International Journal of

Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS International Journal of Agricultural Research
ISSN 1816-4897
DOI: 10.3923/ijar.2022.22.31

Research Article
Maximizing Sesame Crop Yield via Matching the Appropriate Genotype with the Optimum Intra-Row Spacing

[1]Mohamed Hamza, [2]Hussein Mohamed Abd El-Fattah and [2]Sayed Ahmed Safina

[1]Department of Biology, College of Science, Jouf University, Al Jawf, Kingdom of Saudi Arabia
[2]Department of Agronomy, Faculty of Agriculture, Cairo University, Giza 12613, Egypt

Abstract
Background and Objective: The expression of genetic variability of the yield components in sesame is strongly influenced by inter-plant competition. Thus, information on the degree of dependence of seed yield per unit area on each of these components under different levels of intra-row spacing was evaluated and establishing optimum population densities. **Materials and Methods:** Two field experiments were conducted in the Experimental Station of the Faculty of Agriculture, Cairo University, Giza Governorate, Egypt during the summer seasons of 2015 and 2016. The experimental design was the split-plot arrangement in a randomized complete blocks design repeated four times. The main plots were devoted to intra-row spacing (10, 20 and 30 cm) providing three plant densities of 105 000, 70 000 and 35 000 plant fed^{-1}, respectively and sub-plots to three genotypes (D1, 2 and Shandauil-3). **Results:** The highest seed yield (kg) was realized from Line-2 with 105000 plant fed^{-1}. Shandauil-3cv. out yielded significantly the other two genotypes in number of fruiting nodes/plant, capsule length, number of seeds/capsule and fruit zone length. Fatty acids profile reflected little variations not only among sesame genotypes but also intra-row spacing. **Conclusion:** The study acknowledges the higher seed and oil yield of sesame could be obtained by using genotype Line-D1 sowing at 10 cm between hills under the agro-climatic conditions of Giza, Egypt.

Key words: *Sesamum indicum* L., cultivar, intra-row, spacing, density, population, planting, seed, oil

Citation: Hamza, M., H.M.A. El-Fattah and S.A. Safina, 2022. Maximizing sesame crop yield via matching the appropriate genotype with the optimum intra-row spacing. Int. J. Agric. Res., 17: 22-31.

Corresponding Author: Sayed Ahmed Safina, Department of Agronomy, Faculty of Agriculture, Cairo University, Giza 12613, Egypt

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sesame yield is a very complex quantitative character resulting from different factors, the more important of them being the yield per plant and the number of plants per unit area. Optimizing plant density is a very important factor for improving sesame yield. The optimal plant density for sesame can be determined by not only inter and intra-row spacing, but also the number of plants per hill. Plant population that differed from one area to another one depending on farmer's experience and sesame cultivar seriously affects sesame production in Egypt. Many farmers in Egypt did not purchase their seeds every season but they select from the field the best plants and larger seeds to sow in the next season. Therefore, identification of the proper plant density for each sesame genotype becomes vital and allows maximum expression of genetic potential.

Many researchers studied the effect of plant density on the performance of irrigated sesame. It has been found that 60 cm row spacing produced a higher number of capsules/plant, seed index, seed yield, biological yield and harvest index[1]. It also found that increased row spacing from 30 to 60 cm and from 15 to 45 cm, respectively, resulted in shorter plant height, a higher number of capsules per plant, heavier 1000-seed weight and lower seed yield per ha[2,3]. Moreover, row spacing had an insignificant effect on oil content. On the other hand, to maximize seed yield of sesame, farmers should used the spacing of 50 x 20cm [4]. It also reported that there were no significant differences in plant height between plant densities[5]. In addition, increasing plant density significantly decreased the number of branches/plant, number of capsules/plant and seed weight/plant but led to increasing seed yield per unit area. It mentioned that intra-row spacing of 30 and 40 cm produced the best seed yield with no differences[6]. It has been found that increasing plant population to 84000 plant fed^{-1} increased seed yield with small differences in yield were achieved by lower plant population 33000 plant fed^{-1}. This might be attributed to the ability of sesame crops to adapt to different plant densities[7]. The yield components like fertile capsules per plant, seed per capsule and thousand seed weight were highest in the low plant population than highest plant population but oil content (%) was not affected by different levels of plant population[8].

