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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Profitability Assessment of Abscisic Acid Application on Sunflower (*Helianthus annuus* L.) Hybrid under Drought and Well Watered Conditions

Safdar Hussain[1], M. Farrukh Saleem[2], Javaid Iqbal[1], Sajid Mahmood Nadeem[1], Muhammad Ahmad[3] and Muhammad Ibrahim[1]
[1]Department of Agronomy, College of Agriculture, Dera Ghazi Khan-32200, Pakistan
[2]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
[3]Adaptive Research Complex, Dera Ghazi Khan-32200, Pakistan

Abstract: Profitability assessment has prime importance for every crop husbandry practice and cultural operation. For this purpose, two field experiment was carried out to investigate the response of spring planted sunflower hybrids to different irrigation levels/schedules and foliar application of abscisic acid. Two studies were done at the Agronomic Research Farm, University of Agriculture, Faisalabad, Pakistan. In first study, three irrigation schedules viz. four irrigations (25 DAS, bud initiation, flower initiation and achene formation), three irrigations (25 DAS, flower initiation and achene formation) and three irrigations (25 DAS, bud initiation and achene formation) were used. Sunflower hybrid Hysun-33 was subjected to exogenous application of different concentrations (0, 5μm and 10μm) of ABA at bud initiation or at flower initiation. In second study, Three sunflower hybrids viz. DK-4040 (large stature), S-278 (medium stature) and SF-187 (short stature) were subjected to different irrigation regimes and ABA applications i.e., four irrigations; 25 Days after Sowing (DAS), at bud initiation, flower initiation and achene formation and with no ABA spray, three irrigations; 25 Days after Sowing (DAS), at flower initiation and achene formation and with no ABA spray, three irrigations; 25 Days after Sowing (DAS), at flower initiation and achene formation and with ABA spray at bud initiation, three irrigations; 25 Days after Sowing (DAS), at bud initiation and achene formation and with no ABA spray, three irrigations; (25 Days after Sowing (DAS), at bud initiation and achene formation and with ABA spray at flower initiation. In first study, It was observed that three irrigations (25 DAS, at flower initiation and at achene formation), when 5μM ABA was applied at bud initiation under drought resulted in more profitable as compared to exogenous application of same concentration of ABA at flower initiation. So, it is suggested that three irrigations (25 DAS, at flower initiation and at achene formation), with foliar spray of 5μM ABA should be applied at bud initiation under drought. In second study, the dominance and marginal analysis about sunflower hybrids revealed that maximum Marginal Rate of Return (MRR) in sunflower hybrids was observed in T_1 (control). Drought stress at bud initiation or at flower initiation reduced marginal rate of return. ABA application to DK-4040 under drought at bud initiation showed more increase in MRR than SF-187 and S-278.

Key words: Sunflower hybrids, irrigation schedules, ABA application, profitability

INTRODUCTION

Pakistan is chronically deficient in the production of edible oil and situation is getting worse day by day with alarming increase in population growth rate (Asif *et al.*, 2001). Pakistan is the third largest importer of edible oil in the world and spends huge foreign exchange on the import of edible oil which is second to that spent on the import mineral oil (Bukhsh *et al.*, 2011a).

Profitability assessment is of prime importance for every crop husbandry practice and cultural operation. Sunflower has shown differential yield response under drought. Water stress increased the net assimilation rate while it decreased the leaf area ratio in sunflower. Drought significantly decreased yield and its components; however, oil content did not differ significantly. Water stress has significant effect on total dry matter, net assimilation rate, relative growth rate, crop growth rate and leaf area index (Ardakani *et al.*, 2005; Nasri, 2005) but at the same time cost of every irrigation is needed to be evaluated (Daneshian *et al.*, 2005).

One of the possible solutions for the drought amelioration was the application of abscisic acid (ABA) as plant stress hormone. Under drought condition, ABA is synthesized in plant tissue and sent to the guard cell as a stress signal. Here ABA causes stomatal closure

Corresponding Author: Muhammad Ahmad, Adaptive Research Complex, Dera Ghazi Khan-32200, Pakistan

which improves the water relations of plant. ABA entering a leaf can be metabolized rapidly (Loveys, 1984; Gowing *et al.*, 1993; Jia *et al.*, 1996). In sunflower, stomatal control depends on the concentration of ABA in xylem sap (Tardieu *et al.*, 1996). Stomatal closure due to response of water shortage is one of the drought-adaptation mechanisms in plant. Physiological observations associated with the varietals differences in stress tolerance in field crops have been reported (Moons *et al.*, 1995; Pelah *et al.*, 1997) and ABA also produced genetic difference in drought tolerant and drought sensitive plants (Ouvrard *et al.*, 1996) but again there was need to evaluate the economic viability of the application of this hormone (Ardakani *et al.*, 2005; Bukhsh *et al.*, 2011b: Nasri, 2005). For this purpose, the present study has been designed to quantify profitability of impact of exogenous application of ABA in enhancing drought tolerance by sunflower in relation with irrigation scheduling.

