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Improvement of Drought Tolerance in Sunflower (*Helianthus annuus* L.) By Foliar Application of Abscisic Acid and Potassium Chloride

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Abstract: A field experiment was carried out at the Research area, College of Agriculture, Dera Ghazi Khan to measure the response of spring sowing sunflower to foliar application of abscisic acid (ABA) and potassium chloride under drought. In the experiment four irrigations by flooding (25 days after sowing, at bud initiation, at anthesis and at achene formation stage) were applied in control. Foliar application of 2μM ABA and 1% KCl was made at anthesis stage of sunflower hybrids (NK-265 and SF-187) after skipping the irrigation. Foliar application of 2μM ABA and 1% solution of KCl under drought at anthesis stage significantly increased achene yield and oil yield over skipping irrigation with no ABA and no KCl at anthesis stage. Sunflower hybrid NK-265 showed better drought tolerance compared with SF-187 with foliar application of ABA as well as KCl because it showed improvement in growth and yield. Sunflower hybrids NK-265 had significantly increased achene yield and oil yield than SF-187. Drought stress at anthesis stage to sunflower hybrids showed decrease in agronomic parameters and foliar application of ABA as well as KCl under water deficits improved them. ABA as well as KCl application to sunflower hybrids at anthesis under drought improved achene oil content but decreased achene protein content. Exogenous application of ABA or KCl to NK-265 under drought showed more percent increased in achene yield and oil yield than SF-187 over no ABA and no KCl application. Foliar application of ABA as well as KCl on leaf score at anthesis stage was non-significant. It is, therefore, suggested that foliar application of 2μM ABA and 1% solution of KCl under drought at anthesis stage significantly increased achene yield and oil yield over skipping irrigation, no ABA and no KCl at anthesis stage. Sunflower hybrid NK-265 showed better improvement of drought tolerance by foliar application of ABA as well as KCl than SF-187 because it showed more improvement in growth and yield.

Key words: Sunflower, drought stress, foliar application, abscisic acid, potassium

INTRODUCTION

Sunflower is high yielding oilseed crop and has the potential to bridge up the existing gap between consumption and domestic production of edible oil in the country. Furthermore, it is a short duration crop (90-120 days) and can be grown twice a year. It fits well in existing cropping system and can be grown without replacing any major crop.

Water is essential at every stage of plant growth and development. Water deficit reduces crop yield regardless of the growth stage at which it occurs in field crops including sunflower (Jensen and Mogenson, 1984). The productivity and spatial distribution of agronomic and horticultural crop plants of commercial importance are severely restricted by a variety of environmental factors. Among these factors, drought and salts play very significant role in reducing agricultural production (Boyer, 1982). In the face of a global scarcity of water resources, drought has already become a primary factor in limiting crop production.

Sunflower genotypes have performed differently in various environmental conditions which are required to evaluate the good yielding, better adaptive and stable crops varieties (Luquez *et al*., 2002; Prusti *et al*., 1999). Under drought, sunflower head diameter, achenes yield, oil content of achene and oil yield was significantly decreased (Jasinkas, 1999; Kazi *et al*., 2002). At present, around 18% of the global farmland is irrigated (more than 240 million hectares) and up to 40% of the global food supply is produced on this land (Somerville and Briscoe, 2001).

Diminishing water resources in the world emphasizes to limit irrigation for field crops. In some areas of the world the available water supply is not sufficient to produce the maximum yield on the irrigable area. While in other regions, the available moisture for irrigation is already regulated and requires deficit irrigation. For many surface water conservation projects, the annual supply of irrigation water is limited by reservoir capacity and the annual reservoir inflow. These adverse water

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irrigation management for different crops (Martin *et al.*, 1989).

Abscisic acid (ABA) acts as plant stress hormone. Under water deficit conditions, ABA is biosynthesized in plant tissue, approaches to the guard cell of leaf stomata through phloem or xylem and finally acts as a stress signal. Here abscisic acid causes closing of stomata which improve the water relations of plant under drought. When the water deficit is over, the ABA which entered in the leaf can be metabolized rapidly (Jia and Zhang, 1999).