Plant density of sesame plants had a significant effect on plant height, seed weight per plant[9]. In Egypt, therefore, decreasing planting distance from 20 to 10 cm consistently and significantly increased plant height, the height of the first fruiting branch, seed and oil yield perha[10]. Low plant population and incapacity to compensate with yield components limited seed yield at wider row spacing and low plant densities. At the closer row spacing and high plant density, seed yield was limited by the incapability of sesame to express optimum agronomic traits due to plant compaction. Most of the traits such as plant height, seed weight/plant and seed yield ha^{-1} showed a higher value under 50$\times$25 cm spacing with 4-6 plants/hill, resulting in 32000 to 48000 plant ha^{-1} for optimizing the agronomic performance of sesame[11]. It also reported that sesame yield increase with an increase in plant densities up to 400000 plants per ha[12]. It has been mentioned that wider inter-row spacing and intra-row spacing, resulted in decreased seed, oil, protein yields. Plant density 666,666 plants ha^{-1} is therefore recommended for high seed and oil yields of sesame production under irrigated Mediterranean environments[13]. Planting sesame at 60$\times$10 cm spacing gave higher plant height, meanwhile, spacing of 60$\times$20 cm gave a higher number of capsules/plant. However, higher seed and oil yields ha^{-1} achieved by 60$\times$10 cm spacing[14]. In Nigeria, it stated that a plant population density of 166,667 plant ha^{-1} gave 40% more yield than that at 266,667 plants per ha[15]. It also found that the closer inter-row spacing of 37.5 cm surpassed the wider row spacing of 75 cm for oil yield by ca. 34%[16].

The maintenance of local varieties played a great role in avoiding the loss of genetic variability in sesame populations. However, new commercial varieties may be replaced by the local varieties shortly. Thus, these important genetic materials must be categorized and conserved for upcoming sesame breeding programs. Insufficient information especially about quality traits has been given. A great deal of genetic variability, in terms of yield components that contributed to plants yielding ability, is present in currently promising sesame genotypes. This makes it important to develop information on the relative contribution of each of these yield components to seed yield per unit area, as a guide to planting or breeding sesame varieties with an optimum combination of these traits. Cultivars of sesame differed significantly on plant height[2,5,8,9], number of branches per plant, the height of the first capsule[5], number of capsules per plant[2,3,9,15,17], seed index[3,5,9,15,17], seed weight per plant[2,3,9,15], seed yield per unit area[2,9,17], harvest index[8,9], oil percentage[2,9], protein percentage, as well as, oil and protein yields[9]. Meanwhile, it has been found that insignificant effect of genotype on the number of capsules per plant, seed weight per plant, seed yield and harvest index[5]. In addition, seed index was not affected by cultivar[9].

Some papers have been reported the interaction between plant density and genotype affected significantly seed weight per plant[3,9,15], number of capsules per plant[3,9], seed yield[3,9], harvest index[3,9], oil yield, protein percentage and protein yield[9]. On the other hand, an insignificant effect was observed on seed index[9,15]. Such information would be helpful not only in improving agronomic aspects of sesame growing and increasing yield but also, in defining effective breeding objectives. The main objectives of this article were to, evaluate the agronomic performance of two promising lines of sesame vs. the Egyptian Cultivar Shandauil-3 and determine the optimum intra-row spacing for these lines.

MATERIALS AND METHODS

Experimental seasons and site: Two field experiments conducted at the Agricultural Experiment and Research Station of the Faculty of Agriculture, Cairo University, Giza, Egypt (30°02'N and 31°13'E, with an altitude of 22.5 m above sea level) during the two summer seasons of 2015 and 2016.

The preceding winter crop was faba bean (*Vicia faba*) during the two seasons. Soil samples (0-0.3 m) were taken before sowing and soil properties were determined according to the standard method. The experimental soil texture was clay loam with a pH value of 7.82, electrical conductivity (EC) of 0.72 mm hos cm^{-1} and organic matter of 2.89%. Total Nitrogen (N) content was 0.46%, available Phosphorus (P) was 4.81 mg kg^{-1}, available Potassium (K) was 84.00 mg kg^{-1}, available Sodium (Na) was 115 mg kg^{-1}, available Iron (Fe) was 4.6 ppm, available Manganese (Mn) was 4.7 ppm, available Zinc (Zn) was 3.8 ppm and no salinity problems were observed. Meteorological variables in the 2015 and 2016 growing seasons of sesame were obtained from the Central Laboratory for Agriculture Climate (CLAC), ARC, Egypt in Table 1.

