number of spikelet, number of grain per spikelet and grain weight has major effect on grain weight and number of grain per spike. The pervious study only focuses to increase the yield by increasing the number of grain, but yield can also be increased by increasing the grain size (Arora *et al.*, 2017). The grain yield is positively affected by grain size as it increases the weight of grain is also increased which ultimately increase the wheat yield (Kumar *et al.*, 2016; Wu *et al.*, 2015; Russo *et al.*, 2014; Gegas *et al.*, 2010). Wheat grain yield are affected by grain shape and size because large, spherical grain are good for milling where as shriveled and small seed reduce the quality of milling for flour extraction. Wheat market prices are determined by essential quality attributes because they are impacted by grain shape and texture (Lyford *et al.*, 2005; Kumar *et al.*, 2016). Moreover, the information of physical properties of wheat grains is important for scheming a machine for cleaning, storing, sowing, milling, handling, and other useful purposes. Milling sieves are shaped according to sizes of grains such as grain length, grain width and grain height. Drying after harvest and during storage grain sphericity and grain area are important traits (Russo *et al.*, 2014).

Creating new best genotypes with improved grain structures This strategy may be useful for wheat breeders in improving production potential, grain milling process, and baking quality of wheat (Arora *et al.*, 2017; Ahmed *et al.*, 2018). RADAR-graphs were created for mean data using Excel-Stat, and they represent mean values relative to a central point for the attributes that were studied. This chart is seen to be a superior option to column charts since it can display several variables without producing clutter and is simple to grasp (Ahmed *et al.*, 2022b; Mamen *et al.*, 2020). The main aim of this experiment was to identify the association among the yield and grain physical attributes. It helps to recognize the most relevant yield attribute that accountable for grain yield.

Materials and Methods

The present experiment was directed to understand the association of grain's physical attributes with yield attributes in 33 diverse spring wheat (*Triticum aestivum* L.) genotypes during the crop season of 2020-21 under normal field conditions. The seeds of studied genotypes were collected from Regional Agriculture Research Institute (RARI) Bahawalpur, Punjab, Pakistan. The genotypes that were grown in experimental area are shown in Table 1.

Table 1: *Names of genotypes used in the current experiment.*

S.N.	Genotype	S.N.	Genotype	S.N.	Genotype
G1	Anmol-91	G12	Watan01	G23	Khyber-87
G2	Chakwal-86	G13	Seher 2006	G24	BWL-812
G3	Uqab-2000	G14	Pasban-90	G25	PBW-175
G4	FSD 2008	G15	Bahawal-97	G26	PBW 222
G5	Bwp-2000	G16	GA 2002	G27	HD 2307
G6	Bakhtawar-94	G17	Glaxy-2013	G28	DPW-621-50
G7	Bakhar-2002	G18	Gomal-2008	G29	PBW 343
G8	Bakhtawar-93	G19	Parwaz 94	G30	HD 2967
G9	BWL-0814	G20	Ujala 2016	G31	BWL-1793
G10	Chakwal-50	G21	Iqbal-2000	G32	BWL-9022
G11	Ass-11	G22	Anaj 2017	G33	Akbar 2019

The experiment was laid-out in randomized complete block design (RCBD) with three replications. The genotypes were sown on November 15, 2020 using the dibbler having 15cm plant to plant distance and 30cm row to row distance and 2-3 cm deep in the field condition. Type of soil field condition was clay loam. Recommended cultural and management practices were applied to all genotypes throughout the growing season. At the time of Maturity, harvesting was done on 8-15 April 2021, the data was recorded for the number of spikelet per spike (SPS) and number of grains per spike (NGS) was physically counted from randomly selected plants of each genotype while grain yield per plant (GYP) was taken in grams (g).The grain width (GWD)grain length (GL) and grain height (GH) was measured using Vernier caliper in micrometer (mm) that has an accuracy of 0.01mm.The grain sphericity (GS) was calculated using the following formula given by Mohsenin (1970);

$$\Phi = De/L$$

Here;
L = grain length and equivalent diameter (De) can be calculated as;

$$De = (LWH)^{1/3}$$

Here;
L = grain length, W= grain width and H= grain height. The grain area (GA) was measured in mm^2 and calculated by the following formula given by Kachru *et al.* (1994).

$$GA = \frac{13}{11}(W + H)L$$

Here;
L = grain length, W= grain width and H= grain height.