The closing of stomata in sunflower depends on the ABA concentration in xylem sap of the plant (Tardieu *et al.*, 1996). The closing of stomata under water shortage is one of the drought tolerant mechanisms in different varieties of field crops. This helps to conserve the moisture within plant body. Physiological explanations related with the varietal variances in stress tolerance have been reported by Moons *et al.* (1995). Genotypic variations in production of abscisic acid have been observed in drought resistant and drought sensitive sunflower plants with exogenous application of ABA (Ouvrard *et al.*, 1996). Foliar application of ABA under water deficit conditions improved relative leaf water contents and achene yield of sunflower genotypes. This improvement was due to moisture conservation in plant (Hussain *et al.*, 2010, 2012).

Potassium plays an important role in the photosynthesis, ionic balance, synthesis of protein, translocation of assimilates, stomatal regulation, water use and enzyme activation. Potassium is an important macronutrient and osmoticum which helps plant to adjust low water potential under drought stress (Bukhsh *et al.*, 2012). Hence, under drought conditions, the accumulation of potassium increases in plant tissues that improves uptake of water from soil to plants. In general, potassium is accumulated in plants due to decrease in soil water potential. Consequently the water potential in the plant root further lowers and uptake of water continues. In drought potassium maintains the turgor of the plant cell and regulates stomatal functions (Waraich *et al.*, 2011).

In water deficit plants, biosynthesis of ABA increases which stimulates the discharge of potassium from guard cells of plant and finally closes the stomata (Assmann and Shimazaki, 1999). The study has revealed that potassium application under drought moderates the adverse effects of water shortage on plant growth (Sangakkara *et al.*, 2001).

Research work on different crops has already been done to enhance their water use efficiency under water deficit conditions by sowing their recommended cultivars and induction of drought resistance in field crops through foliar spray of abscisic acid as well as potassium chloride. But in current limited water availability scenario, there is need to evaluate and compare the effect of abscisic acid as well as potassium chloride application on growth and yield of different genotypes of sunflower under agro-ecological environments of Dera Ghazi Khan. Therefore, the present study was aimed to explore the effects of water stress (at anthesis stage) on the growth and yield of two sunflower hybrids, to investigate the possibility of enhancement of water conservation in two sunflower hybrids by foliar application of abscisic acid as well as potassium chloride and to make a comparison; either ABA or KCl will help more in ameliorating the detrimental effect of water shortage in sunflower hybrids.

MATERIALS AND METHODS

The current study was carried out at the research area, College of Agriculture, Dera Ghazi Khan. The experiment included the treatments as: (A) Sunflower Hybrids, H_1 = NK-265 and H_2 = SF-187 and (B) ABA and KCl concentrations as: T_1 = Control (four irrigations, 25 days after sowing, at bud initiation, at anthesis and at achene formation stage), T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application, T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl, T_4 = Irrigation skip at anthesis stage and foliar spray of 2µM ABA

The experiment was designed in RCBD with factorial arrangement with three replications. In the present study net plot size of 3.0 m x 5.0 m was used. Seedbed was prepared by using 3 time cultivation followed by planking. Crop was sown in second fortnight of February by using seed rate of 8 kg ha^{-1}. Planting geometry was maintained as (R x R 75 cm and P x P 25 cm). The quantity of nitrogen and phosphorus was applied @ 150 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}. Half N and all of the P_2O_5 were applied at the time of sowing, while remaining nitrogen was applied with 1st irrigation. Soil moisture contents was determined by gravimetric method and relative leaf water contents was measured at 7:00 to 8:00 AM before and after the application of ABA and KCl treatments (at anthesis stage). All other agronomic practices were kept same for all the treatments. Seed oil content was measured through using Soxhelt Fat Extraction Method and the determination of N in seeds was carried out according to micro Kjeldahl method (AACC, 2000) then converted into protein by multiplying it with factor 6.25.

