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# Water Stress Affects the Some Morpho-Physiological Traits of Twenty Wheat (*Triticum aestivum* L.) Genotypes under Field Condition

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**Abstract:** Water stress has become one of the foremost constraints to agricultural development, mostly in areas that are deficient in water. A field trial has been conducted to evaluate the performance of different twenty wheat genotypes under three stress treatments viz., control (T0) = normal watering, stress-1 (T1) = water stress from tillering up to maturity, and stress-2 (T2) = water stress from anthesis to maturity were used as treatments. The results revealed that a highly significant ($p < 0.01$) difference was observed among twenty wheat cultivars for morpho-physiological traits except for several tillers plant$^{-1}$, spikeletspike$^{-1}$, and relative water content. In the early days, 50% flowering was noted in Anmole-91 (64.33 days) under (T0), while Anmol-91 showed a relative decrease (RD-1) (−2.34 days) at days 50% flowering in (T1). The TJ-83 genotype showed an early response (−8.34 day) at days to 50% flowering under stress-2 (T2), but TD-I (−3.34) was observed to be relatively tolerant. Underwater stress from tillering to maturity (T1) SKD-1 was found more susceptible (−36.7 days) than other cultivars. Wheat cultivar Soghat-90 showed maximum RD-1 (−24.7) for grain yield plant$^{-1}$ in stress-1 (T1) from tillering to maturity. Anmole-91, NIA-Sarang, and TD-I observed minimum was (−6) in the same water stress for various traits. Therefore, the findings of present work revealed that the best performing genotypes can be recommended for effective cultivation in future breeding programs.

**Keywords:** water stress; tillering; flowering; anthesis; maturity; wheat genotypes

## 1. Introduction

Wheat is a staple cereal food crop cultivated for the entire worldwide population [1]. Extensive land area in undeveloped countries often comes under sub-tropical areas, where water shortage is the main drawback to wheat crop yield. The lack of water significantly affects the morpho-physiological parameters of the wheat plant [2,3]. Wheat grains are rich in essential elements and good for the human diet globally. It has the most significant importance in Pakistan after rice cultivation [4]. Water scarcity is a big issue for healthy crop production, which affects the overall economy of Pakistan. It is observed that the north parts of the Sindh and a few areas of the Balochistan provinces are seriously facing a lack of water for sustainable agriculture. For better crop production, soil health, availability of water, tillage practices, weed management, plant density, fertilizer, salinity, crop rotation, plant genotype, etc. can be considered the main factors for better wheat crop growth and yield [5,6]. Improving water stress tolerance in crops has become a lengthy, laborious, time consuming and difficult task for adaptation in water shortage condition. Success for this task might be achieved by underlining crop water use efficacy. Larger leaf area, in addition to crop development, was found to be positively correlated with embryo size. Therefore, higher embryos may enhance early plant growth. The selection of cultivars that need low irrigation has also provided improved crop production under drought-resistant environments. In addition, water stress type research studies might be helpful in a breeding program for improving the qualitative and qualitative parameters of wheat genotypes as compared to other cereals under water stress conditions [7]. Water stress significantly decreases the main stem width, which therefore declines the quality of nodes/internodes width and total biomass due to reduction in width, which may cause the plant to produce short leaves, lees root proliferation, and lesser tillers. The water shortage condition affects several spikelets which were noted in positive association with low dry matter production. The spikelet spike$^{-1}$ is associated with a decreased number of flowers. The reduction of grains in the main spike, seed mass, and grain production proposed diminished in terms of dry biomass build-up and as a result, decreased spike length and healthy seeds. Water stress also affects the enlargement of plant cells, which may produce unhealthy seeds and result in poor quality and low weight of the plant. Rathore [8] stated that while genotypes gave a great seed index and more constancy in production under drought, assortment for greater seed yield varieties would be effective under recommended application of irrigation water. At the stage of wheat, flowering water stress is considered a limiting factor of lower wheat production. The literature reported that to improve the water stress in the wheat genotypes is a big challenge for genetic engineers [9]. In this regard, correlation studies have too much significant importance for breeders to produce high-yielding varieties for normal cultivation under water deficit areas. Gupta [10] noted positive associations of water possible for leaf, plant height, leaf area, tiller, biomass, and grain yield. Previous research showed that a great decline in grain yield was observed during the flowering stage under water stress conditions. Drought stress during grain filling exposed a greater than 70% decline in grain output of wheat. Lesser decline in grain yield was noted when water stress was observed during growth stages. In the earlier studies, it was observed that the anthesis stage of the wheat crop has been found to be a very sensitive phenomenon of plants cultivation under water stress conditions [6]. In the former study, Faisal [11] assessed the morphological and physiological parameters of wheat varieties for water stress tolerance at the seedling stage. However, little is known about the morphological and physiological traits and its interaction between 20 wheat genotypes traits by using redundancy analysis cultivation under three water stress conditions. Therefore, the present study has aimed to evaluate the genetic role of some morpho-physiological characters of twenty wheat genotypes under different water stress conditions such as control, stress-1, and stress-2. It is hypothesized that the best performing genotypes will be suggested for a further breeding program.

## 2. Materials and Methods

### 2.1. Study Area and Experimental Set-Up

In the study, for screening of best water stress tolerant genotype, an ex-situ trial was performed during Rabi season at the trail field of Sindh Agriculture University Tandojam. The field was conducted in the field of the botanical experimental garden, near the central library at Sindh Agriculture University Tandojam, Pakistan. In this study, twenty wheat genotypes viz; Chakwal-83, Kohinoor, Abadgar-89, Anmole-91, TJ-83, Imdad-05, Kiran-95, Soghat-90, SKD-1, DRICK, Bhitai, TD-1, Sindh-81, Moomal-02, Marvi, Inqalab-95, Sarsabz, NIA-Sarang, Faisalabad-85, and Mehran-89 were evaluated under Split-Plot Design with three each replication and water treatment. Control (T0) was normal watering, T1 has water stress from tillering to maturity denoted as (Stress-1), and T2 has water stress from anthesis to maturity denoted as (Stress-2). The morpho-physiological traits are represented in Table 1. The study area of the experimental field is indicated in (Figure 1). The study flow diagram is represented in (Figure 2).

**Table 1.** Morpho-physiological parameters were recorded in the 20 wheat genotypes.

| Parameter Designation | Code | Description of the Parameter |
|---|---|---|
| Chlorophyll content | CL | The 2nd youngest leaf blade of the plant was detected by the SPAD−502 chlorophyll meter [12]. |
| Relative water content | RWC | The relative water content was determined as: RWC% = (FW − DW/TW − DW) × 100 [13]. |
| Flag leaf area (mm$^2$) | FLA | FLA was measured by a convenient laser Leaf area meter AG-51, great speed scanner with scan board and data logger. |
| Days to 50% flower | D-50% | The days to 50% flowering were noted from sowing to 50% flowering for individual wheat genotypes. |
| Days to 90% maturity | D-90% | The days to 90% maturity were recorded from sowing to 90% maturity for individual wheat genotypes. |
| | | Plants when physically were found mature, the date was recorded for individual genotype, and days were counted from sowing to 90% maturity. |
| Grain filling period | GYP | The grain filling period was measured by subtracting the anthesis period from days to maturity of genotypes. |
| Plant height (cm) | PH | The PH was noted from the surface of the soil to the tip of a panicle after the maturity of genotypes. |
| Number of tiller per plant | NTPP | A number of tillers were counted in the field for each genotype. |
| Number of grain per spike | NGPS | Counted thrashed grains of a spike. |
| Number of spikelets per spike | NSPS | Spikelets were counted from each spike of the sample plant and noted. |
| Grain yield per plant (g): | GYPP | All spikes of a sample plant were threshed separately and then mixed and weight was taken as grain yield plant$^{-1}$. |
| Biological yield per plant | BYPP | The sample plants at maturity were uprooted and their weight was noted in grams on digital top balance as biological yield plant$^{-1}$. |
| Harvest index per plant (g): | HIPP | The HIPP was measured by dividing grain yield by biological yield plant$^{-1}$. The harvest index is the percentage of grain yield over the biological yield of a plant. |