The collected data of different traits is subjected to analysis of variances (Steel *et al.*, 1997) to check the significance level among different genotypes and mean of genotypes is compared. Excel Stat was used to generate the RADAR-graphs, which show values relative to a central point for plots of observable traits (Ahmed *et al.*, 2022b). It has four basic elements such as element 1 (Center point); the heart of a spider chart (at the center) from which several axes are drawn. Element 2 (Axis); each axis in a radar map represents a variable and is labelled with a name and a range of values. A radar graph must have at least three axes. Element 3 (Grids); when axes in a spider chart are linked, the complete graph is divided into multiple grids that help us display information more effectively. Element 4 (Values); after drawing the graph, we represent different values on each axis and print the chart for each entry by assigning separate colours (Ahmed *et al.*, 2022b; Mamen *et al.*, 2020). Using SPSS ver.23, Pearson's Correlation coefficients (r) were determined to achieve the correlation between grain's physical and yield attributes (Spss, 2012).

Results and Discussion

Analysis of variance presented in Table 2 revealed that the difference among genotypes for studied attributes. Difference among genotypes for spikelet per spike was highly significant as shown in Table 2. All the studied characters exhibited fluctuations in mean value for most of the genotypes. The mean values for all studied attributes in 33 spring wheat genotypes as mentioned in Table 3. There are several graphs available for the presentation of research data. Georg von Mayr devised the radar plot in 1877, and it may be seen as a linked line graph, which reduces the size of the plot (Friendly and Denis, 2001). Radar is a statistical approach that is used to portray data from numerous attributes graphically in a single graph. A radar chart is a two-dimensional chart that displays multivariate data in the form of three or more

Table 2: *Analysis of variance of all seven studied traits in 33 wheat genotypes.*

Source	DF	SPS	NGS	GYP	GL	GWD	GA	GS
Replication	2	216.169	5.962	1.939	3.184	0.044	0.1048	25.010
Genotype	32	305.307 **	86.609*	7.424*	2.5101*	0.874*	0.108*	89.640*
Error	64	35.211	38.175	1.647	1.090	0.251	0.044	19.208
Total	98							

*** = Highly significant, * = Significant, Degree of Freedom (DF), Spikelet per spike (SPS), Number of Grains per Spike (NGS), Grain Yield per Plant (GYP), Grain Length (GL), Grain Width (GWD), Grain Area (GA) and Grain Sphericity (GS).*

Table 3: *Mean values for 33 spring wheat genotypes used in this experiment.*

Genotypes	SPS	NGS	GYP	GL	GWD	GA	GS
G1	18.8	43.5	18.5	7.35	3.07	44.01	56.12
G2	20.3	45	16.4	6.9	3.1	54.01	61.55
G3	19.4	49.1	22.4	7.28	2.96	56.1	57.65
G4	19.4	46.5	19.2	6.88	2.96	47.73	55.9
G5	19.4	47.1	17.6	6.4	2.99	41.6	59.53
G6	19.6	49.5	18.4	7.12	3.01	49.39	54.62
G7	19.6	46	22.3	6.24	2.77	41.52	58.06
G8	19.2	46.5	17.3	6.48	2.8	47.59	58.46
G9	19.4	49.5	16.5	6.55	2.99	46.45	63.9
G10	19.6	47.9	22.5	6.8	2.99	39.61	55.56
G11	19.4	48.2	19.4	6.25	2.99	45.48	57.41
G12	18.4	43.9	20.6	6.45	2.75	43.91	57.61
G13	15	41.9	16.1	6.3	2.65	37.58	54.96
G14	19	45.4	19.7	6.65	3.01	43.51	58.28
G15	17.4	41.3	15.3	6.2	2.68	40.44	54.21
G16	19.6	45.5	19.8	6.27	3.06	42.76	58.72
G17	19	45.7	22.5	6.5	2.82	48.38	56.92
G18	17.6	41.3	19.4	6.7	2.95	43.23	60.14
G19	17.4	42.3	15.3	6.3	2.6	40.61	50.48
G20	21	56.2	23.1	7.35	3.12	56.81	63.65
G21	20	50.8	16.3	6.98	3.06	49.41	56.1
G22	22.6	50.9	22.7	7.52	3.18	55.86	66.44
G23	19.2	43.9	15.3	7.02	3.08	45.78	56.07
G24	20	49.4	21.6	7.04	3.11	51.75	57.19
G25	20.4	48.9	20.4	6.5	2.92	44.48	57.55
G26	18.4	46.4	21.3	6.8	2.98	44.57	59.45
G27	20	49.4	22.4	7.21	3.01	51.13	58.4
G28	19.4	46.1	21.4	6.95	3.09	52.65	57.82
G29	19.6	45.9	22.4	7.08	3.12	47.86	57.1
G30	19.2	46.6	18.5	7.11	3.01	53.95	58.01
G31	18.4	51	22.5	7.25	3.15	49.34	57.83
G32	18.8	45.9	20.4	6.67	3.2	51.52	57.03
G33	21.2	54.3	23.4	7.45	3.25	58.99	62.47

