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IMPACT OF SOWING DATES AND HEAT STRESS ON WHEAT GRAIN FLOUR PHYSICAL AND CHEMICAL PROPERTIES

[a]Muhammad Adeel, [a]Akmal Nazir, [b]Hassan Aziz

[a] *National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.*
[b] *Islamabad Food Authority, Islamabad, Pakistan.*

A B S T R A C T

The main objectives of the present study were to evaluate the influence of terminal heat stress on the physical, chemical, rheological, textural and baking properties of wheat. Four varieties were evaluated using diverse physical methods, chemical methods, rheological methods (Farinograph, Mixograph, RVA), and also tested by bread making quality. For this purpose, four genotypes Millat-11, Punjab-11, V-07096, and V-10110 with recommended date of sowing, late sowing grains were milled and analyzed for their physico-chemical, rheological and textural analysis. Two sowing dates significantly influenced grain morphology i-e; grain length (6.2 to 6.5 mm), grain width (3.2 to 3.6 mm), 1000 grain weight (36.7 to 48.7 g) and test weight (70 to 75.17 kg/ hL). Particle size index varied from 17.81 to 26.84% significantly differed along with grain hardness in the range of 59.33 to 69.33 HI. The chemical constituents were found significantly different such as moisture content (10.05-11.38%), crude protein (11.54-13.05%, crude fat (0.41-0.52%), crude fiber (0.34-0.50%), ash contents (1.23-1.68%) and falling number of 482-621 seconds. Minerals of different elements ranged like zinc 21.42-26.78 ppm, copper (38.05-48.89 ppm), calcium (31.60-46.52 ppm), iron (3.47-6.68 ppm) and manganese (456.44-645.84 ppm) respectively.

Keywords: Heat stress; Wheat; Grain morphology; Minerals

Corresponding Author: Muhammad Adeel
Email: adeelft226@gmail.com

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INTRODUCTION

Wheat is extensively used cereal crop cultivated and consumed around the world. Wheat is staple food source for carbohydrates, fibres and proteins (Khan, 1984). It is used in making of bakery products like pasta, bread, cookies, pastries, cake, chapatti, khamiri roti and biscuits (Hoseney et al., 1988). The physical properties like grain color and size, hardness, vitreousness and weight are important aesthetic factors along with chemical profile (Singh et al., 1998; Wei, 2002). Temperature in the range of 12-22 ˚C is optimum for wheat anthesis and grain filling, exceeding the optimum may result in reduce grain filling resulting in reduced yield (Maçãs et al., 2000; McDonald et al., 1983; Mullarkey and Jones, 2000; Tewolde et al., 2006) which is generally termed as 'heat stress or Terminal heat stress' (Wahid et al., 2007). Heat stress accelerates the rate of grain filling whereas grain filling duration is shortened (Dias and Lidon, 2009). For instance, 5˚C increases in temperature above 20˚C increased the rate of grain filling and reduced the time of filling by 12days. It results in early crop ripening (Yin et al., 2009) with 2.8 day reduction for each degree rise in temperature (Streck, 2005). Photosynthetes production become low along with their assimilation in grain thus reducing shriveled reduced weight seeds (Calderini et al., 2006). Under heat stress, grain protein content increases (Castro et al., 2007) with decreased functionality (Corbellini et al., 1997; Erekul and Köhn, 2006; Guttieri et al., 2000) while synthesis of gliadins remains stable or increases (Majoul et al., 2003). In recent years climatic fluctuation is mostly erratic and most of the times crops faces early summer or heat wave in wheat growing plains of Punjab, KPK and Sindh. So it was imperative that wheat germplasm must be exposed for terminal heat tolerance through a broad understanding of its effects on the qualitative characteristics

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of grain. The study was designed with objective to know the stress response on the wheat flour composition, its rheological and baking properties.

MATERIALS AND METHODS

Wheat Seed Collection

Wheat varieties Millet-11, Punjab-11, V-07096, V-10110 was taken from Department of Crop Physiology, University of Agriculture, Faisalabad (UAF) and taken as normal sowing and late sowing produce, to the Laboratory of National Institute of Food Science & Technology, (UAF) Faisalabad.

Qualitative characterization of normally and late sown grains

Physical characterization of wheat grain

Grain size

The length, width and thickness of one hundred grains taken randomly were measured by using micrometer (vernier caliper).

Thousand kernel weight

Representative sample of each genotype (50g) was and thousand kernel weight was recorded by grain counting and cleaned, unbroken and healthy seeds were used. Seed weight was taken and recorded in grams/1000 kernel.

Test weight

The test weight (kg/HL) of each wheat variety was recorded according to the procedure given in AACC (2000) method No. 55-10.

