Research Article

Genetic response of diverse sunflower genotypes in contrasting moisture regimes for various physiological and growth parameters at early developmental stage

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Abstract
Sunflower has great capacity for bridge the edible oil gap in Pakistan. It ranks second to soybean in worldwide vegetable oil production. A greenhouse experiment was performed in the research area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Eleven (11) advanced lines along with Hysun-37 (Check) were evaluated under complete randomized design (CRD) replicated thrice for two water regimes and three harvestings at early developmental stage. Different morphological and physiological plant traits were recorded to find out genetic analysis of water stress tolerance in sunflower. Results for analysis of variance exhibited significantly differences among all sunflower genotypes for all the traits. Genotypes performed different under contrasting water regimes. Genotypes like A-25, A-50 and A-57 performed best under both normal and water stress condition due to increased shoot length, deep rooting pattern, increased number of root branches and possessing enormous mass of fresh and dry shoot and root traits. Presence of these enviable plant traits make them superior among all genotypes in comparison with hybrid variety. Correlation analysis indicated strong genotypic and phenotypic correlation between shoot length and shoot dry weight. Traits that possessed significant positive phenotypic correlation with shoot length were dry root weight and fresh root weight. Stress tolerant genotypes viz. A-25, A-50 and A-57 could be recommended for utilization in future sunflower breeding program and can be grown under water stress conditions for high yield.

Keywords: Correlation; Genetic variability; Seedling traits; Sunflower

Introduction
Deficiency of water is a crop limiting factor which affected growth and development of sunflower. Pakistan has arid and semi-arid climate, so drought is considered as one of the main problems of crop production in this
The shortage of edible oil in Pakistan is still persisting although the country has made an impressive improvement in agriculture. Only 29% of edible oil requirement of Pakistan is met through the local production and rest 71% of the country’s requirements are met through import costing huge amount of foreign exchange. The imported edible oils are mainly palm oil and soybean oil. The countries from which edible oil imported are Malaysia, Singapore, Argentina, Switzerland, Norway and South Korea. In domestic production, major share comes from cottonseed contributing 63% of local production. Sunflower contributes 16%, rapeseed-mustard (13%) and canola contributes 2%. Sunflower, rapeseed-mustard and canola are the potential crops, which can fulfill some requirements of edible oil in the country [1].

Sunflower is one of main oilseed crops in Pakistan. As an oilseed crop, it was introduced in Pakistan during 1960’s. Amongst non-conventional oilseed crops, sunflower has maximum potential for bridging the edible oil gap in Pakistan. Its seed contains high oil content ranging from 35-40% with some types up to 50% [2, 3]. Sunflower (Helianthus annuus L.) can contribute a big share in improving Pakistan’s local edible oil production due to its short duration, more oil contents, better fitting in the cropping pattern, tolerance to drought and its high yield potential. Sunflower oil is considered to be of supreme quality as it contains soluble vitamin A, D, E and K [4]. Due to high percentage of linoleic acid and low percentage of linolenic acid, that is most desirable character and lacked in other oilseeds its quality is better. Sunflower is grown mostly as a source of vegetable oil and proteins in many countries [5, 6] and is the second most important oilseed crop after soybean worldwide [7]. Sunflower is the 2nd major oilseed crop in Pakistan cultivated on 0.7 million hectares producing 0.144 million tons of oil which is 22% of the local edible oil production [8]. Unfortunately its yield per hectare (1345 kg ha⁻¹) is less than that of other countries like Turkey (2036 Kg ha⁻¹), China (1752Kg ha⁻¹) and USA (2036 kg ha⁻¹)[9]. Therefore, there is a need to evolve hybrids and varieties of sunflower with improved genetic potential for high achene yield and oil contents.

The soil and climatic conditions of Pakistan are highly favorable for sunflower. Area under sunflower cultivation is 216 thousand acres and production of oil is 41 thousand tones [10]. This situation needs improvement in production of oilseed crop cultivation. Unfortunately, its yield per hectare (1345 kg ha⁻¹) is less than that of other countries of the world. Genetic variation is present in sunflower breeding material for a developing country like Pakistan [11-14]. It is unfortunate to spend hard-earned foreign exchange for the procurement of edible oil. This situation signifies the importance of growing non-conventional oilseed crops along with the conventional.