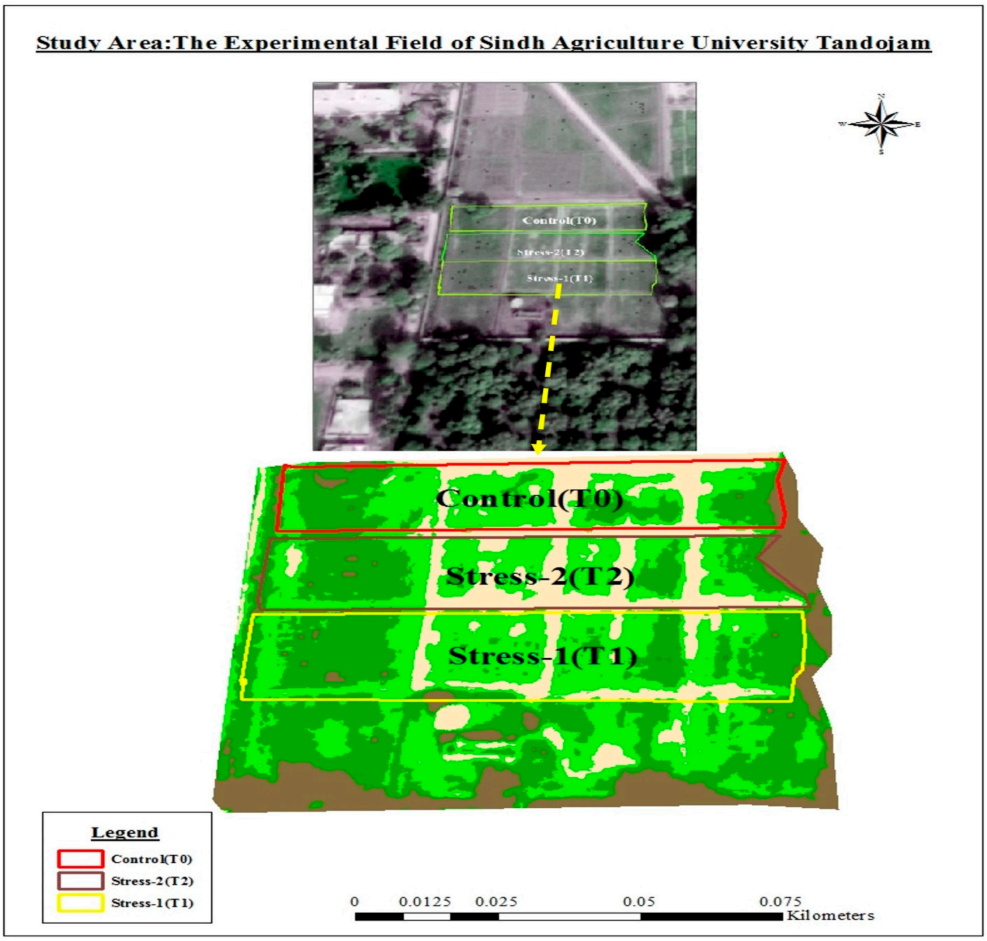


**Figure 1.** The geographical map representing the studied experimental field at Sindh Agriculture University Tandojam, Pakistan.

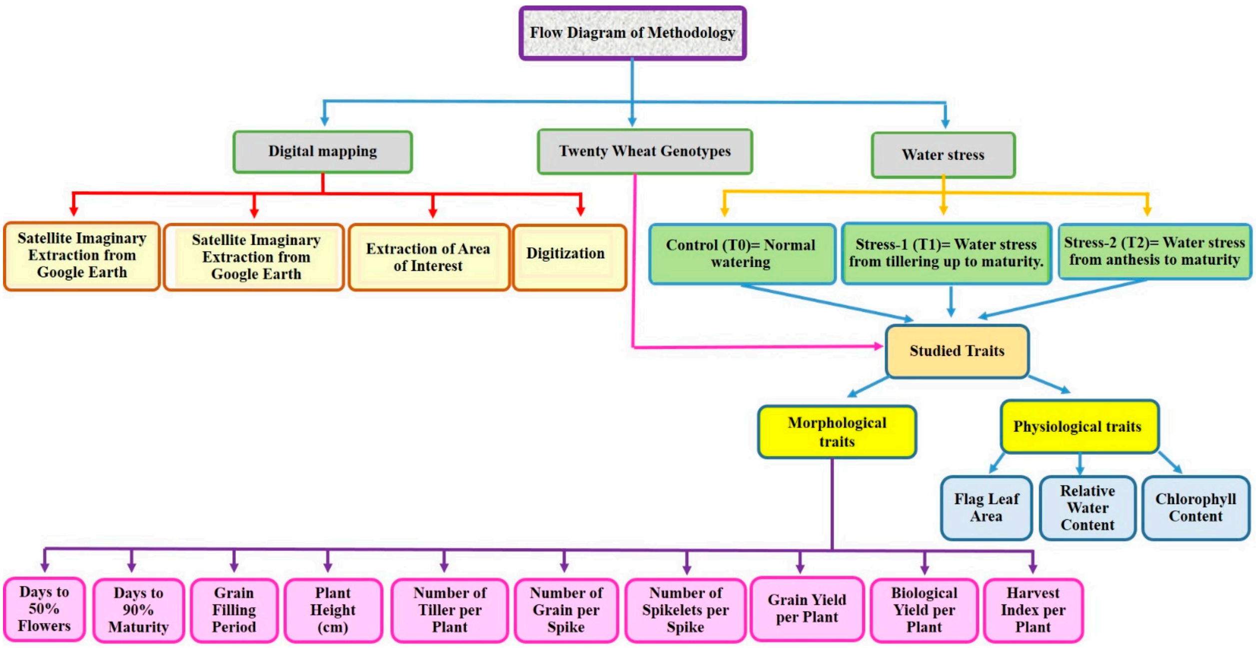


**Figure 2.** Illustrated flow diagram of experimental methodology.

### 2.2. Geospatial Techniques

In this study high-resolution Google earth, Geo eye satellite image of 2021 has been used for making a map of the study area, the method of image rectifying has been carried out with the help of geo-referencing tool in Arc GIS 10.3.1, and digitization has been carried out for making shapefile of the study area (Table 1).

### 2.3. Statistical Analysis

The data have been analyzed by using Excel 2016 and Statistics (v8.1) for Windows. Redundancy analysis (RDA) among morpho-physiological parameters of twenty wheat genotypes has been also used to designed using CANOCO5. Analysis of variance has been carried out [14].

## 3. Results and Discussion

The present study was conducted to access wheat tolerance under water stress. Analysis of variance revealed that cultivars and their interaction with water treatments were significantly different ($p > 0.01$) for most of the studied traits. Cultivars showed different performances underwater treatments. Analysis of variance showed that a highly significant difference in morpho-physiological traits. Genotype × treatment was significantly different for physiological traits such as flag leaf area, relative water content, and chlorophyll content (Table 2).

**Table 2.** Mean square of some morpho-physiological character of wheat genotypes.

| Characters | Mean Squares | | | | |
|---|---|---|---|---|---|
| | **Replication D.F = 2** | **Treatment D.F = 2** | **Genotype D.F = 19** | **Treat × Genotype D.F = 38** | **Error D.F = 118** |
| Days to 50% flowering | 0.69 ns | 516.29 ** | 38.11 ** | 2.16 * | 5.48 |
| Days to 90% maturity | 0.8 ns | 398.18 ** | 217.21 ** | 8.34 * | 6.05 |
| Grain filling period | 0.48 ns | 10.78 ** | 70.82 ** | 5.33 * | 11.95 |
| Plant height | 0.18 ns | 1658.84 ** | 136.72 ** | 8.45 * | 7.4 |
| Tillers per plant | 0.64 ns | 411.62 ** | 13.75 ** | 1.88 * | 0.66 |
| Spikelet per spike | 0.87 ns | 495.61 ** | 11.27 ** | 3.45 * | 2.09 |
| No.grains per spike | 1.04 ns | 815.01 ** | 43.75 ** | 3.92 * | 10.46 |
| 1000 grain weight | 0.51 | 603.55 ** | 49.87 ** | 6.37 ** | 3.88 |
| Biol. Yield per plant | 0.37 | 1989.42 ** | 177.96 ** | 13.05 ** | 5.7 |
| GrainYield per plant | 0.87 ns | 599.36 ** | 81.76 ** | 6.29 ** | 3.77 |
| **Physiological characters** | | | | | |
| Flag leaf area | 4.52 * | 1061.04 ** | 90.73 ** | 12.96 ** | 1.368 |
| Relative water content | 0.69 ns | 192.18 ** | 18.68 ** | 3.39 * | 1.42 |
| Chlorophyll content | 0.82 ns | 71.87 ** | 4.99 ** | 9.24 * | 1.48 |

Significant at * $p < 0.05$; ** $p < 0.01$ level and ns = non-significant.

### 3.1. Days to 50% Flowering and Days to 90% Maturity

The early days to 50% flowering were observed in Anmole-91 followed by SKD-1 (66 days), Moomal-02 (69 days), and Marvi (70.33 days) with application normal watering (T1). The data in (Table 3) showed that except Anmole-91 genotype the most wheat genotypes revealed a decline in days to 50% flowering under drought stress-1 (T1). Imdad-05, SKD-I (−9 days) and Faisalabad-85 (−8.67 days), and TD-1 showed a minimum reduction in days to 50% flowering under same water stress as compared to susceptible Moomal-02 (−19.7), Inqalab-95 (−17.3), and NIA-Sarang (−16.7). Some later studies suggested that the flowering stage was found to be more sensitive to the stressful condition [15]. Wheat genotypes also revealed a decline in days to 50% flowering underwater stress-2 (T2) as compared to normal watering. Early flowering was noted in SKD-1 (61.67 days) followed by Moomal-02 (64.33 days) and Marvi (65 days). Maximum reduction in days to 50% flowering showed in Anmole-91 (−12.67 days) followed by T-83, Bhitai, and NIA-Sarang which showed susceptibility to this water stress. At some extent tolerant were TD-1 (−3.34), Soghat-90, SKD-1 (−4.34), and Chakwal-83 (−4.66), respectively. These results are in support of Yazdansepas [16], who reported significant effects of irrigation on interaction, yield, and related traits while studying terminal drought stress.