MATERIALS AND METHODS

Two field studies were carried out to investigate the response of spring planted sunflower hybrids to different irrigation levels/schedules and foliar application of abscisic acid. Studies were done in 2008 and 2009 at the Agronomic Research Farm, University of Agriculture, Faisalabad, Pakistan.

Study 1

A) Irrigation schedules:

I_1 Four irrigations; 25 DAS, at bud initiation (R_1), at flower initiation (R_5) and at achene formation (R_7)

I_2 Three irrigations; 25 DAS, at flower initiation (R_5) and at achene formation (R_7)

I_3 Three irrigations; 25 DAS, at bud initiation (R_1) and at achene formation (R_7)

B) ABA concentrations:

C_1 Control (no exogenous application of ABA)

C_2 Exogenous application of 5μM ABA at bud initiation (R_1)

C_3 Exogenous application of 5μM ABA at flower initiation (R_7)

C_4 Exogenous application of 10μM ABA at bud initiation (R_1)

C_5 Exogenous application of 10μM ABA at flower initiation (R_7)

Study 2

A) Hybrids:

- H_1 = DK-4040
- H_2 = S-278
- H_3 = SF-187

B) Irrigation and abscisic acid application schedules:

T_1 Four irrigations; 25 DAS, at bud initiation, at flower initiation and at achene formation stage and no ABA

T_2 Three irrigations; 25 DAS, at flower initiation and at achene formation stage and no ABA

T_3 Three irrigations; 25 DAS, at flower initiation and at achene formation and 8μm ABA at bud initiation

T_4 Three irrigations; 25 DAS, at bud initiation and at achene formation and no ABA

T_5 Three irrigations; 25 DAS, at bud initiation and at achene formation and 8μm ABA at flower initiation

The experiments were laid out in Randomized Complete Block Design (RCBD) with factorial arrangement and replicated thrice. Net plot size was 3.0 m x 5.0 m. In first experiment sunflower hybrid (Hysun-33) was sown on 17th and 12th of February 2008 and 2009 respectively. Hybrid seed was planted on ridges with the help of dibbler by using seed rate of 8 kg/ha. Ridges were made 75 cm apart and plant-to-plant distance of 25 cm was maintained. In second experiment three sunflower hybrids viz., Dk-4040, SF-187 and S-278 were sown on the same date as mentioned in first experiment. In both experiment fertilizers were applied at the rate of 150 kg N and 100 kg P_2O_5/ha in the form of urea and Diammonium Phosphate (DAP). Half of nitrogen and whole of phosphorus were applied at sowing, while remaining nitrogen with 1st irrigation. Irrigations were applied as per treatment by flooding. In both experiments, the first irrigation was applied at 4-6 leaf stage (25 DAS), the 2nd irrigation was applied at bud initiation stage (45 DAS) except the plots which were subjected to water stress at this stage, the 3rd irrigation was applied at flower initiation stage (67 DAS) except the plots which were subjected to water stress at this stage. The 4th irrigation was given to all plots at grain formation stage (90 DAS).

Weighted quantity of ABA (as per treatment) was added in a graduated cylinder and volume was made I L in volumetric flask with distilled water. Thereafter Knapsack sprayer was calibrated (250 L/ha) and use to spray solution. Distilled water was sprayed in the control plots. The plants were harvested at maturity, heads were separated by sickle, sun dried, threshed manually and the achene yield per plot was recorded and computed in kg/ha.

After determining the field prices of all inputs total cost for all the experimental treatments was calculated. Costs that vary between experimental treatments (variable cost) were the costs (ha^{-1}) of purchased inputs, labor and machinery. It can be some of all the costs (both cost and opportunity costs) that vary for a particular treatment. A marginal cost is increase in variable cost which occur in changing from one production alternative to another. Marginal net benefit is increase in net benefit which can be obtained by changing from one production alternative to another. Marginal rate of return refers to ratio of marginal benefit to marginal cost expressed on percentage basis while dominated treatment/s has/have higher costs but lower net benefits.