Experimental design and treatments: Two experiments included nine treatments, which were the combinations of three sesame genotypes in Table 2 and three intra-row spacing (10×60, 20×60 and 30×60 cm), resulted in three plant density levels (high 105000, medium 70000 and low 35000 plants per feddan), respectively. The experimental design was used randomized complete blocks in a split-plot arrangement with four replication. The main plots were assigned to intra-row spacing, sub-plot to genotypes. Each sub-plot consisted of three ridges 3.0 m in length, 0.60 m in width and its area was 5.4 m^2.

Cultural practices: Sesame seeded by hand on June, 10 in both seasons and thinned to one plant per hill 30 days after planting. Ridges were spaced at a 60 cm distance. Single super-phosphate fertilizer (15.5% P_2O_5) at the rate of 30 kg P_2O_5 fed^{-1} was added during seedbed preparation. Nitrogen was added at the rate of 40 kg N fed^{-1} in the form of ammonium nitrate (33.5% N). Potassium sulphate (48% K_2O) was applied at the rate of 24 kg K_2O fed^{-1}. Application of both N and K fertilizers started at 15 days from planting via two equal doses at 2 weeks intervals. Irrigation was applied by the flooding system after three weeks for the first irrigation and every two weeks for subsequent ones. A mixture of micronutrients (Zn, Fe, Mn, Cu and B) was also sprayed twice at 21 days intervals as a foliar application, at a rate of 1500 ppm, after thinning. Weed control was performed manually by hoeing twice, the first before the first irrigation and the second before the second irrigation. The normal cultural practices for sesame production were adopted according to the recommended package deal of ARC, Ministry of Agriculture, Egypt.

Data recorded: After 80 days from planting date, the SPAD value of the youngest expanded leaves of sesame was measured by Chlorophyll Meter (SPAD-502 Plus) to evaluate chlorophyll contents. Light intensity was measured and light penetrating the canopy was calculated for each genotype using Lux-meter equipment. The light intensity in lux was measured at midnight at the top, medium and bottom of the plant. Ten plants from each sub-plot were taken at random where the following traits were recorded at harvest, plant height (cm), fruit zone length (cm), number of fruiting nodes/plant, number of capsules/plant, capsule length (cm), number of seeds/capsule, thousand-seed weight (g) and seed weight/plant (g). The seed-oil percentage was determined according to official methods of analysis of the Association of Official Analytical Chemists (AOAC)[18]. In addition, plant mortality percentage was estimated for each plot. Seed yield (kg fed^{-1}) was calculated from all harvested plants of each sub-plot and adjusted to yields per feddan. Oil yield (kg fed^{-1}) was calculated by multiplying the seed-oil percentage by seed yield fed^{-1}.

Statistical analysis: Test of normality distribution was carried out by using SPSS v. 17.0 Computer Package[19]. In addition, data were tested for violation of assumptions underlying the combined analysis of variance by separately analyzing each season and then combined analysis across the two seasons

Table 1: Climatic factors of the studied region during the crop growth period in 2015 and 2016 at Giza Governorate*

Seasons	Months	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Sunshine duration (hrs)	Average wind speed (m sec^{-1})
2015	June	34.4	20.6	47.7	13.9	2.3
	July	36.6	22.7	46.7	13.8	1.9
	August	36.5	26.4	48.7	12.7	1.3
	September	37.7	23.4	47.0	12.2	1.9
	October	32.7	20.7	57.0	11.3	2.0
2016	June	36.0	22.4	53.0	13.9	1.4
	July	35.2	22.4	60.0	13.8	1.3
	August	37.2	23.7	61.0	13.1	1.0
	September	34.8	21.9	59.9	12.2	1.1
	October	30.1	17.3	59.0	11.3	1.1

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

Table 2: Designation and source of sesame genotypes

Sesame genotypes	Source
Shandauil-3 cv.	Agricultural Research Center (ARC)
Line-2	Farmers seed lots, Giza district
Line-D1	Farmers seed lots, Giza district

was performed if homogeneity (Bartlett's test) was insignificant. Estimates of LSD were calculated to test the significance of differences among means using the MSTAT-C computer package[20].