Wheat milling traits

Moisture 14.5% in grain was added to each wheat variety in plastic containers at room temperature for 24 hours and equilibrated to ensure moisture content within grains. The amount of water required for tempering was determined and calculated by using formula given below as per procedure given in AACC (2000) method No. 26-95. Wheat grains were milled through Brabender Quadrumate Senior Mill to get different milling fraction.

$$\text{water required (ml)} = \frac{100 - \text{Origial moisture}(\%)}{100 - \text{Desired moisture}(\%)} - 1 \times \text{weight of sample}$$

Determination of grain hardness

Particle size index

The particle size index (PSI) was determined by following the procedure described in AACC (2000) method No. 55-30.

Grain hardness by near infrared reflectance (NIR)

Each wheat variety was tested for grain hardness by running through NIR analyzer according to the procedure described in AACC (2000) method No. 39-70A.

Falling number

The falling number value of each flour sample was recorded by using falling number apparatus 1900 according to the procedure described in AACC (2000) method No. 56-81.

Chemical characterization of wheat

The flour of each wheat variety was evaluated for chemical composition like moisture, crude protein, crude fat, crude fiber and ash content using methods given below.

Moisture content

The flour obtained from each wheat variety was tested for moisture content by using an air forced draft oven at a temperature of 105 ± 5ºC following the procedure described in AACC (2000) method No. 44-15A.

$$\text{Moisture } (\%) = \frac{\text{Wt. of original sample} - \text{Wt. of dried sample}}{\text{Wt. of original sample}} \times 100$$

Crude protein content

The nitrogen content in flour samples was determined by Kjeldahl's method as described in AACC (2000) method No 46-10. The nitrogen percentage was determined following expression given below; while the crude protein content was calculated by multiplying % nitrogen with a factor 6.25.

$$\text{Nitrogen } (\%) = \frac{\text{Titer of 0.1 N } H_2SO_4 \text{ used} \times 0.0014 \times 250}{\text{Weight of sample} \times \text{Volume of aliquot sample}} \times 100$$

Crude fat

The Soxhlet apparatus was used for the determination of crude fat following the method No. 30-25 (AACC, 2000). Crude fat from 5g of flour was extracted with petroleum ether at a condensation rate of 2-3 drops/second for 16 hours. After distilling excess ether the residues of extraction flask were dried at 100ºC for 30 min. until a constant weight. Crude fat was calculated by the formula given below.

$$\text{Crude Fat } (\%) = \frac{\text{Weight of ether extract}}{\text{Weight of flour sample}} \times 100$$

Crude fiber

The flour samples after fat extraction were evaluated for crude fiber content following the procedure mentioned in AACC (2000) method No. 32-10. The crude fiber was determined in 2g fat free sample and digested with 200 ml boiling 1.25% H_2SO_4, filtered and washed thrice. Then samples were again digested with 200 ml of boiling 1.25% NaOH for 30 minutes, filtered and washed thrice. The resultant residues were dried at 130ºC for 2 hours and weighed. Then these residues were ignited at 600ºC±15ºC, cooled and reweighed. The crude fiber was calculated according to following expression;

$$\text{Crude Fat (\%)} = \frac{\text{Loss in weight on ignition} - \text{blank}}{\text{Weight of flour sample}} \times 100$$

Ash contents

Each flour sample were analyzed for ash content by following the procedure outlined in AACC (2000) method No. 08-01. The flour samples were taken in pre- weighed crucibles and charred on Bunsen burner before incinerating in the muffle furnace where a temperature of 550°C was maintained till the sample converted to grayish white residue.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of flour sample}} \times 100$$

Statistical analysis

The data obtained for each parameter were subjected to statistical analysis to determine the level of significance using analysis of variance in Split-plot design and means were further compared through Latin square design test using Least Significant Difference (LSD) (Steel et al., 1997).

RESULTS AND DISCUSSION

Physical characteristics of wheat

The physical tests and observations of wheat grains describe some of its characteristics rather than evaluation.

Grain size

The data pertaining to grain size of four wheat genotypes in two different sowing dates is presented (Figure 1 and 2**)**. Sowing date influenced grain size significantly but not significant with reference to genotypes. Late sowing was observed with high grain weight as compared to early sowing. The reason might be due to lower temperature in late sown wheat which retarded the growth and grain has to meet a certain degree per day, hence grain size was reduced in late sowing grains.

Grain length

The analysis of variance regarding grain length of different wheat varieties on different sowing dates (Figure 1) showing significant effect on grain length. Significant difference was found among genotypes and interaction with more grain size in late sowing; might be due to high temperature. Higher grain length (cm) was found in the produce of normal sowing varieties (0.64) and lower in late sowing wheat varieties (0.63). The grain length of different Pakistani wheat varieties have been observed by previous researchers, ranged from 5.79-7.118 mm (Butt et al., 1997), 5.77-6.88 mm (Ahmad, 2001) and 5.66-7.64 mm (Mahmood, 2004). Mabille and Abecassis (2003) developed the mathematical equation for grain size of wheat varieties and observed grain length to be ranged from 6.05-7.23 mm.

