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Optimum Planting Date for Three Sesame Cultivars Growing under Sandy Soil Conditions in Egypt

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Abstract: Yield and nutritional quality of sesame may be improved by manipulating the cultural treatments to suit the crop or by testing the available commercial cultivars to find out the one which better cope with the available soil and the prevailing environment. Two field experiments were conducted in the Desert Experimental Station of the Faculty of Agriculture, Cairo University in Wadi El-Natroon, El-Beheira Governorate, Egypt during summer seasons of 2013 and 2014. The experimental design was factorial arrangement in randomized complete blocks repeated three times. The first factor was planting dates of 20th March, 9th April, 29th April and 19th May. The second factor was three cultivars (Giza-32, Shandauil-3 and Sohag-1). Planting sesame on April 9 recorded the highest values of fruit zone length, number of fruiting nodes plant^{-1}, number of capsules plant^{-1}, capsule length, number of seeds capsule^{-1}, 1000-seed weight, seed weight plant^{-1}, as well as, seed and oil yields ha^{-1} in both seasons. Meanwhile, the planting date of 29th April recorded the highest seed oil % and harvest index in both seasons. Shandauil-3 cv. surpassed significantly the other two cultivars in number of fruiting nodes plant^{-1}, number of capsules plant^{-1}, capsule length, number of seeds capsule^{-1}, 1000-seed weight, seed weight plant^{-1}, seed and oil yields ha^{-1}, as well as, harvest index in both seasons. Meanwhile, Giza-32 recorded the highest seed oil % in both seasons. The highest values of seed and oil yields were recorded from planting Shandauil-3 on 9th April. The correlation analyses showed significant and positive association between seed yield and most studied characters especially oil yield, seed yield plant^{-1}, number of capsules plant^{-1},1000-seed weight and number of seeds capsule^{-1}.

Key words: Sesame · *Sesamum indicum* L. · Seed · Oil yield · Planting dates · Cultivar · Sandy soils · Correlation · Egypt

INTRODUCTION

Sesame is an important oil seed crop grown in tropical and subtropical regions of the world. Practically, most of the world sesame area is found in developing countries, with the largest area in India, Myanmar, China, Sudan and Nigeria. In brief, Saxena *et al.* [1] stated that problems of adverse soil conditions, in particular salinity, are more complex than drought in crop × soil × climate interaction and must receive basic and applied research attention to a better understanding of crop responses to these soil conditions. It has a high content of both edible oil (42-54%) and protein (22-25%) [2]. Sesame is a short day plant and occurs naturally between 25°S and 25°N, but up to 40°N in China, Russia and the USA, 30°S in Australia and 35°S in South America, generally below 1250 m [3]. Sesame is very drought tolerant due in part to an extensively branched root system which also improves soil structure. Meanwhile, sesame is intolerant of wet conditions [4]. Nath *et al.* [5] mentioned that sesame can be cultivated in sub-optimal conditions, mainly during February to May (summer) or June to September (rainy season). Malik *et al.* [6] cleared that sesame has wide variety of uses and there are well-developed domestic and international markets for its seed. Martin and Leonard [7] mentioned that sesame is used mostly for edible purposes such as oil and confectionery. It is also used for other purposes *i.e.* manufacture of margarine, soap, paint, perfumes, pharmaceutical products and cookies [8]. Weiss [3] cleared that sesame seed contains essential amino and fatty acids specially linoleic acid. It is a good source of vitamins such as vitamin E and minerals such as calcium and phosphorous and the seed cake is also an important nutritious livestock feed.

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Egypt faces a vast gap between production and consumption of edible oil [9]. Egypt imported in 2013 about 1213740 ton of edible oil which coasted 1074203 $ [10]. Sesame ranks with peanut as two of the most important oil-seed crops grown in Egypt not only for edible oil but mainly in foods processing. Egypt produced 40000 ton seeds of sesame in 2013 [10]. Sesame can be grown successfully in the newly reclaimed sandy soils, Egypt is planting about 30000 ha in 2013 [10]. This approach needs much research in order to determine the optimum time of planting which in turn improves unit land area utilization. Selecting a cultivar with a high average yield is a major factor in ensuring a profitable return of sesame.

Many researchers studied the influence of cultivars and planting date on sesame yield and its attributes. Mulkey *et al.* [11], AlamSarkar *et al.* [8], Olowe [12] and Ali and Jan [2] found that plant height increased by planting sesame on 29th April, 26th February, 1st July and 15th June, respectively. Moreover, number of capsules plant^{-1} and number of seeds capsule^{-1} recorded the highest values by planting on 26th February, 1st July, 22th July and 20th June [8, 12-14]. Higher capsule length was obtained from planting on 22th July and 20th June [13, 2]. Planting sesame on 1st July recorded higher seed weight plant^{-1} [12]. Nath *et al.* [15] as well as, Ali and Jan [14] found that the heaviest 1000-seed weight was recorded on planting dates 1st March and 20th June. Meanwhile, Ogbonna and Umar-Shaaba [13] found insignificant effect of planting date on 1000-seed weight.