quantitative variables (Ahmed *et al.*, 2022b; Mamen *et al.*, 2020). In this study mead data also exhibited in RADAR-graph which will be easy to understand the reader (Figure 1 and 2).

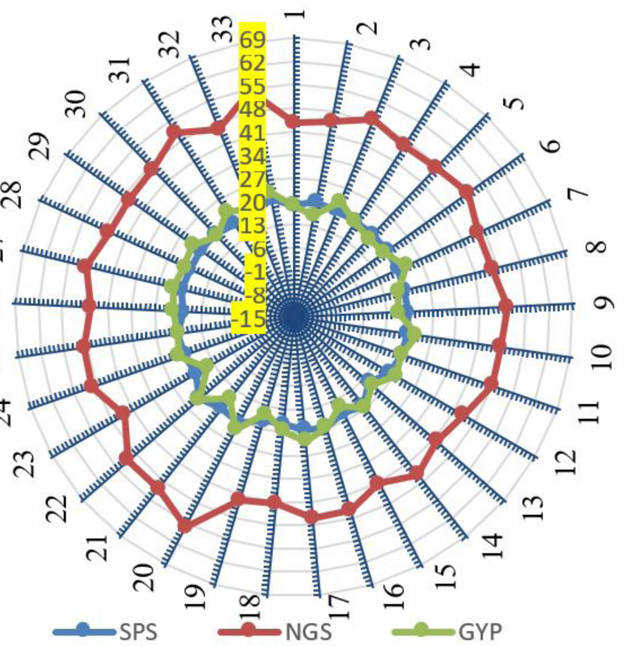

Figure 1: *RADAR graph showing the performance of 33 wheat genotypes for Spikelet per spike (SPS), Number of Grains per Spike (NGS), Grain Yield per Plant (GYP).*

Data recorded for number of spikelets per spike in studied germplasm, the mean values ranged from 15.00 to 22.6 with the 19.26 averaged mean vales (Table 4). The genotype G22 has maximum spikelet per spike (22.6) followed by G20 (21.00) and G25 (20.40) while G13 (15.00) followed by G15 (17.4) and G19 (17.4) has minimum spikelet per spikeas show in Figure 1. The spike length is an important trait in degerming the yield as it increases the yield of plant also increases. Larger spike length in wheat resulted in increased grain yield (Khan *et al.*, 2018). The wheat spike has a varied number of spikelets, ranging from 15-22.6, each with numerous florets. When comparing various spikelets and even within individual spikelets, grains might differ in terms of developmental stage, weight, quantity, and fruiting efficiency (Ahmed *et al.*, 2018; Gegas *et al.*, 2010). The grains in the middle spikelet are larger and heavier than those

Table 4: *Performance of 33 wheat genotypes in seven studied traits.*

Traits	Minimum Mean	Maximum Mean	Grand Mean	Genotype number and their higher Mean Values	Genotype number and their lower Mean Values
Spikelet per Spike	15	22.6	19.26	G22 (22.6), G20 (21.00), G25 (20.40)	G13 (15.00), G15 (17.4), G19 (17.4)
Number of Grains/Spike	41.3	56.2	47.02	G20 (56.2), G33 (54.3), G22 (50.9)	G15 (41.3), G13 (41.9), G19 (42.3)
Grain Yield per Plant (g)	15.3	23.4	19.72	G33 (23.5g), G20 (23.1g), G22 (22.7g)	G19 (15.3g), G15 (15.3g), G13 (16.1)
Grain Length (mm)	6.2	7.52	6.80	G22 (7.52mm), G33 (7.45mm), G20 (7.35mm)	G15 (6.2mm), G19 (6.3mm), G13 (6.3mm)
Grain Width (mm)	2.6	3.25	2.98	G33 (3.25mm), G22 (3.18mm), G20 (3.12mm)	G19 (2.6mm), G15 (2.65mm), G13 (2.68mm)
Grain Area (mm^2)	37.58	58.99	47.52	G33(58.99 mm^2), G20 (56.81mm^2), G22 (55.86 mm^2)	G13 (37.58 mm^2), G15 (40.44 mm^2), G19(40.60 mm^2)
Grain Sphericity (ϕ)	50.48	66.44	58.04	G22 (66.44ϕ), G9 (63.9ϕϕϕ), G 20 (63.65ϕ)	G19 (50.48ϕ), G15 (54.21ϕ), G13 (54.96ϕ)