Grain width

The analysis of variance regarding grain width of different wheat varieties on different sowing dates has been depicted in figure 2. It is obvious from the statistical results that grain width was significantly affected by sowing dates. There was also significant difference found among interaction but non-significant difference found among genotypes. The mean values for grain width of different wheat varieties (Figure 2). The results revealed that the higher grain width (cm) was found in the grains of optimum sown wheat varieties (0.35). The grain width was obtained to be the lower in grains of late sown wheat varieties (0.33). Mahmood (2004) observed the grain width ranged from 2.05 to 3.71 mm in 46 Pakistani wheat varieties. The results in the present study are in concordance with the findings reported by Butt et al. (1997) and Ahmad (2001) who measured the grain width of different Pakistani wheat varieties and reported ranged from 2.823 to 3.468 mm and 3.20 to 3.63 mm, respectively.

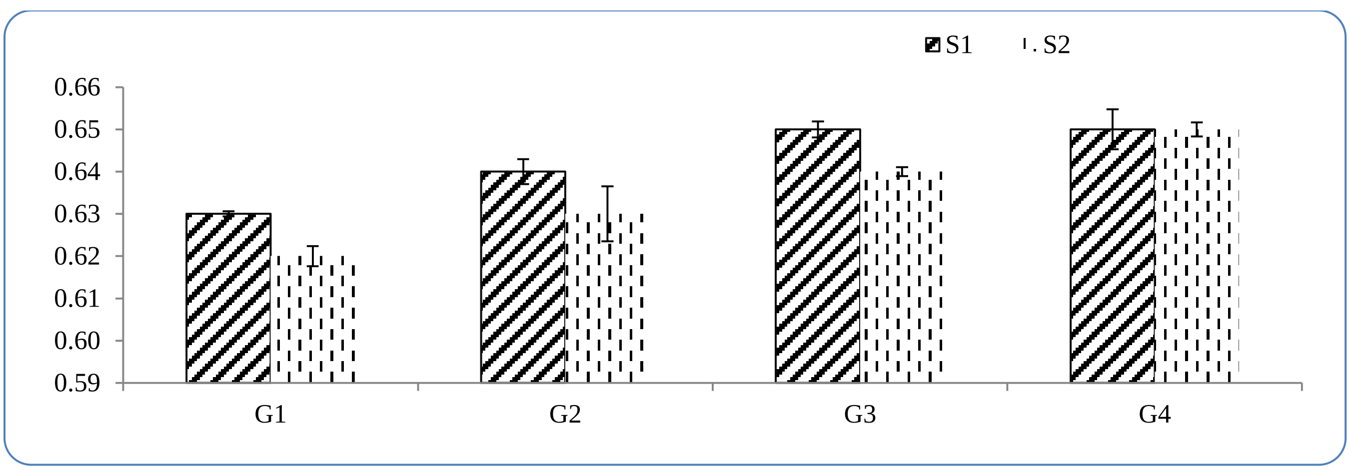

Figure 1. Mean grain length of different wheat genotypes under different sowing dates.

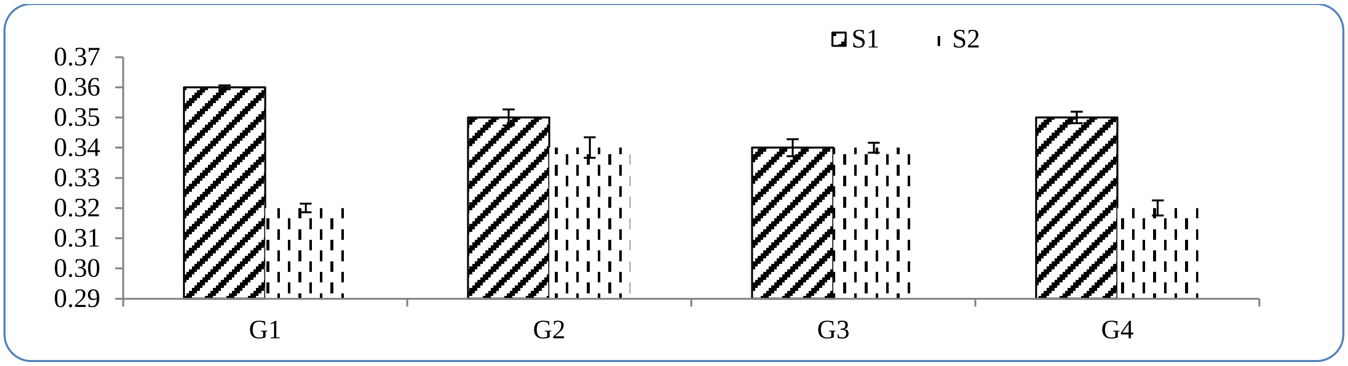

Figure 2. Mean grain width of different wheat genotypes under different sowing dates.

