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Effect of sowing date and abscisic acid on sunflower growth, seed yield and germination

Mudhir Ismail Hwaidi[1]
mudhir.hwaidi@tu.edu.iq

1 Department of Field Crops- College of Agriculture-Tikrit University, Salah Al-Din, Iraq.

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Abstract

Sunflower is an important field crop. However, heat stress decreases seed quality and productivity of it. The aim of this study was to enhance growth, seed yield and germination of the crop throgh applying different sowing dates and spraying abscisic acid. This work was carried out at Department of Field Crops Research Station- College of Agriculture- University of Tikrit. It included two factors, three sowing dates (1/3, 15/3 and 30/3) and four concentrations of abscisic acid (0, 50, 150 and 300 mg L^{-1}). The experiment was applied using Randomized Complete Block Design (RCBD). Results showed a significant effect of the two factors and the interaction between factors on all the studied characteristics except the impact of sowing date on seed germination and speed. The highest values of means were at early planting and the highest concentration of abscisic acid. Early planting and application of abscisic acid under heat stress supports the growth, seed yield and germination of sunflower crop.

Key words: sunflower, sowing date, ABA, growth, seed yield, germination.
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Correspondence Author: Mudhir I Hwaidi-r.-hwaidi@tu.edu.iq

Introduction

Sunflower (*Helianthus annuus* L.) is one of the main sources of edible oil, and is planted in wide enough areas around the world. It is still the fourth among field crops in importance,[1]. Producing high quality sunflower seeds becomes a serious problem due to the changes in global temperatures. The consequences of abiotic stresses adverse impact in field crops at different growth stages are very well documented previously. Sowing date has a direct role in exposing sunflower plants to heat stress especially at reproductive stage that considered as a crucial in producing high quality seed. Sunflower plants were described to be sensitive even to short periods of heat stress, 36/24C° day/night, for 10 days, and seed filling in addition to the other yield components were severely impacted [2]. In an experiment and for giving a clear view in negative impact of heat stress in future[3]. included a prediction model for the impact of climate changes with and without heat stress on sunflower. The model showed a decrease in sunflower seed yield of about 7 to 13% for 2011 to 2071. However, when the potential heat stress factor added to the model the loss in total seed yield became 23 and 34%, respectively. Embryo growth rate found to sensitively respond to temperature degrees during formation at an thesis stage. At 25 °C the growth found to be faster than at 28 °C, [4]. Abscisic acid (ABA) is known as a growth regulator that appears when the plant exposed to stress. Its role in supporting plant growth has been proven through many studies [5]. Studies conducted by some researchers showed that ABA may have a Physiological regulation in plant development [6]. It acts as an inhibitor when it accumulates in small quantities under different stress conditions to help plant survival through controlling stomata closer and reducing plant size [7]. While its encouraging role for plant growth appears when high enough concentrations and under stress conditions exist. Physiological effect of ABA could vary from characteristic to another depending on its signalling path and its relations with other hormones and enzymes, [8]. Results of [8] indicated a decrease in plant height with increasing ABA concentration. However, there was an increase in means of the other growth and yield components characteristics. In addition, [9] reported an increasing in stem diameter with increasing ABA concentrations under stress conditions. [10] found that the encouragement role of ABA in flowering process. Germination is defined by ISTA as the appearance of the essential structure of the seedling; however, it has developing into a plant or no. abscisic acid found with higher concentrations in big size seed than the smaller. However, the role of delaying germination speed is one of ABA roles. At flowering stage of sunflower crop, the unsuitable temperatures that can be described as high enough to cause a significant reduction in quantity and quality of produced seed. Therefore, the aim of this study is to determine the impact of sowing date and ABA application in reducing the adverse influences of heat stress and producing high quality sunflower seeds.

