

CHANGES IN QUALITY COMPONENTS OF DURUM  
WHEAT GENOTYPES UNDER TEMPERATURE  
STRESS AND SUFFICIENT RAINFALL CONDITIONS  
DURING THE GROWTH PERIOD

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**Abstract**

A combination of genetic makeup and environmental factors determine the quality characteristics of durum wheat. Specifically, environmental stressors, such as extreme temperature fluctuations, can have a substantial impact on the productivity and quality of wheat crops. The effect of terminal temperature stress on yield and quality in durum wheat genotypes grown during 2019 and 2020 seasons was studied. These characteristics include thousand kernel weight, protein content, hectoliter weight, wet gluten content, Zeleny sedimentation value, and grain colour. The first year of the study was warmer than the second, resulting in decreased kernel weight, hectoliter weight, and gluten values, as well as increased protein content and Zeleny sedimentation values. This indicates that temperature stress leads to a higher protein content. The study also showed considerable variation in quality traits among genotypes, with certain genotypes demonstrating greater stability in specific quality traits. Genotype by environment interaction significantly affected grain weight, protein content, gluten content and Zeleny sedimentation. These data indicate that temperature stress plays an important role in determining the quality characteristics of durum wheat. Future studies should focus on mitigating the adverse effects of terminal temperature stress and improving the generation of genotypes with optimal quality traits.

**Key words:** durum wheat, temperature stress, quality, protein content, correlation

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**Introduction.** Wheat, a fundamental cereal that has been crucial to human existence over time, is a plentiful source of energy and carbs. An important characteristic of wheat grains is their capacity for long-term storage. Wheat, being a long-lasting and dehydrated food, serves as the main component of essential food items including bread, bulgur, semolina, biscuits, and couscous.

Global wheat production reached 781 million tons in the 2021/22 season, with China, the EU, and India securing the top three positions. Turkey, with a production of approximately 22 million tons in 2023, an 11.4% increase from the previous year, ranked 10th globally. Of this total, 3.1 million tons were durum wheat [1]. Durum wheat (*Triticum durum* L.) is one of the most important wheat species. In comparison to bread wheat, durum wheat has a relatively higher protein content and gluten strength, a considerably higher yellow pigment content, and a harder kernel [2]. The primary use of durum wheat is for the production of high-quality pasta, which accounts for approximately 50% of global durum wheat consumption [3].

Heat stress, especially during the grain filling stage, has a substantial influence on both the quantity and quality of the crop output. Hence, it is imperative to ascertain the impact of this environmental component on the production and quality of durum wheat. Various researchers studying the impact of heat stress on the genotype (G), environment (E), and their interaction ( $G \times E$ ) on the quality of durum wheat have typically observed that the  $G \times E$  interactions are lesser compared to G and/or E [2,4]. The aim of this study is to investigate the effects of terminal heat stress, a significant environmental factor, on durum wheat quality and the biplot relationship between quality and yield.

**Materials and methods.** This investigation was conducted during the 2019 and 2020 cropping seasons under rain-fed conditions at Dicle University in the Diyarbakır city of Türkiye. This study utilized 17 advanced lines (41 IDSN 7007, 46 IDSN 7153, 46 IDSN 7190, 46 IDSN 7201, 47 IDSN 7015, 47 IDSN 7027, 47 IDSN 7031, 47 IDSN 7037, 47 IDSN 7050, 47 IDSN 7060, 47 IDSN 7067, 47 IDSN 7075, 47 IDSN 7097, 47 IDSN 7143, 48 IDSN 7048, 48 IDSN 7055, and 48 IDSN 7114) and three control genotypes (Firat-93, Sena and Svevo). All advanced lines were supplied from CIMMYT. Control genotypes are registered Turkish durum wheat cultivars and are suitable for heat stressed and drought environment. The studies were arranged using a randomized complete block design, with each treatment being replicated three times. The seeds were planted on February 5, 2019, and February 26, 2020, using a 6-row setup with plot size of  $4.8\text{ m}^2$  ( $4 \times 1.2\text{ m}$ ), with a seeding density of 500 seeds per square meter. Plot harvesters were utilized to conduct harvesting operations on June 9, 2019, and June 25, 2020. The fertilization rates for all plots consisted of the application of  $60\text{ kg ha}^{-1}$  of pure nitrogen and phosphorus at sowing time, and  $60\text{ kg ha}^{-1}$  of pure nitrogen at the end of the tillering stage. Herbicides were used to control the weeds. Plants are harvested 15–20 days after physiological maturity.