1000 Kernel weight

The analysis of variance regarding 1000 kernel weight has been shown (Figure 3) with significant difference between of different sowing dates of wheat varieties, among genotypes and interaction. The mean results for 1000 kernel weight have been presented in Table 4.3b. The results revealed that the higher 1000 kernel weight (g) was found in grains of wheat varieties of normally sown (45.29) and lower in late sown wheat varieties (41.45). The results for thousand kernel weight obtained in this study are well supported by the results previously reported as in the range of 28.81-49.01g (Anjum et al., 2002; Randhawa et al., 2002) and later found the varieties exceeding this limit by 39.22-43.16g (Mueen-ud-din, 2009).

Test weight

The test weight is a rough index of flour yield and is considered as one of the important tools in all wheat grading systems. There is rapid decrease in milling yield with the decrease in test weight (Majoul et al., 2003). The results obtained in case of new Pakistani varieties revealed that all wheat varieties exhibited test weight within desirable limits (Klava, 2004). It is obvious from the statistical results that test weight was significantly affected by different wheat varieties on sowing dates (Figure 4). Optimum sown wheat varieties were found higher test weight (kg/hl) (74.92) grains and lower in grains of late sown wheat varieties (70.54). The results of present study are in conformity with the earlier studies reported by (Anjum and Walker, 2000; Anjum et al., 2002; El-Khayat et al., 2006; Klava, 2004) with test weight range of 68.30-81.00kg/hl for different wheat varieties and in spring wheat varieties with test weight range of 66.20-80.20 kg/hl in 130 hard red (Martin et al., 2001).

Determination of particle size index

The statistical results related to particle size index of different wheat varieties for different sowing dates is given in figure 5 with highly significant differences. Higher particle size index was found in grains of wheat varieties of late sown with 23.42% and 20.83% as lower on normal sown time. The findings of present study reported that wheat varieties fell in the medium hard according to the hardness scale given in AACC (2000). The results of present study are in line with the earlier work of Anjum (1991) who evaluated six Pakistani wheat varieties and observed that these fell into the category of medium hard group. Butt et al. (1997) found PSI of 30 Pakistani wheat varieties ranging from 17.32 to 42.41%. Pasha et al. (2009) found PSI ranged from 16.33 to 30.33% in different Pakistani wheat varieties. The Pakistani wheats were found to have hardness level indicated to American Hard White Wheats when different methods for grain hardness measurement were used (Anjum and Walker, 2000). Environmental conditions can have impact on hardness ranging from intermediate to extreme during growth depending on genotype and the stage of growth under which the adverse conditions are experienced. In the present study significant effect of sowing times reflected that PSI is not only genetically controlled but environmental conditions during growth.

Falling number

The analysis of variance regarding falling number of different wheat varieties on two sowing times (normally and late sowing) has been shown in figure 6. It is obvious from the statistical results that falling number were significant difference between of different sowing dates of wheat varieties. There was non-significant difference found among genotypes and interaction (Figure 6) with higher falling (611.08) numbers for timely sown lower (502.25) in late sown wheat varieties. It is based on indirect relationship with alpha amylase activity and falling number values exceeding 400 seconds for varieties with very low or no amylose activity. Already established standard for bread flour varieties should have falling number values in between 200-300 seconds (Anjum, 1991; Butt et al., 1997; Mailhot, 1988).

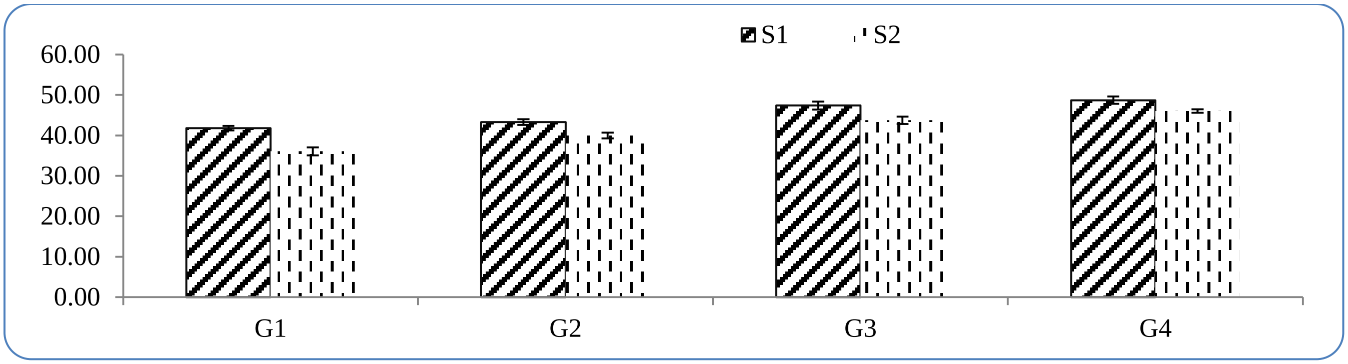

Figure 3. Mean thousand kernel weight of different wheat genotypes under different sowing dates.

