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Evaluation of Sunflower Genotypes for Yield and Quality Parameters under Well-Water Stressed and Non Water Stressesd Environment

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HELIANTHUS annuus L., a cultivated sunflower is very popular field crop for its quality in providing edible oil. Its seed contains 48-58% oil and 88% mono-unsaturated and poly-unsaturated fatty acids. In this experiment twenty sunflower genotypes were used like Corolla, Peshwar-93, Albania, FMC-0046, HO-1, PFS-025, Melabour, Charnika, Thatta, SH-3915, UC-666, A-2, TJ-1, N-17, Turkish, A-1, Ausi-gold, Mehran, ST-2 and B-2 through which genetically diverse characters and sources were evaluated and analyzed under well watered and water stressed conditions. By taking the calculation of mean squares revealed that irrigation treatments produced considerable impact on agronomic, seed yield and oil traits. Hence Genotypes performed significantly different for most of the yield and oil traits whereas, interaction of treatments with genotypes were also noteworthy for most of the characters other than days taken to 75% flowering and 75% maturity and stem diameter, inferring that genotypes responded variably under water stress conditions. Such interactions indicated that some genotypes may be picked-up which performed better in well watered, water stressed conditions and may be selected for both the environments simultaneously For different characters, female inbreds viz. Ho.1, Mehran and Thatta whereas from male parents UC-666 and B-2 recorded high performance early maturity, seed yield, oil and protein% in both the environments. Therefore such male and female inbreds may be involved in breeding programmes to develop potential breeding material with improved agronomic, oil and protein characters.

Keywords: Correlation, Sunflower genotypes, Water stress, Yield and quality traits.

Introduction

The sunflower (*Helianthus annuus* L.) is one of the world's most important oilseed crops. Sunflower achene contains about 50% oil and 20 to 21 percent protein that potentially fulfills the gap between global supply and consumption of sunflower as edible oil and animal feed purposes (Hussain et al., 2017; Naeem et al., 2019). The traditional sunflower oil contains oleic acid, linoleic acid from 90% fatty acids while palmitic acid and stearic acid possess 8 to10% fatty acids (Abdel-Rahem et al., 2021). Ghee Corporation of Pakistan (GCP) pioneered the sunflower growing in Pakistan in 1980s (Anonymous, 2019).

Although the seeds of confectionery sunflower are also consumed as making dairy products, yet it is mostly used for seed oil. Sunflower is got the 4th position after palm oil, soybean oil, and canola oil, accounting up to 12% of the global vegetable oil production (Rauf et al., 2017). The previous year's (2020) sunflower production of the world was 54.96 million tons. The 50.04 million tons is predicted for this year (2021) implied a decline of 4.93 million tons, or 8.97

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percent in global sunflower production (USDA, 2021). Approximately, 2.748 million tons of edible oil which is worth of Rs: 321.535 billion ($ 2.046 billion) was imported by Pakistan. The indigenous production is accounting to only 0.680 million tons, or 24% of total availability, and imports accounting to rest of 1246 million tons (Economic Survey of Pakistan, 2019-2020). Pakistan produced 160,000 metric tons in 2020 (World Agriculture Production, 2021). Sunflower, with its ability to grow in a variety of agro-ecological conditions and moderately drought tolerance, have become a favorable oil crop in the future. Though simulation studies revealed that sunflower yields in Northern Europe would increase as a result of expected climate change, still negative impacts on sunflower yields could occur in southern latitudes (Debaeke et al., 2017). The development of sunflower hybrids recognized this crop as a viable and significant crop around the world due to establishment of public and private breeding institutions (Seiler et al., 2017).

Drought is serious environmental factors that reduce sunflower and other crops' yields. Water stress requires an understanding of the nature of phenotypic traits that can recover the performance under water stress conditions as well as understanding of the complicated physiological and genetic mechanisms involved under stress conditions. In that context, one of the most important objectives of plant breeders is to improve drought tolerance and water productivity in plants for such areas. Taking into account the morphological, physiological, genetic, and molecular pathways that influence drought tolerance can help evolve drought-tolerant cultivars for their cultivation in arid and semi-arid environments (Saremirad & Mostafavi, 2020; Smaeili et al., 2022). It is also considered as one of the most severe ecological factors that reduces sunflower and other crops' yields. Therefore, it is essential to recognize the subtle physiological and genetic mechanisms that increase the performance of sunflower under water stress and also contemplate the nature of phenotypic characters that escalate the performance under stress scenario. In the near future, one of the central issues of plant breeders is envisaged to expand drought tolerance in crop plants and simultaneously increase water use efficiency in plants (Saremirad & Mostafavi, 2020; Hatem et al., 2022). By nature and from genetic point of view, sunflower is drought-prone field crop (Tyagi et al., 2018).

Breeding strategies for evolving drought-tolerant genotypes for a specific environment have been presented as a basic solution to increase crop production (Rauf et al., 2017). Thus plant breeders' main objectives in such situation are diverted to increase crop productivity by choosing drought-tolerant progenies in their breeding accomplishments (Rauf et al., 2017). It is also bitter fact, that development of drought-tolerant crop varieties is intricate task due to lack of information on nearly all physiological variables which indicate the complete genetic mechanism and their relationship to yield and morphological characteristics (Zakhidov et al., 2016). The information needed to develop water-stress-tolerant sunflower varieties is though crucial yet significant differences existed in seed yield and 1000-seed weight which could contribute towards higher seed yield, and their mean squares for different characters under drought and regular irrigated conditions revealed very essential variations among sunflower inbred lines (Farzad et al., 2015). The situation is getting worse when reservoirs of water storage have dropped as a result of silt deposition and also water quantity drops to a dead level. Since rainfall occurrence and quantity are often extremely variable throughout the sunflower growing season, therefore water shortage is expected to affect 14% of Pakistan's total agricultural area 4.9 million hectares (Khan et al., 2015). Such conditions cause unpredictability of water and nutrients uptake in crop plants which may cause retardation in plant growth and development, eventually reduces crop yield and quality (Yankov & Tahsin, 2015). Sunflower genetic resources can be screened efficiently under various environmental conditions, particularly under water stress conditions so as to develop drought-tolerant inbreds for hybrid sunflower development (Geeta et al., 2012). Thus present studies is aimed to developed water stressed tolerant breeding material.