The soils were clay loamy and salinity was low. Organic matter and phosphorus ( $\text{H}_2\text{PO}_4$ ) contents were very low, while potassium ( $\text{K}^+$ ) was very high. Magnesium content was at middle level (616 ppm). The soils contain lime between 10.0–11.0% at a depth of 0–60 cm. Climate data showed the average temperature, total precipitation, and relative humidity for the 2018–2019 growing season are 12.54 °C, 92.73 mm and 69.45%, respectively, while the average temperature, total precipitation, and relative humidity for the 2019–2020 growing season are 11.625 °C, 76.86 mm, and 64.77%, respectively (Table 1). In April-May, which covers the pre-head and milk dough periods, there was more rainfall in the first year compared to the second year.

T a b l e 1  
Climate-related meteorological data for the study period

|             | Years      | Oct. | Nov. | Dec.  | Jan. | Feb. | March | April | May   | June | Mean/<br>Total |
|-------------|------------|------|------|-------|------|------|-------|-------|-------|------|----------------|
| Mean        | 2018–19    | 18.8 | 10.2 | 6.3   | 3.8  | 5.4  | 8.2   | 11.8  | 20.1  | 28.3 | 12.54          |
| temperature | 2019–20    | 19.2 | 9.7  | 6.8   | 3.7  | 3.6  | 10.5  | 13.5  | 19.2  | 26.0 | 11.63          |
| ( °C)       | Long years | 17.5 | 9.6  | 4.0   | 1.7  | 3.70 | 8.3   | 13.8  | 19.3  | 26.0 | 11.54          |
| Total       | 2018–19    | 76.6 | 88.2 | 190.2 | 67.6 | 77.4 | 135.2 | 152.6 | 45.8  | 1.0  | 834.6          |
| rainfall    | 2019–20    | 52.0 | 9.0  | 185.4 | 89.4 | 58.6 | 164.8 | 92.6  | 55.2  | 0.6  | 707.6          |
| (mm)        | Long years | 32.2 | 54.2 | 71.4  | 70.9 | 67.7 | 65.6  | 69.5  | 44.2  | 8.8  | 484.5          |
| Moisture    | 2018–19    | –    | –    | –     | 81.7 | 77.0 | 75.0  | 78.4  | 58.5  | 32.5 | 69.45          |
| (%)         | 2019–20    | –    | –    | –     | 77.6 | 75.1 | 72.4  | 70.98 | 57.45 | 35.1 | 64.77          |

Source: Directorate of the Diyarbakır meteorology station (2020)

In the study thousand grain weight (TGW), protein content (PC), test weight (TW), wet gluten content (WG), Zeleny sedimentation volume (ZS), grain colour analysis  $b^*$  and the relationship between quality parameters and grain yield were investigated. Grain yield (GY) was calculated as kg/da by weighing the seeds obtained after harvest and converting the result to decare. Weighing the 1000 seeds measured in the grain counting machine gave the thousand grain weight (TGW). The amount of protein content (%), moisture content (%), and test weight ( $\text{kg hl}^{-1}$ ) were measured with the NIT System Infratec 1241 Grain Analyzer (Foss, Hillerød, Denmark), which can measure these parameters instantly. The  $b^*$  value is the blue-yellow colour coordinate, ranging from –60 (pure blue) to +60 (pure yellow). The higher the  $b^*$  value, the more yellowness there is. Good-quality durum wheat should have a  $b^*$  value of approximately 27.3 or more.  $b^*$  values were measured with a HunterLab ColorFlex device [5,6].

Analysis of variance, mean and LSD data of the obtained results were analyzed with JMP Pro-17 statistical package program and Biplot graphs were made using GenStat 12th package program and Excel.