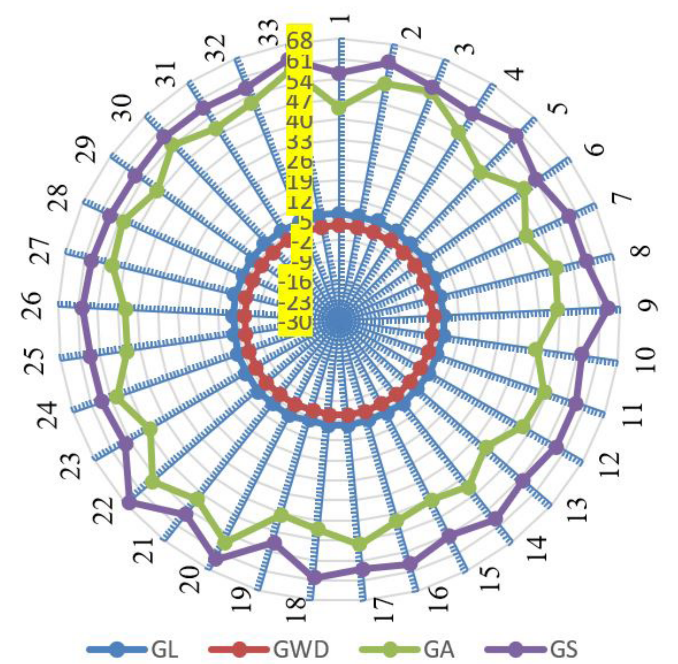

Figure 2: *RADAR graph showing the performance of 33 wheat genotypes for Grain Length (GL), Grain Width (GWD), Grain Area (GA) and Grain Sphericity (GS).*

in the basal and top spikelets. Spikelet numbers, grain weight, and grain numbers per spikel*et al*l have a substantial impact on TGW and grain number per spikelet. The degree and pace of grain filling in single spikelets vary greatly depending on their position on the spike (Khan *et al*., 2018; Ahmed *et al*., 2021).

The number of grains per spike was significant among all genotypes and reported similar results by Guo *et al.* (2015). For this trait, genotype G20 (56.2) followed by G33 (54.3) and G22 (50.9) showed maximum number of grain per spike while G15 (41.3) followed by G13 (41.9) and G19 (42.3) has minimum number of grain per spike among all genotypes in the current study (Figure 1). Mean values ranged from 41.3 to 56.2 while the average value was depicted as 47.02 for this attribute (Table 4).

From Figure 1 and Table 3 it is seen that genotype G33 (23.5g) followed by G20 (23.1g) and G22 (22.7g) has higher grain yield per plant as compared to other genotypes, while genotype G19 (15.3g), G15 (15.3g) and G13 (16.1) has lower yield than all other genotypes. Mean values ranged from 15.3g to 23.4g while the average value was depicted as 19.72g for this trait (Table 4). The improvement in production in the past was mostly due to a greater grain number per area rather than a larger grain size. Wheat yield components are complex, with two primary parameters: grain yield per area and grain yield per spike (Gegas *et al*., 2010; Kumar *et al*., 2016). Multiple interactions and compensatory mechanisms exist between the various yield components, which are influenced by genotype, environment, and their interactions (Russo *et al*., 2014).

Data recorded for number of grain length in studied germplasm, the mean values ranged from 6.2 to 7.52 with the 6.80 averaged mean values (Table 4).The highest mean values of grain length were observed in genotype G22 (7.52mm) followed by G33 (7.45mm) and G20 (7.35mm), while the lowest mean values of grain length were observed in G15 (6.2mm) followed by G19 (6.3mm) and G13(6.3mm) as shown in Figure 2. The largest grain width was observed in G33 (3.25mm) followed by G22 (3.18mm) and G20 (3.12mm) and smallest grain width was observed in G19 (2.6mm) followed by G15 (2.65mm) and G13(2.68mm)as presented in Figure 2 and Table 3. Data recorded for grain width in studied germplasm, the mean values ranged from 2.6 to 3.25 with the 2.98 averaged mean values (Table 4).