Materials and Methods

During the spring growing season of 2019, the experiment was carried-out in a split plots with two treatments (well-watered and water stress from bud formation till seed setting) and four replications at the experimental field of oil seeds research Institute, Tandojam. Water regimes were regarded as the most important component and also considered as a main factor. However irrigation regimes with no water stress (well-watered) received frequent irrigations instead of given any water stress, thus a total of five irrigations were applied (Treatment-I), whereas water stress treatment were mild to severe stress given on 50-day-old plants expecting to flowering bud until seed formation i.e. While 80-day-old plants were sustained by withholding water for a period of 30 days (Treatment-II). The space between plants and rows was fixed about at 25 and 60 cm, respectively. The words like well watered, optimum irrigation, normal irrigation and no water stress will be used interchangeably whereas for water stressed treatment, the words like drought stress, water stress, moisture stress and water stress environment may be used in this manuscript. Twenty genotypes i.e. Corolla, Peshawar-93, Albania, FMC-0046, HO-1, PSF-025, Melabour, Charnika, Thatta, SH-3915, UC-666, A-2, TJ-1, N-17, Turkish, A-1, Ausigold, Mehran, ST-2, B-2 were used for following traits.

1. Days to 75% flowering

The number of days from sowing to completion of 75 % flowering was recorded for the crop and the average was calculated.

2. Days to 75% maturity

The number of days from sowing to completion of 75% maturity documented for the crop and average was worked out.

3. Days to seed formation

The seed formation days were calculated as the number of days from sowing to mature ovule of the plant per replication and plot.

4. Plant height (cm)

Plant height of ten randomly selected as plants of each genotype per replication was measured in centimeter from soil level up to base of head by taking gagging tape.

5. Stem diameter (cm)

of each selected plant of genotypes per replication was measured in centimeter by using of the measuring tape. Average of the selected plants was measured.

6. Head diameter (cm)

It was measured at maturity in cm with the gaging tape. Mean of ten selected plants of each genotype per replication was calculated for this parameter.

7. No. of seeds head^{-1}

The tagged plants were reaped and winnowed individually. The seeds in the heads of the selected plants were counted in each plot and averaged head^{-1} was calculated.

8. Seed index (1000 achene weight, g)

1000 seeds of each genotype per replication were counted from the selected plants and weighed in grams using the electric weighing balance.

9. Seed yield plant^{-1} (g)

The dried capitulum of sunflower from index plants of every genotype in each repeat were respectively winnowed, gutted and weighed in gram.

10. Biological yield/dry matter plant^{-1} (g)

The whole selected plants were desiccated under sun from each genotype and the weighted in g.

11. Seed yield kg ha^{-1}

Achene yield plant^{-1} (g) was transformed in seed yield kg ha^{-1}.

12. Chlorophyll content:

The chlorophyll was calculated by SPAD meter.

13. Linoleic acid

It is calculated according to procedures adopted by Shamshad et al. (2016).

14. Oleic acid

It is calculated according to procedures adopted by Shamshad et al. (2016).

15. Oil content (%)

It is calculated according to procedures adopted by Memon (2015).

16. Protein content

It is calculated according to procedures adopted by Depar (2017).

Statistical analysis

The acquired data was subjected to analysis of variance using the statistical factorial plot model, as described by Gomez & Gomez (1984). Snedecor & Cochran, the simple correlation coefficient was determined (1980).

Results and Discussion

Twenty genetically diverse sunflower genotypes as mentioned before with variable traits and sources were assessed under normal irrigation and water stress conditions to determine their tolerability and seed yield production under moisture deficit conditions. The results obtained from the present investigation are accessible with various headings in the following paragraphs.

The analysis of variance (ANOVA) for seed yield and oil quality characters

The mean squares from ANOVA are revealed that water stress produced considerable impact on agronomic, seed yield and oil parameters (Table 1). Genotypes performed significantly different for most of the yield and oil traits whereas treatments × genotypes were significant for majority of the characters other than 75% flowering and 75% maturity days and stem diameter, that genotypes performed variably over water scarce environments. Such interactions indicated that some genotypes may be picked-up on the basis of their performance in well-watered and drought stress conditions as well. Comparable to present findings, Rajper et al. (2022) perceived significant impact of water stress on agronomic, flowering and seed yield traits. They also noted significant interaction of Treatments × Genotypes implied that genotypes performed variably over the irrigation treatments.

TABLE 1. ANOVA for seed yield and oil quality parameters of sunflower genotypes grown under well watered and water stressed environments

Characters	Mean squares					
	Replication (R)	Treatment (T)	Error (a)	Genotypes (G)	Treatment × genotypes (T × G)	Error (b)
	D.F. 3	D.F. 1	D.F. 3	D.F .19	D.F. 19	D.F.114
Days to 75% flowering	1.06	0.008	0.62	214.79**	1.14	1.91
Days to 75% maturity	2.28	0.60	0.22	198.50**	1.46	3.12
Days to seed formation	1.59	4.22*	0.25	209.99**	7.44**	1.92
Plant height	5.08	2794.75**	4.21	2113.84**	129.70**	4.36
Stem diameter	0.14	10.76**	0.11	6.62**	0.27	0.28
Head diameter	0.81	244.77**	0.30	55.19**	9.28**	1.31
Number of seeds head^{-1}	674.00	1105730.0**	2904.00	233291.00**	17874.00**	6339.00
Seed index	0.42	1850.96**	0.40	257.22**	13.70**	1.13
Seed yield plant $^{-1}$	64.00	279659.00**	5.00	7468.00**	518.00**	10.00
Biological yield/dry matter plant^{-1}	3.26	2992.04**	0.56	964.62**	15.86**	2.86
Seed yield (kg ha^{-1})	5118.00	3477815.0**	1198.00	538392.00**	25843.00**	1874.00
Chlorophyll content	1.29	602.56**	2.63	523.25**	26.20**	1.21
Linoleic acid	3.21	2968.73**	2.05	264.54**	30.09**	1.15
Oleic acid	3.21	2968.73**	2.05	264.54**	30.09**	1.15
Oil content	1.50	39.00**	0.73	85.13**	2.21**	0.54
Protein content	4.12	778.80**	6.12	87.90**	4.33**	0.73

**, * Denotes significance at 1% and 5% probability respectively.

Mean performance of sunflower genotypes for agronomic, seed yield and quality traits under well-watered water stressed conditions