Materials and methods

Field experiment

A field experiment was carried out during spring season of the year 2020 at Department of Field Crops Research Station- College of Agriculture- University of Tikrit for knowing the effect of sowing date and abscisic acid on growth, seed yield and germination of sunflower. Sowing times were 1/3, 15/3 and 30/3. ABA concentrations were 0, 50, 150 and 300 mg L^{-1}, and concentrations were according the recommendations by [11];[12];[13] on field crops. ABA purity of 99% was obtained from certified plant hormone supplier. ABA concentrations were obtained by dissolving desired concentrations in required amount of distilled water, and then sprayed at flowering stage. Before tillage, random samples were taken from the field soil with a depth of 30 cm for the purpose of knowing the physical and chemical properties of experiment field (Table 1). Nitrogen fertilizer, 180 kg ha^{-1}, in the form of urea N 46% was added in two batches, the first at sowing and the second after a month of planting for each sowing date. A full amount, 90 kg ha^{-1}, of triple super phosphate P_2O_5 46% P, and a full amount, 90 kg ha^{-1}, of potassium sulphate 48% K were applied before planting. The meteorological data of maximum and minimum temperatures were collected as shown in Table 2. Field of experiment was plowed using a disc plow, and then it was smoothed in order to prepare suitable seedbed for giving the best germination and growth of seedlings. Experiment field was divided into three replications, and each replicate had 12 experimental units, 20 m^2 of each. The design of the experiment was randomized complete block design (RCBD). The experiment was given the levelling irrigation, and seed of the local variety were planted in lines inside the plots. Distance between lines was 75 cm and between plants inside the line was 25 cm. Seeds were planted at a depth of 2-3 cm according to the nominated sowing times. Crop service operations continued throughout the growth period, and the weeds were removed manually. ABA concentrations were applied completely by spraying on the leaves until the complete wetness. Control treatment was sprayed with distilled water only. After reaching each sowing date to maturity, ten plants from the middle lines were chosen to study: plant height (cm), stem diameter (cm) , capitulum diameter (cm), number of seeds per capitulum (seed $capitulum^{-1}$), 1000 seed weight (g), seed yield (kg ha^{-1}).

Laboratory experiment

For germination test, ISTA 2019 procedure was followed. Three hundred seeds from each treatment were chosen randomly from the pure final production of the experiment. The lot of seeds were divided into 3 replications. Seeds were preheated at 32 C° for 7 days with free air circulation before germination, and then planted between papers in germination containers. Germination incubator where set at 25 C° and light from a cool white lamp for 8 hours. Seeds were irrigated with water of 7 PH. The first count started at 4^{th} day and final count was at the 10^{th} day. Collected date was used for calculating germination percentage and speed of germination.

$$\text{Germination \%} = \frac{\text{number of normal seedlings at the final count}}{\text{total number of seeds}} \text{x } 100$$

Germination speed was calculated as the following equation.

$$\text{Germination speed} = \frac{\text{number of normal seedlings}}{\text{days of first count}} + \cdots + \frac{\text{number of normal seedlings}}{\text{days of final count}}$$

Table 1. Chemical and physical properties of the experiment field.

Properties		units	Values
PH		-------------	7.33
EC		dS m^{-1}	2.55
Available N		mg kg^{-1} soil	21.50
Available P		mg kg^{-1} soil	4.60
Available K		mg kg^{-1} soil	89.20
Organic matter		g kg^{-1} soil	2.55
Soil Separators	Sand	g kg^{-1} soil	524.00
	Silt	g kg^{-1} soil	266.00
	Clay	g kg^{-1} soil	210.00
Texture		Sandy loam	

Table 2. Meteorological data during experiment period.

Month	Temperature C°		Relative humidity
	maximum	minimum	
March	24.7	11.9	33.3
April	31.2	16.3	33.7
May	37.8	21	28.7
June	42.3	23.7	21.9
July	45.2	30.1	19.5

Results and discussion

It is clear from analysis of variance in Table 3 that the effects of study factors and the interaction on studied characteristics were significant except the effect of sowing date on germination percentage and germination speed.