**Table 3.** Impact of water stress on days to 50% flowering and days to 90% maturity of wheat genotypes.

| Genotypes | Days to 50% Flowering | | | | | Days to 90% Maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Control (T0)** | **Stress-1 (T1)** | **Stress-2 (T2)** | **RD-1** | **RD-2** | **Control (T0)** | **Stress-1 (T1)** | **Stress-2 (T2)** | **RD-1** | **RD-2** |
| Chakwal-83 | 85.33 | 69.67 | 80.67 | −15.70 | −4.66 | 129.33 | 116.33 | 123.67 | −13.0 | −5.66 |
| Kohinoor | 79.00 | 62.67 | 73.33 | −16.30 | −5.67 | 127.67 | 112.33 | 123.0 | −15.3 | −4.67 |
| Abadgar-93 | 81.33 | 67.00 | 74.67 | −14.30 | −6.66 | 123.67 | 111.33 | 119.67 | −12.3 | −4.00 |
| Anmole-91 | 64.33 | 66.67 | 77.00 | −2.34 | −12.67 | 133.33 | 120.33 | 126.67 | −13.0 | −6.66 |
| TJ-83 | 79.67 | 67.00 | 71.33 | −12.70 | −8.34 | 124.67 | 114.00 | 120.00 | −10.7 | −4.67 |
| Imdad-05 | 77.33 | 68.33 | 70.67 | −9.00 | −6.66 | 124.00 | 118.00 | 120.67 | −16.0 | −3.33 |
| Kiran-95 | 79.67 | 63.67 | 74.33 | −16.00 | −5.34 | 136.00 | 123.33 | 126.33 | −12.7 | −9.67 |
| Soghat-90 | 84.00 | 73.67 | 79.67 | −10.30 | −4.33 | 128.33 | 111.00 | 122.33 | −17.3 | −6.00 |
| SKD-1 | 66.00 | 57.00 | 61.67 | −9.00 | −4.33 | 149.33 | 116.67 | 68.67 | −36.7 | −30.66 |
| Drick | 82.00 | 67.00 | 76.00 | −15.00 | −6.00 | 128.00 | 121.33 | 122.00 | −6.67 | −6.00 |
| Bhitai | 79.33 | 66.00 | 71.00 | −13.30 | −8.33 | 129.67 | 119.00 | 125.00 | −10.7 | −4.67 |
| TD-1 | 73.67 | 64.33 | 70.33 | −9.34 | −3.34 | 101.33 | 139.00 | 88.33 | −7.33 | −13.0 |
| Sindh-81 | 80.67 | 67.00 | 75.00 | −13.70 | −5.67 | 128.67 | 122.67 | 123.67 | −26.0 | −5.00 |
| Moomal-02 | 69.67 | 50.00 | 64.33 | −19.70 | −5.34 | 124.00 | 107.33 | 113.33 | −16.7 | −10.67 |
| Marvi | 70.33 | 56.33 | 65.00 | −14.00 | −5.33 | 123.00 | 102.33 | 112.00 | −20.7 | −11.00 |
| Inqalab-95 | 79.00 | 61.67 | 71.33 | −17.30 | −7.67 | 127.33 | 114.00 | 119.67 | −13.3 | −7.66 |
| Sarsabz | 77.33 | 67.67 | 71.00 | −9.66 | −6.33 | 130.00 | 121.67 | 124.67 | −8.33 | −5.33 |
| NIA-Sarang | 83.00 | 66.33 | 74.67 | −16.70 | −8.33 | 128.67 | 117.67 | 121.67 | −19.0 | −7.00 |
| Faisalabad-85 | 79.00 | 70.33 | 73.33 | −8.67 | −5.67 | 127.00 | 121.00 | 123.33 | −16.0 | −3.67 |
| Mehran-89 | 80.33 | 64.00 | 75.33 | −16.30 | −5.00 | 125.67 | 118.00 | 121.00 | −17.7 | −4.67 |
| Mean | 77.55 | 64.82 | 72.53 | −12.70 | −5.02 | 124.98 | 112.42 | 117.28 | −12.6 | −7.70 |
| LSD (T) = 0.05% | T.Val = 2.08, S.E = 0.43, Crt. Val = 0.89 | | | * | * | T.val = 2.08, S.E = 0.45, Crt. V = 0.93 | | | * | * |
| LSD (G) = 0.05% | T. val = 2.08, S.E = 1.1, Crt. Val = 2.29 | | | 11 grp | 10 grp | T. val = 2.08, S.E = 1.16, Crt. Val = 2.41 | | | 13 grp | 14 grp |

Note: Control (T0), normal watering; Stress-1 (T1), stress from tillering to maturity; Stress-2 (T2), stress from Anthesis to maturity; RD-1, relative decrease stress-1 values from control (T0); and RD-2, relative decrease stress-2 values from control (T0) denoted in (v-). * shows the significant difference studied parameters of 20 wheat genotypes.

The data in (Table 3) showed that the early days to 90% maturity were observed in TD-1 (99.33 days) followed by Marvi (123 days), Abadgar-93 (123.67 days), Imdad-05 (124 days), and T-83 (124.67 days). However, the late were noted as SKD-1 (149 days), Kiran-95 (136 days), and Anmole-91(133.33 days) respectively under normal watering (T0). Results highlighted that most wheat cultivars reached early maturity under water stress-1 (T1). Marvi matured in 102.33 days, Moomal-02 taken 107.33 days, Soghat-90 taken 111 days, and Abadgar-89 111.33 days. SKD-1 was susceptible and showed decreased days (−36.7 days) as a greater decline in days to 90% maturity. The minimum reduction was noted in Mehran-89 (−7.67 days) and TD-1 (−7.33) correspondingly. Four wheat genotypes viz; Drick (−6.67 days), Imdad-05 (−6 days), Sindh-81 (−6 days), and Faisalabad-83 (−6 days) showed similar responses under the same water stress. Wheat genotypes presented reduced days to 90% maturity under water stress-2 (T2). The greater decrease from days to 90% maturity was noted in SKD-1 (−30.66 days) and minimum in Abadgar-93 (−4 days), Faisalabad-85 (−3.67 days) and Imdad-05 (−3.33 days) correspondingly. Wheat genotypes such as Kohinoor (−4.67 days), TJ-83 (−4.67 days), and Mehran-89 (−4.67 days) revealed comparable consequences under drought stress from anthesis to maturity (T2). These results are in accordance with Sharma and Kumar [17], who found significant genotypic variations in wheat agro-physiological traits characters under drought conditions. Abdulkerim [18] revealed that the days to 50% heading, days to 90% maturity were affected extremely through the main effects of bread wheat genotype and seed rate.

### 3.2. 1000 Grain Weight and Grain Yield Plant$^{-1}$

Under normal watering (T0), wheat genotypes performed differently for 1000 grain weight (g) (Table 4). The greater 1000-grain weight was noted in Abadgar-89 (49.33 g) followed by SKD-1(48.33), Chakwal-83 (43.33), NIA-Sarang (40.67), TJ-83, and Sindh-81 (40). A greater reduction in wheat 1000-grain weight was observed in wheat varieties under water stress from tillering to maturity (T1). The greater 1000-grain weight showed NIA-Sarang (37) followed by T-83 (32), Abadgar-89 (31.67), Kohinoor (31), and Soghat-90 (30.67). Susceptible for 1000 grain weight was noted Imdad-05 (−20 g). The minimum influence was noted in Anmole-91 (−7.33 g) and Moomal-02 (−6 g) respectively. Underwater stress from anthesis to maturity (T2), wheat varieties showed a reduction in 1000-grain weight except for Chakwal-83 (0.67 g) indicated in (Table 4). The higher 1000 grain weight, was noted in SKD-1 (42), followed by NIA-Sarang (38.67), Abadgar-89 (38), Chakwal-83 (35), Kiran-95 (33.33), Imdad-05 and Kohinoor (32), Drick and Sindh-81 (31.33). Chakwal-83 (0.679) was noted as tolerant to this water treatment. Pireivatlou and Yazdansepas [19], also studied the response of yield and components to pre-anthesis and post-anthesis drought stress. They reported a higher 1000 grain weight, which also indicated higher performance in pre-anthesis drought than post-anthesis.