From Figure 2 and Table 3 it is seen that the maximum grain area was seen in genotype G33 (58.99 mm^2) followed by G20 (56.81 mm^2) and G22 (55.86 mm^2), while minimum grain area was seen in G13 (37.58 mm^2) followed by G15 (40.44 mm^2) G19 (40.60 mm^2). Mean values ranged from 37.58 mm^2 to 58.99 mm^2 while the average value was depicted as 47.52 for this character (Table 4). Data recorded for degree of grain sphericity in studied germplasm, the mean values ranged from 50.48ϕ to 66.44ϕ with the 58.04ϕ averaged mean values (Table 4).The genotype G22 (66.44ϕ) followed by G9 (63.9ϕ) and G20 (63.65ϕ) showed largest mean value of grain sphericity, while, genotype G19(50.48ϕ) followed by G15 (54.21ϕ) and G13 (54.96ϕ) exhibited lower mean value among all genotypes in the present study as displayed in Figure 2 and Table 3. Smaller grains are tougher and have poor milling and baking qualities, whereas bigger wheat grains have more endosperm and are heavier (Russo *et al*., 2014; Arora *et al*., 2017; Ahmed *et al*. 2018).

The positive correlation for spikelet per spike was reported with number of grain per spike, grain width and grain sphericity. Spikelet per spike was also positively correlated with grain length and grain area (Table 5). Waqar *et al*. (2010) also found that the spikelet per spike have positive relation between grain per spike as the more spikelet per spike ultimately more grain per spike was recorded. Number of grain per spike is positively linked with grain sphericity and yield per plant. It is also positively correlated with the number of spikelet per spike, grain yield per plant, grain length, grain width, grain sphericity and grain area.

Grain width was positive and highly significantly related with grain yield per plant and significantly correlated to grain sphericity. This trait positively related with number of grain per spike, grain length, grain width and grain area (Table 5). These results also related to the findings of (Russo *et al*., 2014; Arora *et al*., 2017). Number of grain per spike showed positive relation with grain yield per plant, grain length, grain width, grain area and grain sphericity. Grain yield per plant has positive relation with grain sphericity and all other studied attributes like grain length, grain area and grain width. The similar results were reported by Tessmann *et al*. (2019). More crucially, increases in grain yield can be achieved by improving thousand grain weight, grain number per spike, and spike number per unit area (Ahmed *et al*., 2022a). Because of their major impact on grain weight, grain morphological indices are also linked to yield (Ahmed *et al*., 2021; 2018).

Table 5: *Pearson correlation for seven studied traits in 33 wheat genotypes.*

Traits	SPS	NGS	GYP	GL	GWD	GA
NGS	0.44**					
GYP	0.52**	0.67**				
GL	0.51**	0.61**	0.70**			
GWD	0.55**	0.50**	0.73**	0.49*		
GA	0.59**	0.62**	0.71**	0.54**	0.77**	
GS	0.61**	0.49**	0.67**	0.53**	0.67**	0.66*

*** = Highly significant, * = Significant, Spikelet per spike (SPS), Number of Grains per Spike (NGS), Grain Yield per Plant (GYP), Grain Length (GL), Grain Width (GWD), Grain Area (GA) and Grain Sphericity (GS).*

Grain length is positively related and highly significant with grain width and grain area while highly significant and negatively correlated with grain sphericity (Table 5).The results are similar with the findings of Gao *et al*. (2021).Grain width has positively correlated and highly significant with grain area. Grain area is also positively correlated and significant with grain sphericity. Increases in grain length and breadth both lead to increased grain weight, according to a significant positive association between grain length, width and grain weight. In the current study, however, grain width had a greater beneficial influence on grain weight than grain length. Other studies have found moderate to high relationships between grain weight and size. Previously scientists (Alemu *et al*., 2020; Ahmed *et al*., 2018) studied the grain's physical traits in wheat such as grain size (GS), grain thickness (GT), grain sphericity (GS), endosperm size (ES) and grain density (GD). They also said that an increase in grain length, rather than breadth or granular characteristics, is directly linked to an increase in grain weight and volume throughout the milling process. Many variables influence these characteristics, the most important of which is genetic ancestry (Alemu *et al*., 2020; Gao *et al*., 2021).