Table 3. Analysis of variance mean squares for studied characteristics.

Source of variation	R	T	C	T*C	Error
d.f	2	2	3	6	22
Plant height (cm)	5.11	12.67**	11.39**	5.55*	2.13
Stem diameter (cm)	10.0	0.18**	0.10**	0.053*	0.02
Capitulum weight (g)	4.87	13.40*	19.85**	9.08*	3.44
Capitulum diameter (cm)	0.07	0.151*	0.196**	0.155**	0.04
Number of seeds per capitulum	4.98	20.68*	17.78*	14.99*	5.47
1000 seed weight (g)	2.42	2.08*	2.85**	1.54*	0.57
Seed yield (t ha^{-1})	0.11	0.077*	0.31**	0.052*	0.02
Germination %	3.63	2.85 ns	5.61**	4.00*	1.14
Germination speed	0.42	1.71 ns	3.61*	2.75*	0.70

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability

Growth

Results indicated that there were significant differences between in plant height as a due to the influence of the sowing date (Table 4). Earlier planting of sunflower seeds achieved the highest plant height of 138.25 cm. However, the third sowing date recorded the lowest plant height of 104.83 cm. Results of this study is in agreement with findings of [14]. Perhaps the reason of that is due to the high temperatures during the growth of the crop (Table 2), which led to the consumption of photosynthesis products in balancing the plant temperature instead of directing these products in supporting plant height. The data of the aforementioned table also indicate significant differences between the means of plant height under the impact of ABA. The lowest plant height was 104.22 cm at the highest concentration. ABA has a role that inhibits the hormone of auxin roles. Therefore, cell division and elongation decreased and then a decrease in internodes length [8]. The interaction between control and sowing date at the beginning of March recorded the highest plants comparing to the other combinations between the two factors. Results in Table 5 showed that planting sunflower early during March increased stem diameter comparing to the other sowing dates of mid and late March and recorded 2.47 cm. However, it was 2.30 at late planting. ABA significantly increased stem diameter where the highest concentration recorded 2.61 cm but control treatment recorded 2.13 cm. the impact of ABA in increasing stem diameter was mentioned before by [13]. Spray of ABA onto sunflower plants at the beginning of flowering found by this study to increase stem diameter significantly and this could be for two reasons. Application of ABA increases the number of vascular bundles in stem of the plant which led to that significant increase in stem diameter. Interaction between the highest concentration and early planting gave the highest stem diameter of 2.66 cm. In addition; sprayof ABA encourages plants to increase ethylene levels excretion that controls stem diameter, [15].

Table 4. Effect of sowing date and abscisic acid on sunflower plant height (cm).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	156.33 a	142.67 b	132.67 cd	143.89 a
50	136.33 c	122.34 e	111.67 f	123.44 b
150	133.00 cd	122.67 f	90.34 h	112.67 c
300	127.33 de	112.67 g	82.67 i	104.22 d
Mean of (T)	138.25 a	120.08 b	104.83 c	

Table 5. Effect of sowing date and abscisic acid on sunflower stem diameter (cm).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	2.26 f	2.13 g	2.00 h	2.13 d
50	2.40 de	2.30 f	2.20 fg	2.30 c
150	2.56 a-c	2.50 b-d	2.46 cd	2.51 b
300	2.66 a	2.60 ab	2.56 a-c	2.61 a
Mean of (T)	2.47 a	2.38 b	2.30 c	