**Table 4.** Impact of water stress on 1000-grain weight and grain yield plant$^{-1}$ of wheat genotypes.

| Genotypes | 1000-Grain Weight | | | | | Grain Yield Plant$^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control (T0) | Stress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 | Control (T0) | Sress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 |
| Chakwal-83 | 43.33 | 25.33 | 35.00 | −18.00 | 0.67 | 18.00 | 5.00 | 11.00 | −13.0 | −7.0 |
| Kohinoor | 35.33 | 31.00 | 32.00 | −4.33 | −3.33 | 20.00 | 8.33 | 11.00 | −11.7 | −9.0 |
| NIA-Sarang | 40.67 | 37.00 | 38.67 | −3.67 | −2.00 | 37.00 | 18.67 | 23.33 | −18.3 | −13.67 |
| Anmole-91 | 29.00 | 21.67 | 25.33 | −7.33 | −3.67 | 24.33 | 12.00 | 18.67 | −12.3 | −5.66 |
| TJ-83 | 40.00 | 32.33 | 36.00 | −7.67 | −4.00 | 35.67 | 19.67 | 21.00 | −16.0 | −14.67 |
| Imdad-05 | 39.67 | 19.67 | 32.00 | −20.0 | −7.67 | 21.00 | 5.67 | 14.00 | −15.3 | −7.0 |
| Kiran-95 | 38.33 | 23.67 | 33.33 | −14.7 | −5.00 | 16.67 | 7.00 | 13.00 | −9.67 | −3.67 |
| Soghat-90 | 39.67 | 30.67 | 37.33 | −9.00 | −2.34 | 36.67 | 12.00 | 21.33 | −24.7 | −15.34 |
| SKD-1 | 48.33 | 28.67 | 42.00 | −19.7 | −6.33 | 28.33 | 12.33 | 17.67 | −16.0 | −10.66 |
| Drick | 38.00 | 26.67 | 31.33 | −11.3 | −6.67 | 16.00 | 9.00 | 13.00 | −7.0 | −3.00 |
| Bhitai | 38.33 | 23.33 | 28.00 | −15.0 | −10.33 | 11.00 | 5.67 | 10.00 | −5.33 | −1.00 |
| TD-1 | 37.00 | 20.33 | 30.00 | −16.7 | −7.00 | 11.33 | 5.33 | 9.33 | −6.00 | −2.00 |
| Sindh-81 | 40.00 | 21.00 | 31.33 | −19.0 | −8.67 | 16.00 | 8.00 | 11.33 | −8.00 | −4.67 |
| Moomal-02 | 29.00 | 23.00 | 27.00 | −6.00 | −2.00 | 18.00 | 5.67 | 8.67 | −12.3 | −9.33 |
| Marvi | 31.33 | 22.33 | 26.33 | −9.00 | −5.00 | 15.67 | 7.33 | 12.33 | −8.34 | −3.34 |
| Inqalab-95 | 37.67 | 21.33 | 27.67 | −16.3 | −10.00 | 15.00 | 6.00 | 14.67 | −9.00 | −0.33 |
| Sarsabz | 37.33 | 21.00 | 31.00 | −16.3 | −6.33 | 16.00 | 5.67 | 9.33 | −10.3 | −6.67 |
| Abadgar-89 | 49.33 | 31.67 | 38.00 | −17.7 | −11.33 | 35.67 | 18.33 | 23.33 | −17.3 | −12.34 |
| Faisalabad-85 | 30.33 | 21.33 | 25.00 | −9.00 | −5.33 | 20.00 | 8.00 | 16.33 | −12.0 | −3.67 |
| Mehran-89 | 30.67 | 21.67 | 26.67 | −9.00 | −4.00 | 17.00 | 5.00 | 10.67 | −12.0 | −6.33 |
| Mean | 37.67 | 25.18 | 31.70 | −12.5 | −5.62 | 21.47 | 9.23 | 14.50 | −12.2 | −6.97 |
| LSD (T) = 0.05% | T. val = 2.08, S.E = 0.36, Crt. Val = 0.75 | | | * | * | T. val = 2.08, S.E = 0.36, Crt. Val = 0.74 | | | * | * |
| LSD (G) = 0.05% | T. val = 2.08, S.E = 0.93, Crt. Val = 1.93 | | | 8 grps | | T. val = 2.08, S.E = 0.92, Crt. Val = 1.9 | | | 10 grp | |
| LSD (T × G) = 0.05% | T. val = 2.08, S.E = 1.61, Crt. Val = 3.34 | | | 27 grp | | T. val = 2.08, S.E = 1.59, Crt. Val = 3.29 | | | 25 grp | |

Note: * shows the significant difference studied parameters of 20 wheat genotypes.

Grain yield plant$^{-1}$ under normal watering (T0) was highly different (Table 4). The impact of water stress seed production was obvious from the result indicated in (Table 4). Under normal watering (T0), the higher grain yield plant$^{-1}$ was received from NIA-Sarang (37 g) and Soghat-90 (36.67 g) and minimum showed in TD-1 (11.33 g) and Bhitai (11 g) respectively. The results indicated that the wheat varieties were significantly affected by water stress from tillering to maturity (T1). The highest decline in grain yield plant$^{-1}$ was observed in Soghat-90 (−24.67 g) which was screened as susceptible against Drick (−7 g) and TD-I (−6 g) respectively under same the water stress. The former studies highlighted that the maximum decline in genotype seed production was observed when drought stress application practices at blooming [20]. Similarly, drought stress was practiced during the grain filling period as a result more than 70% reduction was found in the seed weight of wheat genotypes, although the minimum decrease in seed production was found when drought stress was observed at tillering stage [21]. In addition, wheat cultivars showed a reduction in grain yield plant$^{-1}$ under water stress from anthesis to maturity (T2). Susceptibility was noted in Soghat-90 (−15.34 g) as compared to TD-I (−2 g) and Bhitai (−1 g) respectively. These results supported Shahryari [22], who reported the significant differences between genotypes for grain yield and contributing characters under terminal drought stress.

### 3.3. Plant Height and Tillers Plant$^{-1}$

The data in (Table 5) showed that Abadgar-89, Bhitai, and Mehran-89 (103.33 cm), and Drick were tall under normal watering (T0). Short statured noted as TD-I and SKD-1 (66 cm). Maximum reduced plant height under water stress from tillering to maturity (T1) was noticed in Moomal-02 (−42), Sarsabz (−39), and Bhitai (−37.33) all susceptible respectively (Table 5). Less influence was noticed in Chakwal-83 (−11.67) and Anmole-91 (−15 cm) under the same water stress. Water stress from anthesis to maturity (T2) affected Kohinoor (−29.33 cm), which showed a greater reduction in plant height, as compared with Moomal-02 (−28 cm) and NIA-Sarang (−23.33 cm). Less influence was noted in Chakwal-83, Anmole-91 (−9 cm) and Faisalabad-85 (−8 cm), respectively.

**Table 5.** Impact of water stress on plant height and tillers plant$^{-1}$ of wheat genotypes.

| Genotypes | Plant Height (cm) | | | | | Tillers Plant$^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control (T0) | Stress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 | Control (T0) | Stress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 |
| Chakwal-83 | 86.00 | 74.33 | 77.00 | −11.67 | −9.00 | 5.33 | 2.33 | 4.00 | −3.00 | −1.33 |
| Kohinoor | 96.33 | 69.77 | 67.00 | −26.56 | −29.33 | 6.67 | 2.67 | 5.33 | −4.00 | −1.34 |
| Abadgar-89 | 103.33 | 71.67 | 83.00 | −31.66 | −20.33 | 9.67 | 3.67 | 6.67 | −6.00 | −3.00 |
| Anmole-91 | 81.67 | 66.67 | 72.67 | −15.00 | −9.00 | 11.00 | 3.67 | 6.33 | −7.33 | −4.67 |
| TJ-83 | 97.00 | 66.00 | 81.67 | −31.00 | −15.33 | 7.67 | 2.67 | 4.67 | −5.00 | −3.00 |
| Imdad-05 | 86.33 | 65.33 | 69.67 | −21.00 | −16.66 | 6.67 | 2.33 | 4.67 | −4.34 | −2.00 |
| Kiran-95 | 86.00 | 55.67 | 63.33 | −30.33 | −22.67 | 7.00 | 3.00 | 4.33 | −4.00 | −2.67 |
| Soghat-90 | 85.67 | 56.00 | 72.33 | −29.67 | −13.34 | 8.33 | 3.33 | 5.33 | −5.00 | −3.00 |
| SKD-1 | 66.00 | 42.33 | 53.67 | −23.67 | −12.33 | 7.67 | 3.67 | 6.33 | −4.00 | −1.34 |
| Drick | 102.67 | 74.00 | 88.00 | −28.67 | −14.67 | 5.67 | 2.33 | 4.67 | −3.34 | −1.00 |
| Bhitai | 103.33 | 66.00 | 87.00 | −37.33 | −16.33 | 6.67 | 3.67 | 6.00 | −3.00 | −0.67 |
| TD-1 | 66.67 | 42.33 | 50.33 | −24.34 | −16.34 | 7.00 | 2.33 | 5.00 | −4.67 | −2.00 |
| Sindh-81 | 100.00 | 76.33 | 77.33 | −23.67 | −22.67 | 7.33 | 2.67 | 5.00 | −4.66 | −2.33 |
| Moomal-02 | 85.00 | 43.00 | 57.00 | −42.00 | −28.00 | 5.67 | 2.33 | 4.67 | −3.34 | −1.00 |
| Marvi | 77.00 | 53.00 | 64.00 | −24.00 | −13.00 | 6.67 | 2.67 | 4.67 | −4.00 | −2.00 |
| Inqalab-95 | 102.00 | 65.33 | 84.67 | −36.67 | −17.33 | 5.33 | 2.67 | 5.00 | −2.66 | −0.33 |
| Sarsabz | 97.67 | 58.67 | 76.00 | −39.00 | −21.67 | 5.67 | 2.33 | 4.67 | −3.34 | −1.00 |
| NIA-Sarang | 100.33 | 72.00 | 77.00 | −28.33 | −23.33 | 10.33 | 5.00 | 7.67 | −5.33 | −2.66 |
| Faisalabad-85 | 91.33 | 61.67 | 83.33 | −29.66 | −8.00 | 6.33 | 2.67 | 4.67 | −3.66 | −5.66 |
| Mehran-89 | 103.33 | 68.67 | 86.33 | −34.66 | −17.00 | 7.33 | 3.00 | 5.67 | −4.33 | −1.66 |
| Mean | 90.88 | 62.44 | 73.57 | −28.45 | −17.32 | 7.20 | 2.95 | 5.27 | −4.30 | −2.13 |
| LSD (T) = 0.05% | Tl = 2.08, S.E = 2.22, Crt. Val = 4.62 | | | * | * | 2.08, S.E = 0.15, Crt. V = 0.31 | | | * | * |
| LSD (G) = 0.05% | T. l = 2.08, S.E = 1.28, Crt. Val = 2.67 | | | 13 grp | | T. = 2.08, S.E = 0.38, Crt. Val = 0.8 | | | 9 grps | |
| LSD (T × G) = 0.05% | T = 2.08, S.E = 2.22, crt. = 4.62 | | | 22 grp | | T. val = 2.08, S.E = 0.66, Crt. = 1.38 | | | 16 grp | |