Achene yield (kg ha^{-1}): The plants were harvested at maturity, heads were separated by sickle, sun dried, threshed manually and the achene yield per plot was recorded. The random achene samples were taken from each plot and their moisture content was determined. The achene yield was adjusted to 10% moisture content and presented in kg ha^{-1}.

Oil yield (kg ha^{-1}): In order to determine oil yield, the oil content was determined by Soxhlet Fat Extraction method (AACC, 2000) from random samples taking from each plot. Thereafter, the achene yield was converted to oil yield.

Leaf score: Total numbers of leaves were counted from five randomly selecting plants of each plot at fortnight interval. Counting was begun 30 Days after Sowing (DAS) and terminated 90 DAS.

Relative leaf water content (%): The third leaf from top (fully expanded youngest leaf) of two plants from each treatment was taken to determine the relative leaf water content. Soon after cutting at the base of lamina, leaves were sealed in plastic bags and quickly transferred to the laboratory. Fresh Weight (FW) was taken within two hours after excision of leaves. Then Turgid Weight (TW) was determined after soaking leaves in distilled water for 16-18 h at room temperature. After soaking, leaves were quickly and carefully blotted dry with tissue paper to compute turgid weight. Dry Weight (DW) was obtained after drying the leaf samples in oven for 72 h at 70°C. Relative Leaf Water Content (RLWC) was calculated from the formula (Schonfeld *et al.*, 1988) and then averaged:

$$\text{RLWC (\%)} = (\text{FW-DW})/(\text{TW-DW}) \times 100$$

Where:
FW = Fresh weight of leaf
DW = Dry weight of leaf
TW = Turgid weight of leaf

Achene oil content (%): Oil content in seeds was determined by Soxhlet Fat Extraction method (AACC, 2000). Seeds were dried in an oven at 105°C for about 8 h. To estimate moisture content, seeds were weighed before and after drying. Two grams of achenes per thimble were grinded in a coffee mill for oil content analysis. Thimbles were weighed separately, ground seeds were added and the final weight was determined. Afterwards, the thimbles were put in extractors. Six dry and clean round bottom 250 ml flasks were weighed and their weight recorded. Solvent (petroleum ether) was added to flasks, connected to the extractors and placed on heating mantles connected to condensers.
Flasks were heated and extraction was continued for at least 6 hours, extraction was stopped, thimbles were removed and then the flasks were reheated, so that all of the solvent could be collected in the Soxhlet extractors. The apparatus was allowed to be cool and flasks were dried at 105°C for 1 hr. After cooling, the flasks and oil were weighed together. Percent oil content was computed by using the following equation:

$$\text{Oil (\%)} = \frac{\text{Wt. of flask} + \text{oil} - \text{Wt. of flask}}{\text{Wt. of flask} + \text{seed} - \text{Wt. of flask}} \times 100$$

Protein content (%): Nitrogen in achenes was determined according to Kjeldahl method (AACC, 2000). One gram of each sample was transferred along with the Kjeldahl flask; a digestion Tablet was added to 5 ml of concentrated H_2SO_4 and then content was mixed thoroughly. The flask was placed on the digestion assembly and after that both heater and the exhaust fan were turned on. The digestion continued with occasional shaking of flask. When the solution became clear and all organic matter had been oxidized, then digestion was continued for another 30 minutes.
The cooled digestats was transferred to a 100 ml volumetric flask and made up its volume to 100 ml by rinsing the flask with distilled water. Pipette 5 ml from the volumetric flask and poured into a Markam Still Apparatus. Ten ml of NaOH (4% w/v) was added gradually through the funnel stopper (did not remove the stopper, otherwise ammonia may escape). The funnel was plugged firmly and then a few ml of the distilled water was added. Distilled it for five minutes and collected in a conical flask containing 5 ml of 2% boric acid. After 5 minutes distillation, collected the droppings from the condenser for one minute. Washed the tip of the condenser into the flask and titrated against standardized H_2SO_4. Percent crude protein was calculated using the following formula:

$$\text{Crude protein (\%)} = \frac{(V_1 - V_2)}{100\ W} \times 14 \times 6.25 \times 100$$

Where:
V_1 = Sample titration (in ml)
V_2 = Blank titration (in ml)
N = Normality of standardized H_2SO_4
W = Sample weight

Data regarding all the parameters were collected using standard techniques and was analysed by using Fisher's Analysis of Variance Technique. LSD test at 5% probability was used to associate the changes among treatments' means (Steel and Torrie, 1980).