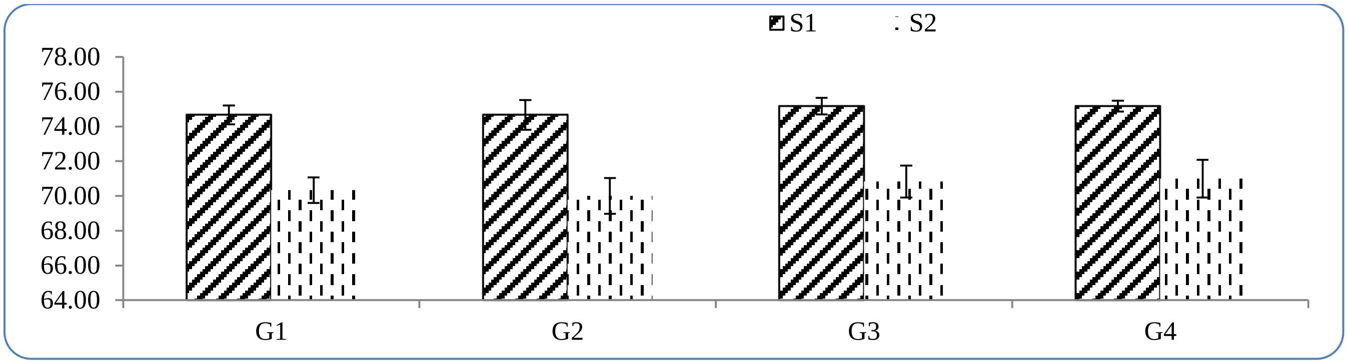

Figure 4. Mean test weight of different wheat genotypes under different sowing dates.

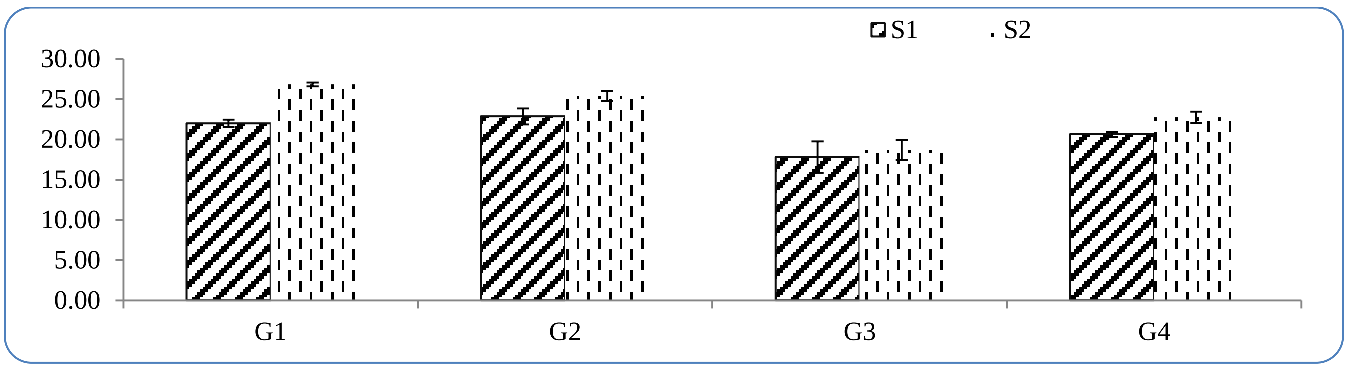

Figure 5. Mean particle size index of different wheat genotypes under different sowing dates.

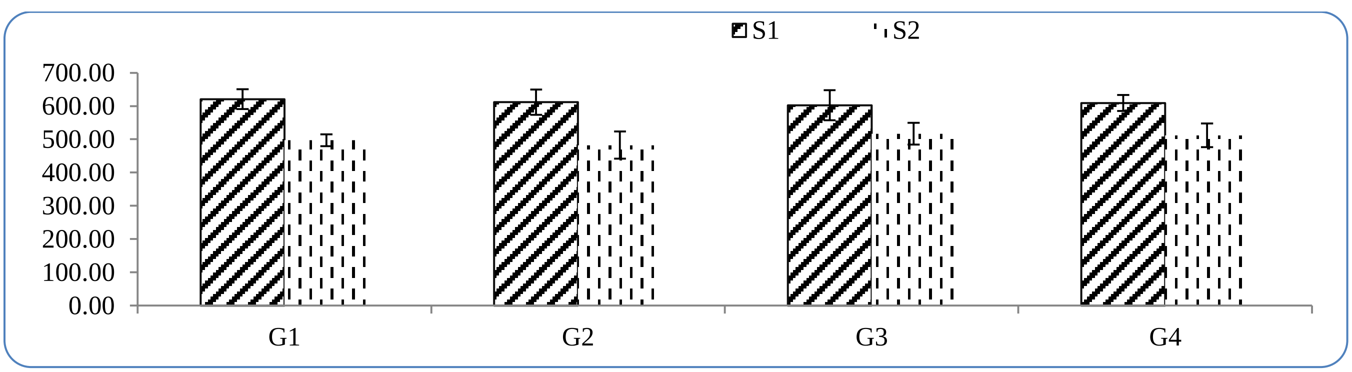

Figure 6. Mean falling number of different wheat genotypes under different sowing dates.