The optimum time of sesame planting for achieving higher seed yield ha^{-1} was determined by many investigators *i.e.*, 29th April, early planting, in Egypt, on April or May, 1st March in India, 26th February in Bangladesh, 1st July in Nigeria, 22th July in Nigeria and 20th June in Pakistan [11, 3, 16, 17, 15, 8, 12, 13, 14]. Also, the highest value of harvest index was achieved from planting on 20th June [14].

The local and world mean seed yield of sesame are very low, it can be achieve higher yield through suitable cultivars and optimum planting date. The low yield could be due to lacke of improved cultivars, low harvest index, susceptibility to disease, pests and environmental stresses, as well as, capsule shattering. Cultivars of sesame differed significantly on plant height, number of capsules plant^{-1}, number of seeds capsule^{-1}, capsule length, seed weight plant^{-1}, thousand-seed weight, seed yield ha^{-1} and harvest index [12, 2, 15, 14, 3, 18]. The interaction between planting date and cultivar affected significantly plant height, number of capsules plant^{-1}, seed weight plant^{-1}, thousand-seed weight and seed yield ha^{-1} [12, 2, 15]. On the other hand, Ali and Jan [2, 14] found insignificant effect on plant height, number of capsules plant^{-1}, number of seeds capsule^{-1}, capsule length, 1000-seed weight, seed yield ha^{-1} and harvest index.

The objectives of the present research were to determine the optimum planting date and suitable cultivar for higher productivity in sandy soils and identify characters of strongest association with seed yield towards the final yield as a basic requirement for any crop improvement.

MATERIALS AND METHODS

Experimental Site and Treatments: Two field experiments were laid out under drip irrigation in the Desert Experimental Station, Fac. of Agric., Cairo Univ. in Wadi El-Natroon, El-Beheira Governorate (located between 30°32'30" and 30° 33'0" N and between 29° 57'15" and 29°58'15" E with an altitude of 45 meters) during summer seasons of 2013 and 2014. Climatic data of experimental location are presented in Table (1). Soil and irrigation water properties are presented in Table (2). Soil of the experimental site was sandy, saline and poor in nutrients (NPK), as well as, organic matter. Irrigation water was saline. This analysis of soil and water reflects the nature of sandy soils. Sesame is adaptable to many soil types, but it thrives best in well drained, fertile soils of medium texture and with pH ranging from 5.5 to 8.0, but most cultivars are intolerant of salinity.

Growth and subsequent yield will be reduced on gravely on sandy soils due to their poor moistures retention capacity [4]. Three Egyptian cultivars of sesame (Giza-32, Shandauil-3 and Sohag-1) were planted via four planting dates of 20th March, 9th April, 29th April and 19th May and were harvested at 20th August, 10th September, 16th September and 20th September, respectively. Mono super-phosphate fertilizer (15.5% P_2O_5) at the rate of 72 kg P_2O_5 ha^{-1} was added during field preparation as basal application. Nitrogen was added at rate of 144 kg N ha^{-1} in the form of ammonium nitrate (33.5% N). Potassium sulphate (48% K_2O) was applied at the rate of 120 kg K_2O ha^{-1}.

Table 1: Mean monthly of climatic data* at experimental location in Wadi El-Natroon during sesame growing seasons

Year	Month	Maximum temperature (°C)	Minimum temperature (°C)	Maximum relative humidity (%)	Minimum relative humidity (%)	Average wind speed (km h^{-1})
2013	March	23.14	13.92	79.19	45.85	8.30
	April	24.87	14.24	79.71	41.85	6.72
	May	27.20	14.97	82.31	41.55	6.01
	June	28.29	15.05	84.13	47.91	6.10
	July	28.61	15.49	87.67	54.98	6.48
	August	29.47	16.94	87.56	56.72	6.07
	September	29.02	19.26	84.54	51.04	5.66
	October	27.63	20.41	80.51	51.49	6.40
2014	March	23.16	14.01	79.15	45.92	8.22
	April	24.89	14.23	79.73	41.84	6.74
	May	28.12	14.96	82.22	41.74	6.22
	June	28.25	15.08	84.13	47.85	6.09
	July	28.74	15.39	87.59	54.78	6.51
	August	29.77	16.96	87.66	56.88	6.08
	September	29.17	19.23	84.61	51.12	5.62
	October	27.58	20.14	80.45	51.76	6.43

* Data obtained by the Central Laboratory for Agriculture Climate (CLAC), Agricultural Research Center, Egypt

Table 2: Soil and irrigation water properties at the experimental site in 2013 and 2014 seasons

Soil analysis	2013	2014
Physical properties		
Sand %	94.85	92.50
Silt %	4.00	4.78
Clay %	1.15	2.72
Texture	Sandy	Sandy
Chemical properties		
Soil (pH)	7.89	7.53
Ec (ds/m)	5.23	5.36
Organic Matter (%)	0.30	0.25
Total $CaCo_3$ (%)	2.55	5.96
Available N (mg kg^{-1})	0.63	8.6
Available P (mg kg^{-1})	1.45	2.24
Available K (mg kg^{-1})	150	180