RESULTS AND DISCUSSION

The result regarding harvested plants fed^{-1}, plant mortality % at harvest, plant height, capsule no/plant, chlorophyll content, light intensity, seed yield fed^{-1} and oil yield fed^{-1} showed a highly significant effect (p>0.01) of plant density (spacing), whereas seed index and Oil content % had a significant effect (p>0.05) of spacing (A) in Table 3.

Table 3 showed that mean squares due to sesame genotypes (B) were highly significant (p>0.01) for harvested plants fed^{-1} (1000 plant), plant height, first capsule height cm, capsule no/plant, seed weight g/plant, seeds weight g/ capsules, seed index, chlorophyll content, light intensity, seed yield kg fed^{-1} and oil yield kg fed^{-1}. Meanwhile, plant mortality percentage at harvest and fruiting zone length (cm) showed significant (p>0.05) mean squares due to sesame genotypes. On the other hand, the rest traits were not affected by sesame genotypes (Table 3).

The interaction between spacing and genotypes (A×B) had a highly significant (p>0.01) effect on chlorophyll content (50), oil content (12.4%) and oil yield fed^{-1} (1385). As well as, had a significant (p>0.05) effect on light intensity (806), seed yield fed^{-1} (1233). Contrary, the rest traits did not affect by spacing×genotypes interaction (Table 3).

Effect of sesame genotypes: Significant differences were found between the three genotypes in light intensity, chlorophyll content, harvested plants fed^{-1}, plant mortality percentage at harvest, plant height, oil content, seed yield fed^{-1} and oil yield fed^{-1}.Whereas, first capsule height, fruiting zone length, fruiting nodes no/plant, internodes length, No. of capsules/nod, No. of capsule/plant, seeds weight/capsules, Seed index and seed weight were not affected in Table 4. Sesame genotypes have differed significantly for intercepted light intensity within sesame plants (Table 4). Sesame genotype Line-2 had higher values of intercepted light intensity (109.21) within sesame plants as compared with sesame genotypes. The SPAD values of sesame were significantly affected by sesame genotypes (Table 4). Sesame genotype Line-D1 leaves showed higher SPAD values (42.10) than other genotypes.

Sesame genotypes have differed significantly for harvested plants fed^{-1} (Table 4). Sesame genotype Line-D1 had higher values of harvested plants fed^{-1} (66.30) as compared with the other studies sesame genotypes.

Significant differences were found between the three genotypes in the plant mortality percentage at harvest (Table 4). The Shandauil-3 cultivar produced more Plant mortality percentage at harvest (14.30) than other genotypes. The maximum and minimum plant height were recorded in Line-D1 (173.42 cm) and Shandauil-3 cv. (159.04 cm) genotypes, respectively, because of genetic influences.

Cultivars of sesame differed significantly in plant height[2,5,8,9]. Increasing height is affected by internodes growth resulting from producing Giber line hormone under light deficit conditions. The environmental factors such as the quantity and quality of light prompt plant height increase in higher plant densities, particularly in unequidistant plant distribution. The level of light, as well as the red and far-red ratio, plays an important role in stem elongation and consequently on final plant height.

Significant differences were found between the three genotypes in the Seed yield, kg fed^{-1} (Table 4). The maximum and minimum seed yield fed^{-1} recorded in

Table 3: Mean square for the effects of plant density on growth and yield of sesame