Chemical Properties of Bread wheat varieties

Wheat quality is suitability for bread making and related purposes like milling, physical, chemical and rheological characteristics for economic significance. Wheat quality characteristics are determined by different chemical tests like moisture contents (important for wheat storage), protein contents, amylase activity, crude fiber, and ash contents.

Moisture content

The moisture content varied from 10.05 to 11.38% among wheat varieties. The higher moisture content was observed in normally sown wheat varieties (11.25 %) whilst the lower was found in late sown wheat varieties (10.25 %) (Figure 7). The wheat of very low moisture is brittle and of high moisture content (>13.5%) has a tough character (Klava, 2004); 10.25 to 13.31%; 8.19 to 11.94% (Ahmad, 2001; Hrušková and Faměra, 2003), 8.92–11.68 g/100g (Pasha et al., 2009), 11.39-11.82% (Noorka et al., 2009), 11.78-12.09% (Mueen-ud-din, 2009) and 8.92 to 11.68 g/100g (Butt et al., 1997). Moisture content is an important factor for measurement of wheat kernel texture. Study is supported by the finding of different researchers (Slaughter et al., 1992) who reported that moisture is dependent on genetic makeup of varieties and agronomic as well as climatic conditions.

Crude protein

Protein content is not only an indicator of direct nutritional value, but it also has a significant impact on dough rheological properties. It is frequently correlated with bread-making quality. Good bread flour has strong gluten that is indicated by high protein quantity. Protein ranged from 8-15% of a wheat kernel and is the second major component of the endosperm. The crude protein varied from 11.54 to 13.05% (Figure 8). The higher crude protein was observed in late sown wheat varieties (12.82 %) whilst the lower was found in timely sown wheat varieties (11.67%). The protein content has been reported to be influenced by the genetic as well as non-genetic factors like soil, climatic conditions and use of fertilizer etc. (Kent and Evers, 1994). Similar findings has been given from different scientists and researchers which exhibited that protein content in Pakistani wheat varieties grown under different conditions were ranged from 10.43 to 14.74% (Ahmad, 2001; Anjum et al., 2002). Pasha et al. (2009) studied different wheat varieties and reported that protein content ranged from 10.00-13.4g/100g of flour. Noorka et al. (2009) observed protein content ranged from 11.22 to 12.78% in different wheat varieties. Randhawa et al. (2002) estimated protein content varied from 11.82 to 14.10%. The data of present study was very closely related to the achievement of Mueen-ud-din (2009) who investigated the protein content of different wheat varieties varied from 11.71 to 12.05%.

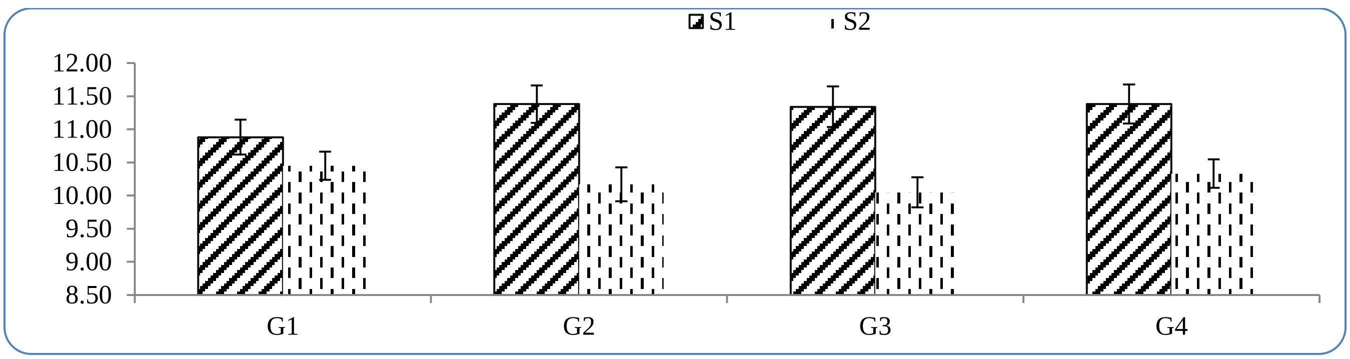

Figure 7. Mean moisture content of different wheat genotypes under different sowing dates.