Water stress develops when water efflux from the plant is greater than water influx into the plant. Physiological changes which occur in plants in response to water stress conditions are loss of turgor, closing of stomata and reduction in cell enlargement and reduced leaf area. All these effects ultimately decrease photosynthesis and respiration [15-16]. Photosynthesis decreased as reduction in contents of chlorophyll due to diminishing the irrigation water. The decrease correlates with root water contents in the leaves [17-19]. As a result overall production of crop decreased. Same case was also found in rapeseed and mustard and it was observed that drought stress severely hindered germination and early seedling growth of rapeseed cultivars [20]. Under water or salt stress conditions, growth and development in sunflower is
affected on vegetative stage or reproductive stage. The biomass in leaves, stems and seeds all were considerably decreased with irrigation salinity increase and a loss of about 25% in stem biomass was detected [21]. Sunflower has good potential for water stress tolerance because it has well developed root system and ability to stand well against temporary wilting. To withstand moisture stress condition, water stress tolerant varieties with low water requirement are need of the day. Consequently this study is undertaken to investigate the effect of water stress on sunflower at seedling stage. Further it is aimed to search for the genes imparting water stress tolerance; high emergence percentage and high seed yield and make up various parameters that influence yield directly and indirectly under water stress conditions. This knowledge will be of great value in designing future program for the development of sunflower cultivars for water stress resistance and will help in early identification of genotypes, which show attributes for water stress tolerance.

Materials and methods
The research studies reported in this write up were conducted in the green house of the Department of the Plant Breeding and Genetics, Ghazi University, D. G. Khan. The experimental material comprised of 11 sunflower populations (A-9, A-10, A-25, A-32, A-39, A-40, A-50, A-57, A-61 and A-94) and one hybrid (Hysun-37). The experiment was laid out in a Completely Randomized Design (CRD) under factorial arrangement with three replications and two treatments (normal and water stress). The seeds were sown in metallic trays filled with fresh river sand keeping plant to plant and row to row distance 1cm and 2cm, respectively. Water stress was created by withholding water i.e, 50% of normal, to find out its effect on all genotypes under study. After 20, 30 and 40 days of sowing the seedlings were uprooted. Data were recorded from the experiment for shoot length, root length, fresh shoot weight, fresh root weight, root branches, dry shoot weight, dry root weight, shoot water contents, root water contents, emergence percentage (%) and relative growth rate. The data collected were subjected to statistical analysis including analysis of variance and Least Significance Test (LSD) following the methods described by [22]. Further analysis for genotypic and phenotypic correlation among various characters was carried out using formula given [23] both under normal and water stress conditions.

Results and discussion
Analysis of variance
Results in Table 1 for analysis of variance for 12 seedling traits like fresh root length, fresh shoot length, fresh shoot weight, fresh root weight, root branches, dry shoot weight, dry root weight, shoot water contents and root water contents, emergence percentage (%), and relative growth rate indicated that all genotypes were different from each other due to highly significance values. Similarly highly significant results were obtained for both treatments i.e, well-watered and drought conditions for all traits except for emergence percentage. Results for harvests also exhibited highly significant variations all seedling traits except for emergence percentage. Interactions between genotypes, treatments and harvests at all levels were highly significant in all traits. These results indicated that all genotypes showed their behavior different under well-watered and drought conditions for all studied traits except or emergence percentage. Existence of genetic variability in plant material helps to find out the best line following selection method. Similar results for presence of genetic variability in sunflower were found by [13-14, 24-28] as they found genetic diversity in plant materials of sunflower in
their experiments and confirmed that existence of increased genetic diversity in plant material is a crucial part for successful sunflower varietal improvement program.

Comparison of mean expressions
Shoot elongation is an important trait that enables the plant to cope with drought stress. A-39 (39.09), A-25 (34.20), A-50 (35.77), A-57 (35.81) had increased in shoot length under well irrigated conditions (Figure 1) and showed best performance as increase in shoot length under normal conditions is desirable for increased in biomass of the plant while moisture stress reduced shoot length in all genotypes of sunflower. A-57, A-39, A-50 and A-32 having values (35.81), (27.61), (25.88), (25.37) respectively showed comparatively more growth than other genotypes under drought conditions. Present study indicated that under water stress condition, shoot elongated compared with normal conditions so that plant extension and development as well as chemical and biochemical progressions like respiration and photosynthesis were in agreement with [12,26, 29-30]. According to these, water stress declined shoot elongation. Some researchers worked on salinity for evaluation of sunflower genotypes and found that salinity decreased shoot length of sunflower [31].

Roots of plants is an important part of the plant to acquire moisture and minerals deep from soil thus such sunflower genotypes having increased root elongation possess more tolerant to drought.