Note: * shows the significant difference studied parameters of 20 wheat genotypes.

Under normal watering (T0), wheat genotype Anmole-91 (11) showed the greatest number of tillers rather than NIA-Sarang (10.33) and Abadgar-89 (9.67) (Table 5). A lower number of tillers was noted in Chakwal-83, Inqalab-95, Sarsabz, Drick, and Moomal-02 (5.67). The data in (Table 5) revealed that the maximum decline in tillers plant$^{-1}$ was observed in Anmole-91 (−7.33), Abadgar-89, NIA-Sarang, TJ-83, Soghat-90 (−5), TD-1, Sindh-81 (−4.66), and Imdad-05 (−4.34) respectively. The reduction in the number of tiller plant$^{-1}$ was noted in Faisalabad-85 (−5.66) followed by Anmole-91 (−4.67) underwater stress-2 (T2). The Tolerant were noted as Drick, Moomal-02 and Sarsabz (−1.0), Inqalab-95 (−0.33), and Bhittai (−0.67). Yazdansepas [16] found that significant differences in water treatments and interactions. They found variations in genotypes under water stress and normal watering for yield and related traits.

### *3.4. Flag Leaf Area and Relative Water Content*

As shown in (Table 6), the maximum flag leaf area was observed under normal watering (T0), showed in Anmole-91 (18,390) followed by NIA-Sarang (17,925) and SKD-I (17,233). The shortest flag leaf was showed in Sarsabz (12,854) and Moomal-02 (12,955), respectively. As shown in (Table 6) also revealed that the greater decrease in flag leaf area was shown in Anmole-91 (−6827) as compared to SKD-I (−6169) underwater stress-1 (T1). Whereas, the less affected were Soghat-90 (−1729) and Inqalab-95 (−1691) respectively. The greater flag leaf area was noted in NIA-Sarang, SKD-1, TJ-83, Abadgar-89, and Anmole-91. Water stress from anthesis to maturity was shown in (T2) as a result the variety Anmole-91 (−3565) indicated that the greater reduction in flag leaf area rather than NIA-Sarang (−2789) and Kohinoor (−2767). While the less reduction was noted in Imdad-05 (−270) and Soghat-90 (−614), respectively in the flag leaf area. Solomon and Labuschange [23] also studied water stress effects on morpho-physiological characters and reported that significant differences were found in genotypes, interactions, and water stress treatments. They stated that flag leaf area was significantly affected by water stress and that drought-tolerant genotypes have fast early growth.

**Table 6.** Impact of water stress on flag leaf area and relative water content of wheat genotypes.

| Genotypes | Flag Leaf Area ($mm^2$) | | | | | Relative Water Content (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control (T0) | Stress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 | Control (T0) | Sress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 |
| Chakwal-83 | 16,034 | 11,566 | 13,711 | −4468 | −2323 | 63.50 | 48.87 | 53.50 | −14.63 | −10.00 |
| Kohinoor | 14,840 | 10,977 | 12,073 | −3863 | −2767 | 63.60 | 54.70 | 60.33 | −8.90 | −3.27 |
| Abadgar-89 | 16,089 | 14,193 | 15,183 | −1896 | −906 | 71.80 | 60.70 | 68.83 | −11.10 | −2.97 |
| Anmole-91 | 18,390 | 11,563 | 14,825 | −6827 | −3565 | 66.47 | 60.37 | 62.00 | −6.10 | −4.47 |
| TJ-83 | 14,235 | 11,031 | 13,463 | −3204 | −772 | 70.53 | 61.50 | 56.67 | −9.03 | −13.86 |
| Imdad-05 | 15,268 | 12,320 | 14,998 | −2948 | −270 | 59.60 | 53.87 | 52.93 | −5.73 | −6.67 |
| Kiran-95 | 13,343 | 10,860 | 11,453 | −2483 | −1890 | 59.63 | 43.43 | 52.10 | −16.20 | −7.53 |
| Soghat-90 | 14,262 | 12,533 | 13,648 | −1729 | −614 | 69.23 | 52.73 | 61.50 | −16.50 | −7.73 |
| SKD-1 | 17,233 | 11,064 | 14,778 | −6169 | −2455 | 76.27 | 62.53 | 56.63 | −13.74 | −19.64 |
| Drick | 15,158 | 12,856 | 14,133 | −2302 | −1025 | 60.17 | 48.40 | 52.70 | −11.77 | −7.47 |
| Bhitai | 13,069 | 10,859 | 11,688 | −2210 | −1381 | 62.80 | 55.20 | 58.30 | −7.60 | −4.50 |
| TD-1 | 14,952 | 11,679 | 13,440 | −3273 | −1512 | 63.73 | 47.43 | 54.33 | −16.30 | −9.40 |
| Sindh-81 | 13,795 | 10,856 | 12,595 | −2939 | −1200 | 63.13 | 52.87 | 54.43 | −10.26 | −8.70 |
| Moomal-02 | 12,955 | 11,063 | 12,206 | −1892 | −749 | 62.00 | 52.57 | 54.53 | −9.43 | −7.47 |
| Marvi | 13,814 | 10,981 | 12,746 | −2833 | −1068 | 63.13 | 15.07 | 53.37 | −48.06 | −9.76 |
| Inqalab-95 | 15,025 | 13,334 | 13,325 | −1691 | −1700 | 53.93 | 50.93 | 53.60 | −3.00 | −0.33 |
| Sarsabz | 12,854 | 10,755 | 12,028 | −2099 | −826 | 68.33 | 50.07 | 51.83 | −18.26 | −16.5 |
| NIA-Sarang | 17,925 | 14,759 | 15,136 | −3166 | −2789 | 70.97 | 66.63 | 56.10 | −4.34 | −14.87 |
| Faisalabad-85 | 15,625 | 12,332 | 14,832 | −3293 | −793 | 59.90 | 42.03 | 50.00 | −17.87 | −9.90 |
| Mehran-89 | 14,782 | 11,862 | 13,527 | −2920 | −1555 | 61.50 | 54.70 | 52.27 | −6.80 | −9.23 |
| Mean | 14,982.4 | 11,872.15 | 13,489.4 | −3110.25 | −1508 | 64.51 | 51.73 | 55.80 | −12.78 | −8.71 |
| LSD (T) = 0.05% | T. vl = 2.08, S.E = 67.53, Crt.Val = 140.25 | | | * | | T. val = 2.08, S.E = 0.59, Crt. Val = 1.22 | | | * | |
| LSD (G) = 0.05% | T. vl = 2.08, S.E = 174.37, Crt.Vl = 362.12 | | | 11 grp | | T. val = 2.08, S.E = 1.52, Crt. Val = 3.16 | | | 9 grps | |
| LSD (T × G) = 0.05% | T. val = 2.08,S.E = 302.02, Crt.Val = 627.2 | | | 27 grp | | T. val = 2.08, S.E = 2.64, Crt. Val = 5.48 | | | 21 grp | |

Note: * shows the significant difference studied parameters of 20 wheat genotypes.