Seed Yield

It was clear from results presented in Table 6 that there were significant difference between means of capitulum diameter under the impact of sowing date, ABA and the interaction. Sowing date at early period gave the heaviest capitulum per plant 428.47 g but 422.08 g was recorded at late planting. Results of this study agree with results mentioned before by [16]. The impact of heat stress caused by late planting was predicted. Planting at the beginning of March did not expose the crop to high temperatures as long as the mid and late sowing date from sowing date until the maturity of capitulums. This probably gave the plant enough time to use photosynthesis products to be used in increasing means of the other yield components which was reflected positively on capitulum weight. Furthermore, exposing sunflower crop to stress as indicated by this study and previously mentioned by [17] decrease capitulum diameter. Results of the same table indicated an increase in capitulum weight due to the spray of ABA. The widest capitulum was obtained from the treatment of the highest concentration of ABA, 466.11 g. However, control treatment recorded 395.81 g. roles of ABA in increasing seed weight through increasing seed filling rate under stress conditions was proved before, [13]. Interaction between the highest ABA concentration used in this study and planting at the beginning of March gave the heaviest capitulum of sunflower crop and as indicated by results of this study, Table 6.

Table 6. Effect of sowing date and abscisic acid on sunflower capitulum weight (g).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	400.12 j	394.33 j	393.00 j	395.81 d
50	414.10 g	412.66 gh	411.33 h	412.69 c
150	430.00 d	424.00 e	421.00 f	425.00 b
300	469.66 a	465.66 a	463.00 c	466.11 a
Mean of (T)	428.47 a	424.16 ab	422.08 b	

Results in Table 7 showed that early sowing date by this study recorded the widest capitulum of 21.32 cm, but late planting recorded the 19.22 cm. results of this study came in agreement with results of [2]. Capitulum weight gives an indicator about how the nutritional situation of the plant was during different plant growth stages. When plants exposed to heat stress, due to high temperatures (Table 2), all the physiological process are directed to reach an equilibrium of plant temperature and this could be achieved through using photosynthesis products in raising respiratory level in addition to change the hormonal situation of plants and morphological changes could be exist to minimize the exposed area of plants to high temperature stress, [18]. In addition, the widest capitulum was recorded when ABA was sprayed with its highest concentration and reached 23.36 cm. However, at control was 17.18 cm. probably the reason of increasing capitulum diameter du e to the spray of ABA was related the role of ABA in increasing tolerance of sunflower plants to stress by enhancing the relative water content of sunflower plants through controlling stomata closer without adverse impact on gaseous exchange for keeping adequate levels of photosynthesis, [19].

Table 7. Effect of sowing date and abscisic acid on sunflower capitulum diameter (cm).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	18.33 g	17.01 i	16.21 j	17.18 d
50	20.11 e	19.21 f	18.01 h	19.11 c
150	22.31 c	21.14 d	20.21 e	21.22 b
300	24.54 a	23.11 b	22.43 c	23.36 a
Mean of (T)	21.32 a	20.12 ab	19.22 b	

Number of seeds per capitulum decreased significantly with delayed sowing date. At the beginning of sowing date the number of seeds per capitulum was 975.40, but was 964.05 at late planting, Table 8. Results of this study agreed with results by Villalobos et al 1996 who indicated 28 C° as an optimum temperature degree for during different sunflower growth stages. Therefore, when temperature degrees during flowering stage goes over the optimum temperature degree, Table 2, for successful pollination and double fertilization, the number of formed seeds is decreased or even a kind of abortion could happen due to the adverse impact of high temperature degrees in reproductive organs and eventually a significant percentage of non-filled seeds are produced. Spray of ABA to sunflower plants under heat stress conditions increased seeds number per capitulum, Table 8. The highest concentration of ABA gave a seed number of, 995.54. However, the control recorded seed number per capitulum of about 936.86. Results of this study showed the important role of ABA in increasing seed number per capitulum and that was in agreement with [10] who indicated the important of ABA in flowering process. ABA plays a major role in enhancing resistance of flowering organs to heat stress and then achieving a good levels of pollination and double fertilization. Results of the study showed the highest number of seeds per capitulum was at the interaction between the highest concentration of ABA and early planting of sunflower seeds.

Table 8. Effect of sowing date and abscisic acid on sunflower seeds number per capitulum.