Achene yield was adjusted down ward (10%) to reflect the difference between the experimental yield and the expected yield of farmer from the same treatment. Net benefits were calculated by subtracting the total variable cost from the gross benefits for each treatment. Dominance analysis was carried out by first listing the treatments in the order of increasing variable costs. Any treatment that had net benefits that were less than or equal to those of a treatment with lower variable cost was taken to be dominated, D. Finally marginal analysis was carried out to compare the extra (or marginal) costs with the extra (or marginal) net benefits. For this purpose Marginal Rate of Return (MRR) was calculated by dividing the marginal net benefits (change in the net benefits) by the marginal cost (change in cost) and expressed as a percentage (Byerlee, 1988; CIMMYT, 1988). In the choice of treatments for practical use/recommendations, the dominated treatments are dropped due to higher costs involved. Data collected were analyzed by using Fisher's analysis of variance technique in MSTAT-C. LSD test at 5% probability was used to compare the differences among treatments' means. Analysis over years was made by using factorial experiment under Randomized Complete Block Design (Steel *et al*., 1997).

RESULTS AND DISCUSSION

The results of study 1 (Table 1) clearly indicated that well watered, drought stress and exogenous application of stress hormone ABA under drought and well watered conditions had pronounced impact on achene yield, adjusted achene yield, achene value, cost of ABA, cost that vary and net benefits. Well watered conditions had maximum net benefits and drought stress to crop either at bud or at flower initiation decreased it. Exogenous application of ABA under drought stress improved net benefits. More improvement in net benefits was observed when 5μM ABA was applied at bud initiation under drought as compared to exogenous application of same concentration of ABA at flower initiation.

The Dominance and Marginal analysis of study 1 (Table 2) revealed that during 2008 and 2009 under drought stress application of 5μM ABA at bud initiation increased percent MRR (Marginal Rate of Return) as compared to exogenous application of same concentration of ABA at flower initiation. These results indicated that sunflower production under water deficits conditions due to limited water availability could be more benefited when farmer applied 5μM ABA at bud initiation.

Table 1: Pre-sowing field soil analysis

	Determination	Unit	Value 2008	Value 2009
A	Physical Analysis			
	Sand	%	66.6	64.5
	Silt	%	16.6	18.5
	Clay	%	16.8	17
	Textural class	Sandy clay loam		
B	Chemical Analysis			
	pH		8.2	8.00
	EC	DS m^{-1}	1.37	1.42
	Organic matter	%	0.74	0.70
	Total nitrogen	%	0.046	0.047
	Available phosphorus	Ppm	6.52	6.58
	Available potassium	Ppm	171	170

The increase in net benefits and MRR under drought and application of 5μM ABA at bud initiation was due to increase in achene yield. The achene yield of sunflower was increased as ABA application under drought stress conserve plant moisture (Hussain *et al*., 2010). Hussain *et al*. (2012) further indicated that exogenous application of ABA under water deficit conditions increased achene yield of sunflower hybrid as head diameter, number of achenes per head, 1000-achene weight, crop growth rate, leaf area and leaf area index also increased. These results are in line with the findings of Ardakani *et al*. (2005) and Nasri (2005) that under drought conditions exogenous application of ABA at bud initiation gave more achene yield than that of its application at flower initiation stage.

Results of study 2 (Table 4) depicted that well watered conditions, water deficit at bud and at flower initiation and foliar application of ABA at these critical stages of sunflower hybrids (DK-4040, S-278 and SF-187) had prominent effect on achene yield, adjusted achene yield, achene value, cost of ABA, cost that vary and net benefits of hybrids. The performance of DK-4040 under drought stress was better as compared to S-278 and SF-187. Sunflower hybrid DK-4040 under drought stress at bud initiation and water application at flower initiation and at achene formation stage with application of 10μM ABA at bud initiation had more achene yield and net benefits as compared to drought stress at bud initiation without ABA. Water deficit at flower initiation was more detrimental as it decreased more achene yield and net benefits. Foliar application of ABA under water deficits at flower initiation although increased achene yield and net benefits but this improvement was less as compared to application ABA at bud initiation after skipping the irrigation at the respective stage.