Relative water content is an important screening technique to identify drought-tolerant genotypes. Data presented in (Table 6) showed that SKD-1 (76.27) retained high water content under normal watering (T0) followed by Abadgar-89 (71.8) and NIA-Sarang (70.97). The lowest of all concerning water content was Inqalab-95 (53.93) in the same watering. The data in (Table 6) showed that the maximum relative water content was noted in Marvi (−48.06) as compared with Sarsabz (−18.26) under drought stress (T1). The lowest reduction of water content was in Inqalab-95 (−3.00) and NIA-Sarang. Table 6 found that the greater decline was noted in KD-I (−19.64) as compared with Sarsabz (−16.5) and NIA-Sarang (−14.87) in respect to stress-2 (T2). The lowest reduced water content showed Inqalab-95 (−0.33), followed by Abadgar-89 (−2.27). Solomon and Labuschange [23] revealed that the morpho-physiological traits, especially physiological traits were highly affected by water stress.

### *3.5. Grain Filling Period and Biological Yield Plant$^{-1}$*

The grain filling period Kiran-95 (56.33) genotype took a large period for grain filling as compared to Moomal-02 (54.33), Marvi and Sarsabz (52.67) under normal watering (T0) (Table 7). Besides, four wheat genotypes, viz; SKD-1 (−27.66), Soghat-90 (−7.34), Marvi (−6.67), and TD-1 (−2) found to decline as compared with other wheat cultivars under water stress from tillering to maturity (T1). The wheat cultivar SKD-1 showed the lowest grain filling period (−26.33), followed by TD-1 (−9.67) underwater stress-2 (T2).

**Table 7.** Impact of water stress on grain filling period and biological yield plant$^{-1}$ of wheat genotypes.

| Genotypes | Grain Filling Period (days) | | | | | Biological Yield Plant$^{-1}$ (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Control (T0)** | **Stress-1 (T1)** | **Stress-2 (T2)** | **RD-1** | **RD-2** | **Control (T0)** | **Stress-1 (T1)** | **Stress-2 (T2)** | **RD-1** | **RD-2** |
| Chakwal-83 | 44.00 | 46.67 | 43.00 | 2.67 | −1.00 | 42.67 | 13.33 | 26.67 | −29.34 | −16.00 |
| Kohinoor | 48.67 | 49.67 | 49.33 | 1.00 | 0.66 | 48.67 | 20.00 | 32.00 | −28.67 | −16.67 |
| Abadgar-89 | 42.33 | 44.33 | 45.00 | 2.00 | 2.67 | 81.67 | 38.67 | 50.33 | −43.00 | −31.34 |
| Anmole-91 | 49.00 | 53.67 | 49.67 | 4.67 | 0.67 | 58.33 | 29.33 | 44.00 | −29.00 | −14.33 |
| TJ-83 | 45.00 | 47.00 | 48.67 | 2.00 | 3.67 | 72.33 | 39.00 | 46.33 | −33.33 | −26.00 |
| Imdad-05 | 48.00 | 49.67 | 50.00 | 1.67 | 2.00 | 52.00 | 19.33 | 36.00 | −32.67 | −16.00 |
| Kiran-95 | 56.33 | 59.67 | 52.00 | 3.34 | −4.33 | 40.67 | 15.67 | 26.67 | −25.00 | −14.00 |
| Soghat-90 | 44.67 | 37.33 | 42.67 | −7.34 | −2.00 | 74.33 | 27.33 | 43.33 | −47.00 | −31.00 |
| SKD-1 | 33.33 | 50.67 | 7.00 | −27.66 | −26.33 | 59.00 | 27.00 | 39.00 | −32.00 | −20.00 |
| Drick | 46.00 | 54.33 | 46.00 | 8.33 | 0.00 | 40.33 | 26.00 | 32.67 | −14.33 | −7.66 |
| Bhitai | 50.33 | 53.00 | 54.00 | 2.67 | 3.67 | 31.00 | 15.00 | 25.00 | −16.00 | −6.00 |
| TD-1 | 27.67 | 29.67 | 18.00 | −2.00 | −9.67 | 27.33 | 13.67 | 23.33 | −13.66 | −4.00 |
| Sindh-81 | 48.00 | 57.33 | 48.67 | 9.33 | 0.67 | 41.67 | 20.00 | 32.00 | −21.67 | −9.67 |
| Moomal-02 | 54.33 | 57.33 | 49.00 | 3.00 | −5.33 | 42.67 | 16.67 | 23.67 | −26.00 | −19.00 |
| Marvi | 52.67 | 46.00 | 47.00 | −6.67 | −5.67 | 40.00 | 18.00 | 29.67 | −22.00 | −10.33 |
| Inqalab-95 | 48.33 | 49.67 | 48.33 | 1.34 | 0.00 | 39.67 | 14.00 | 31.67 | −25.67 | −8.00 |
| Sarsabz | 52.67 | 56.67 | 53.67 | 4.00 | 1.00 | 44.00 | 15.00 | 21.67 | −29.00 | −22.33 |
| NIA-Sarang | 45.67 | 51.33 | 47.00 | 5.66 | 1.33 | 71.00 | 36.67 | 49.67 | −34.33 | −21.33 |
| Faisalabad-85 | 48.67 | 50.67 | 50.00 | 2.00 | 1.33 | 41.33 | 19.67 | 37.00 | −21.66 | −4.33 |
| Mehran-89 | 45.33 | 53.00 | 45.67 | 7.67 | 0.34 | 37.33 | 12.00 | 23.33 | −25.33 | −14.00 |
| Mean | 46.55 | 49.88 | 44.73 | −0.28 | −1.82 | 49.30 | 21.82 | 33.70 | −27.48 | −15.60 |
| LSD (T) = 0.05% | T. val = 2.08, S.E = 0.63, Crt. Val = 1.31 | | | * | | T. val = 2.08, S.E = 0.44, Crt. Val = 0.91 | | | * | |
| LSD (G) = 0.05% | T. val = 2.08, S.E = 1.63, Crt. Val = 3.38 | | | 10 grp | | T. val = 2.08, S.E = 1.13, Crt. Val = 2.34 | | | 10 grp | |
| LSD (T × G) = 0.05% | T. val = 2.08, S.E = 2.82, Crt. Val = 5.86 | | | 22 grp | | T. val = 2.08, S.E = 1.96, Crt. Val = 4.06 | | | 27 grp | |

Note: * shows the significant difference studied parameters of 20 wheat genotypes.

The results in (Table 7) highlighted that under normal watering (T0), the highest biological yield was observed in Abadgar-89 (81.67 g), as compared to Soghat-90 (74.33 g), TJ-83 (72.33 g), and NIA-Sarang (71 g). The varieties such as T-83, Abadgar-89, and NIA-Sarang showed high biological yield as compared to other wheat cultivars. The susceptible genotype was Soghat-90 (−47) as compared with Abadgar-89 (−43), NIA-Sarang (−34.33) and T-83 (−33.33). The greater biological yield was noted in Abadgar-89 (50.33) as compared with NIA-Sarang (49.67), T-83 (46.33), Anmole-91 (44), and Soghat-90 (43.33) underwater stress-2 (T2). Susceptible were Abadgar-89 and Soghat-90. Tolerant for this stress were TD-1 and Faisalabad-85. Solomon and Labuschange [23] also indicated highly influence on water stress. The greater decrease in biological yield plant$^{-1}$ (g) was noted in Soghat-90 (−47 g), followed by Abadgar-89 (−43 g) and NIA-Sarang (−34.33 g) underwater stress-1 (T1). As a result, the TD-1 genotype observed the lowest decline (−13.66). Underwater stress from anthesis to maturity (T2) liable variety was Abadgar-89 (−31.34 g) followed by Soghat-90 (−31 g), TJ-83 (−26 g), Sarsabz (−22.33 g), NIA-Sarang (−21.33 g) and SKD-1

(−20 g) respectively. However, the lowest biological yield noted in Sarsabz (21.67), TD-1 (−4.00) and Faisalabad-85 (−4.33) under the same water stress were tolerant.

### 3.6. Number of Spikelet Spike$^{-1}$ and Number of Grains Spike$^{-1}$

The data in (Table 8) indicated that the NIA-Sarang (72) showed the highest grain number rather than Soghat-90 (65) and TJ-83 (64.33) under normal watering (T0). The maximum number of grains in Soghat-90 (−37.67) followed by TJ-83 (−33.66) and Abadgar-89 (−33.34) under stress-1 (T1). The NIA-Sarang genotype showed high grains followed by T-83 (30.67), and Abadgar-89 (30.33). Soghat-90 (−23) genotype showed the maximum decline in the number of grains as compared to TJ-83 (−22.66) and NIA-Sarang (−21.33), while the lowest reduction was observed in Moomal-02 (−7.67) genotype under water stress-2 (T2). As a result, the maximum grains were noted in NIA-Sarang (50.67) genotype followed by Abadgar-89 (46), Soghat-90 (42), TJ-83 (41.67), and SKD-1 (41.33), respectively.

