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Alleviation of Drought Effect on Sunflower (*Helianthus annus* L.) c.v. Sakha-53 Cultivar by Foliar Spraying with Antioxidant

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ABSTRACT

Two pot experiments were carried out during two successive summer seasons of 2013 and 2014 at the experimental greenhouse of National Research Centre, Dokki, Giza, Egypt to study alleviation of drought effect on sunflower cv. Sakha-53 cultivar by foliar spraying with antioxidant. The main results were :-

- Growth characters, i.e. plant height, number of leaves/plant, stem dry weight, leaves dry weight/plant, head dry weight, total plant dry weight and blades area/plant, as well as, yield components, i.e. seed index, head diameter, head dry weight, seed yield/plant, shelling %, oil and protein % significantly decreased under the water stress conditions. On the contrary, total carbohydrate % per seeds increased under water stress treatment.
- Spraying sunflower plants with 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid seemed to be the most favourable treatments to increase growth characters, yield and its components and chemical constituents of sunflower dry seeds; compared with, control, 100 mg/l ascorbic acid and 200 mg/l salicylic acid.
- The effect of interaction between skipping two irrigation at pudding stage and foliar spraying with different concentrations of antioxidant indicate that sunflower plants was sensitive to water stress at pudding stage, also, foliar spraying with 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid can be lowest the harmful effect in growth characters, yield and its components, as well as, chemical constituents of sunflower dry seeds caused by water stress conditions.
- The simple correlation coefficient between seed yield/plant and each of plant height. Leaves area/plant, head dry weight, head diameter and seed index and its all possible combinations were positive and highly significant (except between leaves area/plant and seed index was positive and significant).

It is noteworthy to mention that the characters most responsible for variation in seed yield/plant directly and indirectly was in order of importance : plant height, head dry weight, head diameter, and leaves area/plant, and these parameters could contribute much of sunflower seed yield since R^2 was 96.913% of the total variation and the total correlation between these four parameters and seed yield/plant was most pronounced in plant height (r = 0.95), head dry weight (r = 0.94), head diameter (r = 0.929) and leaves area/plant (r = 0.882) , respectively.

Key words: Drought, sunflower, *Helianthus annus*, foliar spraying, antioxidant

Introduction

Most of the countries of the world are facing the problem of drought. The insufficiency of water is the principle environmental stress and to entre heavy damage in many port of the world for Agricultural products (Khan *et al*., 2010 Farshadfor *et al*., 2011, Amjad *et al*., 2011 Ahmadizadeh *et al*., 2011 a and b, and Ahmadizadeh, 2013). Drought stress is one of the most adverse factors for plant growth and productivity (Reddy *et al*, 2004, Ahmed *et al*, 2005 and Makbul *et al*, 2011). Drought stress can reduce growth and seed yield of sunflower (Nazariyan *et al*, 2009, Mossain *et al*, 2010, Baloglu *et al*, 2011, Gholinezhud *et al*, 2012 and Dehkhoda *et al*, 2013). Response of plants to water stress depends on several factors, such as developmental stage, intensity and duration of stress and cultivar genetics (Ahmadizadeh, 2013). The plant response is complex because it reflects over space and time the integration of stress effects and response at all underlging levels of organization (Yordanov *et al*, 2003). It inhibits the photosynthesis of plants, causes charges in chlorophyll content and components and damage to the photosynthetic apparatus activities and decrease the activities of enzyme in the Calvin cycle in photosynthesis (Abedi and Pakmiyat, 2010). It is worthy that, tolerance to abiotic stresses is very complex due to the interact of interactions between stress factors and various molecular,

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biochemical and physiological phenomena affecting plant growth and development (Yordanov *et al*, 2003, Jaleal *et al*, 2009 and Ahmadizadeh, 2013).

Thus, the purpose of this research was to study alleviation of drought effect on growth, yield and chemical constituents of sunflower (*Helianthus annus* L.), c.v. Sakha-93 cultivar foliar spraying with antioxidant.