T a b l e 2

The means and variance analysis for thousand grain weight, protein content and test weight of durum wheat genotypes

| Genotype     | Thousand grain weight (g) |          |          | Protein content (%) |          |          | Test weight (kg hl <sup>-1</sup> ) |        |         |
|--------------|---------------------------|----------|----------|---------------------|----------|----------|------------------------------------|--------|---------|
|              | 2019                      | 2020     | Mean     | 2019                | 2020     | Mean     | 2019                               | 2020   | Mean    |
| 41 IDSN 7007 | 25.81pqr                  | 34.80g   | 30.31k   | 14.87a-f            | 13.20j-p | 14.04cde | 80.2                               | 82.9   | 81.6d-g |
| 46 IDSN 7153 | 31.64ij                   | 41.92cd  | 36.78cde | 14.82a-g            | 12.23op  | 13.53e   | 79.9                               | 82.9   | 81.4d-g |
| 46 IDSN 7190 | 23.01s                    | 30.15j-m | 26.58l   | 15.21a-d            | 13.30i-o | 14.25cde | 81.2                               | 86.2   | 83.7bc  |
| 46 IDSN 7201 | 31.83ij                   | 37.87f   | 34.85f   | 14.90a-f            | 12.50nop | 13.70de  | 83.8                               | 86.0   | 84.9a   |
| 47 IDSN 7015 | 29.66k-n                  | 40.35de  | 35.00f   | 15.32a-d            | 12.17p   | 13.74de  | 81.4                               | 85.8   | 83.6bc  |
| 47 IDSN 7027 | 25.40qr                   | 38.56ef  | 31.98hij | 15.87a              | 12.33op  | 14.10cde | 80.4                               | 86.3   | 83.3bc  |
| 47 IDSN 7031 | 29.65k-n                  | 41.90cd  | 35.77ef  | 15.03a-e            | 12.77m-p | 13.90de  | 80.0                               | 85.7   | 82.8cd  |
| 47 IDSN 7037 | 28.24mno                  | 34.29gh  | 31.27ijk | 15.57abc            | 15.30a-d | 15.43a   | 81.0                               | 84.1   | 82.5cd  |
| 47 IDSN 7050 | 32.62hi                   | 40.94d   | 36.78cde | 14.72b-g            | 13.90f-l | 14.31cd  | 80.7                               | 84.2   | 82.5cde |
| 47 IDSN 7060 | 28.89mn                   | 37.01f   | 32.95gh  | 14.47c-h            | 13.77g-m | 14.12cde | 81.1                               | 84.1   | 82.6cd  |
| 47 IDSN 7067 | 27.72nop                  | 42.08cd  | 34.90f   | 15.17a-d            | 13.53h-n | 14.35cd  | 80.2                               | 84.3   | 82.3c-f |
| 47 IDSN 7075 | 31.28jk                   | 43.66bc  | 37.47c   | 14.35d-i            | 13.47h-n | 13.91de  | 79.8                               | 83.5   | 81.7d-g |
| 47 IDSN 7097 | 26.88opq                  | 37.62f   | 32.25ghi | 15.56abc            | 13.30i-o | 14.43bcd | 82.2                               | 85.2   | 83.7abc |
| 47 IDSN 7143 | 30.19jkl                  | 41.01d   | 35.60ef  | 15.56abc            | 12.80l-p | 14.18cde | 77.7                               | 83.8   | 80.7fg  |
| 48 IDSN 7048 | 29.40k-n                  | 37.49f   | 33.44g   | 15.53abc            | 14.87a-g | 15.20b   | 78.9                               | 82.9   | 80.9efg |
| 48 IDSN 7055 | 31.61ij                   | 40.34de  | 35.97def | 14.74b-g            | 13.97e-k | 14.35cd  | 78.0                               | 83.2   | 80.6g   |
| 48 IDSN 7114 | 24.88rs                   | 36.77f   | 30.83jk  | 14.87a-g            | 12.90k-p | 13.88de  | 80.4                               | 84.6   | 82.5cd  |
| FIRAT-93     | 40.82d                    | 47.42a   | 44.12a   | 15.61ab             | 14.00e-k | 14.81abc | 83.7                               | 84.9   | 84.3ab  |
| SENA         | 31.32ijk                  | 43.17c   | 37.25cd  | 14.23d-j            | 13.13j-p | 13.68de  | 80.8                               | 84.5   | 82.6cd  |
| SVEVO        | 34.73g                    | 45.55ab  | 40.14b   | 15.73ab             | 15.17a-d | 15.45a   | 82.9                               | 83.9   | 83.4abc |
| Mean         | 29.78b                    | 39.65a   | 34.71    | 15.11a              | 13.43b   | 14.27    | 80.70b                             | 84.45a | 82.6    |
| LSD (Y*G)    |                           | 0.97**   |          |                     |          | 0.56**   |                                    |        | ns      |
| LSD (G)      |                           | 0.69**   |          |                     |          | 0.39**   |                                    |        | 0.79**  |
| LSD (Y)      |                           | 0.42**   |          |                     |          | 0.20**   |                                    |        | 0.33**  |
| CV (%)       |                           | 3.44     |          |                     |          | 4.76     |                                    |        | 1.65    |