Sunflower is generally considered as moderately drought tolerant crop. Though water stress affects all growing stages of sunflower, yet extreme reduction in yield was qualified when stress is imposed at reproductive growth phases (Reddy et al., 2003; Vijay, 2004). Karaata (1991) carried-out trial to identify highly drought susceptible growth stages of sunflower and observed higher decrease in seed yield during flowering stage being highly critical. Likewise, Vijay (2004) determined the response of seed yield to irrigation at four different phases: preliminary stage (15-20 days after planting, DAP), capitulum formation stage (30-35 DAP), flowering phase (50-60 DAP), and grain formation (70-80 DAP). It was observed that maximum seed yield was achieved with irrigation applied at flowering. Drought during the vegetative phase of the plants affects both final biological and economic yields. Low absorption of photosynthesis during the reproductive phase may reduce head diameter. Reduction in head diameter further decreases the number of rows per head and number of achenes per head (Alza & Fernandez-Martinez, 1997; Rauf & Sadaqat, 2007). It has been predicted that stress at developmental phase drops seed yield from 15-25%, while 50% reduction occurred when stress was imposed at flowering stage (Reddy et al., 2003). The screening results with respect to average performance of twenty sunflower genotypes for agronomic, seed yield and oil parameters are accessible in Tables 2 to 9 and trait wise performance is discussed here under:

Days to 75% flowering

The range of variation in normal irrigation was marked as 52.20 to 72.45 days while in water stress, it varied from 53.25 to 72.85 days (Table 2). These figures show low genetic variations among the genotypes for days to 75% flowering. In normal irrigation, the genotypes attended 75% flowering at an average of 61.51 days whereas 61.53 days were got under stress conditions. Statistically treatment effect was non-significant. Among the genotypes, 10 genotypes did not show any decline due to water stress while 10 genotypes shown very small reduction in days taken to 75% flowering under water stress conditions. The genotype UC-666 took less (52.20 and 52.88 days) days to flowering followed by Charnika (54.35 and 53.25 days) and PSF-025 (55.58 and 54.60 days) in normal and in water stress conditions respectively which were considered as early maturing parents. In fact, water stress was initially imposed at the time flowering bud stage, therefore reduction in flowering was not expected too much, yet whatever the difference in days to 75% flowering observed was due to genetic variation among the genotypes. On an average, water stress caused -4.16 days delay in 75% flowering under water stress conditions as stated by Rajper et al. (2022). They further noted that in water stressed conditions Charnika, TJ-1and Thatta recorded lowest number of days (75% flowering) whilst A-1 took highest number of days to 75% flowering in moisture stressed conditions. Analogous outcomes were noted by Arshad et al. (2010) and Buriro et al. (2015) who perceived that moisture deficiency caused hasty blooming. They also noted reduced days to 75% flowering under water stress (79 days) against more days taken to flowering in normal irrigation (61 days).

Days to 75% maturity

The genotype like UC-666 was early maturing because it required 103.00 and 103.05 days followed by 104.90 and 103.70 days of Charnika, in normal and water deficient environments correspondingly (Table 2). However, the maximum decrease for 75% maturity owing to stress happened with genotypes TJ-1, Thatta and FMC0046 and about 10 genotypes showed no any decline in days to 75% maturity, while other 10 genotypes had displayed little effect triggered by water stress. The range of maturity days in normal conditions were 103.0 to 121.02 while in stress, it was 103.05 to 117.47. To conclude the results, stress could not cause significant impact on 75% maturity days (Table 3). Contrary to our findings, Arshad et al. (2010), Buriro et al. (2015) and Rajper et al. (2022), noted that water stress caused a significant delay in 75% maturity in sunflower.

Days to seed formation

Water stress was averagely caused a small reduction of -0.32 days in seed formation. Though statistically significant variation between two environments was presented, yet numerically there was some difference in response to genotypes to water stress. The range of days taken by the genotypes to form a seed in normal condition was 67.80 to 87.60 whereas it was between 68.0 to 88.03 days under water stress environment (Table 3). Not so much difference is marked between no-stress and water stress environments. From

20 genotypes evaluated, UC-666 took less days to seed formation (67.80 and 68.00days) followed by Charnika (68.25 and 71.00 days) and Turkish (70.30 and 69.65 days) in normal and water stress environments respectively. Though not too much genetic difference or difference caused by moisture stress was perceived yet, some of the genotypes recorded comparatively less reduction while others gave relatively more decline due to water stress. However, higher reduction in days to seed formation was recorded in genotypes TJ-1, FMC-0046 and Mehran. On the other side, relatively small decline in days to seed formation was noted in Turkish and PSF-025.

TABLE 2. Mean performance of sunflower genotypes for 75% flowering and 75% maturity days grown under well watered and water stressed environments

Genotypes	Days to 75% flowering		*Diff.	Days to 75%maturity		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	59.53	59.33	-0.20	108.57	108.85	0.27
Peshawar-93	59.83	60.03	0.20	110.37	110.65	0.27
Albania	64.88	65.43	0.55	114.57	115.47	0.90
FMC 0046	60.78	60.45	-0.33	110.75	110.57	-0.17
HO.1	68.75	67.80	-0.95	118.22	117.17	-1.05
PSF.025	55.58	54.60	-0.97	105.90	104.82	-1.07
Melabour	61.98	61.03	-0.95	110.80	111.05	0.25
Charnika	54.35	53.25	-1.10	104.90	103.7	-1.20
Thatta	63.05	61.98	-1.08	111.82	111.55	-0.27
SH-3	58.90	59.30	0.40	109.70	109.27	-0.42
UC-666	52.20	52.88	0.67	103.00	103.05	0.05
A-2	61.78	61.75	-0.03	111.62	111.65	0.02
TJ-1	58.70	59.20	0.50	108.57	108.55	-0.02
N-17	72.45	72.85	0.40	121.02	122.82	1.80
Turkish	54.98	54.18	-0.80	104.95	104.00	-0.95
A-1	66.63	67.50	0.88	116.22	117.47	1.25
Ausi-gold	66.13	67.10	0.98	116.32	117.12	0.80
Mehran	61.43	62.25	0.82	111.00	112.17	1.17
ST-2	63.65	63.85	0.20	114.52	114.17	-0.35
B-2	64.80	65.88	1.08	114.75	115.92	1.17
Mean	61.51	61.53		111.38	111.50	0.012
L.S.D at 5% (T)	0.39			0.23		
L.S.D at 5% (G)	1.36		0.013	1.75		
L.S.D at 5% (T x G)	1.92			2.42		

*Diff= difference between well watered and water stressed.