Materials and Methods

The present investigation was carried out during two successive summer seasons of 2013 and 2014 at the experimental greenhouse of National Research Centre, Dokki, Giza, Egypt, to study alleviation of drought effect on sunflower (*Helianthus annus* L.); cv. Sakha-53 cultivar by foliar spraying with antioxidant. The experiment included ten treatments which were the combination of two water stress treatments (irrigation every three days as normal irrigation and skipping two irrigation at pudding stage (to impose drought) 50-55 days after sowing) and five concentrations of antioxidant, i.e tap water as control treatment, 100 mg/l and 200 mg/l ascorbic acid as well as 100 and 200 mg/l salicylic acid.

Sunflower seeds were obtained from the Oil Crops Research Section, Agricultural Research Centre, Ministry of Agriculture. The seeds were selected for uniformity in size, shape and colour and sown in clay pots 50 cm in diameter. Each pot contained 20 kg clay loam soil. Ten seeds were sown in each pot. Fifteen days after sowing, the seedlings were thinned to the most three uniform plants in each pot. Each pot received equal and adequate amount of water (except water stress treatments) and fertilizer. Phosphorus as superphosphate (15.5 % P_2O_5) was mixed before sowing and nine grams nitrogen as ammonium sulphate (20.5% N) in three applications (three grams for each) at intervals of two weeks started from 21 days after sowing. Other agricultural processes were performed according to normal practice recommended by Oil Crops Research Section, Agricultural Research Centre, Ministry of Agriculture. Ascorbic acid and salicylic acid (100 and 200 mg/l) were sprayed twice, the first spray was applied at 60 days after sowing and the second spray was ten days later, i.e 70 days age. Distilled water was sprayed in the same previous manner on plant which served as control. Tepol (1 ml/l) was added before spraying as a weeting agent. The volume of the spraying solution was maintained just to cover completely the plant foliage till drip.

Plant height, number of leaves/plant, stem dry weight "g/plant" and leaves dry weight g/plant were estimated at 80 days after sowing by harvesting three guarded plants at random from four replicates (each replicate contain 12 pots). Also area of leaves cm^2/plant was measured according to the method described by Bremner and Taha (1966).

For each treatments twelve plants (plant per pot) representing four replicates were left for yield determination. The yield was harvested after complete drying of pods. Both total plant weight "g", head dry wt. "gm", head diameter "cm", dry weight of seeds/head, shelling percentage (i.e seed weight/head weight %) and seed index, i.e 1000 seeds weight/g were estimated.

For determination of chemical constituents in dry seeds; total carbohydrate was determined using phenol sulphuric acid methods according to Dubios *et al* (1956). Protein extraction was carried according to Anderson and Beardal (1991) and estimated by the Microkjeldahl method (Pirie, 1955). In addition, seed oil percentage was dteremined by using Soxhelf apparatus and petroleum ether 40-60 ^{O}C as a solvent according to A.O.A.C. (1984).

The data obtained were subjected to the proper statistical analysis according to Snedecor and Cochran (1990). For comparison between means, L.S.D. test at 0.05 level was used.

Simple correlation coefficient for all possible combinations between seed yield/plant and each of plant height, blades area/plant, head dry weight, head diameter and seed index were practiced according to Snedecor (1956). Simple correlation coefficient of cource do not permit the estimation of the direct effect of a particular yield factor, since this variable is in some way associated with one or more variables which are in turn associated with yield. Therefore, the path coefficient analysis which measures the direct influence of one variable upon another and permits the separation of the simple correlation coefficient into components of direct and indirect effects was calculated according to Wright (1934).

Results and Discussion

Growth characters:-

Effect of water stress:

Data presented in Table (1) observed clearly that skipping two irrigation at pudding stage (i.e. 50-55 days after sowing) significantly decreased plant height, number of leaves/plant, stem dry weight/plant, leaves dry weight/plant, head dry weight, total plant dry weight and leaves area/plant compared with sunflower plants imposed to normal irrigation (without skipping irrigation) i.e. control treatment. The negative significant effect on growth characters caused by drought stress could be explained on the basis of the loss of which effects the