G: genotype, Y: Year, Y\*G: genotype\*year interaction, b\*: grain colour analysis, LSD: least significant differences, \*, \*\*, \*\*\* Significant at  $P < 0.05$ ,  $P < 0.01$ ,  $P < 0.001$ , respectively

T a b l e 3

The means and variance analysis values for gluten content, Zeleny sedimentation and grain colour (b) of durum wheat genotypes

| Genotype     | Gluten content (%) |          |          | Zeleny sedimentation (%) |          |          | b*     |        |
|--------------|--------------------|----------|----------|--------------------------|----------|----------|--------|--------|
|              | 2019               | 2020     | Mean     | 2019                     | 2020     | Mean     | 2019   | 2020   |
| 41 IDSN 7007 | 28.22lmn           | 29.67i-n | 28.94fgh | 45.02c-h                 | 41.33h-k | 43.18h   | 25.27  | 24.32  |
| 46 IDSN 7153 | 28.65k-n           | 27.67mn  | 28.16h   | 50.93a                   | 40.67i-l | 45.80d-h | 23.85  | 24.11  |
| 46 IDSN 7190 | 28.90k-n           | 36.00c-f | 32.45cde | 48.73a-d                 | 42.33g-j | 45.53e-h | 24.46  | 23.91  |
| 46 IDSN 7201 | 28.82k-n           | 29.00k-n | 28.91gh  | 50.59a                   | 39.00jkl | 44.79e-h | 24.83  | 24.54  |
| 47 IDSN 7015 | 28.95k-n           | 32.00f-l | 30.47e-h | 50.74a                   | 38.00kl  | 44.37fgh | 24.44  | 24.48  |
| 47 IDSN 7027 | 29.39j-n           | 29.67i-n | 29.53fgh | 50.67a                   | 37.00l   | 43.83gh  | 24.36  | 23.96  |
| 47 IDSN 7031 | 29.15k-n           | 31.67g-m | 30.41e-h | 50.83a                   | 39.33jkl | 45.08e-h | 24.93  | 24.34  |
| 47 IDSN 7037 | 29.01k-n           | 40.00abc | 34.51ab  | 50.95a                   | 49.00abc | 49.98a   | 24.14  | 23.85  |
| 47 IDSN 7050 | 28.30k-n           | 34.67d-h | 31.48efg | 49.28ab                  | 44.67d-i | 46.97b-f | 24.61  | 23.58  |
| 47 IDSN 7060 | 27.44n             | 33.67e-i | 30.55e-h | 44.93c-h                 | 44.00f-i | 44.47fgh | 25.20  | 24.14  |
| 47 IDSN 7067 | 28.63k-n           | 33.33e-j | 30.98e-h | 50.70a                   | 42.67g-j | 46.69c-g | 24.83  | 23.54  |
| 47 IDSN 7075 | 27.80mn            | 35.33d-g | 31.57d-g | 47.58a-f                 | 42.33g-j | 44.95e-h | 24.91  | 23.85  |
| 47 IDSN 7097 | 28.88k-n           | 34.67d-h | 31.77c-e | 50.85a                   | 42.00g-k | 46.43d-g | 23.90  | 23.79  |
| 47 IDSN 7143 | 30.21i-n           | 30.33i-n | 30.27e-h | 51.07a                   | 42.00g-k | 46.54d-g | 23.82  | 23.89  |
| 48 IDSN 7048 | 29.78i-n           | 41.33ab  | 35.56ab  | 51.11a                   | 48.00a-f | 49.55abc | 25.89  | 23.85  |
| 48 IDSN 7055 | 28.51k-n           | 37.00cde | 32.75a-d | 50.63a                   | 44.33e-i | 47.48a-e | 24.53  | 23.74  |
| 48 IDSN 7114 | 28.25lmn           | 32.00f-l | 30.13e-h | 45.67b-g                 | 42.33g-j | 44.00gh  | 24.69  | 23.87  |
| FIRAT-93     | 30.66h-n           | 38.00a-d | 34.33abc | 51.36a                   | 45.00c-h | 48.18a-d | 22.89  | 22.95  |
| SENA         | 28.65k-n           | 32.33f-k | 30.49e-h | 48.84abc                 | 42.33g-j | 45.59d-h | 22.94  | 23.59  |
| SVEVO        | 30.31i-n           | 43.00a   | 36.65a   | 51.30a                   | 48.33a-e | 49.82ab  | 23.58  | 23.04  |
| Mean         | 28.93b             | 34.07a   | 31.5     | 48.59a                   | 42.73b   | 46.2     | 24.40a | 23.87b |
| LSD (Y*G)    |                    |          | 2.03**   |                          |          | 2.07**   |        | ns     |
| LSD (G)      |                    |          | 1.43**   |                          |          | 1.46**   |        | 0.36** |
| LSD (Y)      |                    |          | 0.67**   |                          |          | 0.77**   |        | 0.14*  |
| CV (%)       |                    |          | 7.88     |                          |          | 5.49     |        | 2.60   |