RESULTS

Achene yield (kg ha^{-1}): Water stress at anthesis stage of sunflower hybrids had significantly decreased the achene yield. The mean data showed that achene yield was more in sunflower hybrid NK-265 than SF-187. The foliar application of ABA as well as potassium chloride, treatment and their interaction showed significant impact on 1000-achenes weight. When drought applied at anthesis stage (T_2), it significantly decreased 1000-achenes weight as compared to other three treatments (T_1, T_3 and T_4). The mean effect on cultivars achene yield was statistically significant and more achene yield was found in NK-265 as compared to SF-187 sunflower hybrid. The overall hybrid means had showed that significant on both sunflower achene yield but more yields was recorded in NK-265 as compared to SF-187. Drought stress statistically decreased achene yield compared to no stress (T_1). The bad effect of drought stress at anthesis stage could be reduced by exogenous application of ABA as well as KCl. Maximum and minimum% decrease in NK-265 of achene yield was 30.98 at T_2 and 5.61% at T_4. Maximum and minimum% decreased in achene of SF-187 was 16.99% and 4.11% respective (Table 1).

Achene oil yield (kg ha^{-1}): Drought stress and foliar application of ABA as well as KCl under drought stress at anthesis had significant effect on achenes oil yield of both sunflower hybrids and treatments. Mean data showed that NK-265 hybrid produced more achene oil yield than that of SF-187. Drought stress had significantly decreased the achenes oil yield of both sunflower hybrids. Exogenous application of ABA as well as KCl ameliorated the adverse effects of drought. Maximum achene oil yield was noted in the plots where sunflower hybrids were not faced drought while minimum achene oil yield was noted in T_2 (irrigation skip at anthesis stage and no application of ABA as well as KCl). Although the interaction between hybrids and treatments was non-significant but showed the difference between interaction (Table 2). When drought applied at anthesis stage (T_2), it significantly decreased achenes oil yield as compared to other three treatments (T_1, T_3 and T_4). In sunflower hybrids NK-265, the maximum and minimum% decrease of achene oil yield 38.05% was observed in (T_2) and 9.86% in T_4 while in SF-187 the maximum and minimum% decrease of achene oil yield was 33.98% in T_2 and 8.93% in T_4 respectively was noted (Table 2).

Leaf score (%): Foliar application of ABA as well as KCl on leaf score at anthesis stage was non-significant. Periodic data in Fig. 1 clearly indicated that number of leaves per plant gradually increased up to 90 Days after Sowing (DAS).

Relative leaf water content before application of treatments (%): Water shortage at anthesis stage of sunflower hybrids had non-significant effect on relative leaf water content of sunflower hybrids (Table 3).

Relative leaf water content 7 days after application of treatments (%): Water stress at anthesis stage of sunflower hybrids had significantly decreased the leaf water content after 7th days application of treatments to

Table 1: Effect of exogenous application of abscisic acid as well as potassium chloride on achene yield (kg ha^{-1}) of sunflower hybrids

	Sunflower Hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	2486.30 a	2017.00 c	2251.70 A
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	1716.00 d	1674.40 d	1695.20 C
	-30.98	-16.99	
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	2133.80 bc	1693.40 d	1913.60 B
	-14.18	-16.04	
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 μM ABA	2346.80 ab	1934.00 cd	2140.40 A
	-5.61	-4.11	
Mean	2170.70 A	1829.70 B	

LSD for treatments 168.42; LSD for varieties 87.913; LSD for interaction 289.00.
Means sharing the similar letter within column and treatment don't differ significantly at the 5% probability level; ABA= abscisic acid; KCl= potassium chloride.