rate of cell expension, and ultimate and size. Loss of turgidity is probably the sensitive process of water stress. Thus, caused a decreament in growth rate, stem elongation and leaf expension. The depression in cell division and enlargement has been carefully discussed (Krumer and Boyer, 1995). The results shows that water stressed plants even waterd regulatory afterward did not recover to their normal bahaviour to compensate the adverse effect caused by the exposure to drought conditions. From the presented data in Table (1) it can be concluded that sunflower plants cv. Sakha-53 cultivar appeared too sensitive to water stress during pudding stage. Our results confirmed with results obtained by Nazariyan *et al* (2009), Massia *et al* (2010), Baloglu *et al* (2010), Gholinezhud *et al* (2012) and Dehkhoda *et al* (2013). It is worthy to mention that irrigation at late jointing is recommended due its great effect on head survival. This implies that development and physiological processes at late jointing are critical in determining final seed yield and water stress should be avoid at this growth stage. Then, the depression in growth parameters by missing two irrigation in pudding stage was pronounced, where, ever plants were subjected to soil moisture stress at budding stage. Such response might be attributed to lack of meristematic activity and/or reduction in photosynthetic capacity under such unfavorable conditions (Krammer and Boyer, 1995, Shaugguan *et al*, 1999 and Nayyar and Gupta, 2006). In addition, it inhibit the photochemical activities and decrease the activities of enzyme in the Calven cycle in photosynthesis (Abedi and Pakniyat, 2010). Moreover, tolerance to abiotic stresses is very complex due to the interact of interactions between stress factors and various molecular, biochgemical and physiological phenomena affecting plant growth and development (Yordanov *et al*, 2003, Jaleel *et al*, 2009 and Ahmadizadah, 2013). Such response to drought stress might be attributed to lack of water absorbed, inadequate uptake of essential element, inhibition of meristimatic activity and/or reduction in photosynthetic capacity under such unfavorable conditions (Ahmed *et al*, 2005). Thus, assimilates translocated to new developing head primodical were reduce and which were not enough to mention or develop this organ.

Effect of antioxidant concentrations :

The data illustrated in Table (1) observed that plant height, number of leaves/plant, stem dry weight/plant, leaves dry weight/plant, head dry weight/plant, total plant dry weight and leaves area/plant significantly affected by foliar spraying with antioxidant. It is note worthy that foliar spraying with 100 mg/l ascorbic acid caused significantly stimulatory effect on plant height, number of leaves/plant, stem and leaves dry weight and plant dry weight, head dry weight/plant, as well as, leaves area/plant compared with control treatment. Increasing concentration of ascorbic acid up to 200 mg/l caused another significant increament in all previous growth characters under study compared with control and 100 mg/l ascorbic acid treatment. These results may be due to that spraying ascorbic acid influencing many physiological processes; such as stimulate respiration activities, cell division and many enzymes activities; as reported by Oertil (1987), Hanna *et al* (2001), Abdel-Hamed *et al* (2004), Irfan *et al* (2006), Zewail (2007) and Bakry *et al* (2012). Also, the positive response of sunflower plants may due to that ascorbic acid activity on same enzymes which are important in regulation of photosynthetic carbon reduction (Helsper *et al*, 1982).

With respect to foliar application with salicylic acid, foliar application with 100 mg/l increased significantly plant height, number of leaves/plant, stem dry weight/plant, leaves dry weight/plant, head dry weight/plant, total plant dry weight and leaves area/plant compared with control treatment. Furthermore, the results in Table (1) indicate, also, that increasing the concentration of salicylic acid to 200 mg/l caused significant increase in growth characters under study compared with control treatment, however, reffect significant decreament in its values compared with 100 mg/l salicylic acid. Our results are confirmed with those obtained by El-Khallal *et al* (2009), Delavare *et al* (2010), and Magda Shalaby *et al* (2013) on different plant species. The promotive effect of salicylic acid could be attributed to its bioregulator effects on physiological and biochemical processes in plants such as ion uptake, cell elongation, cell division, cell differentiation, sink and source regulation, enzymatic activities, protein synthesis and photosynthetic activity and to increases in the antioxidant capacity of plant (Paskin, 1992, Blokhine *et al*, 2003 and El-Tayeb, 2005). Salicylic acid as antistress substance may enhanced the plant tolerance to environmental stress (Sreenivasulu *et al*, 2000 and Magda Shalaby *et al*, 2013). The enhancing effect of salicylic acid on the leaves area/plant mentioned that enhancing effect of salicylic acid on the availability and movement of nutrients could result in stimulating different nutrients in the leaves. Our results confirmed with those obtained by Hanna *et al* (2001), Abdel-Hamed *et al* (2004), Irfan *et al* (2006) and Bakry *et al* (2012).