TABLE 3. Mean performance of sunflower genotypes for seed formation days and plant height grown under well watered and water stressed environment

Genotypes	Days to seed formation		*Diff.	Plant height (cm)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	74.88	77.50	2.62	153.65	148.25	-5.40
Peshawar-93	74.60	75.65	1.05	131.40	131.57	0.17
Albania	79.15	80.58	1.42	162.37	151.00	-11.37
FMC 0046	75.88	71.75	-4.12	146.05	139.00	-7.05
HO.1	83.85	82.70	-1.15	163.25	163.10	-0.15
PSF.025	70.55	69.80	-0.75	170.30	170.67	0.37
Melabour	77.15	75.93	-1.22	171.22	157.50	-13.72
Charnika	68.25	71.00	2.75	127.37	117.50	-9.87
Thatta	78.25	77.25	-1.00	145.55	145.82	0.27
SH-3	74.20	74.60	0.40	157.95	157.95	0.00
UC-666	67.80	68.00	0.20	135.40	134.62	-0.77
A-2	76.83	77.10	0.27	152.75	135.00	-17.75
TJ-1	79.28	74.00	-5.27	164.80	144.50	-20.30
N-17	87.60	88.03	0.42	143.57	125.50	-18.07
Turkish	70.30	69.65	-0.65	182.97	164.75	-18.22
A-1	81.95	82.53	0.57	135.75	126.50	-9.25
Ausi-gold	81.40	81.85	0.45	175.97	152.25	-23.72
Mehran	76.73	74.73	-2.00	155.12	153.05	-2.07
ST-2	76.00	76.25	0.25	121.77	112.00	-9.77
B-2	70.75	70.00	-0.75	132.35	131.87	-0.47
Mean	76.27	75.94		151.48	143.12	
L.S.D at 5% (T)	0.25			1.03		
L.S.D at 5% (G)	1.37		-0.32	2.06		-8.35
L.S.D at 5% (T x G)	1.90			3.00		

*Diff= difference between well watered and water stressed.

Plant height (cm)

This character was declined averagely by -8.35cm whereas minor decrease in plant height was noted in genotype HO.1 and maximum in Ausi-gold and TJ-1 under water stress environment. It means about 8 days reduction in plant height was caused by stress. The range of variation in normal irrigation was 121.77 to 182.97cm and it was 112.00 to 170.67cm in moisture deficit conditions (Table 3). The minimum plant height was recorded by ST-2 (121.77 and 112cm) followed by Charnika (127.37 and 117.50cm) and Peshawar 131.40 and 131.57 cm). Parallel to our findings, Rajper et al. (2022) noted an average decline of -18.28cm in plant height under moisture deficiency and genotypes Thatta A-2 and N-17 recorded lowest reduction in plant height in adverse circumstances. The lowest plant height of 129.00cm was recorded in sunflower crop irrigated two times against plants irrigated four or six times (Buriro et al., 2015).

Stem diameter (cm)

The smaller decrease owing to water stress was seen in genotypes Peshawar-93 followed by PSF-025 was considered as drought tolerant, whereas higher declines were noted in genotype Melabour being stress susceptible. On an average, -0.51cm stem diameter was decreased due to moisture deficiency (Table 4). Stem diameter of genotypes in non-stress varied from 2.82 to 5.90cm while it fluctuated from 2.27 to 5.47cm in genotypes grown under stress environment. Among the genotypes, maximum (5.90 and 5.52cm) stem diameter was observed in HO.1 under regular and drought irrigation conditions respectively. The higher stem diameter was measured in genotypes HO.1, Mehran and Thatta under stress conditions, thus these genotypes were less vulnerable to water stress environments. The crop irrigated five times (normal irrigation) measured stem girth of 5.59cm against 3.59cm of crop irrigated two times (Buriro et al., 2015).

Head diameter (cm)

The capitulum size of genotypes in normal conditions fluctuated between 12.25 to 18.25cm and under stress; it ranged from 7.37 to 18.52 cm. Thus, substantial variations either in non-stress or in stress was recorded in genotypes with respect to head diameter. The genotypes HO.1, Thatta and Mehran measured maximum head diameter in normal irrigation. Almost the same genotypes measured bigger heads in stress environment also. The lower reductions under moisture scarcity was observed in genotypes UC-666, SH-3915and PSF-026, however the average decline was -2.47cm in head diameter owing to stress conditions and such genotypes were considered as drought tolerant (Table 4). Reduction in head diameter owing to water stress decreases the number of rows per head and number of achenes per head and these results are in association of yield constituents to severe water stress (Alza & Fernandez-Martinez, 1997; Rauf & Sadaqat, 2007). Comparable to present results, Rajper et al. (2022) observed water stress caused an average decline of -6.53cm in head size in entire genotypes, yet minimum decline in head diameter was noted in TJ -1, A-1 and N-17 under drought conditions.

TABLE 4. Mean performance of sunflower genotypes for stem diameter and head diameter grown under well watered and water stressed environments

Genotypes	Stem diameter (cm)		*Diff.	Head diameter (cm)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	3.17	2.52	-0.65	13.12	10.57	-2.55
Peshawar-93	3.97	3.90	-0.07	15.02	14.70	-0.32
Albania	3.37	3.00	-0.37	13.27	9.00	-4.27
FMC 0046	3.97	3.05	-0.92	14.45	10.00	-4.45
HO.1	5.90	5.52	-0.37	18.25	18.52	0.27
PSF.025	4.30	4.17	-0.12	15.47	15.32	-0.15
Melabour	4.85	3.07	-1.77	16.27	11.12	-5.15
Charnika	2.82	2.27	-0.55	11.72	8.50	-3.22
Thatta	5.87	5.22	-0.65	18.15	17.57	-0.57
SH-3915	4.85	4.40	-0.45	16.15	16.05	-0.10
UC-666	4.77	4.00	-0.77	15.27	15.22	-0.05
A-2	3.70	3.32	-0.37	13.82	11.42	-2.40
TJ-1	3.67	3.35	-0.32	12.80	8.00	-4.80
N-17	4.32	3.67	-0.65	14.90	10.25	-4.65
Turkish	3.55	3.35	-0.20	13.87	7.37	-6.50
A-1	3.50	2.87	-0.62	12.77	10.85	-1.92
Ausi-gold	4.30	3.75	-0.55	14.35	11.12	-3.22
Mehran	5.82	5.47	-0.35	17.52	17.32	-0.20
ST-2	3.07	2.62	-0.45	12.25	7.62	-4.62
B-2	4.27	4.15	-0.12	14.45	13.87	-0.57
Mean	4.20	3.68		14.69	12.22	
L.S.D. at 5% (T)	0.16			0.27		
L.S.D. at 5% (G)	0.52		-0.51	1.13		-2.47
L.S.D. at 5% (T x G)	0.74			1.58		

*Diff= difference between well watered and water stressed.