Root length enlarged deep the soil in search of water in water stress conditions while roots are not increased in deep as water is available easily for normal growth and development of the plant. Under normal conditions, the genotypes A-9(11.26), A-57(11.31), A-50(9.10), A-25(7.98) showed good performance for this trait (Figure 2). While A-29(10.04), A-50 (9.76) and A-50 (9.76), A-57 (9.90) showed increased length of root under shortage of water. Elongation of roots under drought conditions enhanced the ability of plant to grow well and it is drought tolerant parameter. [12, 31] favored these results and observed that root length increased under stress conditions due to presence of resistant genes to cope with stress.

Fresh shoot weight is an important parameter to measure the growth of plant under normal and drought conditions as it contributed to increase the biomass production of the plant. The lines which showed best performance for this character were A-50, A-57, A-25, A-61, having values (2.95), (2.65), (2.68), (2.76) respectively under normal conditions while genotypes showing good performance under water stress, lines A-61(2.10), A-57(2.03), A-25(2.02), A-50(1.98), A-29(2.63) showed best performance(Figure 3). Shoot fresh weight contributed biomass per plant so under normal irrigation conditions, fresh weight of sunflower was increased but under water stress condition is was gradually decreased as less water was available for plant so growth of the plant was affected. These results were in agreement of the research of [32, 33] who also worked on sunflower to find effect of water stress on its growth and development.

A-29(0.70), A-57 (0.60), A-40 (0.54) exhibited best results for fresh root weight (Figure 4) under well-watered conditions while A-29 (1.09), A-25 (0.98), A-10 (0.96), A-57 (0.81) revealed high values for root weight under stressful environment. Increased size of roots of sunflower genotypes was crucial under water stress conditions and this trait favored the plant to survive efficiently under limited water as deep roots help the plant to take water from sub-surface of soil to combat shortage of water. Results in favor of presented research were found by [12, 31, 34-35] while contradictory results were found by [36] who
found that fresh root weight was reduced under water stress condition. Plant trait root branches (Figure 5) increased in most of genotypes under drought conditions in comparison with normal conditions as enhanced root branches amplified root fresh weight thus it improved the capability of plant to survive well to cope with water stress efficiently. So, A-32(36.13), A-50(32.17), A-57(28.44) performed best in case of root branches under normal irrigation conditions and A-57(40.91), A-32(42.72), A-50(32.0) under drought conditions. It indicated that fresh root weight was increased due to increased number of root branches [12].

In (Figure 6) indicated that A-50(36), A-25(34), A-39, A-57(28) exhibited more dry shoot weight in well-watered conditions. Dry shoot weight was adversely affected by water stress so lines having comparatively reduction in the weight were A-50 (23). While (Figure 7) having mean performance of dry root weight which is also one of the important seedling trait to increase dry biomass per plant. A-57, A-39, A-94 (0.07) having high values than other lines in normal irrigations while A-57, A-94 and A-39 also performed well under drought conditions.

Under well-watered conditions (Figure 8), most of genotypes increased their shoot water contents as compared to water stress conditions. In genotype A-61 (91.1), A-57 (89.92) had increased while had also increased water contents in shoots of Hysun-37 (90.71) similarly, under water stress conditions, A-61 possessed increased shoot length (90.2) and other genotypes also exhibited increased shoot moisture contents. In root water contents (Figure 9), A-25, A-29 and A-10(92.09), (91.31) and (89.58) performed best than other genotypes due to presence of increased moisture in their roots while under water stress conditions, these genotypes showed best performance due to increased root water contents and proved as drought tolerant genotypes in this experiment. These results are in agreement of findings of [12].

In emergence percentage (Figure 10), genotypes A-29(93.94), A-25 (92.93) and A-57(90.91) showed increased plant population under well-watered conditions due to highest values. While under drought conditions, A-9 (93.94), A-25 (93.94), A-57 (80.81), A-61 (80.81) showed increased number of plants. This trait indicated that if more of plants per genotype germinated under water stress conditions then these genotypes exhibited tolerance to water stress.

The lines having increased growth rate were A-50(2.20), A-25(1.67), A-57(1.20) under normal conditions while growth rate was reduced in drought conditions because growth rate based on dry shoot weight (Figure 11). Dry shoot weight was declined in water stress so relative growth rate was also declined under water stress conditions. Lines of sunflower having comparatively good performance were A-50(1.32), A-57(0.95). Sunflower lines with good performance under drought conditions will grow vigorously due to presence of genes for drought tolerance. These results are in agreement with results of [14].