Effect of interaction :

Table (1) shows that the interaction between draught stress and different concentrations of antroxidant caused significant effects on growth characters. Data illustrated show also that the most effective treatments for growth characters was 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid under normal irrigation (i.e. without skipping irrigations). On the other hand, foliar spraying with 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid can overcome the depression in growth characters results by water stress conditions. Thus, generally, foliar

application with 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid are the most effective treatment in alleviation water stress demeged on sunflower plants.

Table 1: Effect of skipping two irrigation at budding stage and foliar spraying with antioxidant on growth characters of sunflower. (Average of 2013 and 2014 seasons).

		Plant height "cm"	No. of leaves/plant	Stem dry weight "g/plant"	Leaves dry weight "g/plant"	Head dry weight "g"	Total plant dry weight "g/plant"	Leaves area cm^2/plant
Normal irrigation (no skipping)		91.33	16.60	5.05	2.93	4.97	12.95	206.43
Skipping two irrigation during pudding stage		83.97	14.80	3.93	2.53	4.09	10.55	180.54
L.S.D. at 5% level		0.90	1.28	0.37	0.20	0.17	0.55	9.18
Tap water (0.0 mg/l)		81.34	13.84	3.10	1.69	4.05	8.84	123.08
100 mg/l Ascorbic acid		83.34	15.17	4.08	2.44	4.49	11.01	181.08
200 mg/l Ascorbic acid		91.84	18.17	5.45	3.41	4.75	13.61	231.28
100 mg/l Salicylic acid		91.08	16.50	5.09	3.15	4.90	13.14	228.22
200 mg/l Salicylic acid		90.17	14.84	4.75	2.98	4.47	12.20	203.76
L.S.D. at 5% level		0.64	1.13	0.27	0.14	0.12	0.39	1.37
Normal irrigation (no skipping)	Tap water (0.0 mg/l)	84.00	14.00	3.48	1.91	4.50	9.89	136.24
	100 mg/l Ascorbic acid	84.67	16.33	4.73	2.75	4.95	13.43	188.00
	200 mg/l Ascorbic acid	95.67	19.00	5.63	3.45	5.30	14.38	256.64
	100 mg/l Salicylic acid	96.33	17.00	5.75	3.35	5.20	14.30	228.88
	200 mg/l Salicylic acid	96.00	16.67	5.66	3.20	4.92	13.78	222.40
Skipping two irrigation during pudding stage	Tap water (0.0 mg/l)	78.67	13.67	2.71	1.46	3.60	7.70	109.92
	100 mg/l Ascorbic acid	83.00	14.00	3.42	2.12	4.02	9.56	174.16
	200 mg/l Ascorbic acid	88.00	17.33	5.26	3.36	4.20	12.82	205.92
	100 mg/l Salicylic acid	85.83	16.00	4.43	2.95	4.60	10.98	227.56
	200 mg/l Salicylic acid	84.33	13.00	3.83	2.75	4.02	8.60	185.12
L.S.D. at 5% level		1.09	1.92	0.46	0.21	0.20	0.66	2.33

Yield components :-

Effect of water stress :