S.V	d.f	Harvested plants, fed^{-1} (1000 plant)	Plant mortality % at harvest	Plant height, (cm)	First capsule height, (cm)	Fruiting zone length, (cm)	Fruiting nodes no/plant
Season	1	46**	227**	24.5	3.13	45.1	385.5
R (S)	6	2.2	8	77.4	187.35	200.7	58.8
Spacing A	2	60**	333**	1245**	242.04	1430	348.2
SA	2	1.4	4.3	907*	641.38	229.5	4.6
Error	12	1.7	14.1	157.6	193.21	481.2	131.8
Genotypes B	2	25214**	59*	3620**	1128**	709*	180.4
SB	2	16**	50.8	4.3	8.17	20	87.8
AB	4	2.9	16.8	167.1	103.58	55	72.9
SAB	4	0.8	2.9	180.1	76.54	455.6	171.5
Error	36	2.8	17.2	104.1	118.87	173.2	76.3
S.V	d.f	Capsule no/ plant	Seed weight, g/plant	Internodes length, (cm)	Seeds weight, g/capsules	No. capsules/ nood	Seed index g
Season	1	933	19	1.176	0.001	0.66	0.133*
R (S)	6	576	6.3	0.882	0.001	1.48	0.005
Spacing A	2	677	24.1	0.596	0.001	2.89	0.095*
SA	2	209	6.6	0.052	0	0.59	0.007
Error	12	4408	11.1	1.033	0.005	6.55	0.018
Genotypes B	2	12333**	597**	0.452	0.101**	6.57	0.453**
SB	2	937	17.5	0.793	0.001	4.55	0.071
AB	4	4153	8.6	0.561	0.003	5.53	0.046
SAB	4	420	2.5	0.615	0.002	2	0.044
Error	36	1910	5.6	0.475	0.003	2.96	0.025
S.V	d.f	Chlorophyll content	Light intensity	Seed yield, kg fed^{-1}	Oil content %	Oil yield, kg fed^{-1}	
Season	1	358**	2392**	3017*	91.7**	9375**	
R (S)	6	5.8	549	488	9.87*	637*	
Spacing A	2	1162**	2939**	320063**	13.69*	67073**	
SA	2	112**	792*	2234	1.17	502	
Error	12	11.7	199	511	3.09	144	
Genotypes B	2	325**	13471**	232363**	0.72	56552**	
SB	2	4.3	1344*	1519*	1.36	156	
AB	4	50**	806*	1233*	12.4**	1385**	
SAB	4	5.8	327	1139*	1	247	
Error	36	5.1	306	410	2.91	286	

*, **Indicate to significant and highly significant 0.05 and 0.01 levels of probability, respectively

Table 4: Yield components, quality traits and yields of sesame as affected by genotypes (combined data of 2015 and 2016 seasons)

	Varieties			
Traits	Line-2	Line-D1	Shandauil-3 cv.	$LSD_{0.05}$
Light intensity	109.21	90.13	89.96	8.87
Chlorophyll content	33.81	42.10	28.27	2.15
Harvested plants , fed^{-1} (1000 plant)	65.04	66.30	63.16	0.82
Plant mortality % at harvest	9.53	6.95	14.30	2.36
Plant height, (cm)	167.04	173.42	159.04	7.89
First capsule height, (cm)	74.54	69.00	69.08	NS
Fruiting zone length, (cm)	92.50	104.42	89.96	NS
Fruiting nodes no/plant	35.64	39.55	31.93	NS
Internodes length, (cm)	2.70	2.82	3.01	NS
No capsules/node	4.15	3.94	4.62	NS
Capsule no/plant	141.78	146.12	135.55	NS
Seeds weight, (g/capsules)	0.15	0.16	0.15	NS
Seed index, (g)	6.07	6.15	6.02	NS
Seed weight, (g/plant)	18.75	19.31	16.91	NS
Seed yield, (kg fed^{-1})	702.67	841.93	612.73	14.22
Oil content (%)	50.44	48.97	50.01	1.11
Oil yield, (kg fed^{-1})	355.45	411.74	306.09	7.54

Table 5: Yield and yield components, quality traits and physiological traits of sesame as affected by spacing (combined data of 2015 and 2016 seasons)