Chemical properties of irrigation water

		Ec		Ions concentration meq/L						
Season	pH	ds/m	PPM	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+
2013	7.6	4.1	2624	2.9	30.1	9.0	3.9	4.3	33.3	0.64
2014	7.8	4.2	2688	3.5	28.8	7.7	5.5	4.5	31.6	0.54

Application of both of N and K fertilizers was started at 15 days from planting through six equal doses at 7-day intervals. Fertigation system was used. A mixture of micronutrients (Fe, Zn, Mn, Cu and B) was also sprayed three times at 21-day intervals as a foliar application, at a rate of 1500 ppm, after thinning. All the required cultural practices were adopted uniformly as necessary during the two growing seasons. The preceding crop of sesame experimental fields was sugar beet during the two seasons.

Experimental Design and Statistical Analysis: The experimental design was factorial arrangement in randomized complete blocks design, with three replications. The first factor was four planting dates. The second factor was three sesame cultivars. Each sub-plot consisted of 5 rows of 5 m long and 0.60 m wide with an area of 15 m^2. Seeds were sown in hills 20 cm apart, thereafter were thinned to 2 plants $hill^{-1}$ to give 168000 plant ha^{-1}. Data were analyzed according to procedures outlined by Steel *et al.* [19] using MSTAT-C computer

package [20]. The differences among treatment means were compared by Least Significant Differences test (LSD) at 0.05 level of probability. The product moment correlation coefficients between seed yield ha^{-1} and all studied traits were estimated.

Recorded Data: At harvest, ten guarded plants were randomly taken from each plot to estimate the following traits: plant height (cm), fruiting zone length (cm), number of fruiting nodes $plant^{-1}$, number of capsules $plant^{-1}$, capsule length (cm), number of seeds $capule^{-1}$, thousand-seed weight (g) and seed yield $plant^{-1}$ (g). Seed-oil (%) was determined according to A.O.A.C. [21]. Also, seed yield (kg ha^{-1}) was weighed from the whole area of each plot and adjusted to yield per hectare. Oil yield (kg ha^{-1}) was calculated by multiplying seed-oil percentage by seed yield ha^{-1}. Harvest index (HI%) was calculated by dividing seed yield ha^{-1} on airly dried biological yield ha^{-1} * 100

RESULTS AND DISCUSSION

Analysis of Variance: Analysis of variance for 2013 and 2014 seasons (Table 3) show that highly significant differences were existed among planting dates for all studied traits in both seasons except harvest index in the second one. Mean squares due to cultivars were also highly significant for all studied characters in both seasons. All mean squares due to planting dates × cultivars interaction were highly significant for all traits in both seasons, except fruiting zone length was insignificant and capsule length was significant in 2013 season. Meanwhile, difference was highly significant with all studied traits except 1000-seed weight in 2014 season. Coefficients of variation (C.V) for all studied traits were ranged from 0.95 to 11.22% in 2013 and from 0.46 to 10.56% in 2014.

Effect of Planting Dates: Sesame yields and all of its attributes were significantly affected by planting dates in both seasons with the exception of HI in the second season (Table 3). Results in Table (4) show that the tallest plants, higher fruiting zone length, higher number of fruiting nodes $plant^{-1}$, higher number of capsules $plant^{-1}$, higher values of capsule length, higher number of seeds $capsule^{-1}$, the heaviest 1000-seed weight and higher seed weight $plant^{-1}$. As well as, greater seed and oil yields ha^{-1} were recorded by planting sesame on 9th April in both seasons. The highest value of seed oil % and HI was obtained from planting sesame on 29th April in both seasons without significant differences with other planting dates in 2014 season for HI. Planting sesame at higher temperature during 29th April and 19th May (Table 1) lead to lower requires of accumulation heat units and promoted sesame plants to reproductive stage and decreased the duration from sowing to maturity compared to planting on 9th April and 20th March. On the other hand, under early sowing date the plant had enough vegetative growth, adequate photosynthetic activity and assimilates than sowing latter in the season. Also, the reason of taller plants, higher number of fruiting nodes and capsules $plant^{-1}$, maximum capsule length and higher number of seeds $capsule^{-1}$ in early planting could be the effect of prolonged photoperiod which might have resulted in more assimilates in capsules resulting in larger number of the prior traits. Earlier planting date gained prolonged growth period with ideal growth condition produced heavier seed weight $plant^{-1}$ and 1000-seed weight as compared to late planting. Consequently, the optimum planting date was 9th April which promoted most of yield attributes. Similar trends were obtained by Mulkey *et al.* [11], Nath *et al.* [15], AlamSarkar *et al.* [8] who reported that the early planting dates in their experiment (26th February to 29th April) were the optimum dates for higher yield and its components. Conversely, Olowe [12], Ogbonna and Umar-Shaaba [13], as well as, Ali and Jan [2, 14] mentioned that the late planting dates (20th June to 1st August) were the optimum ones.