Table (2) indicate that missing two irrigation at pudding stage (i.e. 50-55 days after sowing) caused significant decreament in seed index, head diameter, head dry weight, seed yield/plant, shelling %, oil % and protein %, meanwhile total carbohydrate % was significantly increased by draught stress compared with control treatment. The significant decreament in yield and yield components (except total carbohydrate %) caused by draught stress may be due to the loss of which effects the rate of cell expension, and ultimate and size. Loss of turgidity is probably the sensitive process of water stress. Thus, caused a decreament in growth rate, stem enlargement, and leaf expension. The depression in cell division and enlargement has been carefully discussed. The results shows that water-stressed plants even watered regulatory afterward did not recover to their normal behavior to compensate the adverse effect caused by the exposure to draught conditions. From the data illustrated in Table (2) it can be concluded the sunflower plants c.v. Sakha-53 cultivar appeared to sensitive to water stress during pudding stage. Moreover, our obtained results are in harmony with results reported by Nazariyan *et al* (2009), Massia *et al* (2010), Baloglu *et al* (2010), Gholinzehud *et al* (2012) and Dekhoda *et al* (2013). The irrigation in late jointing is recommended due to its great effect on head survival. This implies that developmental and physiological processes at late jointing are critical in determing final seed yield and water stress should be avoid at this growth stage. Thus, the depression in yield components by skipping two irrigation in pudding stage was pronounced, where, ever plants were subjected to soil moister stress at budding stage. Such response may be due to the lack of meristematic activity and/or reduction in photosynthetic capacity under such unfavourable conditions (Kramez and Boyer, 1995, Shanggen *et al*, 1999, and Nayyer and Gupta, 2006). Moreover, it inhibit the photochemical activities and decrease the activities of enzyme in the Calven cycle in photosynthesis (Abedi and Pakniyat, 2010). Moreover, tolerance to abiotic stresses is very complex due to the interact of interactions between stress factors and various molecular, biochemical and physiological phenomena affecting plant growth and development (Yordanov *et al*, 2003, Jaleel *et al*, 2009 and Ahmadizadah, 2013). Such response to draught stress may be caused to the lack of water observed, inadequate uptake of essential element, inhibition of meristimatic activity and/or reduction in photosynthetic capacity under such unfavourable conditions (Ahmed *et al*, 2005). Thus assimilates translocated to new developing head primodial were reduce and which were not enough to mention or develop this organ.

Effect of antioxidant conditions :

Data in Table (2) observed that seed index, head diameter, head dry weight, seed yield/plant, as well as, shelling %, oil % and protein % and total carbohydrate % significantly affected by foliar application with antioxidant. Furthermore, foliar application with 100 mg/l ascorbic acid had significant simulative effect on seed index, head diameter, seed yield/plant, shelling, oil, protein and total carbohydrate percentages compared with

control treatment (tap water treatment). Increasing concentration of ascorbic acid from 100 mg/l to 200 mg/l caused significant increament in yield components (except seed index oil % and total carbohydrate % per seed where the increase failed to reach the significant level at 5% level). On the other hand, the increases in yield components values caused by 200 mg/l ascorbic acid compared with control treatment were significant. Our increament in yield components herine may be due that foliar application with ascorbic acid influencing many physiological processes, i.e. such as stimulate respiration activities, cell division and many enzymes activities (Oertil, 1987, Hanna *et al*, 2001, Abdel-Hamed *et al*, 2012). Again, the stimulative effect of ascorbic acid on sunflower yield may be due to its some enzymes which are important to regulation of photosynthetic carbon reduction (Helsper *et al*, 1992). Our results are in harmony with those obtained by Hanna *et al*, (2001), Abdel-Hamed *et al*, (2004), Irfan *et al* (2006) and Bakry *et al* (2012).

It is worthy that foliar spraying with 100 mg/l salicylic acid caused significant increament in yield components studied for sunflower plants, i.e seed index head diameter, head dry weight, seed yield/plant, as well as, shelling, oil protein and oil % compared with control treatments. Moreover, increasing salicylic acid concentration up to 200 mg/l caused significant increase significant decreament in yield components compared with 100 mg/l salicylic acid treatment. The increament in yield and its components in this study by salicylic acid treatments are in good harmony with those obtained by El-Khallal *et al* (2005), Delavare *et al* (2010) and Magda Shalaby *et al* (2013) on different plant species. Also, this promotive response to salicylic acid could be attributed to its bioregulator effects on physiological and biochemical processes in plants as ion uptake, cell elongation, cell division, cell differentiation, sink and source regulation, enzymatic activities, protein synthesis and photosynthetic activity, also to the increases in the antioxidant capacity of plant (Paskin, 1992, Blokhina *et al*, 2003 and El-Tayeh, 2005). Salicylic acid may enhanced the plant tolerance to environmental stress (Sreenivasulu *et al*, 2000 and Magda Shalaby *et al*, 2013) the promotive effect of salicylic acid on the leaves area/plant mentioned that enhancing effect on the availability and movement of nutrients could result in stimulating different nutrients in the leaves, thus this reflect on increasing yield components.

Effect of interaction :

Table (2) observed that the interaction between drought stress and different concentrations of antioxidant caused significant effects on yield and its components. The highest significant values from yield components were collected with 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid under normal irrigation (i.e. without skipping irrigations). Generally, foliar spraying with 200 mg/l ascorbic acid and/or 100 mg/l salicylic acid are the most favourable treatment to alleviate water stress at pudding stage caused to sunflower plants.