The dominance and marginal analysis (Table 5) cleared that DK-4040 showed marginal net benefits and MRR in

Table 2: Average economic analysis of study 1 during 2008-2009

	C1	C2	C3	C4	C5	Remarks
	I1					
Achene yield (kg ha^{-1})	2861	2752	2634.5	2632	2509	kg ha^{-1}
Adjusted achene yield (kg ha^{-1})	2575	2477	2371	2369	2258	10% less than actual yield
Achenes value	115866.5	111451	106696.5	106594	101614.5	Rs.1800/40 kg
Cost of irrigation	600	600	600	600	600	Rs.150/irrigation labour charges
Cost of ABA ha^{-1}	0	8000	9600	20800	24960	Rs.80000/g
Spray charges	0	250	250	250	250	Rs.250/spray
Sprayer rent	0	50	50	50	50	Rs.50 ha^{-1}
Total cost that vary	600	8900	10500	21700	25860	Rs. ha^{-1}
Net benefits	115266.5	102551	96696.5	84894	75754.5	Rs. ha^{-1}
	I2					
	C1	C2	C3	C4	C5	Remarks
Achene yield (kg ha^{-1})	1967.5	2490.5	1859.5	2230	1543	kg ha^{-1}
Adjusted achene yield (kg ha^{-1})	1770.5	2241.5	1673.5	2007.5	1388.5	10% less than actual yield
Achenes value	79679	100862	75310	90320.5	62494.5	Rs.1800/40 kg
Cost of irrigation	450	450	450	450	450	Rs.150/irrigation labour charges
Cost of ABA ha^{-1}	0	8000	9600	20800	24960	Rs.80000/g
Spray charges	0	250	250	250	250	Rs.250/spray
Sprayer rent	0	50	50	50	50	Rs.50 ha^{-1}
Total cost that vary	450	8750	10350	21550	25710	Rs. ha^{-1}
Net benefits	79229	92112	64960	68770.5	36784.5	Rs. ha^{-1}
	I3					
	C1	C2	C3	C4	C5	Remarks
Achene yield (kg ha^{-1})	1832.5	1723.5	2433	1389.5	2005.5	kg ha^{-1}
Adjusted achene yield (kg ha^{-1})	1649.5	1551	2189.5	1251	1805	10% less than actual yield
Achenes value	74216.5	69801.5	97527.5	56279.5	81222.5	Rs.1800/40 kg
Cost of irrigation	450	450	450	450	450	Rs.150/irrigation labour charges
Cost of ABA ha^{-1}	0	8000	9600	20800	24960	Rs.80000/g
Spray charges	0	250	250	250	250	Rs.250/spray
Sprayer rent	0	50	50	50	50	Rs.50 ha^{-1}
Total cost that vary	450	8750	10350	21550	25710	Rs. ha^{-1}
Net benefits	73766.5	61051.5	88177.5	34729.5	55512.5	Rs. ha^{-1}

I_1 = Four irrigations (25 DAS, at bud initiation (R_1), at flower initiation (R_5) and at achene formation (R_7) stage); I_2 = Three irrigations (25 DAS, at flower initiation (R_5) and at achene formation (R_7) stage; I_3 = Three irrigations (25 DAS, at bud initiation (R_1) and at achene formation (R_7) stage); C_1 = Control (no exogenous application of ABA); C_2 = Exogenous application of 5 µMABA @ 250 L solution/ha at bud initiation (R_1) stage; C_3 = Exogenous application of 5µM ABA @ 300 L solution/ha at flower initiation (R_7) stage; C_4 = Exogenous application of 10µM ABA @ 250 L solution/ha at bud initiation (R_1) stage; C_5 = Exogenous application of 10µM ABA @ 300 L solution/ha at flower initiation (R_7) stage.

Table 3: Average dominance and marginal analysis of study 1 during 2008-2009

Treatments	TC (Rs. ha^{-1})	NB (Rs. ha^{-1})	MC (Rs. ha^{-1})	MNB (Rs. ha^{-1})	MRR (%)
No drought stress					
I_1C_1	600	115516.5	-	-	D
I_1C_2	8900	102551	-	-	D
I_1C_3	10500	96696.5	-	-	D
I_1C_4	21700	84894	-	-	D
I_1C_5	25860	75754.5	-	-	D
Drought stress at bud initiation					
I_2C_1	450	79229	-	-	D
I_2C_2	8750	92112	1600	12883	805.18
I_2C_3	10350	64960	-	-	D
I_2C_4	21550	68770.5	-	-	D
I_2C_5	25710	36784.5	-	-	D
Drought stress at flower initiation					
I_3C_1	450	73766.5	-	-	D
I_3C_2	8750	61051.5	-	-	D
I_3C_3	10350	87177.5	1600	10211	651.68
I_3C_4	21550	34729.5	-	-	D
I_3C_5	25710	55512.5	-	-	D