Conclusions and Recommendations

Total 33 genotypes are examined for their association of grain and yield attribute using randomized complete block design (RCBD). There is a clear difference was seen for studied grain attributes among all genotypes. The grain attribute like grain width, grain length and grain area also have positive association between each other and with yield related attributes. The genotypes G33 followed by G20 and G22 showed good performance while the genotypes G19 followed by G15 and G13 exhibited lowest performance in yield and grain's physical attributes. The genotypes which exhibited the best result among all these attribute is considered as high yielding and can be used for further selection criteria for other genotypes. The current finding can help as selection criteria for improvement and development of new variety that is high yielding which fulfill the demand of food security.

Novelty Statement

This study will help the breeders for the selection of high yielding genotypes by only identifying plant yield and physical grain's attributes to develop the high yielding wheat varieties.

Author's Contribution

Hafiz Ghulam Muhu-Din Ahmed: Conceptualization, formal analysis, writing - original draft, supervision, resources.
Aziz Ullah: Formal analysis and visualization.
Muhammad Asim Bhutta: Funding acquisition, visualization, investigation, writing - review and editing.
Ammara Yasmeen: Validation
Hafeez ur Rehman: Software
Umar Farooq: Data curation

Conflict of interest
The authors have declared no conflict of interest.

References

Ahamed, H.G.M.D., Khan, A.S., Kashif, M. and Khan, S.H. 2018. Genetic analysis of yield and physical traits of spring wheat grain. J. Nat. Sci. Foundation Sri Lanka, 46 (1): 23 – 30. https://doi.org/10.4038/jnsfsr.v46i1.8262

Ahmed, H.G.M.D., Iqbal, M.N., Iqbal, M.A., Zeng, Y., Ullah, A., Iqbal, M., and Hussain, S. 2021. Genome-Wide Association Mapping for Stomata and Yield Indices in Bread Wheat under Water Limited Conditions. Agronomy, 11(8): 1646. https://doi.org/10.3390/agronomy11081646

Ahmed, H.G.M.D., Naeem, M., Zeng, Y., Rashid, M. A. R., Ullah, A., Saeed, A. and Qadeer, A. 2022a. Genome-wide association mapping for high temperature tolerance in wheat through 90k SNP array using physiological and yield traits. Plos one, 17(1): e0262569. https://doi.org/10.1371/journal.pone.0262569

Ahmed, H.G.M.D., Ullah, A., Bhutta, M.A., Bibi, A., Rehman, H.U., and Farooq, U. 2022b. Radar analysis of spring wheat genotypes at seedling stage against limited water conditions. Sarhad J. Agric., 38(2): 548-554. https://doi.org/10.17582/journal.sja/2022/38.2.548.554

Alemu, A., Feyissa, T., Tuberosa, R., Maccaferri, M., Sciara, G., Letta, T. and Abeyo, B. 2020. Genome-wide association mapping for grain shape and color traits in Ethiopian durum wheat (*Triticum turgidum* ssp. durum). Crop J., 8(5): 757-768. https://doi.org/10.1016/j.cj.2020.01.001

Arora, Sanu, Narinder S., Satinder K., Navtej S.B., Cristobal U., Jesse P., and Parveen C. 2017. Genome-wide association study of grain architecture in wild wheat Aegilopstauschii. Front. Plant Sci., 8: 886. https://doi.org/10.3389/fpls.2017.00886

Economic Survey of Pakistan, 2020-21. Ministry of Finance, Economic Advisor's Wing, Islamabad.

Friendly, M. and Denis, D.J. 2001. Milestones in the history of thematic cartography, statistical graphics, and data visualization. 32:11. http://www. datavis. ca/milestones

Gao, Y., Xu, X., Jin, J., Duan, S., Zhen, W., Xie, C. and Ma, J. 2021. Dissecting the genetic basis of grain morphology traits in Chinese wheat by genome wide association study. Euphytica., 217(4):1-12. https://doi.org/10.1007/s10681-021-02795-y

Gegas, V.C., Nazari, A., Griffiths, S., Simmonds, J., Fish, L., Orford, S. and Snape, J.W. 2010. A genetic framework for grain size and shape variation in wheat. Plant Cell., 22(4): 1046-1056. https://doi.org/10.1105/tpc.110.074153

Guo, J., Zhang, Y., Shi, W., Zhang, B., Zhang, J., Xu, Y. and Cheng, S. 2015. Association analysis of grain-setting rates in apical and basal spikelets in bread wheat (*Triticum aestivum*L.). Front. Plant Sci., 6: 1029. https://doi.org/10.3389/fpls.2015.01029

Kachru, R.P., Gupta, R.K. and Alam, A. 1994. Physico-chemical constituents and engineering properties of food crops. Scientific Publishers.