Table 2: Effect of skipping two irrigation at budding stage and foliar spraying with antioxidant on yield and its components of sunflower. (Average of 2013 and 2014 seasons).

		Seed index "1000 seed/gm"	Head diameter "cm"	Head dry weight "gm"	Seed yield "gm/plant"	Shelling %	Oil % per seeds	Protein % per seeds	Total carbohydrate % per seeds
Normal irrigation (no skipping)		27.63	8.42	15.46	9.20	59.50	34.09	16.03	20.99
Skipping two irrigation during pudding stage		24.88	6.94	12.19	6.22	50.99	33.33	15.30	22.49
L.S.D. at 5% level		1.42	1.38	1.45	1.21	3.47	0.51	0.67	1.50
Tap water (0.0 mg/l)		21.23	6.75	11.14	5.57	50.00	32.53	15.15	20.16
100 mg/l Ascorbic acid		26.44	7.48	13.94	7.49	53.69	33.74	15.54	21.81
200 mg/l Ascorbic acid		27.00	7.92	14.72	8.67	58.87	33.99	15.96	22.24
100 mg/l Salicylic acid		28.44	8.25	15.12	8.92	58.99	36.19	16.06	23.14
200 mg/l Salicylic acid		26.22	8.00	14.52	7.90	54.79	32.11	15.65	21.36
L.S.D. at 5% level		1.40	0.15	0.07	0.12	0.09	1.11	0.04	0.61
Normal irrigation (no skipping)	Tap water (0.0 mg/l)	24.29	7.50	12.38	6.51	52.58	32.58	15.80	18.90
	100 mg/l Ascorbic acid	27.76	8.25	15.81	8.52	53.89	33.42	15.99	21.07
	200 mg/l Ascorbic acid	28.24	8.83	16.58	10.11	60.98	33.50	16.30	21.40
	100 mg/l Salicylic acid	30.67	8.83	16.60	10.55	63.55	38.01	16.10	22.38
	200 mg/l Salicylic acid	27.21	8.67	15.93	10.30	64.66	32.06	15.97	21.20
Skipping two irrigation during pudding stage	Tap water (0.0 mg/l)	22.17	6.00	9.90	4.62	46.67	32.48	14.49	21.41
	100 mg/l Ascorbic acid	25.11	6.70	12.06	6.45	53.48	34.05	15.09	22.54
	200 mg/l Ascorbic acid	25.75	7.00	12.85	7.22	56.19	34.48	15.61	23.08
	100 mg/l Salicylic acid	26.16	7.67	13.65	7.29	53.41	34.36	16.01	23.90
	200 mg/l Salicylic acid	25.23	7.33	12.50	5.50	44.00	31.26	15.32	21.52
L.S.D. at 5% level		2.38	0.25	0.12	0.20	0.15	1.89	0.07	1.04

Correlation studies:

The main estimates of the correlation coefficient between sunflower seed yield/plant and other characters under study are presented in Table (3). Data show positive and high significant relation between seed yield and each of plant height, leaves area/plant, head dry weight, head diameter and seed index, between plant height and

each of leaves area/plant head dry weight and head diameter and seed index, as well as, between head dry weight and each of leaves area/plant and seed index. Moreover the relationships between head diameter and leaves area/plant; as well as; seed index were positive and high significant. On the other hand, the association between leaves area/plant and seed index was positive and significant.

Path coefficient :

The effect of direct and indirect path coefficients of plant height, leaves area/plant, head dry weight, head diameter and seed index are shown in Table (4). These estimates were computed by partitioning the total correlation coefficient into its components. Plant height proved to have a high direct on seed yield/plant compared with head dry weight, head diameter and leaves area/plant. Seed index; i.e. 1000 seed weight; had a negative direct effect on seed yield/plant. The average mean of the direct effect was 0.652, 0.198, 0.040 and -0.003 for these five characters, respectively (Table 4). As mentioned before (Table 3) total correlation coefficient was most pronounced in plant height (r = 0.95), head dry weight (r = 0.94), head diameter (r = 0.929), leaves area/plant (r = 0.882) and seed index (r = 0.832).

Table 3: Correlation between yield and certain characters in sunflower plants (Sakha-53 cultivar). (Averages of 2013 and 2014 experiments).