	Spacing cm			
Traits	10 cm	20 cm	30 cm	$LSD_{0.05}$
Light intensity	76.92	89.58	122.79	10.24
Chlorophyll content	38.63	34.24	31.31	1.32
Harvested plants , fed^{-1} (1000 plant)	97.61	64.10	32.80	0.97
Plant mortality % at harvest	9.84	12.01	8.93	2.43
Plant height, (cm)	178.46	167.13	153.92	5.97
First capsule height, (cm)	77.38	71.54	63.71	6.38
Fruiting zone length, (cm)	101.08	95.58	90.21	7.71
Fruiting nodes no/plant	36.67	37.84	32.61	NS
Internodes length, (cm)	5.94	6.09	6.21	0.4
No capsules/nood	4.70	4.34	3.67	NS
Capsule no/plant	156.89	151.39	115.17	25.59
Seeds weight, g/capsules	4.70	4.34	3.67	0.03
Seed index, (g)	5.94	6.09	6.21	0.13
Seed weight, g/plant	14.32	16.79	23.87	0.39
seed yield, kg fed^{-1}	820.17	713.54	623.62	11.86
Oil content (%)	49.87	49.61	49.94	NS
Oil yield, kg fed^{-1}	408.13	353.87	311.28	9.9

Table 6: Interaction effect of genotypes×spacing of sesame on some studied traits (combined data of 2015 and 2016 seasons)

Genotypes	Spacing cm	Light intensity (100 lux)	Chlorophyll content	Seed weight g/plant	Seed yield kg fed^{-1}	Oil yield kg fed^{-1}
Line-2	10 cm	78.25	36.00	14.74	815.96	422.14
	20 cm	102.25	33.79	16.79	687.01	347.21
	30 cm	147.13	31.64	24.71	605.04	296.99
Line-D1	10 cm	77.00	49.04	14.54	942.39	451.70
	20 cm	81.88	41.30	17.74	844.61	414.08
	30 cm	111.50	35.96	25.65	738.80	369.45
Shandauil-3 cv.	10 cm	75.50	30.85	13.67	702.17	350.55
	20 cm	84.63	27.63	15.83	609.00	300.31
	30 cm	109.75	26.34	21.24	527.02	267.40
$LSD_{0.05}$		17.74	17.74	0.68	20.54	17.15

Line-D1 (841.93 kg fed^{-1}) and Shandauil-3 cv. (612.73 kg fed^{-1}) genotypes, respectively, because of genetic influences and differences in yield components. Genotypes had significantly affected seed oil percentage and oil yield (Table 4). These results are in agreement with other studies that reported significant differences among sesame genotypes in mean seed yield, oil percentage and oil yield[2,9,17].

Among all genotypes, the Line-2genotype had a maximum oil percentage (50.44%). The higher oil percentage of line-2genotype because the colour of Line-2 seed was darker than another genotype. Among genotypes, Line-D1 genotype and Shandauil-3 cv. genotype possessed the maximum and minimum oil yield respectively (Table 4). The reason is that the oil yield is high because of the high yield of the Line-D1 genotype per feddan compared with the other genotypes. These results are consistent with other studies[2,9].

Effect of plant density: The results of this study showed that all the levels of planting geometry affected significantly ($p<0.05$) the traits of sesame, while plant density had no effect on these traits fruiting nodes number/plant, number of capsules/node and oil content in sesame seeds in Table 5. Increasing plant density by planting geometry of 60 cm between ridges ×10 cm between hills resulted in maximum chlorophyll content (38.63), plant height (178.46 cm), first capsule height (77.38 cm), fruiting zone length (101.08 cm), capsule number/plant (156.89), seed weight/capsule (4.70g), seed yield (820.17 kg fed^{-1}) and oil yield (408.13 kg fed^{-1}). While planting geometry of 60 cm between ridges × 30 cm between hills resulted in maximum light intensity (122.79), seed index (6.21 g) and seed weight/plant. It may be due to increased dry matter accumulation and lack of competition between adjacent plants. Decreasing plant density increased intra specific competition, which eventually caused a reduction in the number of seeds capsules. Planting geometry affected the plant height of sesame significantly. The crop, which was sown at planting geometry of 60×10 cm, produced significantly taller plants than at other planting geometry. The increase in plant height in the case of 60×10 cm planting geometry

Table 7: Relative fatty acid composition as affected by sesame genotype × intra-row spacing interaction (combined data of 2015 and 2016 seasons)