**Table 8.** Impact of water stress on a number of spikelet spike$^{-1}$ and number of grains spike$^{-1}$ of wheat genotypes.

| Genotypes | Number of Spikelet Spike$^{-1}$ | | | | | Number of Grains Spike$^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Control (T0)** | **Stress-1 (T1)** | **Stress-2 (T2)** | **RD-1** | **RD-2** | **Control (T0)** | **Sress-1 (T1)** | **Stress-2 (T2)** | **RD-1** | **RD-2** |
| Chakwal-83 | 24.33 | 12.67 | 18.33 | −11.66 | −6.00 | 36.67 | 18.67 | 25.67 | −18 | −11 |
| Kohinoor | 23.00 | 13.00 | 18.33 | −10.00 | −4.67 | 44.00 | 27.33 | 36.00 | −16.67 | −8 |
| Abadgar-89 | 23.67 | 15.00 | 20.33 | −8.67 | −3.34 | 63.67 | 30.33 | 46.00 | −33.34 | −17.67 |
| Anmole-91 | 24.33 | 15.67 | 21.00 | −8.66 | −3.34 | 50.67 | 26.00 | 37.67 | −24.67 | −13 |
| TJ-83 | 22.33 | 13.67 | 18.33 | −8.66 | −4.00 | 64.33 | 30.67 | 41.67 | −33.66 | −22.66 |
| Imdad-05 | 22.33 | 12.33 | 17.67 | −10.00 | −4.66 | 43.00 | 20.33 | 33.00 | −22.67 | −10 |
| Kiran-95 | 20.33 | 13.67 | 17.67 | −6.66 | −2.66 | 45.33 | 23.00 | 36.33 | −22.33 | −9 |
| Soghat-90 | 22.33 | 13.00 | 19.67 | −9.33 | −2.66 | 65.00 | 27.33 | 42.00 | −37.67 | −23 |
| SKD-1 | 24.33 | 14.33 | 17.67 | −10.00 | −6.66 | 61.67 | 29.67 | 41.33 | −32 | −20.34 |
| Drick | 22.33 | 12.33 | 18.33 | −10.00 | −4.00 | 45.33 | 28.00 | 36.00 | −17.33 | −9.33 |
| Bhitai | 20.33 | 11.00 | 17.00 | −9.33 | −3.33 | 43.33 | 21.33 | 32.33 | −22 | −11 |
| TD-1 | 21.67 | 12.33 | 15.67 | −9.34 | −6.00 | 37.00 | 16.00 | 27.00 | −21 | −10 |
| Sindh-81 | 23.67 | 10.33 | 18.33 | −13.34 | −5.34 | 49.67 | 27.67 | 38.67 | −22 | −11 |
| Moomal-02 | 21.67 | 9.67 | 18.33 | −12.00 | −3.34 | 36.67 | 20.67 | 29.00 | −16 | −7.67 |
| Marvi | 17.67 | 11.67 | 15.67 | −6.00 | −2.00 | 44.67 | 24.67 | 35.00 | −20 | −9.67 |
| Inqalab-95 | 19.67 | 14.33 | 17.00 | −5.34 | −2.67 | 44.00 | 23.67 | 34.67 | −20.33 | −9.33 |
| Sarsabz | 16.33 | 12.33 | 15.67 | −4.00 | −0.66 | 36.67 | 22.67 | 27.67 | −14 | −9 |
| NIA-Sarang | 22.33 | 19.00 | 20.33 | −3.33 | −2.00 | 72.00 | 36.33 | 50.67 | −35.67 | −21.33 |
| Faisalabad-85 | 18.33 | 12.33 | 16.33 | −6.00 | −2.00 | 43.67 | 21.33 | 31.00 | −22.34 | −12.67 |
| Mehran-89 | 17.67 | 14.33 | 15.67 | −3.34 | −2.00 | 49.67 | 25.00 | 39.00 | −24.67 | −10.67 |
| Mean | 21.43 | 13.15 | 17.87 | −8.28 | −3.57 | 48.85 | 25.03 | 36.03 | −23.82 | −12.82 |
| LSD (T) = 0.05% | T. val = 2.08, S.E = 0.26, Crt. Val = 0.55 | | | * | | T. val = 2.08, S.E = 0.59, Crt. Val = 1.23 | | | * | |
| LSD (G) = 0.05% | T. val = 2.08, S.E = 0.68, Crt. Val = 1.42 | | | 10 grp | | T. val = 2.08, S.E = 1.53, Crt. Val = 3.17 | | | 8 grps | |
| LSD (T × G) = 0.05% | T. val = 2.08, S.E = 1.18, Crt. Val = 2.45 | | | 20 grp | | T. val = 2.08, S.E = 2.64, Crt. Val = 5.48 | | | 26 grp | |

Note: * shows the significant difference studied parameters of 20 wheat genotypes.

As shown in (Table 8), the number of spikelets under normal watering (T0) was high in Anmole-91, Chakwal-83, and SKD-1 (24.33) as compared to Abadgar-89 and Sindh-81 (23.67) and lowest noted in Sarsabz (16.33). The relative efficacy of wheat cultivars for a number of spikelets showed that Sindh-81 (−13.34) was largely affected followed by Moomal-02 (−12), Chakwal-83 (−11.66), Drick, and Imdad-05 (−10), respectively, under water stress-1 (T1). The maximum decrease in the number of spikelet spike$^{-1}$ was found in SKD-1 (−6.66) as compared to Chakwal-83 (−6) and TD-1 (−6), but the lowest reduction was noted in Sarsabz (−0.66) underwater stress-2 (T2).

### 3.7. Chlorophyll Content and Harvest Index Plant$^{-1}$

The data in (Table 9) revealed that under normal watering (T0), TJ-83 (54.57), observed the highest chlorophyll content, as compared to NIA-Sarang (53.33), SKD-1 (53.03), and TD-1 (52.4). Nevertheless, the minimum chlorophyll content was observed in Sarsabz (44.63). The maximum decrease of chlorophyll was found in TJ-83 (−10.97) genotype, rather than Chakwal-83 (−9.47), Drick (−7.87), and Bhittai (−7.34) underwater stress-1

(T1). The lowest chlorophyll content was noted in Faisalabad-85 (−1.37), which showed tolerance rather than other studied genotypes. Meanwhile, TJ-83 genotype showed the highest decrease in chlorophyll content (−9.1), as compared to Soghat-90 (−7.9), SKD-1 (−7.56), Anmole-91 (−7.4), TD-1 (−6.97), Abadgar-89 (−6.9), Bhittai (−6.44), Moomal-02 (−5.66), NIA-Sarang (−5), Mehran-89 (−4.97), Chakwal-83, Drick and Marvi (−4.07) underwater stress-2 (T2). On the other hand, the lowest reduction was noted in Kohinoor (−0.1), Faisalabad-85 (−0.9), and Inqalab-95. Drought stress can also influence plants in terms of decrease in chlorophyll content [24].

**Table 9.** Impact of water stress on chlorophyll content and harvest index plant$^{-1}$ of wheat genotype.

| Genotypes | Chlorophyll Content | | | | | Harvest Index Plant$^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control (T0) | Stress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 | Control (T0) | Sress-1 (T1) | Stress-2 (T2) | RD-1 | RD-2 |
| Chakwal-83 | 50.90 | 41.40 | 46.27 | −9.47 | −4.60 | 40.80 | 36.40 | 39.40 | −4.40 | −1.40 |
| Kohinoor | 48.00 | 41.83 | 47.90 | −6.17 | −0.10 | 40.37 | 38.73 | 39.07 | −1.64 | −1.30 |
| Abadgar-89 | 50.37 | 43.33 | 43.47 | −7.04 | −6.90 | 39.83 | 36.97 | 38.90 | −2.86 | −0.93 |
| Anmole-91 | 51.07 | 44.60 | 43.67 | −6.47 | −7.40 | 42.77 | 39.63 | 40.87 | −3.14 | −1.90 |
| TJ-83 | 54.57 | 43.60 | 45.47 | −11.0 | −9.10 | 41.03 | 37.13 | 39.47 | −3.90 | −1.56 |
| Imdad-05 | 46.63 | 43.60 | 44.07 | −3.03 | −2.56 | 40.90 | 35.83 | 39.33 | −5.07 | −1.57 |
| Kiran-95 | 47.43 | 41.30 | 44.70 | −6.13 | −2.73 | 42.17 | 34.53 | 39.60 | −7.64 | −2.57 |
| Soghat-90 | 51.87 | 44.57 | 43.97 | −7.30 | −7.90 | 41.47 | 36.67 | 41.03 | −4.80 | −0.44 |
| SKD-1 | 53.03 | 47.53 | 45.47 | −5.50 | −7.56 | 41.27 | 35.97 | 40.23 | −5.30 | −1.04 |
| Drick | 48.97 | 41.10 | 44.37 | −7.87 | −4.60 | 41.30 | 37.13 | 41.13 | −3.99 | −0.17 |
| Bhitai | 48.67 | 41.33 | 42.23 | −7.34 | −6.44 | 41.83 | 36.40 | 41.37 | −5.43 | −0.46 |
| TD-1 | 52.4 | 46.63 | 45.43 | −5.77 | −6.97 | 41.27 | 38.07 | 40.67 | −3.20 | −0.60 |
| Sindh-81 | 45.93 | 42.73 | 44.00 | −3.20 | −1.93 | 41.73 | 37.20 | 40.10 | −4.53 | −1.63 |
| Moomal-02 | 48.93 | 43.93 | 43.27 | −5.00 | −5.66 | 40.87 | 36.70 | 39.80 | −4.17 | −1.07 |
| Marvi | 51.77 | 45.20 | 47.70 | −6.57 | −4.07 | 40.50 | 38.50 | 39.97 | −2.00 | −0.53 |
| Inqalab-95 | 45.60 | 41.60 | 44.60 | −4.00 | −1.00 | 41.03 | 38.23 | 40.07 | −2.80 | −0.96 |
| Sarsabz | 44.63 | 40.90 | 42.53 | −3.73 | −2.10 | 41.87 | 38.00 | 39.93 | −3.87 | −1.94 |
| NIA-Sarang | 53.33 | 50.93 | 48.33 | −2.40 | −5.00 | 41.27 | 39.60 | 40.57 | −1.67 | −0.70 |
| Faisalabad-85 | 47.40 | 46.03 | 46.50 | −1.37 | −0.90 | 41.73 | 38.47 | 40.07 | −3.26 | −1.66 |
| Mehran-89 | 46.20 | 43.43 | 41.23 | −2.77 | −4.97 | 42.37 | 38.47 | 40.43 | −3.90 | −1.94 |
| Mean | 49.38 | 43.78 | 44.76 | −5.61 | −4.63 | 41.32 | 37.43 | 40.10 | −3.89 | −1.22 |
| LSD (T) = 0.05% | T. val = 2.08, S.E = 0.5, Crt. Val = 1.04 | | | * | | T. val = 2.08, S.E = 0.27, Crt. Val = 0.52 | | | * | |
| LSD (G) = 0.05% | T. val = 2.08, S.E = 1.29, Crt. Val = 2.68 | | | 9 grps | | T. val = 2.08, S.E = 0.92, Crt. Val = 1.81 | | | 6 grp | |
| LSD (T × G) = 0.05% | T. val = 2.08, S.E = 2.23, Crt. Val = 4.64 | | | 20 grp | | T. val = 2.08, S.E = 1.59, Crt. Val = 3.13 | | | 24 Grp | |