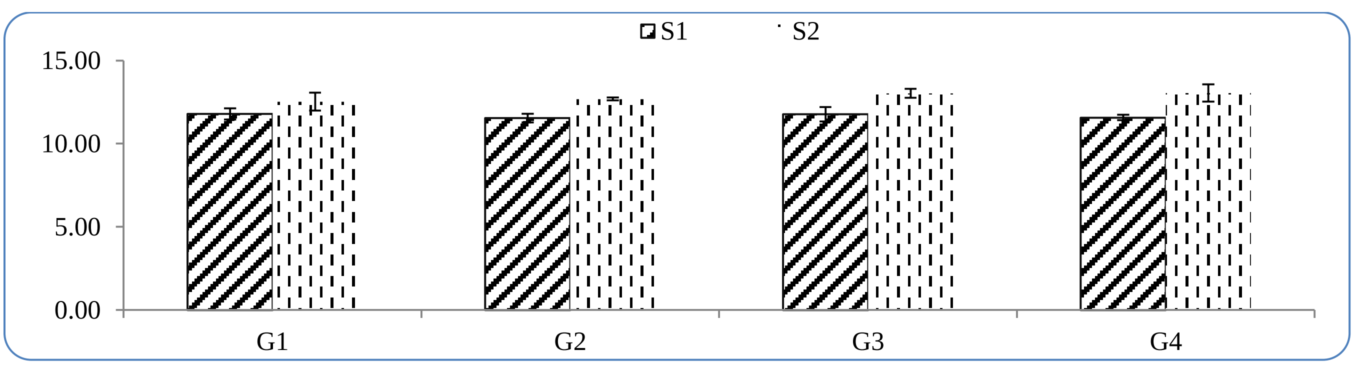

Figure 8. Mean crude protein of different wheat genotypes under different sowing dates.

Crude fat

The results for crude fat of different wheat varieties at different sowing time have been described (Figure 9). It is evident from the results that the crude fat was significantly affected due to differences in sowing dates of the wheat varieties. Mean values (Figure 9) regarding fat content showed that the fat content exhibited in the range of 0.41 to 0.52%. The higher crude protein was observed in normally sown wheat varieties (0.50 %) whilst the lower was found in late sown wheat varieties (0.43%). The results with respect to crude fat in the present study are similar to the earlier studies of Ahmad (2001) who reported variation in crude fat from 0.33 to 0.65% in some Pakistani wheat varieties.

Fiber content

Crude fiber content showed that the crude fiber exhibited in the range of 0.34 to 0.50% (Figure 10). The higher crude fiber was observed in normally sown wheat varieties (0.48%) whilst the lower was found in late sown wheat varieties (0.36%). The higher crude fiber was observed in normally sown wheat varieties (0.48%) whilst the lower was found in late sown wheat varieties (0.36%). These results are supported from previous findings (Akhtar et al., 2005; Ikhtiar and Alam, 2007).

Ash content

Mean values regarding ash content showed that the ash content exhibited in the range of 1.23 to 1.68% (Figure 11). The higher ash content was observed in normally sown wheat varieties (1.64%) whilst the lower was found in late sown wheat varieties (1.32%). The ash content of flour represents the mineral residues of organic matter and important aspect of milling industry (Wei, 2002). The clarity of flour is assessed by the amount of ash in flour. It is largely present in bran portion of wheat and affected by the atmospheric factors like temperature and relative humidity. The data is supported by similar findings 0.31-0.50% and 1.03-1.54% ash content rang in different Pakistani wheat varieties (Akhtar et al., 2005; Mueen-ud-din, 2009) observed flour of different wheat varieties for ash content and reported that it ranged from 0.56- 0.60%. The results presented in this study are supported by the finding of Noorka et al. (2009) who reported that ash content of different wheat varieties varied from 1.55-1.83%. Randhawa et al. (2002) observed ash content that ranged from 1.32 to 1.72%. Pasha et al. (2009) illustrated that ash content varied from 1.17-1.65g/100g flour of different wheat varieties. The difference between wheat varieties may be due to variation in their genetic variability and climatic conditions.