Many seedling traits were decreased in size due to shortage of water. Results of [37] were similar with results obtained from this study. They confirmed that sunflower yield was affected with variant irrigation applications at different growth stages with the strongest retort observed at early growth stages which eventually affected yield of sunflower unfavorably.

**Heritability estimates**

Efficacy of selection for a plant trait depends on level of its heritability and genetic variation. Existing heritable variability shows that the population has elevated genetic potential for improvement of the characters by selection programmes.
Greatest heritability was found in dry shoot weight, shoot length and fresh shoot weight with values (99.2), (99.1) and (99.0) (Figure 12) respectively under normal irrigation conditions. Results under water stress conditions for heritability (Figure 13) indicated all traits having good ability to transfer genes to next generations as these traits also possessed high value of heritability. Traits like fresh shoot weight and root branches per plant had maximum heritability to transfer genes to next generations and lowest heritability was found in shoot water contents (65%) under water stress conditions while remaining traits possessed good heritability to transfer genes for these traits. These results of heritability were in agreement of [14] who also found that drought stress affects on various plant traits at seedling stage.

**Correlation analysis**

Correlation analysis was done to determine which trait is more suitable for increasing yield of the plant. Association between a specific trait and other traits contributed to increase growth of the plants is crucial for direct and indirect selection of genotypes for increased seed yield ultimately. Results for correlation analysis under well-watered conditions (Table 2) indicated that shoot length had positive and significant correlation with root length (0.478), fresh shoot weight (0.521) and dry shoot weight (0.516). Root length was significantly associated with fresh shoot weight (0.418), dry root weight (0.509) and emergence percentage (0.484). While plant trait fresh shoot weight was associated with dry shoot weight (0.759), relative growth rate (0.242). In (Table 3) indicated that positive and significant relationship with fresh root weight and dry root weight (0.646) at genotypic level. Similarly root branches had significantly positive relationship with relative growth rate (0.242) while dry shoot weight had momentous correlation with dry root weight and relative growth rate (-0.556). Dry root weight had negative association with shoot water contents (-0.345), root water contents (-0.392) and relative growth rate (-0.178). Shoot water contents had vital and positive relationship with emergence percentage (0.416).

Results for relationship between relative various seedling traits under water stress conditions was indicated in Table-3. It was found that a positive and noteworthy association was found between shoot length and other seedling traits like root length (0.347), dry shoot weight (0.618), relative growth rate (0.315). While root length had significantly positive relationship between fresh shoot weight (0.479), dry root weight (0.340). Moreover, fresh shoot weight was absolutely associated with fresh root weight (0.258), dry shoot weight (0.263) and dry root weight (0.331) at genotypic level. Similarly, fresh root weight had crucial association with dry shoot weight (0.059), dry root weight (0.167) and root water contents (0.753) while root branches were increased with increase of dry root weight due to presence of significant correlation (0.382). Dry shoot weight and relative growth rate had positive and important relationship (0.578) under water stress condition according to Table-3. Similarly, an imperative association was found dry root water and shoot water contents (0.578). These results are in favor of [12, 38].
Figure 1. Mean Performance of different sunflower genotypes under normal and drought stress

Figure 2. Mean Performance of different sunflower genotypes under normal and drought stress
Figure 3. Mean Performance of different sunflower genotypes under normal and drought stress

Figure 4. Mean Performance of different sunflower genotypes under normal and drought stress
Figure 5. Mean Performance of different sunflower genotypes under normal and drought stress

Figure 6. Mean Performance of different sunflower genotypes under normal and drought stress
Figure 7. Mean Performance of different sunflower genotypes under normal and drought stress

Figure 8. Mean Performance of different sunflower genotypes under normal and drought stress
Figure 9. Mean Performance of different sunflower genotypes under normal and drought stress (RWC)

Figure 10. Mean Performance of different sunflower genotypes under normal and drought stress

Means (Normal) | 86.87  | 90.91  | 60.61  | 92.93  | 93.94  | 69.7   | 82.83  | 74.75  | 58.59  | 90.91  | 91.92  | 75.76  
Means (drought)| 87.88  | 93.94  | 66.67  | 93.94  | 85.86  | 63.64  | 80.81  | 71.72  | 67.68  | 80.81  | 80.81  | 86.87  

sunflower genotypes
Figure 11. Mean Performance of different sunflower genotypes under normal and drought stress