Note: * shows the significant difference studied parameters of 20 wheat genotypes.

Under normal watering (T0), Anmole-91 (42.77) showed that the highest harvest index as compared to Mehran-89 (42.37) and Kiran-95 (42.17) underwater stress-1 (T1) (Table 9). The genotype Kiran-95 (−7.64) showed the highest decrease in harvest index as compared to Bhittai (−5.43), SKD-1 (−5.3), and Imdad-05 (−5.07). Whereas, the lowest decline in harvest index was observed by the Abadgar-89 genotype. Kiran-95 (−2.57) indicated a great decline in harvest index, while the lowest reduction in harvest index was noted in Drick (−0.17) underwater stress-2 (T2).

### *3.8. Redundancy Analysis between the Morpho-Physiological Traits of Twenty Wheat Genotypes*

Redundancy analysis (RDA) was performed to explore the association among the morpho-physiological traits viz., plant height, grain filling period, days to 50% flowering, days to 90% maturity, harvest index plant$^{-1}$, biological yield, 1000 grain weight, grain yield plant$^{-1}$, tillers plant$^{-1}$, number of grains spike$^{-1}$, number of spikelets spike$^{-1}$, relative water content, flag leaf area and chlorophyll content underwater treatment viz., control, stress-1 and stress-2 (Figure 3a–c). The RDA revealed that morpho-physiological traits of twenty can explain (32.87%) of the total variance. The results showed that grain yield per plant, number of grains per spike, number of spikelets per spike were clustered to gather with chlorophyll content, and observed far from plant height, harvest index per plant, grain filling period, and days to 50% flowering. In addition, 1000 grain weight, tillers per plant, biological yield per plant, and days to 90% maturity were clustered to gather with relative water content, and flag leaf area and far from plant height, harvest index per plant, grain filling period, and days to 50% flowering under control treatment (Figure 3a). The data in (Figure 3b) indicated that the RDA showed that morpho-physiological traits of twenty can explain (30.32%) of the total variance. The harvest index plant$^{-1}$, tillers plant$^{-1}$, grain yield plant$^{-1,}$ and days to 90% maturity were clustered to gather with chlorophyll content and observed far from the grain filing period. Furthermore, the number of spikelets spike$^{-1}$, biological yield plant$^{-1}$, number of grains spike$^{-1}$, and 1000 grain weight were clustered to gather with flag leaf area. Besides, days to 50% flowering and plant height were clustered to gather relative water content in stress-1 treatment. As shown in (Figure 3c) the RDA data indicated that the morpho-physiological traits of twenty can explain (29.94%) of the total variance in stress 2 treatment. The data revealed that 1000 grain weight, biological yield plant$^{-1}$, and grain yield plant$^{-1}$ were clustered to gather with chlorophyll content, and found far from grain filling period, days to 90% maturity, harvest index plant$^{-1}$, and plant height. Moreover, the number of grains spike$^{-1}$, number of spikelets spike$^{-1}$, tillers plant$^{-1}$ were clustered to gather with flag leaf area. Also, the days to 50% flowering was positively associated with relative water content. Likewise, Zerga [25,26] reported such a correlation in wheat. Besides, Gupta [10] found that two wheat genotypes indicated a positive correlation between leaf area and grain yield. Abdulkerim [18] stated that the interaction consequence of genotype and seed rate considerably affected thousand kernels weight, number of effective tillers and number of kernels spike$^{-1}$ and wheat yield. Banerjee [27] observed that a significantly higher correlation between normalized water stresses tolerance index and thermal image-based stress indices in ten wheat genotypes.

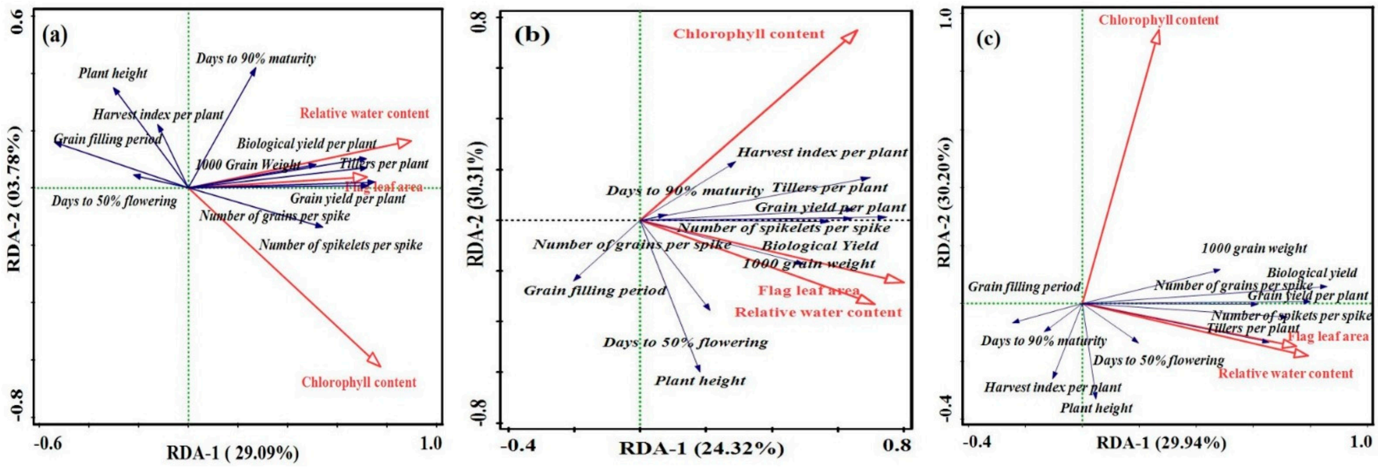


**Figure 3.** Redundancy analysis (RDA) showing the association between the morpho-physiological traits of twenty wheat genotypes under different water treatments such as control (**a**), stress-1 (**b**), and stress-2 (**c**).

## 4. Advantages and Disadvantages of Research Work

- The advatage of the recommended wheat cultivars screenout was that the cultivars will response in grain yield under arid areas of Pakistan;
- These cultivars will need lower inputs against irrigated areas;
- The studied cultivars will take part in food security in drought prone areas;
- The disadvantages of present study can be considered, namely that the studied cultivars may produce less grain yield in arid areas as compared to irrigated areas;
- Lower biomass will be obtained under arid areas as compared to irrigated areas.

## 5. Conclusions

It was concluded that different water treatments affected some morpho-physiological traits of twenty wheat genotypes under the ex-situ condition. Indeed, the wheat cultivars showed the highest susceptibility under water stress from tillering to maturity (T1) in respect of normal watering (T0) and water stress-2 (T2) from anthesis to maturity. Though some wheat genotypes revealed high yield under water stress, it would be better to select wheat genotypes under normal watering. Kiran-95 genotype took a large period for grain filling as compared to Moomal-02 (54.33), Marvi, and Sarsabz under normal watering (T0). Besides, wheat cultivars Anmole-90, Chakwal-83, Faisalabad-85, NIA-Sarang, TJ-83, TD-1, and Sarsabz were found best performing lines as compared to other genotypes. It is suggested that the best performing genotypes must be focused on the mechanism and molecular level of research between morpho-physiological traits of twenty wheat genotypes under water deficit areas.

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