Effect of Cultivars: Results in Table (4) reveal that sesame cultivars varied significantly in plant height, fruiting zone length, number of fruiting nodes $plant^{-1}$, number of capsules $plant^{-1}$, capsule length, number of seeds $capsule^{-1}$, 1000-seed weight, seed weight $plant^{-1}$, seed oil%, seed and oil yields ha^{-1}, as well as, HI in both seasons. The highest and significant mean values of plant height and fruiting zone length were obtained from the cultivar Giza-32 in both seasons. Meanwhile, the sesame cultivar Shandauil-3 significantly surpassed the other two cultivars in number of fruiting nodes $plant^{-1}$, number of capsules $plant^{-1}$, capsule length, number of seeds $capsule^{-1}$, 1000-seed weight, seed weight $plant^{-1}$, seed and oil yields ha^{-1}, as well as, HI in both seasons. Meanwhile, Giza-32 recorded the highest seed oil % in both seasons.

Superiority of Shandauil-3 cv. may be due to their genetic constitution and its capability of withstanding stress conditions of sandy soil than other cultivars which

Table 3: Mean squares of analysis of variance for all studied traits of sesame cultivars under four planting dates, in 2013 and 2014 season

Source of variation	df	Plant height	Fruiting zone length	No. of fruiting nodes plant^{-1}	No. of capsules plant^{-1}	Capsule length	No. of seeds capule^{-1}	1000-seed weight	Seed weight plant^{-1}	Seed oil content	Seed yield ha^{-1}	Oil yield ha^{-1}	HI
						2013 season							
Reps	2	17.764	18.980	2.335	0.601	0.03083	23.808	0.00119	2.141	0.3956	2157	498	21.63
Planting date (P)	3	609.626**	166.299*	131.379**	293.199**	0.34694**	975.482**	3.27439**	229.857**	34.9969**	955201**	274137**	67.38**
Cultivar (C)	2	333.230**	119.874**	238.339**	185.941**	0.59083**	444.274**	0.17882**	164.229**	11.7612**	38338**	88682**	1403.77**
P × C	6	59.097**	22.889 ns	64.399**	58.047**	0.09972*	302.530**	0.29538**	10.229**	2.1426**	128793**	31798**	59.29**
Error	22	14.658	25.591	4.615	2.890	0.03932	18.241	0.00618	2.287	0.6459	6890	1891	9.41
C.V (%)		3.83	8.14	10.06	4.41	6.52	7.40	1.78	5.22	1.66	6.34	6.82	11.22
						2014 season							
Reps	2	75.931	85.019	3.852	1.130	0.0675	6.361	0.00829	4.841	0.5317	8.396	1357	1.21
Planting date (P)	3	573.509**	642.063**	69.482**	93.661**	0.18889**	657.205**	0.36147**	76.230**	80.5828**	715342**	241859**	11.28 ns
Cultivar (C)	2	800.640**	254.339**	130.610**	174.519**	0.54333**	777.877**	0.33204**	148.891**	7.1172**	2004216**	417736**	3065.27**
P × C	6	113.187**	141.329**	20.094**	117.784**	0.14556**	113.110**	0.00968 ns	10.067**	2.0486**	83175**	18301**	21.28**
Error	22	18.438	30.828	4.152	5.149	0.02083	19.221	0.00563	1.923	0.4849	9049	1884	4.4
C.V (%)		4.45	8.59	10.56	6.89	4.98	8.11	2.09	5.21	1.46	8.18	7.79	9.61

ns,* and ** indicate non-significance and significance at 5% and 1% probability level, respectively

Table 4: Effect of four planting dates on studied traits of three cultivars of sesame, in 2013 and 2014 seasons