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	945. 01 j	935.25 k	930.32 l	936.86 d
50	970.11 g	966.66 h	960.12 i	965.63 c
150	985.21 d	980.85 e	975.63 f	980.56 b
300	1001.25 a	995.11 b	990.11 c	995.54 a
Mean of (T)	975.40 a	969.47 b	964.05 c	

Seed weight of sunflower is one of the most important characteristics because it is the main component in seed yield in addition to seed filling characteristic. Results of this study indicated a decrease in 1000 seed weight with delaying the time of planting. The highest weight was 49.67 g at early planting. However, it was 45.56 g at late planting, Table 9, and these results were identical to the results by [2]. Seed weight of sunflower crop is sensitive to heat stress at all growth sub-stages of seed filling process therefore seed weight is significantly reduced when temperature degree reaches above 35 C°, [20]. Results of this study showed a decrease in 1000 seed weight because of increasing temperature degrees with delaying planting, Table 2. Spray of ABA at flowering stage on sunflower plants under heat stress significantly increased 1000 seed weight as indicated by the results in Table 9. The highest heaviest 1000 seed weight was 53.53 g at the highest concentration of sprayed ABA. Hence, the lightest was 38.18 g at control. Results of this study came identical with results by [8]. Presumably, the spray of ABA to sunflower plants at flowering stage encouraged root system to deeply penetrate into soil and absorbing more water and nutrients, and then supporting the process of CO2 with required nutritious elements for metabolism and increased the rate of moveable carbon produced substances for metabolism processes that provide the main source of seed filling. Interaction between the highest sprayed concentration of ABA and early planting recorded the highest 1000 seed weight 56.14 g.

Table 9. Effect of sowing date and abscisic acid on sunflower 1000 seeds weight (g).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	40.22 h	37.66 d	36.66 d	38.18 d
50	49.01 ef	46.00 g	46.32 g	47.11 c
150	52.31 bc	49.65 de	48.01 f	49.99 b
300	56.14 a	53.21 b	51.24 cd	53.53 a
Mean of (T)	49.67 a	46.63 b	45.56 b	

Sunflower crop seed yield is a component of number and weight of seeds. When environmental conditions are unfavoured by the crop, consequently, seed yield would be adversely impacted. The previous results in Tables 8 and 9 showed the impact of heat stress on seed number and weight per capitulum and the role of ABA in increasing plant tolerance to heat stress, and then increasing yield components characteristics means. Results in Table 10 showed that the highest seed yield was 2.03 (t ha^{-1}) at early planting as indicated by this study. In addition, the highest seed yield was 2.43 (t ha^{-1}) at the highest concentration of sprayed ABA. Results of this study agreed with the previous results published by [2] and [10]. The reduction of seed yield under the impact of heat stress was an outcome of adverse influence of heat stress on pollination and double fertilization of reproductive parts. In addition, seed filling process requires the optimum temperature degree for optimum filled seeds, [20]. However, the crop in this study has exposed to heat stress, Table 2. Although the adverse impact of heat stress, spray of ABA significantly supported reproductive organs and that led to successful process of pollination and double fertilization and that was reflected on seed weight and seed number, Tables 8 and 9.

Table 10. Effect of sowing date and abscisic acid on sunflower seed yield (t ha^{-1}).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	1.53 d	1.48	1.39 e	1.47 d
50	1.94 c	1.91 d	1.89 de	1.91 c
150	2.15 b	2.13 c	1.99 d	2.09 b
300	2.49 a	2.45 ab	2.36 b	2.43 a
Mean of (T)	2.03 a	1.99 b	1.98 b	

Germination

A high percentage of germination is possible with optimal seed quality. The findings of this study proved the importance of ABA to seed quality. Although that, the highest germination percentage and speed were obtained from the control treatment and values were 91.50% and 71.8, respectively. The lowest germination percentage and speed were when the highest concentration of ABA was sprayed and values were 36.85% and 37.30, respectively. Although ABA has the role in improving seed quantity and quality under stress conditions, its impact on germination percentage and speed was unclear because its role in delaying seed germination and reducing the rate of germination speed as well. Even at the conclusion of the last day of counting, as advised by the ISTA germination technique, the percentage and speed of germination were much lower than the control. [5] and [8] established a link between ABA content and seed size. It is common knowledge that large, high-quality seeds, such as those obtained in this study, have a high percentage of germination and fast germination rates. However, the findings of this investigation suggested a type of dormancy that might be physiological. The association between seed size and ABA content has been shown earlier and additionally the relation between ABA content and dormancy of seed was fully discussed by [21]. As a result, the findings of this study support prior research on the effect of ABA in improving sunflower seed quality and delaying germination.