Table 2: Effect of exogenous application of abscisic acid as well as potassium chloride on achene oil yield (kg ha^{-1}) of sunflower hybrids

	Sunflower hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	940.06	725.64	832.85 A
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	582.4	479.04	530.72 D
	-38.05	-33.98	
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	772.31	581.5	676.91 C
	-17.84	-19.86	
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 μM ABA	847.4	660.87	754.14 B
	-9.86	-8.93	
Mean	785.54 A	611.76 B	

LSD for treatments 19.933; LSD for varieties 14.095.
Means sharing the similar letter within column and treatment don't differ significantly at the 5% probability level; AB: Abscisic acid; KCl: potassium chloride.

sunflower hybrids. It was statistically significant affect and showed higher relative leaf water content was observed in NK-265 as compared SF-187. Drought stress statistically decreased leaf water content in T_2 (skipping irrigations at anthesis stage and no application of ABA as well as KCl) as compared to no stress (T_1). Detrimental effect of drought stress at anthesis stage was reduced by exogenous application of ABA (T_4) as well as KCl (T_3). In sunflower hybrids NK-265 and SF-187, maximum% decrease in relative leaf water content was 14.40 and 20.05% in T_2 while minimum% decrease was 8.93% in T_4 and 13.85% in T_3 respectively was noted as compared to their respective control (T_1) (Table 4).

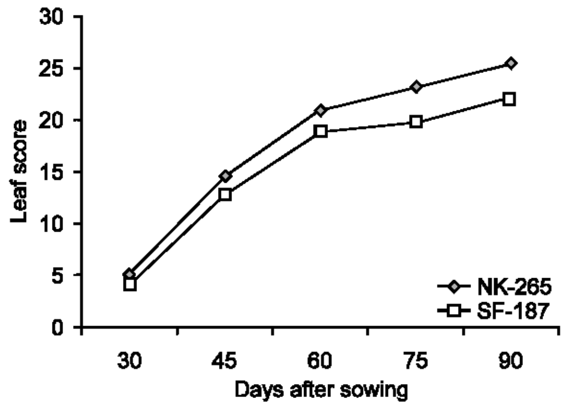

Fig. 4.1: Leaf score of two sunflower hybrids; NK-265 and SF-187

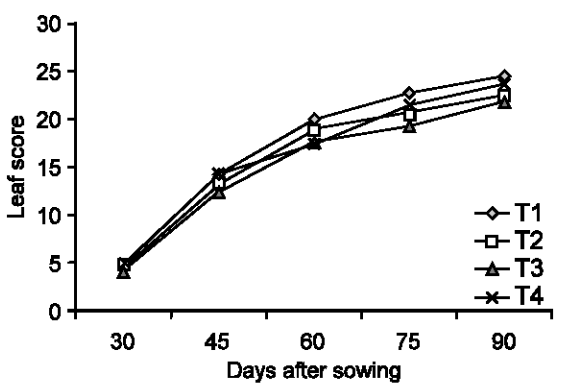

Fig. 1: Effect of treatments concentrations on leaf score in sunflower hybrids; T_1 = Control (four irrigations); T_2 = Irrigation skip at anthesis stage, no ABA as well as no KCl application; T_3 = Irrigation skip at anthesis stage as well as foliar spray of 1% solution of KCl; T_4 = Irrigation skip at anthesis stage as well as foliar spray of 2µM ABA

Achene oil content (%): Drought stress and foliar application of ABA as well as KCl under drought stress at anthesis had significant effect on achenes oil content of both sunflower hybrids. Achenes oil content of sunflower hybrids were significantly affected by different treatments. It was significantly more when the sunflower crop faced no drought stress. It was statistically showed that the interaction between cultivars and treatments of both sunflower hybrids had significant affect. Although the achenes oil content were significant but the interaction between non-significant as compared to control (T_1). Drought significantly decreased the oil content and more reduction was observed when stress was applied at anthesis stage (T_2). Adverse effect of drought in both sunflower hybrids could be ameliorated by exogenous application of ABA (T_4) as well as KCl (T_3) (Table 5). In sunflower hybrids NK-265 and SF-187 the maximum and minimum% decrease in the achenes oil content was 10.19%, 20.57% in T_2 and 4.23%, 4.45% in T_3, respectively as compared to their respective control.