I_1 = Four irrigations (25 DAS, at bud initiation (R_1), at flower initiation (R_5) and at achene formation (R_7) stage); I_2 = Three irrigations (25 DAS, at flower initiation (R_5) and at achene formation (R_7) stage; I_3 = Three irrigations (25 DAS, at bud initiation (R_1) and at achene formation (R_7) stage); C_1 = Control (no exogenous application of ABA); C_2 = Exogenous application of 5µMABA @ 250 L solution/ha at bud initiation (R_1) stage; C_3 = Exogenous application of 5µM ABA @ 300 L solution/ha at flower initiation (R_7) stage; C_4 = Exogenous application of 10µM ABA @ 250 L solution/ha at bud initiation (R_1) stage; C_5 = Exogenous application of 10µM ABA @ 300 L solution/ha at flower initiation (R_7) stage; D = Dominate

TC = Total cost that vary, NB = Net benefits, MC = Marginal costs, MNB = Marginal net benefits, MRR = Marginal rate of return

Table 4: Average economic analysis of study 2 during 2008-2009

	H_1					
	T_1	T_2	T_3	T_4	T_5	Remarks
Achene yield (kg ha^{-1})	3339.5	1889	2798	1253.5	2542	kg ha^{-1}
Adjusted achene yield (kg ha^{-1})	3005.5	1700.5	2518	1128.5	2287.5	10% less than actual yield
Achenes value	135246	76513	113323.5	50762.5	102935.5	Rs.1800/ 40 kg
Cost of irrigation	600	450	450	450	450	Rs.150/ irrigation labour charges
Cost of ABA ha^{-1}	0	0	16640	0	19968	Rs.80000/ g
Spray charges	0	0	250	0	250	Rs.250/ spray
Sprayer rent	0	0	50	0	50	Rs.50 ha^{-1}
Total cost that vary	600	450	17390	450	20749.5	Rs. ha^{-1}
Net benefits	134646	76063	95933.5	50312.5	82217.5	Rs. ha^{-1}
	H_2					
	T_1	T_2	T_3	T_4	T_5	Remarks
Achene yield (kg ha^{-1})	2826	1642	2398	1164	1878.5	kg ha^{-1}
Adjusted achene yield (kg ha^{-1})	2543	1477.5	2158	1047.5	1691	10% less than actual yield
Achenes value	114443	66493.5	97119.5	47140	76081.5	Rs.1800/ 40 kg
Cost of irrigation	600	450	450	450	450	Rs.150/ irrigation labour charges
Cost of ABA ha^{-1}	0	0	16640	0	19968	Rs.80000/ g
Spray charges	0	0	250	0	250	Rs.250/ spray
Sprayer rent	0	0	50	0	50	Rs.50 ha^{-1}
Total cost that vary	600	450	17390	450	20749.5	Rs. ha^{-1}
Net benefits	113843	66043.5	79729.5	46690	55363.5	Rs. ha^{-1}
	H_3					
	T_1	T_2	T_3	T_4	T_5	Remarks
Achene yield (kg ha^{-1})	3233.5	2008	2834.5	1483	2452.5	kg ha^{-1}
Adjusted achene yield (kg ha^{-1})	2910	1807	2551	1334.5	2207	10% less than actual yield
Achenes value	130952.5	81325.5	114798.5	60058	99323.5	Rs.1800/40 kg
Cost of irrigation	600	450	450	450	450	Rs.150/ irrigation labour charges
Cost of ABA ha^{-1}	0	0	16640	0	19968	Rs.80000/ g
Spray charges	0	0	250	0	250	Rs.250/ spray
Sprayer rent	0	0	50	0	50	Rs.50 ha^{-1}
Total cost that vary	600	450	17390	450	20749.5	Rs. ha^{-1}
Net benefits	130352.5	80875.5	97408.5	59608	78605.5	Rs. ha^{-1}

H_1: DK-4040; H_2: S-278; H_3: SF-187; T_1 = Four irrigations (25 DAS, at bud initiation, at flower initiation and at achene formation stage) and no ABA; T_2 = Three irrigations (25 DAS, at flower initiation and at achene formation stage) and no ABA; T_3 = Three irrigations (25 DAS, at flower initiation and at achene formation stage) and ABA solution spray @ 250 L/ha at bud initiation stage; T_4 = Three irrigations (25 DAS, at bud initiation and at achene formation stage) and no ABA; T_5 =Three irrigations (25 DAS, at bud initiation and at achene formation stage) and ABA solution spray @ 250 L/ha at flower initiation stage.