	Sesame genotype											
	Line-2				Line-D1				Shandauil-3 cv.			
	Intra-row spacing				Intra-row spacing				Intra-row spacing			
Fatty acid composition (FAC)	10 cm	20 cm	30 cm	Mean	10 cm	20 cm	30 cm	Mean	10 cm	20 cm	30 cm	Mean
Saturated fatty acids (SFA)												
Myristic 14:0	ND	ND	0.15	0.15	ND	ND	-	#DIV/0!	-	-	-	#DIV/0!
Palmitic 16:0	9.17	8.73	9.54	9.15	9.13	9.02	8.30	8.82	8.68	8.55	8.80	8.68
Margaric 17:0	0.07	0.07	0.09	0.08	0.06	0.07	0.08	0.07	0.07	0.06	0.06	0.06
Stearic 18:0	4.70	4.68	4.87	4.75	4.59	4.63	4.66	4.63	4.70	4.66	4.79	4.72
Arachidic 20:0	0.54	0.60	0.55	0.56	0.55	0.54	0.62	0.57	0.60	0.59	0.58	0.59
Behenic 22:0	0.11	0.14	0.13	0.13	0.13	0.12	0.16	0.14	0.14	0.14	0.14	0.14
ΣSFA	14.59	14.22	15.18	14.66	14.46	14.38	13.82	14.22	14.19	14.00	14.37	14.19
Unsaturated fatty acids (USFA)												
Monounsaturated (MUSFA)												
Palmitoleic 16:1	0.11	0.12	0.16	0.13	0.12	0.12	0.11	0.12	0.15	0.11	0.14	0.13
Ginkgolic17:1	0.04	0.04	0.06	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04
Oleic 18:1	40.06	40.56	40.76	40.46	39.47	40.21	39.87	39.85	40.85	40.42	40.86	40.71
Paullinic 20:1	0.19	0.21	0.20	0.20	0.20	0.19	0.22	0.20	0.21	0.21	0.21	0.21
ΣMUSFA	40.40	40.93	41.18	40.84	39.83	40.57	40.25	40.22	41.25	40.78	41.25	41.09
Polyunsaturated (PUSFA)												
Linoleic 18:2 (ω_6)	44.62	44.48	43.17	44.09	45.40	44.70	45.62	45.24	44.18	44.88	44.02	44.36
α Linolenic 18:3 (ω_3)	0.28	0.29	0.27	0.28	0.26	0.27	0.26	0.26	0.28	0.26	0.27	0.27
γ Linolenic 18:3 (ω_6)	0.08	0.06	0.04	0.06	0.03	0.06	0.03	0.04	0.08	0.05	0.06	0.06
ΣPUSFA	44.98	44.83	43.48	44.43	45.69	45.03	45.91	45.54	44.54	45.19	44.35	44.69
ΣUSFA	85.38	85.76	84.66	85.27	85.52	85.60	86.16	85.76	85.79	85.97	85.60	85.78
Saturated unsaturated ratio	0.17	0.17	0.18	0.17	0.17	0.17	0.16	0.17	0.17	0.16	0.17	0.17
Oleic linoleic ratio	0.90	0.91	0.94	0.92	0.87	0.90	0.87	0.88	0.92	0.90	0.93	0.92
$\omega_3\omega_6$ ratio	0.0063	0.0063	0.0065	0.0062	0.0063	0.0057	0.0060	0.0057	0.0057	0.0063	0.0058	0.0061

may be due to narrow row spacing, when the number of plants m^{-2} increases then the competition for light increases and the plant grows taller to intercept maximum light.

However, minimum values were recorded for chlorophyll content, plant mortality % at harvest, plant height, first capsule height, fruiting zone length, capsule number/plant, seed weight/capsule, seed yield and oil yield of sesame underplanting geometry of 60 cm between ridges ×30 cm between hills (Table 5).

These results are following the findings that reported taller plants with an increase in plant population[20]. The crop which was sown at planting geometry of 60×10 cm produced significantly maximum some traits of sesame. This may be due to optimum plant population and having more chance to get nutrients. These results are in line with other studies that demonstrated that increasing plant density significantly decreased the number of branches/plant, the number of capsules/plant and seed yield per plant[5].

Low plant density reduced seed yield/plant due to inter and intra plants competition for necessary resources required for growth and development of the seed. Also with increasing plant density, each plant tries to improve its branches using more environmental resources due to competition. This leads to making more materials and transferring lots of low toward aerial members, especially to the seeds, producing bigger seeds and better seed yield. The observed yield improvement was probably due to increased leaf area index from the better use of sunlight that boosted photosynthesis in the growing season. It also reported that sesame yield increase with an increase in plant densities up to 400000 plants per ha[12]. On the other hand, decreasing planting distance from 20-10 cm consistently and significantly increased plant height, the height of the first fruiting branch, seed and oil yield per ha[10].