Number of seeds head^{-1}

Averagely, -166.25 declines in seed number head-1 was recorded under adverse or moisture deficient circumstances. The seeds head-1 ranged from 743.91 to 1334.91 in normal conditions and 641.25 to 1266.25 seeds head-1 in water stress situation (Table 5). Among the genotypes, a maximum number of seeds head-1 was produced by HO.1, Mehran and Thatta in normal as well as under drought stress conditions. Relatively, the genotypes like B-2, SH-3 and HO.1 gave smaller declines in seed formation under moisture stress conditions. Water stress caused a decline of -92.66 seeds head-1 on an average owing to drought stress. Inbreds A-2, Charnika, Thatta and A-1 set added seeds head-1 in both optimal irrigation and moisture deficient environments (Rajper et al., 2022). Analogous to present results, Buriro et al. (2015) reported marked reduction in number of seeds head^{-1} in two irrigations (1065.0 seeds) against maximum number of seeds head^{-1} in normal irrigations (1913.0 seeds head^{-1}).

TABLE 5. Mean performance of sunflower genotypes for seeds head-1 and seed index grown under well watered and water stressed environments

Genotypes	Number of seeds head^{-1}		*Diff.	Seed index (g)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	913.75	716.75	-197.00	39.25	30.75	-8.50
Peshawar-93	1043.52	951.70	-91.82	46.00	40.75	-5.25
Albania	923.99	755.00	-168.99	40.32	34.00	-6.32
FMC 0046	1069.09	698.75	-370.34	41.00	30.00	-11.00
HO.1	1334.99	1266.25	-68.74	50.00	44.75	-5.25
PSF.025	1135.11	995.20	-139.90	47.75	43.50	-4.25
Melabour	1122.81	917.27	-205.54	36.50	29.00	-7.50
Charnika	743.91	658.65	-85.25	37.87	30.00	-7.87
Thatta	1285.73	1158.55	-127.18	50.00	46.00	-4.00
SH-3915	1120.24	1068.43	-51.81	46.00	40.00	-6.00
UC-666	1140.33	1019.14	-121.18	45.00	39.00	-6.00
A-2	954.10	740.00	-214.10	38.00	28.25	-9.75
TJ-1	961.75	670.75	-291.00	41.10	34.00	-7.10
N-17	972.87	695.00	-277.87	35.00	29.00	-6.00
Turkish	918.33	755.00	-163.33	43.25	34.00	-9.25
A-1	882.51	776.23	-106.27	36.25	31.75	-4.50
Ausi-gold	990.58	641.25	-349.33	44.25	30.75	-13.5
Mehran	1300.12	1175.25	-124.86	49.00	46.25	-2.75
ST-2	836.41	703.92	-132.48	34.00	27.25	-6.75
B-2	973.30	935.12	-38.17	45.50	41.00	-4.50
Mean	1031.17	864.91		42.30	35.50	
L.S.D. at 5% (T)	27.11		-166.25	0.31		-6.80
L.S.D. at 5% (G)	78.86			1.05		
L.S.D. at 5% (T x G)	111.58			1.47		

*Diff= difference between well watered and water stressed.

Seed index (g)

The average seed index of 42.30g was weighed in normal situation and 35.50g in water stress condition which produced an average decline of -6.80g due water stress imposed artificially (Table 5). The variation in seed index under normal irrigation was 34.00 to 50.00g, while it varied from 27.25 to 44.75g in water stress. Nevertheless, generally smaller drop in seed index was recorded among the genotypes. The seed index of Thatta was greater in both the environments showing their tolerance to water deficiency. The genotypes Mehran, Thatta and PSF-025 however recorded minimum declines whilst Ausi-gold, FMC-0046 and Turkish showed sharp decreases in seed index due to moisture deficiency. Rajper et al. (2022) carried out an experiment to examine the impact of moisture deficient condition seed index and noted that drought stress produced a substantial decline in 1000-grainmass and genotypes A-2, N -17and A-1 recorded very low reductions in seed index, thus these genotypes demonstrated their tolerance to deficient moisture. It was stated that such genotypes were tolerant to moisture stress for seed index. Some other researchers also recorded reduction in seed index due to water stress (Pekcan et al., 2015). Moisture deficiency triggered substantial decrease in 1000-grain mass, yet genotypes like A-2, N -17and A-1 showed low declines in seed index and those inbreds demonstrated their tolerance under optimum irrigation.

Seed yield plant^{-1} (g)

Considerable variation in genotypes for seed yield was observed which varied from 39.90 to 67.75g in non-stress and from 30.12 to 59.95g yields per plant under stress. On an average, moisture stress caused -8.64g reductions in seed yield plant^{-1} (Table 6), yet the average seed yield of genotypes in normal conditions was 52.37g while under water stress was 43.72g. The maximum seed yield plant-1 was produced by UC-666, SH-3 and PSF-025 under water stress conditions showing their drought tolerance. The genotypes UC-666 and Peshawar-93 and SH-3915 showed their sustainability with small reduction in yield under water deficit conditions.

Esmaeilian et al. (2012) designed an experiment to evaluate the impact of moisture deficiency on seed yield of sunflower. Three levels of irrigation schedules were used as full irrigation, withholding irrigation at flowering stage, and withholding irrigation at seed filling stage. Their results revealed that seed yield decreased significantly due to water stress when stress was imposed at either of the growth stages.

Biological yield/dry matter plant^{-1} (g)

Significant genetic variations were noted among genotypes for biological yield which ranged from 149.75 to 285.75g in normal irrigations and 93.15 to 202.00g in drought stress conditions (Table 6). In non-stress, the average biological yield plant^{-1} was recorded as 229.36g against 145.74g in water stress environment; hence, adverse moisture conditions caused an average decline of -83.61g in biological yield per plant. The least comparative reductions in biological yield was observed in genotypes like FMC-0046 and ST-2, however mild reductions were noted in Melabour and HO.1 while higher declines were seen under water stress in genotypes UC-666, Mehran and Ausi-gold. Rajper et al. (2022) stated that drought stress caused an average decline of -65.18g and genotypes TJ-1, N-17 and Thatta recorded maximum seed index in water stress condition. Analogous to our outcomes, some previous researchers like (Hemmati & Soleymani, 2013; Buriro et al., 2015; Pekcan et al., 2015; Mahmood et al., 2019) also noted the effect of drought stress on biological yield.

Seed yield (kg ha^{-1})

Under water stress, an average reduction of -294.65 seed yield (kg ha^{-1}) was recorded, nonetheless the average seed yield in non-stress and in drought stress were noted as 1992.45 and 1697.80kg ha^{-1} respectively. Fairly high variation in seed yield under normal (1630.75 to 2297.52kg ha^{-1}) and under water stress (1338.75 to 2148.15 kg ha^{-1}) was recorded (Table 7). Nevertheless genotypes SH-3915, HO.1 and Albania gave low reductions under water stress condition as compared to other genotypes under evaluation. The higher seed yield was produced by genotypes HO.1, B-2 and Mehran under both normal and water stress environment thus showing their consistency in high yielding ability and tolerance to stress environments. Buriro et al. (2015) studied the effect of normal and deficient irrigation on seed yield and observed that crop which received normal irrigation gave 2200 kg ha-1, while crop which received deficient irrigation produced 960.33kg ha^{-1}. It means water stress caused huge decline in seed yield of sunflower.