G: genotype, Y: Year, Y\*G: genotype\*year interaction, b\*: grain colour analysis, LSD: least significant differences, \*, \*\*, \*\*\*, \*\*\*\* Significant at  $P < 0.05$ ,  $P < 0.01$ ,  $P < 0.001$ , respectively

**Results and discussion.** The analysis of variance and mean values for important quality traits such as thousand grain weight, protein content, test weight, gluten content, Zeleny sedimentation, and grain colour  $b^*$  in durum wheat genotypes are presented in Tables 2 and 3. Significant disparities were seen in all quality traits between years and genotypes, based on the average results over a two-year period. Although the interaction between genotype and year did not have a significant effect on hectoliter weight and colour value, it did have a significant effect on other quality indicators. This suggests that annual variations under terminal heat stress did not affect colour or hectoliter weight. Yellow colours have high heritability, which is largely controlled by additive genetic effects and which has a strong genotypic component and low genotype  $\times$  environment interaction [7,8].

The study revealed that the durum wheat lines used generally had a reduced grain weight compared to the controls. The mean thousand grain weight was 34.71 g, with the control variety Firat-93 having the highest value. The genotypes exhibited an average protein content of 14.27%. The 47 IDSN 7027 line achieved the highest protein value of 15.87% in the initial year. Two controls (Firat-93 and Svevo) and two lines (47 IDSN 7037 and 48 IDSN 7048) had statistically higher protein values than the two-year average. Although the average hectoliter weight of the control genotypes ( $83.4 \text{ kg hl}^{-1}$ ) was higher than that of the lines used ( $82.4 \text{ kg hl}^{-1}$ ), the highest hectoliter weight was obtained from the 46 IDSN 7201 line ( $84.9 \text{ kg hl}^{-1}$ ). Firat-93 and Svevo, the control genotypes, had very high gluten and Zeleny sedimentation values. When the lines were examined in terms of gluten and Zeleny sedimentation, the 47 IDSN 7037 and 48 IDSN 7048 lines had statistically similar values to the controls. In terms of  $b^*$  yellow value, all lines had higher values than the control genotypes. This situation indicates that in recent years, increasing the yellow colour of the grain has become an important criterion in the selection of lines in durum wheat breeding studies. During the grain filling period, which occurs in May and June, when the first year was hotter compared to the second year, there was a significant decrease in thousand grain weight, hectoliter weight, and gluten values. On the other hand, protein and Zeleny values increased significantly in the first year. Some researchers support the general phenomenon of an increase in protein value due to heat stress. These findings are consistent with previous studies that have reported the negative impact of terminal heat stress on grain weight and volume and the positive impact on protein content [9,10]. As supported by studies such as SIBLEY et al. [11], and YILDIRIM et al. [12], rainfall variability significantly influences grain filling, stay-green, and plant growth. Therefore, the observed changes for protein content in our study can be linked to the combined effects of both heat stress and rainfall variability. According to TEKDAL and YILDIRIM [13], in durum wheat exposed to heat stress, characteristics such as test weight and grain weight significantly decrease, while properties such as sedimentation, colour, protein, and vitreousness increase.