Table 11. Effect of sowing date and abscisic acid on sunflower seed germination (%).

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	91.24 a	91.24 a	92.01 a	91.50 a
50	85.44 bc	84.21 bc	85.32 b	85.00 b
150	68.32 d	67.00 d	69.24 d	68.19 c
300	34.25 ef	39.45 e	36.85 ef	36.85 d
Mean of (T)	69.81 a	70.48 a	70.85 a	

Table 12. Effect of sowing date and abscisic acid on sunflower seed germination speed.

Abscisic acid (C) mg L^{-1}	Sowing date (T)			Mean of (C)
	1/3	15/3	30/3	
0	71.89 a	72.39 a	71.14 a	71.81 a
50	65.23 b	66.40 b	64.23 b	65.29 b
150	41.23 c	39.89 cd	41.21 c	40.78 c
300	35.98 e	39.25 cd	36.65 ef	37.30 d
Mean of (T)	53.58 a	54.48 a	53.30 a	

Conclusion

Earlier sowing date of sunflower for producing high quality seed is preferred comparing to late planting according to the results of this study because the delay in planting causes a significant decrease in seed quality characteristics. Spray of ABA to sunflower plants improved crop growth, seed yield and germination characteristics and increased the ability of the plant to tolerate the adverse impact of stress. Although high quality seeds of sunflower could be produced under heat stress after spraying abscisic acid, germination percentage and speed of germination was lower at the highest concentration of ABA, and it was due to the role of ABA in stimulating physiological dormancy.

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تأثير موعد الزراعة وحامض الأبسسك على نمو زهرة الشمس وحاصل البذور والإنبات

مظهر اسماعيل هويدي[1]

mudhir.hwaidi@tu.edu.iq

[1] قسم المحاصيل الحقلية- كلية الزراعة- جامعة تكريت صلاح الدين- العراق.

- تاريخ استلام البحث 26/12/2023 وتاريخ قبوله 11/01/2023

المستخلص

يقلل الإجهاد الحراري من جودة وانتاج بذور زهرة الشمس. الهدف من هذه الدراسة هو تحسين النمو وحاصل البذور والإنبات للمحصول عن طريق الزراعة بمواعيد مختلفة والرش بحامض الابسسك. نفذ هذا العمل في محطة بحوث قسم المحاصيل الحقلية – كلية الزراعة – جامعة تكريت. تضمنت الدراسة عاملين ، ثلاثة مواعيد زراعة (3/1 و 3/15 و 3/30) وأربعة تراكيز من حامض الابسسك (0 ، 50، 150 و 300 ملغم لتر$^{-1}$). تم تطبيق التجربة باستخدام تصميم القطاعات العشوائية الكاملة (RCBD). أظهرت النتائج تأثيراً معنوياً للعاملين والتداخل بينهما على جميع الصفات المدروسة ما عدا تأثير موعد الزراعة على نسبة الانبات وسرعته. كانت أعلى القيم للمتوسطات عند الزراعة المبكرة وأعلى تركيز لحامض الابسسك. إن الزراعة المبكرة والرش بحامض الابسسك تحت ظروف الشد الحراري يحسن من نمو وإنتاج بذور وإنبات محصول زهرة الشمس الشمس.

الكلمات المفتاحية: زهرة الشمس، موعد الزراعة، حامض الابسسك، النمو ، حاصل البذور ، الإنبات.