TABLE 6. Mean performance of sunflower genotypes for seed yield and biological yield grown under well watered and water stressed environments

Genotypes	Seed yield plant^{-1} (g)		*Diff.	Biological yield plant^{-1} (g)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	49.25	36.25	-13.00	208.50	107.75	-100.75
Peshawar-93	66.77	59.95	-6.82	242.75	149.50	-93.25
Albania	41.17	38.40	-2.77	201.50	118.75	-82.75
FMC 0046	44.25	35.75	-8.50	194.75	138.95	-55.80
HO.1	65.00	54.25	-10.75	264.50	196.45	-68.05
PSF.025	67.00	57.50	-9.50	254.25	166.45	-87.80
Melabour	40.75	36.00	-4.75	207.50	145.55	-61.95
Charnika	39.90	30.12	-9.77	196.50	115.15	-81.35
Thatta	60.75	54.00	-6.75	270.75	202.00	-68.75
SH-3915	67.75	59.25	-8.50	235.75	160.25	-75.50
UC-666	71.22	64.92	-6.30	264.50	155.50	-109.00
A-2	42.47	35.00	-7.47	216.50	135.25	-81.25
TJ-1	42.17	35.37	-6.80	219.75	124.50	-95.25
N-17	46.50	30.75	-15.75	228.50	147.00	-81.50
Turkish	44.65	36.45	-8.20	229.00	149.00	-80.00
A-1	44.05	34.72	-9.32	206.75	121.00	-85.75
Ausi-gold	48.50	40.00	-8.50	233.50	127.15	-106.35
Mehran	60.75	50.00	-10.75	285.75	177.60	-108.15
ST-2	44.42	36.00	-8.42	149.75	93.15	-56.60
B-2	60.07	49.75	-10.32	276.50	184.00	-92.50
Mean	52.37	43.72		229.36	145.74	
L.S.D. at 5% (T)	0.37		-8.64	1.13		-83.61
L.S.D. at 5% (G)	1.67			3.07		
L.S.D. at 5% (T x G)	2.33			4.36		

*Diff= difference between well watered and water stressed.

TABLE 7. Mean performance of sunflower genotypes for seed yield (kg ha^{-1})and chlorophyll content grown under well watered and water stressed environments

Genotypes	Seed yield (kg ha^{-1})		*Diff.	Chlorophyll content (rg)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	1742.72	1437.80	-304.92	35.85	31.87	-3.97
Peshawar-93	2109.42	1961.32	-148.10	44.25	39.50	-4.75
Albania	1630.75	1367.50	-263.25	27.30	25.57	-1.72
FMC 0046	1952.50	1385.00	-567.50	23.27	21.37	-1.90
HO.1	2297.52	2045.00	-252.52	39.00	37.50	-1.50
PSF.025	2245.85	1988.75	-257.10	42.00	38.50	-3.50
Melabour	2076.65	1677.50	-399.15	35.25	30.50	-4.75
Charnika	1670.70	1366.50	-304.20	31.70	27.37	-4.32
Thatta	2261.07	2148.15	-112.92	56.52	53.05	-3.47
SH-3915	2204.77	1990.00	-214.77	48.75	48.25	-0.50
UC-666	2100.65	1960.95	-139.70	44.75	26.65	-18.1
A-2	1736.05	1470.00	-266.05	35.50	30.00	-5.50
TJ-1	1666.40	1377.50	-288.90	31.50	29.50	-2.00
N-17	2047.75	1660.00	-387.75	38.50	33.00	-5.50
Turkish	1898.97	1460.00	-438.97	26.77	24.17	-2.60
A-1	1877.65	1470.00	-407.65	29.47	25.95	-3.52
Ausi-gold	2036.62	1740.00	-296.62	38.75	35.75	-3.00
Mehran	2264.20	2042.75	-221.45	41.00	39.25	-1.75
ST-2	1754.22	1338.75	-415.47	42.47	39.72	-2.75
B-2	2274.65	2068.55	-206.10	46.00	43.50	-2.50
Mean	1992.45	1697.80		37.93	34.05	
L.S.D. at 5% (T)	17.41			0.81		
L.S.D. at 5% (G)	42.88		-294.65	1.09		-3.88
L.S.D. at 5% (T x G)	61.27			1.68		

*Diff= difference between well watered and water stressed.

Chlorophyll content (relative greenness, rg)

The higher chlorophyll content was noted in Thatta (56.52rg), SH-3 (48.75rg) and B-2 (46.00rg) in normal condition, while Thatta produced maximum (53.05rg) chlorophyll content followed by SH-3 (48.55rg) and B-2 (34.50rg) in water stress environment. The relative greenness decreased due to stress and average decline of -3.88rg was noted under stress environment (Table 7). Present findings are in consonance with those of Antonio et al. (2017) who perceived that water stress induced a decline in the chlorophyll contents, resulting in linear and nonlinear decreases in chlorophyll content index also.

Oleic acid (%)

Due to water stress, an average decline of -8.61% in oleic acid was observed (Table 8). The averages of oleic acid in normal irrigation and in stress environments were recorded as 26.55 and 17.93% respectively. Substantial genetic variations among the genotypes with respect to oleic acid was seen which varied from 13.57 to 35.00% in normal irrigation and 11.00 to 28.50% in water stress environment. The lower reductions were noted in Melabour, ST-2 and UC-666 demonstrated their drought stress tolerance whereas highest declines were seen in A-2 and TJ-1 implying their susceptibility due to water stress. The maximum oleic acid was noted in Peshawar-93, SH-3 and Thatta under normal conditions, yet Peshawar-93, Thatta and SH-3 also produced higher oleic acid in stress with little bit change in rank order. Thus results indicated that these genotypes can produce high oleic acid in water deficient conditions. Baldini et al. (1999) conducted an experiment on drought stress and their results revealed that drought stress caused a significant reduction of about 15% in the concentration of oleic acid in standard hybrid. Assessment of the qualitative parameters of sunflower seeds showed that water stress caused a marked decrease in oil quantity and unsaturated fatty acids of oil, however this negative effect was greater in water stress at seed filling stage with respect to water stress at flowering stage (Esmaeilian et al., 2012).