	Seed yield "g/plant"	Plant height "cm"	Leaves area "cm^2/plant"	Head dry weight "gm"	Head diameter "cm"	Seed index "1000 seeds/g"
Seed yield "g/plant"	--	0.95**	0.882**	0.94**	0.929**	0.832**
Plant height "cm"		--	0.872**	0.94**	0.936**	0.846**
Leaves area "cm^2/plant"			--	0.924**	0.824**	0.108*
Head dry weight "gm"				--	**0.91	**0.799
Head diameter "cm"					--	**0.873
Seed index "1000 seeds/g"						--

Table 4: Partitioning of simple correlation between seed yield/plant and some growth characters and some yield components. (Average of 2013 and 2014 experiments).

Source		Source	
Seed yield via. plant height :		Seed yield via. head diameter :	
Direct effect	0.652	Direct effect	0.074
Indirect effect via. leaves area/plant	0.036	Indirect effect via. plant height	0.636
Indirect effect via. head dry weight	0.193	Indirect effect via. leaves area/plant	0.035
Indirect effect via. head diameter	0.072	Indirect effect via. head dry weight	0.187
Indirect effect via. seed index	-0.003	Indirect effect via. seed index	-0.003
Total correlation	0.95	Total correlation	0.929
Seed yield via. leaves area/plant :		Seed yield via. seed index :	
Direct effect	0.040	Direct effect	-0.003
Indirect effect via. plant height	0.591	Indirect effect via. plant height	0.574
Indirect effect via. head dry weight	0.190	Indirect effect via. leaves area/plant	0.03
Indirect effect via. head diameter	0.063	Indirect effect via. head dry weight	0.164
Indirect effect via. seed index	-0.002	Indirect effect via. head diameter	0.067
Total correlation	0.882	Total correlation	0.832
Seed yield via. head dry weight :			
Direct effect	0.198		
Indirect effect via. plant height	0.636		
Indirect effect via. leaves area/plant	0.039		
Indirect effect via. head diameter	0.07		
Indirect effect via. seed index	-0.002		
Total correlation	0.940		

Table (5) shows that the direct effect of plant height was 45.349% of the variation, being higher than that of head dry weight (4.051%), head diameter (0.576%), leaves area/plant (0.192%) and seed index (0.001%). The joint effect of plant height with leaves area/plant; head dry weight; head diameter and seed index amounted to 5.01, 26.314, 9.83 and 0.384% of variation, respectively. The joint effect of leaves area/plant with head dry weight, head diameter and seed index were amounted to 1.642, 0.576, and 0.001% of the variation, respectively, meanwhile, the joint effect of head dry weight with head diameter and seed index amounted to 2.89 and 0.96% of the variation, respectively. On the other hand, the joint effect of head diameter with seed index have a small contribution in seed yield/plant and was amounted 0.001% of variation.

It is worthy to mention that plant height, head dry weight, head diameter and leaves area could contribute much of sunflower seed yield since R^2 was 96.913% of the total variation and the total correlation between these four parameters and seed yield/plant was most pronounced in plant height (r = 0.95); head dry weight (r = 0.94), head diameter (r = 0.929), leaves area/plant (r = 0.882), respectively.

Table 5: Direct and joint effects of some growth characters and yield components as percentages of yield variation in sun flower plants (cv. Sakha-53 cultivar.)

Characters	Coefficient of determination	Percentage contributed
Plant height "cm"	0.443	45.349
Leaves area "cm^2/plant"	0.002	0.192
Head dry weight "g"	0.040	4.051
Head diameter "cm"	0.006	0.576
Seed index "g"	0.001	0.001
Plant height x Leaves area	0.05	5.01
Plant height x Head dry weight	0.262	26.314
Plant height x Head diameter Plant height x Seed index	0.098	9.830
Leaves area x Head dry weight	-0.004	0.384
Leaves area x Head diameter	0.016	1.642
Leaves area x Seed index	0.006	0.576
Head dry weight x Head diameter	0.0001	0.001
Head dry weight x Seed index	0.029	2.89
Head diameter x Seed index	-0.0001	0.096
	0.0001	0.001
R^2	0.949	96.913
Residual	0.051	3.087
Total	1.00	100.000

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