In order to examine the relationships between the quality values of the genotypes, and the relationships of the quality values both among themselves and with yield, a biplot scatter plot (a) and a multivariate correlation analysis (b) were conducted (Fig. 1).

The correlation analysis of quality traits and related characteristics in wheat plays a crucial role in enhancing quality and determining appropriate genotype selection criteria. The biplot scatter plot (a) and multivariate correlation analysis (b) for the traits examined in this study are presented in Fig. 1. Significant and positive relationships were found between grain yield and protein content, gluten content, and Zeleny sedimentation, while a significant negative relationship was observed with yellow b\* (LAB-b). A negative correlation between yield and grain protein concentration is typically observed. In this study, the absence of water stress may have enhanced nitrogen uptake and transport, while high average daily temperatures may have promoted increased protein production. A significant positive correlation was also identified between protein content, gluten content, and Zeleny sedimentation. Similarly, AHMED and FAYYAZ-UL-HASSAN [14], reported that the impact of climatic conditions on quality traits due to late planting was predominant, and an inverse relationship was observed between certain quality traits and grain yield. YILDIRIM et al. [15], reported that among the quality traits in durum wheat, only test weight was associated with yield under rain-fed conditions, while no relationship was found between quality and yield under irrigated conditions. In environments stressed by heat and drought, KIZILGEÇİ and YILDIRIM [16], found that grain weight and test weight were related to yield. Among the quality traits, protein, sedimentation, and gluten content were found to be correlated with each other. Similar to this study, the colour value was negatively correlated with other quality traits and yield. Likewise, in heat-stressed environments, test weight was found to be related to yield, while protein and gluten were correlated among the quality traits [16]. TEKDAL and YILDIRIM [17], found that protein and vitreousness were positively related to each other in 150 genotypes of durum wheat grown in two locations under heat stress. However, these traits were negatively related to test weight and kernel weight. In local durum wheat varieties, it has been observed that quality traits such as vitreousness, protein content, and thousand kernel weight tend to cluster together. KIZILGEÇİ et al. [18], reported that in F5 durum wheat populations, yield, protein content, and colour traits were not correlated with each other. Additionally, KARAMAN et al. [19], found a relationship between sedimentation and colour value among quality traits in durum wheat genotypes.

In recent years, the biplot analysis method has been used to determine the performance of varieties, the relationships between traits, and the stability of varieties in different environments [20]. In the biplot presented in Fig. 1, PC1 (50.14%) and PC2 (19.95%) together represent 70.09% of the total variance. The biplot is divided into three mega environments (1- PC-Gluten-Zeleny-GY, 2- TW-