Linoleic acid (%)

The maximum linoleic acid was produced by B-2 (87.00%) followed by Thatta (84.77%) and SH-3 (83.75%) in normal conditions. The performances of these genotypes were equally better under stress environment (Table 8). Considerable genetic variations existed among the genotypes as 45.55 to 87.00 in normal conditions and 34.00 to 82.50 % under water stress. Lower reductions were noted in genotype HO-1 followed by UC-666 and SH-3 under water stress condition, nonetheless an average reduction of -8.30% was observed under water stress conditions in genotypes under investigation (Tables 4-8). The highest declines however was noted in ST-2, Albania and A-1. Ensiye & Khorshid (2010) studied the response of safflower to irrigation regimes and reported that the oil quantity and oleic and linoleic acid percentage were reduced by drought stress, significantly.

TABLE 8. Mean performance of sunflower genotypes for oleic acid and linoleic acids grown under well watered and water stressed environments

Genotypes	Oleic acids (%)		*Diff.	Linoleic acid (%)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	18.50	11.50	-7.00	62.10	50.00	-12.10
Peshawar-93	35.00	28.50	-6.50	74.04	66.50	-7.547
Albania	21.05	14.50	-6.54	68.55	53.50	-15.05
FMC 0046	23.64	16.75	-6.89	71.50	60.25	-11.25
HO.1	31.50	25.00	-6.50	78.55	77.00	-1.55
PSF.025	31.00	24.75	-6.25	81.62	76.50	-5.12
Melabour	13.57	11.50	-2.07	60.75	51.00	-9.75
Charnika	22.50	14.00	-8.50	67.06	55.00	-12.00
Thatta	32.50	26.75	-5.75	84.77	81.50	-3.27
SH-3915	32.58	26.50	-6.08	83.75	81.50	-2.25
UC-666	29.72	24.50	-5.22	80.50	78.50	-2.00
A-2	28.05	13.00	-15.05	70.52	67.00	-3.52
TJ-1	25.28	11.25	-14.03	71.10	60.00	-11.10
N-17	25.52	12.25	-13.27	45.55	34.00	-11.55
Turkish	27.12	13.50	-13.62	67.14	56.50	-10.64
A-1	25.29	11.50	-13.79	63.64	51.00	-12.64
Ausi-gold	21.69	11.00	-10.69	70.68	62.50	-8.18
Mehran	29.75	26.00	-3.75	81.17	74.50	-6.67
ST-2	25.52	12.50	-13.02	72.14	56.75	-15.39
B-2	31.25	23.50	-7.75	87.00	82.50	-4.50
Mean	26.55	17.93		72.11	63.8	
L.S.D. at 5% (T)	0.71			0.98		
L.S.D. at 5% (G)	1.06		-8.61	0.95		-8.30
L.S.D. at 5% (T x G)	1.60			1.60		

*Diff= difference between well watered and water stressed.

Oil content (%)

The average oil content % of the genotypes owing to moisture stress declined by -0.98%, yet this reduction was low in some cultivars like PSF-025, N-17 and TJ-1. The maximum oil quantity was recorded in UC-666 (42.00, 40.00%), Thatta and SH-3 under non stress and water stress environments respectively (Table 9). The genetic variation of 27.65 to 42.00% and 27.37 to 40.00% was recorded in oil content of genotypes in normal and in stress conditions correspondingly. Soleimanzadeh et al. (2010) investigated the response of sunflower to drought stress and reported that seed yield and oil yield of this plant significantly decreased due to drought stress. In another study, Esmaeilian et al. (2012) reported that drought stress caused a significant reduction in yield and oil quantity in sunflower.

Protein content (%)

The average protein content in normal situation was recorded as 19.51% in normal and the same was 15.10 % under water stress conditions; however genotypes Turkish, B-2 and N-17 showed smaller reductions under water stress condition as compared to other genotypes (Table 9). Reasonable genetic variations in genotypes were observed that ranged from 16.00 to 24.25% in well-watered and 10.50 to 20.50 in moisture scarcity. The maximum but similar protein content of 24.25% was observed in both HO-1 and PSF-025, followed by Mehran under normal conditions while only HO-1 maintained its rank with maximum oil content under water stress. An increase in protein concentration under water stress has been observed in sunflower (Esmaeilian et al., 2012). They further reported that water stress at flowering stage increased protein content.

TABLE 9. Mean performance of sunflower genotypes for oil content (%) and protein content (%) grown under well watered and water stressed environments

Genotypes	Oil content (%)		*Diff.	Protein content (%)		*Diff.
	Well watered	Water stressed		Well watered	Water stressed	
Corolla	33.22	32.82	-0.40	17.25	12.75	-4.50
Peshawar-93	38.00	33.87	-4.12	22.75	19.75	-3.00
Albania	30.70	29.72	-0.97	16.75	13.50	-3.25
FMC 0046	34.02	33.60	-0.42	16.00	11.50	-4.50
HO.1	36.32	35.60	-0.72	24.25	20.50	-3.75
PSF.025	36.02	36.00	-0.02	24.25	18.50	-5.75
Melabour	35.15	34.77	-0.37	15.50	12.25	-3.25
Charnika	27.65	27.37	-0.27	18.50	11.75	-6.75
Thatta	40.75	38.00	-2.75	22.00	17.00	-5.00
SH-3915	40.25	38.00	-2.25	23.00	15.25	-7.75
UC-666	42.00	40.00	-2.00	21.75	18.50	-3.25
A-2	33.00	32.57	-0.42	17.75	12.00	-5.75
TJ-1	30.80	30.55	-0.25	15.25	10.50	-4.75
N-17	34.35	34.20	-0.15	15.00	12.00	-3.00
Turkish	33.20	32.77	-0.42	18.00	16.00	-2.00
A-1	32.77	32.35	-0.42	20.25	14.50	-5.75
Ausi-gold	34.87	33.42	-1.45	16.75	12.50	-4.25
Mehran	38.25	37.00	-1.25	24.00	20.25	-3.75
ST-2	33.22	32.77	-0.45	18.00	12.50	-5.50
B-2	36.37	35.77	-0.60	23.25	20.50	-2.75
Mean	35.04	34.06	-0.98	19.51	15.10	-4.41
L.S.D. at 5% (T)	0.43			1.24		
L.S.D. at 5% (G)	0.72			0.85		
L.S.D. at 5% (T x G)	1.08			1.66		

*Diff= difference between well watered and water stressed.