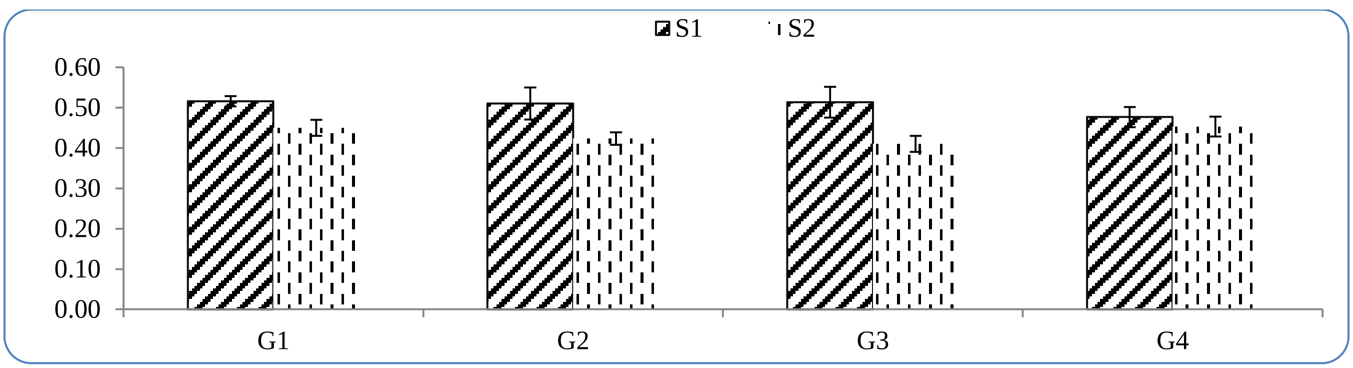

Figure 9. Mean crude fat of different wheat genotypes under different sowing dates.

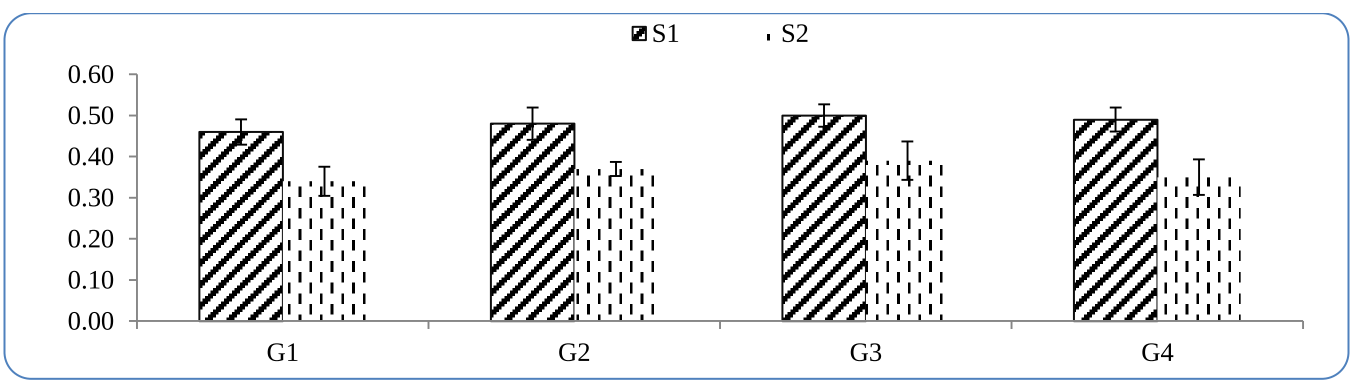

Figure 10. Mean crude fiber of different wheat genotypes under different sowing dates.

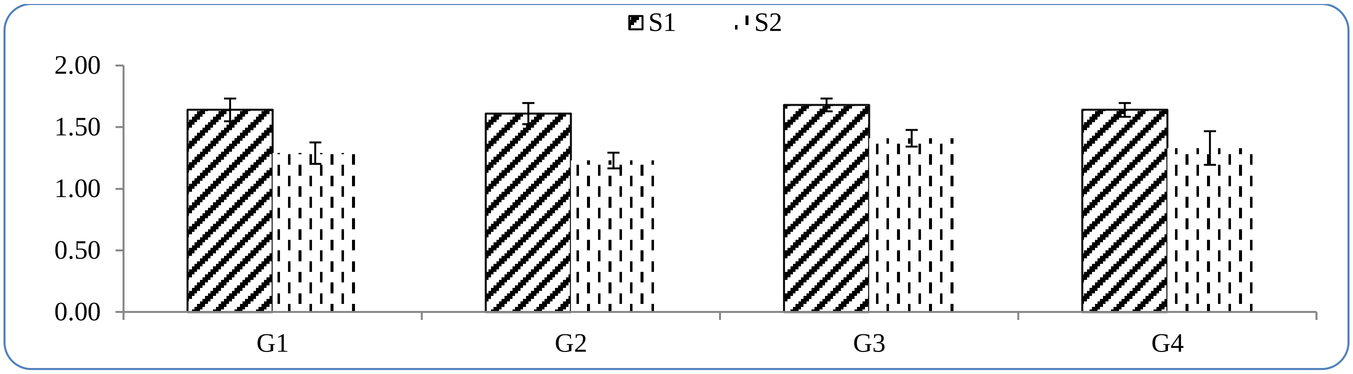

Figure 11. Mean ash content of different wheat genotypes under different sowing dates.

CONFLICTS OF INTEREST

The authors declared no conflict of interest.

AUTHOR'S CONTRIBUTION

All the authors contributed equally in the manuscript.

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