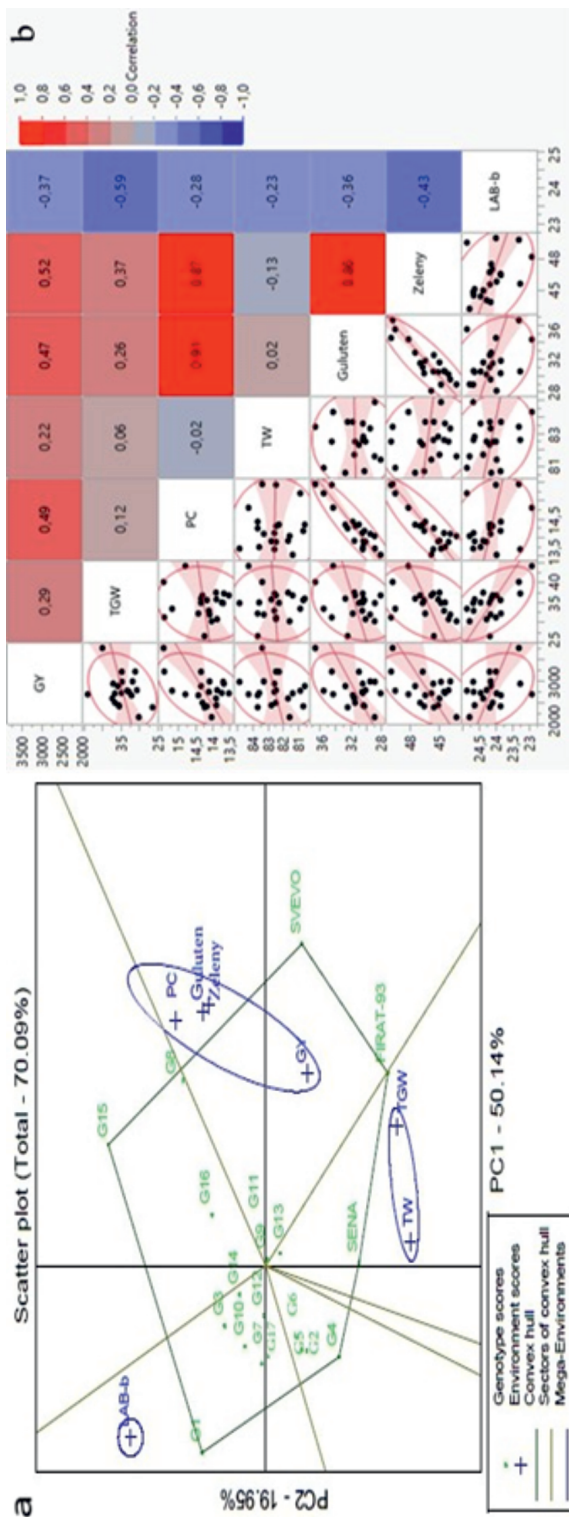


Fig. 1. Biplot scatter plot analysis (a) between genotypes and traits and multivariate correlation analysis; (b) between traits (G1:41 IDSN 7007, G2:46 IDSN 7153, G3:46 IDSN 7190, G4:46 IDSN 7201, G5:47 IDSN 7015, G6:47 IDSN 7027, G7:47 IDSN 7031, G8:47 IDSN 7037, G9:47 IDSN 7050, G10:47 IDSN 7060, G11:47 IDSN 7067, G12:47 IDSN 7075, G13:47 IDSN 7097, G14:47 IDSN 7143, G15:48 IDSN 7048, G16:48 IDSN 7055, G17:48 IDSN 7114, FIRAT-93, SENA, SVEVO)

TGW, 3- yellow b\* (LAB-b)) and six sectors (Fig. 1). Among all the traits examined, the lines 46 IDSN 7153, 47 IDSN 7031, 47 IDSN 7050, 47 IDSN 7067, 47 IDSN 7075, 47 IDSN 7097, and 48 IDSN 7114 stood out as the most stable lines. In terms of PC-Gluten-Zeleny-GY, the line 47 IDSN 7037, in terms of TW-TGW, the line Firat-93, and in terms of yellow b\* (LAB-b), the line 41 IDSN 7007 were found to be prominent.

**Conclusions.** The study revealed that terminal heat stress caused by late planting has significant effects on the quality parameters of durum wheat. Specifically, it was observed that terminal heat stress increases protein content and Zeleny sedimentation values, highlighting terminal heat stress as a critical environmental factor in determining the quality parameters of durum wheat. The observed differences among genotypes indicate that some genotypes are more stable in terms of certain quality traits. The biplot analysis revealed that the lines 46 IDSN 7153, 47 IDSN 7031, 47 IDSN 7050, 47 IDSN 7067, 47 IDSN 7075, 47 IDSN 7097, and 48 IDSN 7114 were the most stable in terms of quality traits across environments. This emphasises the importance of selecting durum wheat genotypes with stable grain quality under heat stress in wheat breeding programmes. Future research is expected to contribute to the development of strategies aimed at improving wheat quality by more comprehensively examining the responses of different genotypes to various environmental stress conditions.

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