Trait	Plant height (cm)	Fruiting zone length (cm)	No. of fruiting nodes plant^{-1}	No. of capsules plant^{-1}	Capsule length (cm)	No. of seeds capule^{-1}	1000-seed weight (g)	Seed weight plant^{-1} (g)	Seed oil (%)	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})	HI (%)
Treatments					2013 season							
Planting Date (P)												
20th March	88.23	56.48	18.78	38.07	3.03	50.17	4.57	26.60	47.80	1165.2	556.83	26.96
9th April	104.76	66.57	25.99	44.31	3.24	66.93	4.82	34.58	48.74	1694.4	826.78	27.00
29th April	100.57	63.96	22.96	40.96	3.11	66.33	4.74	31.45	50.90	1433.7	729.24	31.00
19th May	106.47	61.44	17.73	30.90	2.78	47.28	3.52	23.19	46.17	943.5	435.93	24.38
Cultivars (C)												
Giza-32	104.86	65.20	20.61	38.83	3.02	56.35	4.46	29.08	49.53	1272.7	635.27	24.23
Shandauil-3	94.40	58.88	26.15	42.35	3.28	64.32	4.50	32.59	47.98	1503.4	724.11	39.37
Sohag-1	100.76	62.25	17.33	34.49	2.833	52.37	4.27	25.19	47.70	1151.5	552.21	18.41
L.S.D$_{0.05}$ (P)	3.74	4.95	2.10	1.66	0.19	4.18	0.08	1.48	0.79	81.15	42.51	3.00
L.S.D$_{0.05}$ (C)	3.24	4.28	1.82	1.44	0.17	3.62	0.07	1.28	0.68	70.28	36.82	2.60
L.S.D$_{0.05}$ (P×C)	6.48	n.s.	3.64	2.88	0.34	7.23	0.13	2.56	1.36	140.56	73.63	5.19
					2014 season							
Planting Date (P)												
20th March	84.77	55.27	18.94	31.27	2.99	49.59	3.57	25.96	46.18	1115.0	510.39	21.72
9th April	102.33	72.29	22.49	37.58	3.00	62.97	3.78	30.20	49.26	1399.9	686.02	21.64
29th April	100.27	71.23	19.98	32.46	2.92	59.22	3.68	27.08	50.81	1354.3	688.04	23.32
19th May	98.80	59.72	15.78	30.36	2.69	44.41	3.32	23.16	44.17	784.3	345.74	20.61
Cultivars (C)												
Giza-32	102.94	67.76	19.62	32.40	2.85	54.91	3.58	27.08	48.26	1077.8	526.82	13.97
Shandauil-3	87.34	59.34	22.43	36.96	3.13	61.63	3.76	29.86	46.76	1608.1	757.58	40.21
Sohag-1	99.34	66.78	15.85	29.38	2.72	45.60	3.43	22.86	47.80	804.2	388.24	11.29
L.S.D$_{0.05}$ (P)	4.20	5.43	1.99	2.22	0.14	4.29	0.07	1.36	0.68	93.00	42.44	n.s.
L.S.D$_{0.05}$ (C)	3.64	4.70	1.73	1.92	0.12	3.71	0.06	1.17	0.59	80.54	36.75	1.78
L.S.D$_{0.05}$ (P×C)	7.27	9.40	3.45	3.84	0.24	7.42	n.s.	2.35	1.18	161.08	73.50	3.55

n.s. = non significant

Table 5: Effect of planting date × cultivar interaction on seed and oil yields of sesame (kg ha^{-1}), in 2013 and 2014 seasons

	Planting Date (P)				
	20th March	9th April	29th April	19th May	
	Seed yield (kg ha^{-1})				
Cultivar (C)			2013 season		Mean
Giza-32	1153.8	1642.0	1371.6	923.5	1272.7
Shandauil-3	1274.1	2204.1	1523.5	1011.9	1503.4
Sohag-1	1067.7	1237.2	1406.2	895.1	1151.5
Mean	1165.2	1694.4	1433.7	943.5	1309.2
L.S.D$_{0.05}$ (P×C)	140.56				

Table 5: Continued

	Planting Date (P)				
	20th March	9th April	29th April	19th May	
	Seed yield (kg ha^{-1})				
			2014 season		
Giza-32	849.8	1450.4	1354.3	656.8	1077.8
Shandauil-3	1753.1	1769.5	1814.8	1094.8	1608.1
Sohag-1	742.2	979.8	893.8	601.2	804.2
Mean	1115.0	1399.9	1354.3	784.3	1163.4
L.S.D$_{0.05}$ (P×C)	161.08				
			Oil yield (kg ha^{-1})		
			2013 season		
Giza-32	570.0	831.9	713.4	425.9	635.3b
Shandauil-3	598.7	1062.9	762.7	472.0	724.1a
Sohag-1	501.8	585.5	711.6	409.9	552.2c
Mean	556.8	826.8	729.2	435.9	637.2
L.S.D$_{0.05}$ (P×C)	73.63				
			2014 season		
Giza-32	400.8	719.4	689.3	297.8	526.8
Shandauil-3	785.3	845.2	921.5	478.3	757.6
Sohag-1	345.0	493.5	453.3	261.1	388.0
Mean	510.4	686.0	688.0	345.7	557.6
L.S.D$_{0.05}$ (P×C)	73.50				

was reflected on mean number of its fruiting nodes plant^{-1}, number of capsules plant^{-}, ^{1}capsule length, number of seeds capsule^{-1}, 1000-seed weight and seed weight plant^{-1}. These results are in agreement with those obtained by Weiss [3], Nath *et al.* [15], Olowe [12], as well as, Ali and Jan [2, 14] who reported that cultivars differed significantly on sesame yield and its attributes. In contrast, El-Sanatawy *et al.* [17] in Egypt, found that Giza-32 cv. surpassed Toshka-1 and Shanduil-3 cv. in fruiting zone length, No. of capsules plant^{-1}, seed weight plant^{-1}, seed oil %, as well as, seed and oil yields fad^{-1} (faddan = 4200 m^2). Also, Giza-32 had the lowest significantly weight for 1000-seed.

Effect of the Interaction Between Planting Dates and Cultivars: Results in Table (4) indicate that plant height, number of fruiting nodes plant^{-1}, number of capsules plant^{-1}, capsule length, number of seeds capsule^{-1}, seed weight plant^{-1}, seed oil %, seed and oil yields ha^{-1}, as well as, HI were significantly affected by the interaction between planting dates and sesame cultivars in both seasons. On the other hand, fruiting zone length was affected significantly by planting date × cultivar interaction in the 2nd season only. Also, 1000-seed weight was significantly affected by planting date × cultivar interaction in the 1st season.