Karki, P., Subedi, E., Acharya, G., Bashyal, M., Dawadee, N. and Bhattarai, S. 2021. A review on the effect of heat stress in wheat (*Triticum aestivum* L.). Arch. Agric. Environ. Sci., 6(3): 381-384. https://doi.org/10.26832/24566632.2021.0603018

Khan, A.D.E.E.L., Khaliq, I., Ahmad, M., Ahmed, H.G.M.D., Khan, A.G. and Farooq, M.S. 2018. Comparative performance of spring wheat (*Triticum aestivum* L.) through heat stress indices. Pak. J. Bot., 50(2): 481-488.

Kumar, A., Mantovani, E.E., Seetan, R., Soltani, A., Echeverry-Solarte, Jain, S., Simsek, S., Doehlert, D., Alamri, M.S., Elias, E.M., Kianian, S.F. and Mergoum, M. 2016. Dissection of genetic factors underlying wheat kernel shape and size in an elite × non-adapted cross using a high-density SNP linkage map. Plant Gen., 9(1). https://doi.org/10.3835/plantgenome2015.09.0081

Li, Y., Cui, Z., Ni, Y., Zheng, M., Yang, D. and Jin, M. 2016. Plant density effect on grain number and weight of two winter wheat cultivars at different spikelet and grain positions. PloS one. 11(5): e0155351. https://doi.org/10.1371/journal.pone.0155351

Lyford, C., W. Kidd, P.R. Duarte and C. Deyoe. 2005. Prediction of flour extraction in a hard red winter wheat using the single kernel characterization. J. Food Quality, 28: 279-288. https://doi.org/10.1111/j.1745-4557.2005.00036.x

Mamen, A., Braaum, L.E. and Fredriksen, P.M. 2020. Presenting health status in children using a radar plot. Sports, 8(4): 53. https://doi.org/10.3390/sports8040053

Mohsenin, N.N. 1970. Physical properties of plant and animal materials. 1. Structure, physical characteristics and mechanical properties. 758 pages Gordon & Breach Science Publishers Inc. New York, USA.

Russo, M.A., Ficco, D.B.M., Laido, G., Marone, D., Papa, R. and Blanco, A. 2014. A dense durum wheat× T. dicoccum linkage map based on SNP markers for the study of seed morphology. Mol. Breed., 34(4): 1579-1597. https://doi.org/10.1007/s11032-014-0181-5

Spss, I. 2012. IbmSpss Statistics Version 21; International Business Machines Corp: Boston, MA, USA. pp. 126.

Steel, R.G.D., Torrie, J.H. and Dicky and D.A. 1997. Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, 352-358.

Tessmann, E.W. and Van Sanford, D.A. 2019. Associations between morphological and FHB traits in a soft red winter wheat population. Euphytica., 215(11): 1-16. https://doi.org/10.1007/s10681-019-2509-z

Waqar-Ul-Haq, M.M. and Akram, Z.A.H.I.D. 2010. Estimation of interrelationships among yield and yield related attributes in wheat lines. Pak. J. Bot., 42(1): 567-573. http://www.pakbs.org/pjbot/PDFs/42(1)/PJB42(1)567.pdf

Wu, Q.H., Chen, Y.X., Zhou, S.H., Fu, L., Chen, J.J., Xiao, Y. and Liu, Z.Y. 2015. High-density genetic linkage map construction and QTL mapping of grain shape and size in the wheat population Yanda 1817× Beinong6. PloS One. 10(2): e0118144. https://doi.org/10.1371/journal.pone.0118144

Zhao, W., Wang, X., Wang, H., Tian, J., Li, B., Chen, L. and Li, M. 2016. Genome-wide identification of QTL for seed yield and yield-related traits and construction of a high-density consensus map for QTL comparison in *Brassica napus*. Front. Plant Sci., 7: 17. https://doi.org/10.3389/fpls.2016.00017