Achene protein content (%): Mean data showed that the achene protein content of both sunflower hybrids had significantly differed to each other and higher value was observed in NK-265. Maximum achenes protein content was calculated in (T_2) as compared to the other treatments (T_1, T_3 and T_4). The interactive effect of treatment and cultivars was significant and clearly showed that in drought environmental condition the production of protein was much more as compared to no stress (T_1). In sunflower hybrid NK-265 the maximum and minimum% decreased in achene protein content 42.33% in T_2 and 12.44% was observed in T_4 was observed while in sunflower hybrid SF-187, the maximum and minimum% increased in achene protein content was 23.97% in T_2 and 9.06% in T_3 was noted (Table 6).

Table 3: Effect of exogenous application of abscisic acid as well as potassium chloride on relative leaf water content before application of treatments (%) of sunflower hybrids

	Sunflower hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	74.967	75.05	75.008
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	72.213	73.183	72.698
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	74.59	76.12	75.355
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 µM ABA	74.027	74.55	74.288
Mean	73.949	74.726	

ABA: Abscisic acid; KCl: Potassium chloride.

Table 4: Effect of exogenous application of abscisic acid as well as potassium chloride on relative leaf water content 7 days after application of treatments (%) of sunflower hybrids

	Sunflower hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	64.17 a	65.55 a	64.86 A
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	54.93 d	52.41 e	53.67 C
	-14.4	-20.05	
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	58.14 b	56.47 c	57.30 B
	-9.4	-13.85	
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 μM ABA	58.44 b	56.26 cd	57.35 B
	-8.93	-14.17	
Mean	58.92 A	57.67 B	

LSD for treatments 1.058; LSD for varieties 0.748; LSD for interaction 1.497.

Means sharing the similar letter within column differ significantly at the 5% probability level; ABA: Abscisic acid; KCl: Potassium chloride.

Table 5: Effect of exogenous application of abscisic acid as well as potassium chloride on achene oil content (%) of sunflower hybrids

	Sunflower hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	37.80 a	35.98 abc	36.89 A
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	33.95 c	28.58 d	31.26 C
	-10.19	-20.57	
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	36.20 ab	34.38 bc	35.29 B
	-4.23	-4.45	
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 μM ABA	36.11 abc	34.14 bc	35.13 B
	-4.47	-5.11	
Mean	36.01 A	33.27 B	

LSD for treatments 1.308; LSD for varieties 0.683; LSD for interaction 2.245.

Means sharing the similar letter within column and treatment don't differ significantly at the 5% probability level; ABA: Abscisic acid; KCl: Potassium chloride.

Table 6: Effect of exogenous application of abscisic acid as well as potassium chloride on achene protein contents (%) of sunflower hybrids

	Sunflower hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	20.81 cd	19.52 d	20.16 C
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	29.62 a	24.20 b	26.91 A
	-42.33	-23.97	
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	24.42 b	21.29 bcd	22.85 B
	-17.34	-9.06	
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 μM ABA	23.40 bc	21.65 bcd	22.52 B
	-12.44	-10.91	
Mean	24.56 A	21.66 B	

LSD for treatments 1.954; LSD for varieties 1.019; LSD for interaction 3.352.

Means sharing the similar letter within column and treatment don't differ significantly at the 5% probability level; ABA: Abscisic acid; KCl: Potassium chloride.