Figure 12. Heritability under normal conditions for seedling traits in sunflower

Figure 13. Heritability under waster stress conditions for seedling traits in sunflower
Table 1. Mean squares for analysis of variance for seedling traits in sunflower

| Plant Traits | Genotypes | Treatments | Harvests | Genotypes × Treatments | Genotypes × Harvests | Treatments × Harvests | Genotypes × Treatments × Harvest | Error |
|--------------|-----------|------------|----------|------------------------|----------------------|-----------------------|---------------------------------|-------|
|              | d.f.      | 11         | 1        | 2                      | 11                   | 22                    | 2                               | 22    | 144 |
| SL           |           | 77.516**   | 5400.0** | 6761.04**              | 12.663**             | 22.519**              | 48.00**                         | 5.525** | 1.1830 |
| RL           |           | 14.512**   | 4.164**  | 61.025**               | 3.562**              | 7.044**               | 72.833**                        | 4.435** | 0.1860 |
| FSW          |           | 0.655**    | 22.737** | 57.489**               | 0.078**              | 0.275**               | 4.786**                         | 0.055** | 0.0090 |
| FRW          |           | 0.220**    | 4.486**  | 2.865**                | 0.031**              | 0.093**               | 0.169**                         | 0.021** | 0.0020 |
| RB           |           | 440.50**   | 2243.6** | 1145.12**              | 37.118**             | 134.934**             | 15.492*                         | 25.401** | 3.7200 |
| DSW          |           | 0.015**    | 0.364**  | 0.853**                | 0.0050**             | 0.008**               | 0.005**                         | 0.0031** | 0.0001 |
| DRW          |           | 0.002**    | 0.033**  | 0.024**                | 0.0001**             | 0.001**               | 0.001**                         | 0.0001** | 0.0001 |
| SWC          |           | 11.334**   | 17.845** | 8.364**                | 0.0001**             | 11.924**              | 258.10**                        | 5.165** | 1.6190 |
| RWC          |           | 45.537**   | 33.044** | 76.444**               | 6.069**              | 48.344**              | 128.573**                       | 5.087** | 1.7971 |
| E%           |           | 2193.6**   | 30.99    | 49.357                 | 242.580**            | 472.95**              | 572.681**                       | 242.578** | 41.3171 |
| RGR          |           | 0.392**    | 1.389**  | -                      | -                    | -                     | -                               | -     | 0.113 |

*= Significant at 5% level and **= Significant at 1% level
SL= Shoot Length, RL= Root Length, FSW=Fresh Shoot Weight, FRW= Fresh Root Weight, RB= Root Branches, DSW= Dry Shoot Weight, DRW= Dry root Weight, SWC= Shoot Water Contents, RWC= Root Water Contents, E%= Emergence Percentage and RGR= Relative Growth Rate
Table 2. Genotypic (Above diagonal) and phenotypic (below diagonal) Correlation Coefficients among various Seedling traits under normal conditions

| Characters | SL  | RL  | FSW | FRW | RB  | DSW | DRW | SWC | RWC | E%  | RGR |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| SL         |     | 0.478* |   | 0.521* | -0.095 | -0.114 | 0.516* | 0.145* | -0.339 | -0.248 | 0.14 | 0.078 |
| RL         | 0.442** |     | 0.418* | 0.208 | -0.254 | 0.056 | 0.509** | -0.391 | -0.391 | 0.484* | -0.408 |
| FSW        | 0.511** | 0.391** |     | -0.290* | 0.013 | 0.759** | -0.16 | -0.27 | -0.27 | -0.051 | 0.242* |
| FRW        | -0.091 | 0.182 | -0.281 |     | -0.036 | -0.28** | 0.646** | 0.058 | 0.414 | 0.269 | -0.529* |
| RB         | -0.116 | -0.219 | 0.008 | -0.034 |     | 0.058 | 0.188 | -0.036 | 0.319 | -0.343 | 0.240* |
| DSW        | 0.507** | -0.051 | 0.74** | -0.277 | 0.056 |     | -0.373** | -0.844 | -0.067 | -0.276 | -0.556** |
| DRW        | 0.148 | 0.542** | -0.154 | 0.640** | 0.187 | -0.366 |     | -0.345** | -0.392** | -0.032 | -0.178** |
| SWC        | -0.322 | 0.389** | -0.271 | 0.060 | -0.033 | -0.835 | 0.331 |     | -0.204 | 0.378 | -0.591 |
| RWC        | -0.228 | -0.439 | -0.439 | 0.407** | -0.292 | -0.063 | -0.439 | -0.175 |     | 0.416* | -0.527 |
| E%         | 0.143 | 0.154** | -0.036 | 0.265 | -0.340 | -0.264 | -0.028 | -0.360** | -0.425** |     | -0.828 |
| RGR        | 0.067 | -0.348 | -0.348 | -0.469 | 0.215 | 0.510** | -0.161** | -0.517 | -0.437 |     | -0.762 |