Correlation coefficient of various traits

The correlation is highly promising statistics being applied different sciences specially plant breeding projects to compute the extent and kind of relationship between two or more characters. This statistics reveal changes in two variables where affirmative association suggest the degree that two characters escalate in similar direction while negative relationship suggests the magnitude that escalations in one parameter causes deleterious effect or vice versa. Farhatullah & Khalil (2006) detected that some several agronomic characters were associated with seed yield. In another study, Tabrizi et al. (2019) established that seed head^{-1} and 1000-grain mass features with high association with each other may be used as reliable selection criteria for improving grain and oil of sunflower in optimal and moisture scarce circumstances.

The findings of current research with respect to associations of various developmental and oil traits with seed yield of sunflower inbreds planted in optimum irrigation and under drought conditions are depicted in Table 10. The correlation coefficients discovered that seed yield exhibited significantly positive association with stem diameter (r =0.56**), head diameter (r =0.57**), number of seeds head^{-1} (r =0.61**), seed index (r =0.76**), biological yield plant-^{1} (r =0.74**), seed yield kg ha^{-1} (r =0.78**), chlorophyll content (r =0.71**), linoleic acid (r =0.68**), oleic acid (r=0.73**), oil content (r=0.82**) and protein (r=0.83**) while it was negatively associated with days to seed formation (r= -0.25*), yet negatively but non-significantly linked with 75% flowering (r=-0.18) and maturity (r= -0.15) in controlled irrigation. Similar to normal conditions, stress condition also indicated that seed yield plant^{-1} established significantly positive relationship with plant height (r=0.33**), stem diameter (r=0.68**), head diameter (r=0.82**), number of seeds head-^{1} (r=0.78**), seed index (r=0.82**), biological yield plant-^{1} (r=0.65**), seed yield kg ha-^{1} (r=0.84**), chlorophyll (r=0.55**), linoleic acid (r=0.82**), oleic acid (r=0.89**), oil content (r=0.76**) and protein content (r=0.77**), while 75% flowering days (r=-0.24*), and 75% maturity days (r=-0.24*) and seed formation days (r=-32**) was significantly but negatively associated with seed yield plant^{-1}. Except biological yield, chlorophyll, oil and protein content, the correlations either in positive or negative directions was greater in water stress conditions as compared to normal irrigation. The higher degree of correlation coefficients in stress environment indicated that water stress may have triggered some genes that caused more correlation values than in normal irrigation conditions. However correlations of seed yield with other traits were greater in water stress than in normal irrigation. Negative correlations of seed yield with days 75% flowering, maturity and seed formation suggested that early flowering and early maturing plant may have set fewer seeds, thus produced low achene yield plant^{-1}. Negative associations of 50% flowering days with head size, seed index and oil yield were reported by several previous researchers (Patil, 1993; Habib et al., 2007; Sujatha & Nadaf, 2013). Similar to our findings, Pandya et al. (2016) noted that 70% flowering, days to flower initiation showed negative relationship with seed yield per plant. Analogous to our results, Anandhan et al. (2010) recorded that oil% was significantly and advantageously correlated with yield plant^{-1} (r= 0.964**).

Current findings further suggested that more importantly positively association between morphological, all seed yield, oil and protein content was recorded. Hence numerous characters may be obtainable and may be used for enhancing grain yield, oil and protein contents. Similar to our findings, Tabrizi et al. (2019) determined correlations of agronomic, seed yield and oil traits and noted that under well watered circumstances, seeds head^{-1} and capitulum size were positively associated with plant yield whereas the sturdiest relationships of oil yield were recorded with grain yield, number of seeds head^{-1} and head size in same conditions. In moisture deficit conditions, results/correlation similar to optimal conditions were also noted. Outcomes as a whole revealed that seed numbers and seed index can be reliable selection benchmarks to increase grain production in optimal as well as moisture deficient environments.

Plant breeders commonly prefer yield components that indirectly increase yield. Indirect selection of yield components such as 1000-seed weight, plant height, and head diameter can increase grain yield. Therefore, it is important to know the relationships among yield traits in sunflower to get higher yields (Kaya et al., 2007). Moisture deficiency is considered as the greatest restraining factor for crop productivity (Passioura, 2007; Rauf, 2008). The key difficulty in breeding resistant plant genotypes under optimal and drought stress environments is the knowledge of correlations between plant traits in optimum and moisture deficit circumstances . In agreement to our findings, Tabrizi et al. (2019) observed simple correlations in normal irrigation conditions and observed that seeds head^{-1} (r= 0.966**) and capitulum size (r= 0.912**) were exceedingly interrelated with grain yield, respectively, whereas the high relationship of oil yield was noted with achene yield (r= 0.90**), achenes head^{-1} (r= 0.88**) and head size (r= 0.83**). These correlations were attributable to pleiotropic influence of one gene or physical linkages between several genes (Burke et al., 2002; Darvishzadeh et al., 2011). Yasin & Singh (2010) and Kholghi et al. (2011) established constructive relationship of achenes head^{-1}, seed index and head size while Darvishzadeh et al. (2011) noted positive associations between head size and achenes head^{-1}. Similar to normal irrigation, drought stress revealed positive associations, seed and oil yield were significantly correlated with achenes head^{-1} (r= 0.962**, r= 0.959**) and capitulum size (r= 0.812**, r= 0.781**) respectively. From such results it was recommended that selections centered on head size and achenes head^{-1} can be useful in enhancing seed yield of sunflower in low moisture circumstance. Riaz et al. (2019) resolved from their correlations studies that achene/head, achene weight, plant height and head diameter are important yield-related traits could be considered as selection criteria to increase achene yield in sunflower.

Conclusion

The genotypes viz. Ho.1, Mehran, Thatta, UC-666 and B-2 recorded high performance early maturity, seed yield, oil and protein contents in both the environments. Therefore, such genotypes may be involved in breeding programmes to develop potential breeding material with improved agronomic, oil and protein characters.

TABLE 10. Correlation of coefficient of seed yield with other related traits in well watered and water stressed environments

Traits	Correlation coefficients (r)	
	Well watered	Water stressed
Days to 75% flowering	-0.18	-0.24*
Days to 75% maturity	-0.15	-0.24*
Days to seed formation	-0.25*	-0.32**
Plant height	-0.08	0.33**
Stem diameter	0.56**	0.68**
Head diameter	0.57**	0.82**
Number of seed head^{-1}	0.61**	0.78**
Seed index	0.76**	0.82**
Biological yield plant^{-1}	0.74**	0.65**
Seed yield (kg ha^{-1})	0.78**	0.84**
Chlorophyll content	0.71**	0.55**
Linoleic acid	0.68**	0.82**
Oleic acid	0.73**	0.89**
Oil content	0.82**	0.76**
Protein content	0.83**	0.77**

**,*= Denotes significance at 1 and 5% probability levels.

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