Table 5: Dominance and marginal analysis of study 2 during 2008-2009

Treatments	TC (Rs. Ha^{-1})	NB (Rs. Ha^{-1})	M.C. (Rs. Ha^{-1})	MNB (Rs. Ha^{-1})	MRR (%)
H_1					
T_2	450	76063	-	-	D
T_4	450	50312.5	-	-	D
T_1	600	134646	150	58583	39055.33
T_3	17390	95933.5	16790	19870.5	118.345
T_5	20718	82217.5	3328	6154.5	184.925
H_2					
T_2	450	66043.5	-	-	D
T_4	450	46690	-	-	D
T_1	600	113843	150	47799.5	31866.17
T_3	17390	79729.5	16790	13686	81.51
T_5	20718	55360.5	-	-	D
H_3					
T_2	450	80875.5	-	-	D
T_4	450	59608	-	-	D
T_1	600	130352.5	150	49477	32984.5
T_3	17390	97408.5	16790	16533	98.46
T_5	20718	78605.5	-	-	D

H_1: DK-4040; H_2: S-278; H_3: SF-187; T_1 = Four irrigations (25 DAS, at bud initiation, at flower initiation and at achene formation stage) and no ABA; T_2 = Three irrigations (25 DAS, at flower initiation and at achene formation stage) and no ABA; T_3 = Three irrigations (25 DAS, at flower initiation and at achene formation stage) and ABA solution spray @ 250 L/ha at bud initiation stage; T_4 = Three irrigations (25 DAS, at bud initiation and at achene formation stage) and no ABA; T_5 = Three irrigations (25 DAS, at bud initiation and at achene formation stage) and ABA solution spray @ 250 L/ha at flower initiation stage; D: Dominated.

TC = Total cost that vary, NB = Net benefits, MC = Marginal costs, MNB = Marginal net benefits, MRR = Marginal rate of return

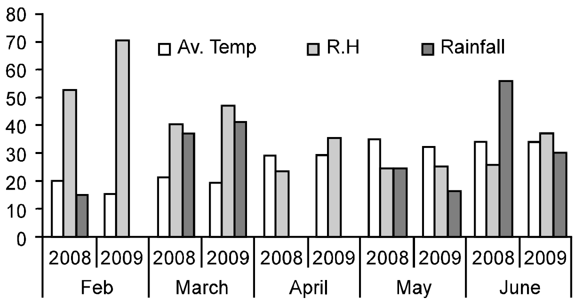

Fig. 1: Mean temperature (°C), relative humidity (%) and rainfall (mm) during experimental period (February-June)

control (T_1), drought stress and exogenous application of ABA at bud (T_3) and flower initiation (T_5). The other two sunflower hybrid viz., S-278 and SF-187 had only marginal net benefits and MRR in well watered and ABA application under drought stress at bud initiation stage. So the findings of our study clearly guided that under water deficit conditions among the tested hybrids, DK-4040 seemed to be more productive and its potential could be further enhanced by application of stress hormone ABA.

Genotypic variation in drought tolerance was observed in sunflower hybrids. Exogenous application of ABA under water deficits condition increased net benefits and MRR. This was due to better performance of some sunflower hybrids under drought as they sustained their achene yield by improving plant water status (Hussain *et al.*, 2010, 2012).

Conclusion: Study 1 showed that three irrigations (25 DAS, at flower initiation and at achene formation), with 5µM ABA application at bud initiation under drought resulted in more profitable as compared to exogenous application of same concentration of ABA at flower initiation. It is further concluded from the findings of study 2 that in drought prone area among tested hybrids sunflower hybrid DK-4040 prove to be more profitable hybrid and its potential can be further improved by exogenous application of ABA. We have further concluded that flower initiation stage is more critical stage and we should never missed irrigation at this stage otherwise huge monetary loss can be occurred.

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