*= Significant at 5% level and **= Significant at 1% level
SL= Shoot Length, RL= Root Length, FSW=Fresh Shoot Weight, FRW= Fresh Root Weight, RB= Root Branches, DSW= Dry Shoot Weight, DRW= Dry root Weight, SWC= Shoot Water Contents, RWC= Root Water Contents, E%= Emergence Percentage and RGR= Relative Growth Rate
Table 3. Genotypic (above diagonal) and Phenotypic (below diagonal) Correlation Coefficient among Various Seedling traits under water stress conditions

| Characters | SL  | RL | FSW  | FRW  | RB  | DSW  | DRW  | SWC | RWC | E% | RGR  |
|------------|-----|----|------|------|-----|------|------|-----|-----|----|------|
| SL         |     |    | 0.347* | 0.165 | 0.005 | 0.351 | 0.618** | 0.213 | -0.226 | -0.231 | -0.115 | 0.315* |
| RL         | 0.332* |    | 0.479* | -0.041 | -0.085 | 0.202 | 0.340** | 0.292 | -0.425 | 0.272 | -0.135 |
| FSW        | 0.167 |    | 0.466** | 0.258* | -0.078 | 0.263** | 0.331** | 0.185 | -0.073 | 0.091 | -0.104* |
| FRW        | 0.010 |    | -0.039 | 0.250 | 0.064 | 0.059** | 0.167** | 0.085 | 0.753** | 0.284 | -0.559 |
| RB         | 0.345* |    | -0.087 | -0.076 | 0.062 | -0.104 | 0.382** | 0.121 | -0.160 | -0.048 | 0.003 |
| DSW        | 0.554** |    | -0.171 | 0.233 | 0.053 | -0.103 | 0.016 | -0.280* | -0.193 | -0.128 | 0.578** |
| DRW        | 0.200* |    | 0.314* | 0.322* | 0.159 | 0.360** | 0.578** | -0.446* | 0.235 | -0.211** |
| SWC        | -0.150 |    | 0.228* | 0.711** | 0.057 | 0.109 | -0.401 | 0.463** | -0.233 | 0.263 | -0.352 |
| RWC        | -0.211 |    | -0.398 | -0.398 | 0.740** | -0.151 | -0.471 | -0.471 | -0.185 | 0.033 | -0.482 |
| E%         | -0.095 |    | 0.256 | 0.256 | 0.281 | -0.046 | -0.114 | 0.224 | 0.205 | 0.035 | -0.691 |
| RGR        | 0.287 |    | -0.135 | -0.135 | -0.508 | -0.006 | 0.591** | -0.354 | -0.354 | -0.436 | -0.625 |

*= Significant at 5% level and **= Significant at 1% level
SL= Shoot Length, RL= Root Length, FSW=Fresh Shoot Weight, FRW= Fresh Root Weight, RB= Root Branches, DSW= Dry Shoot Weight, DRW= Dry root Weight, SWC= Shoot Water Contents, RWC= Root Water Contents, E%= Emergence Percentage and RGR= Relative Growth Rate
**Conclusion**

On the basis of present study, it is concluded that genotypes A-10, A-50, A-57 and A-61 exhibited best performance in comparison with hybrid variety had best performance for plant traits like increased shoot length, increased root length, more fresh shoot and root weight, dry shoot and root weight under water stress conditions as well as under well-watered conditions. Moreover, association between most of vegetative plant traits have mostly positive and significant association with each other like and number of leaves have positive correlation with root length, fresh root weight and other traits like fresh shoot weight, fresh root weight, dry root weight and plant height. So genotypes A-10, A-50, A-57 and A-61 are recommended for further sunflower breeding program and can be grown under water stress conditions for high seed yield.

**Authors’ contributions**

Envisioned the project, designed and performed the experiment: S Mahpara, Performed statistical analysis: S Mahpara, S Salman, MA Bashir, SKamaran& MI Ullah, Wrote and edited the paper: SMahpara, FUKhan, Z Shah, A Ullah & M Shahnawaz.

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