Results in Table (5) clear that the heaviest seed yield ha^{-1} (2204.1 and 1814.8 kg) resulted from planting the cultivar Shandauil-3 on 9th April and 29th April in 2013 and 2014 seasons, respectively with insignificant differences between 9th and 29th April in 2014. The highest and significant oil yield ha^{-1} values (1062.9 and 921.5 kg) resulted from planting the cultivar Shandauil-3 on 9th and 29th April in both seasons, respectively.

Data averaged across seasons (Fig. 1) indicated that planting sesame on 19th May with the cultivar Giza-32 recorded the tallest plants (112.8 cm). Data averaged across seasons (Fig. 2) indicated that planting sesame on 29th April with the cultivar Giza-32 recorded the longest fruit zone (74.3 cm). Data averaged across seasons (Fig. 3) and (Fig. 4) indicated that planting sesame on 9th April with the cultivar Shandauil-3 recorded the largest number of fruiting nodes plant^{-1} (28.8) and number of capsules plant^{-1}, respectively. Data averaged across seasons (Fig. 5) indicated that planting sesame on 20th March with the cultivar Shandauil-3 recorded the longest capsule (3.5 cm). Data averaged across seasons (Fig. 6) and (Fig. 7) indicated that planting sesame on 29th April with the cultivar Shandauil-3 recorded the maximum number of seeds capsule^{-1} (76.1) and 1000-seed weight (4.5 g). Data averaged across seasons (Fig. 8) and (Fig. 9) indicated that planting sesame on 9th April with the cultivar

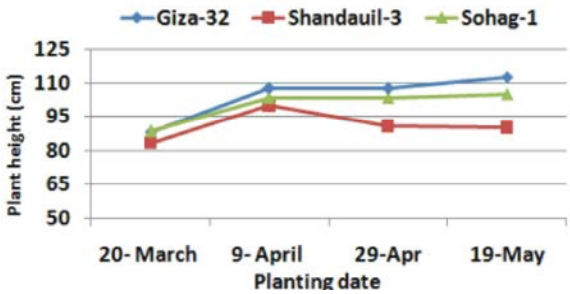

Fig. 1: Plant height (cm) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

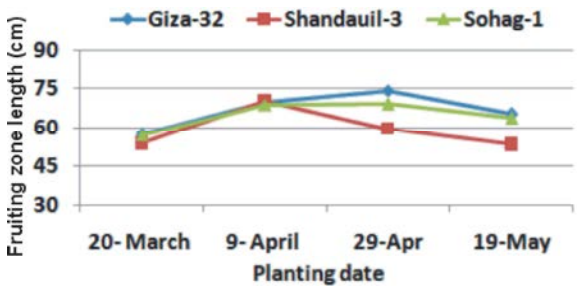

Fig. 2: Fruiting zone length (cm) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

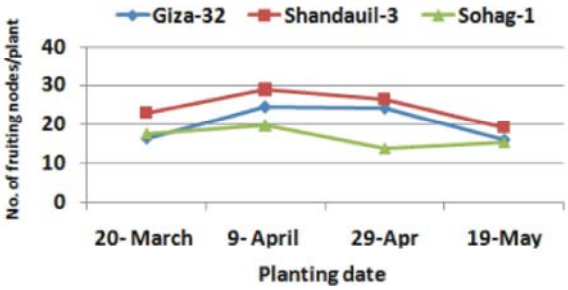

Fig. 3: No. of fruiting nodes/plant as affected by interaction between planting date and sesame cutivars (Combined across seasons)

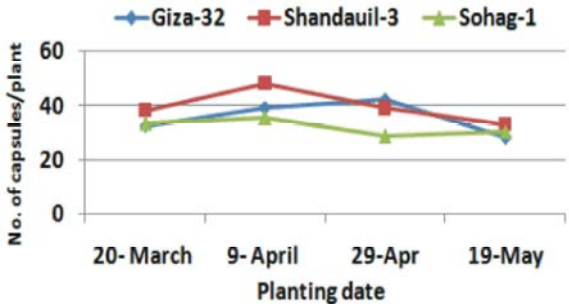

Fig. 4: No. of capsules/plant as affected by interaction between planting date and sesame cutivars (Combined across seasons)

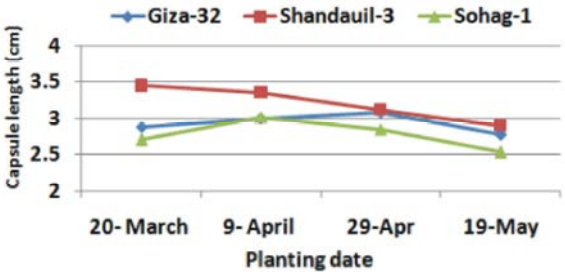

Fig. 5: Capsules length (cm) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