Table 7: Effect of exogenous application of abscisic acid as well as potassium chloride on soil moisture content of sunflower hybrids

	Sunflower hybrids		
Treatments	NK-265	SF-187	Mean
T_1 = Control (four irrigations)	26.06	25.1	25.58
T_2 = Irrigation skip at anthesis stage, no ABA and no KCl application	25.35	24.75	25.05
	-2.72	-1.39	
T_3 = Irrigation skip at anthesis stage and foliar spray of 1% solution of KCl	24.77	24.58	24.67
	-4.95	-2.07	
T_4 = Irrigation skip at anthesis stage and foliar spray of 2 μM ABA	25.21	24.79	25
	-3.26	-1.24	
Mean	25.34	24.81	

Means sharing the similar letter within column and treatment don't differ significantly at the 5% probability level; ABA: Abscisic acid; KCl: Potassium chloride.

DISCUSSION

Achene yield of sunflower hybrids was significantly different under drought and normal irrigation. More achene yield was noted in NK-265 compared to SF-187. Water deficits to sunflower hybrids at anthesis stage reduced achene yield. This reduction in achene yield of sunflower hybrids under drought might have occurred due to decrease in: Head diameter (Hussain *et al*., 2012 and 2010) number of achenes per head (Liu *et al*., 2004) and 1000-achene weight which finally decreased achene yield. Foliar application of ABA as well as KCl to sunflower hybrids under drought at antehsis stage increased achene yield which might be due to conservation of water (Hussain *et al*., 2012 and Bukhsh *et al*., 2012).

Sunflower genotypes showed differential oil yield response under drought and normal irrigation. Drought stress significantly decreased oil yield of sunflower hybrids. Reduction in oil yield of sunflower under drought was also observed by Hussain *et al*. (2010). This reduction in oil yield under drought might be due to decrease in: Achene yield as well as translocation of photosynthate to sink. Results of the current study also depicted that exogenous application of ABA as well as KCl under drought increased oil yield which might be due to conservation of water in plants and improvement in transport of photosynthate to sink.

Genotypic variation in leaf relative water content was observed and sunflower hybrid NK-265 (tall statured) under drought had maximum relative leaf relative water content as compared to SF-187 (short statured). This indicated that NK-295 showed more tolerance to drought as compared to SF-187 as it maintained higher relative water content in its leaf and was able to absorb more water under adverse water potential conditions in soil. Water deficit to sunflower hybrids at anthesis stage had reduced leaf relative water content. Reduction in relative leaf relative water content under drought drastically affected sunflower growth and development (Tezara *et al*., 2002). Exogenous application of ABA as well as KCl under drought significantly increased relative leaf relative water content of sunflower hybrids (Bukhsh *et al*., 2012). This improvement in relative leaf water content might be due to conservation of moisture in plants (Hoad *et al*., 2001).

Genotypic differences in achene oil content were observed among sunflower hybrids. Achene oil content of sunflower hybrids was reduced under drought at anthesis stage. Razi and Asad (1999) had observed no change in achene oil content under drought. Achene oil content might be increased by exogenous application of ABA as well as KCl as its application might led to partial stomatal closure and enhanced root penetration (Alfredo and Setter, 2000) which might have increased availability of water for oil synthesis and translocation which increased achene oil content.

Results of the current study observed that drought stress significantly increased achene protein content of sunflower hybrids. Achene protein content was more increased when drought stress was faced at anthesis stage. This increase in protein content might be due to negative relation of oil and protein content (Debaeke *et al*., 1998). However, when ABA as well as KCl applied under drought it decreased achene protein content because it might have relieved the plants from drought condition. Exogenous application of ABA as well as KCl under drought had non-significant effect on leaf score. This might be due to application of low concentration of ABA which did not defoliate the leaves in both sunflower hybrids.

Conclusions: Foliar application of 2μM ABA and 1% solution of KCl under drought at anthesis stage significantly increased achene yield and oil yield over skipping irrigation, no ABA and no KCl at anthesis stage. Similarly, sunflower hybrid NK-265 showed better improvement of drought tolerance by foliar application of ABA and KCl than SF-187 because it showed more improvement in growth and yield.

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