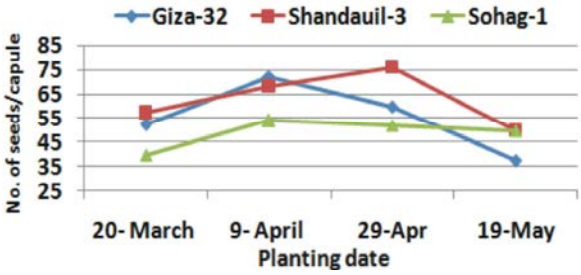

Fig. 6: No. of seeds/capsules as affected by interaction between planting date and sesame cutivars (Combined across seasons)

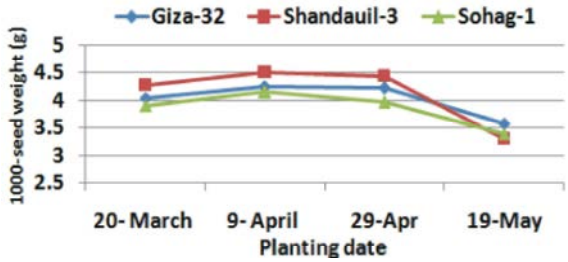

Fig. 7: Thousands seed weight (g) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

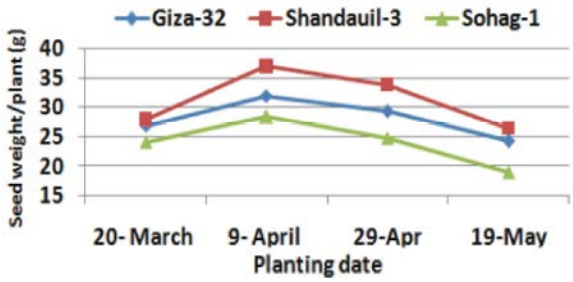

Fig. 8: Seed weight/plant (g) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

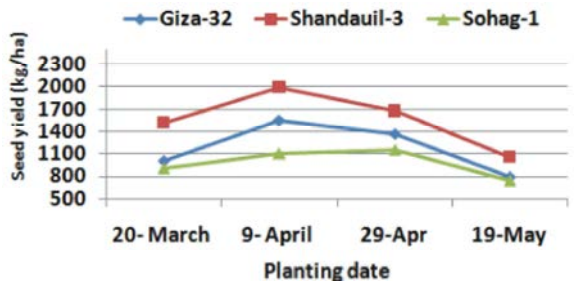

Fig. 9: Seed yield/ha (kg) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

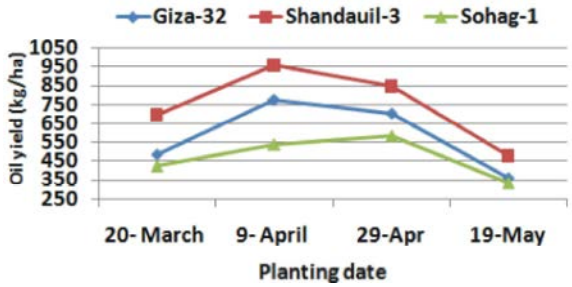

Fig. 11: Oil yield (kg/ha) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

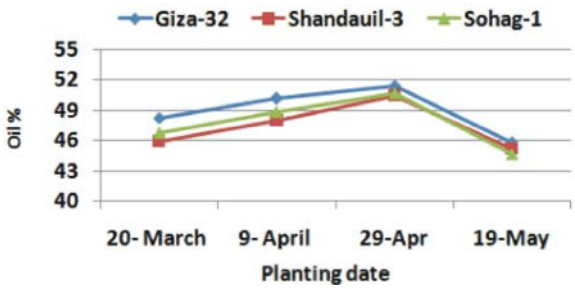

Fig. 10: Seed oil percentage as affected by interaction between planting date and sesame cutivars (Combined across seasons)

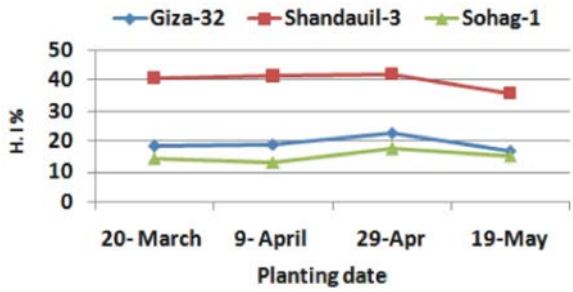

Fig. 12: Harvest index (%) as affected by interaction between planting date and sesame cutivars (Combined across seasons)

Table 6: Correlation coefficients among sesame characters across four planting dates and three cultivars, in 2013 and 2014 seasons

Characters	Seed yield (kg ha^{-1})	Plant height (cm)	Fruiting zone length (cm)	No. of fruiting nodes plant^{-1}	No. of capsules plant^{-1}	Capsule length (cm)	No. of seeds capule^{-1}	1000-seed weight (g)	Seed weight plant^{-1} (g)	Seed oil (%)	Oil yield (kg ha^{-1})	HI (%)
Plant height (cm)	-0.02	1										
	(-0.27)	(1)										
Fruiting zone length (cm)	0.31	0.77**	1									
	(0.04)	(0.85**)	(1)									
No. of fruiting nodes plant^{-1}	0.70**	-0.10	0.08	1								
	(0.79**)	(-0.11)	(0.14)	(1)								
No. of capsules plant^{-1}	0.81**	-0.15	0.20	0.76**	1							
	(0.61**)	(0.02)	(0.25)	(0.67**)	(1)							
Capsule length (cm)	0.66**	-0.12	0.06	0.59**	0.79**	1						
	(0.67**)	(-0.34)	(-0.05)	(0.62**)	(0.36**)	(1)						
No. of seeds capule^{-1}	0.64**	-0.05	0.18	0.70**	0.56**	0.44**	1					
	(0.85**)	(-0.10)	(0.19)	(0.60**)	(0.56**)	(0.42**)	(1)					
1000-seed weight (g)	0.71**	-0.17	0.19	0.54**	0.75**	0.65**	0.55**	1				
	(0.83**)	(-0.21)	(0.17)	(0.76**)	(0.53**)	(0.58**)	(0.83**)	(1)				
Seed weight plant^{-1} (g)	0.88**	-0.05	0.17	0.79**	0.83**	0.73**	0.69**	0.75**	1			
	(0.75**)	(-0.20)	(0.07)	(0.73**)	(0.51**)	(0.48**)	(0.76**)	(0.85**)	(1)			
Seed oil (%)	0.48**	-0.01	0.28	0.31	0.46**	0.26	0.58**	0.53**	0.49**	1		
	(0.30)	(0.32)	(0.55**)	(0.29)	(0.09)	(0.13)	(0.46**)	(0.53**)	(0.39*)	(1)		
Oil yield (kg ha^{-1})	0.99**	-0.01	0.34*	0.70**	0.81**	0.64**	0.68**	0.73**	0.88**	0.16	1	
	(0.99**)	(0.20)	(0.12)	(0.78**)	(0.60**)	(0.63**)	(0.88**)	(0.86**)	(0.76**)	(-0.16)	(1)	
HI (%)	0.61**	-0.31	-0.16	0.63**	0.56**	0.62**	0.43**	0.35*	0.64**	0.58**	0.58**	1
	(0.79**)	(-0.57)	(-0.35)	(0.56**)	(0.47**)	(0.61**)	(0.54**)	(0.56**)	(0.57**)	(0.72**)	(0.43**)	(1)

* and ** indicate significance at 5% and 1% probability level, respectively. Values in parentheses correspond to 2014 season.

Shandauil-3 recorded the highest values of seed weight plant^{-1} (36.9 g) and seed yield ha^{-1} (1986.8 kg). Data averaged across seasons (Fig. 10) indicated that planting sesame on 29th April with the cultivar Giza-32 recorded the highest seed oil content (51.45%). Data averaged across seasons (Fig. 11) and (Fig. 13) indicated that planting sesame on 9th and 29th April with the cultivar Shandauil-3 recorded the highest values of oil yield ha^{-1} (954.05 kg) and HI (41.69%).

The Interrelationships among Sesame Traits: The correlation coefficients between seed yield ha^{-1} and most traits was significant and positive (Table, 6). Highly significant and positive correlations was observed between seed yield and oil yield ha^{-1} (0.99**), seed weight plant^{-1} (0.88**), number of capsules plant^{-1} (0.81**), thousand seed weight (0.71**), number of fruiting nodes (0.70**) in the first season. Also, highly significant and positive association was observed between seed yield and oil yield ha^{-1} (0.99**), number of seeds capsules^{-1} (0.85**), thousand seed weight (0.83**), number of fruiting nodes (0.79**) in the second one. Negative and insignificant correlation was detected between seed yield and plant height in both seasons.

In this connection positive and significant relationships were found between seed yield and plant height, number of capsules plant^{-1}, number of seeds capsule^{-1}, seed weight plant^{-1} and harvest index [12, 22, 23]. By contrast, Kamel *et al.* in Egypt [24] did not find any association between HI and any of the studied traits including yield. The cultivar they used was an old commercial cultivar (Giza-25) with modest HI which ranged from 14.7 to 19.7 (as an average of three seasons). Besides, this research work was the first one in Egypt that payed attention to harvest index in sesame and considered it as a very important trait that connect physiological and yield (*i.e.*, source and sink) outputs. In that context, Shabana and Abu-Hagaza [22] revealed that 61% of the variation in seed yield of 55 sesame lines and cultivars may be attributed to the joint effects of HI and plant seed weight.

CONCLUSION

Results of this research under sandy soil conditions in North Egypt refer that seed and oil yields of sesame were increased by planting on 9th April. Shandauil-3 cv. is recommended for economical seed and oil yields and it may be grown successfully under similar conditions. The highest seed and oil yields were obtained from planting Shandauil-3 on 9th and 29th April. Seed yield is very closely and significantly related to oil yield (r=0.99**) and seed weight plant^{-1} (r=0.88**) in 2013 and oil yield (r=0.99**) and number of seeds capsule^{-1} (r=0.85**) in 2014.

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