Effect of the interaction between sesame genotypes and plant densities: Table 6 revealed that the sesame traits were significantly affected due to the interaction between sesame genotypes and the plant density. Such traits were previously showed significant mean squares in Table 3. The interaction of the high plant density (low distance between hills 10 cm) with the genotype Line-D1 resulted in the highest chlorophyll content (49.04), seed yield (942.39 kg fed^{-1}) and oil yield (451.70 kg fed^{-1}). While the interaction between low plant density (30 cm between hills) and genotype Line-D1 gave higher seed weight/plant (25.65 g). The maximum light intensity (147.13) was recorded when the genotype Line-2 sesame planting low density (30 cm between hills). The interaction of the lowest plant density (30 cm between hills) with the genotypes Shandauil-3 cv. resulted in the lowest chlorophyll content (26.34), seed yield (527.02 kg fed^{-1}) and oil yield (267.40 kg fed^{-1}), while the interaction between high plant density (10 cm between hills) with genotype schandweil-3 cv. gave lower light intensity (75.50) and seed weight/plant (13.67 g). Some papers have been reported the differences in the performance of sugar beet varieties under different plant densities[3,9,15].

Fatty acid composition: From the processing point of view, the unsaturation ratio of vegetable oils is a key factor in edible oil stability. The fatty acid composition of sesame seed may vary with the variety, origin, colour, growing conditions and size of the seed. Table 7 showed that fatty acid composition and some oil parameters (saturated unsaturated ratio, oleic linoleic ratio and ω_3 ω_6 ratio) of three sesame genotypes under three intra-row spacing. From the previous Table, fatty acids profile reflected a few variations among not only sesame genotypes but also intra-row spacing. Sesame oil of genotypes under varied intra-row spacing belongs to the oleic-linoleic acid group. It has less than 15% saturated fatty acid, mainly palmitic (8.55-9.54%) and stearic (4.66-4.87%) acids. Oleic and linoleic acids contribute more than 80% of the total fatty acids in sesame oil. The percentages of oleic acid (39.47-40.86%) and linoleic acid (43.17-45.62%) in the total fatty acids of sesame oil are very close to each other (Table 7). It has been found that sesame oil is one of the most stable edible oil regardless of its great amount of unsaturation fatty acids[21]. It also reported that with FAO/WHO codex Alimentarius standard of the sesame oil fatty acid composition[22].

From a breeding point of view, Table (7) it's clear that the two lines (2 and D1) have a great amount of linoleic acid (ω_6) and α-linolenic acid (ω_3), which are essential fatty acids and are the vital fatty acids involved in the metabolic pathway of prostaglandin synthesis. It seems that the promising two lines could be used as a parent for any sesame breeding program with the object of obtaining varieties with high oleic and linoleic (ω_6) fatty acids compared with the local cultivar (Shandauil-3) achieving different demands for nutritional or industrial consumptions. This finding is in agreement with those obtained who mentioned that the strong negative associations between C18 fatty acids may be supportive in developing the cultivars rich in either oleic or linoleic acids[22].

CONCLUSION

It could be concluded that a higher seed and oil yield of sesame could be obtained by using genotype Line-D1 sowing at 10 cm between hills under the agro-climatic conditions of Giza, Egypt.

SIGNIFICANCE STATEMENT

This research is based on a study to evaluate the agronomic performance of two promising lines of sesame vs. the Egyptian cultivar Shandauil-3 and determines the optimum intra-row spacing for these lines. This study can get to acknowledge the role of intra-row spacing in the development of yield attributes and contribution to yield and quality. The study can further open entrance for the research to evaluate the performance of existing sesame genotypes under intra-row spacing. In places where the least research studies have been done in sesame crops (such as my home country), the study can set as an idea on how intra-row spacing can influence some genotypes of sesame yield and quality.

REFERENCES

1. Jan, A., S. Ali, M. Adail and A. Khan, 2014. Growth and yield components of sesame (*Sesamum indicum* L.) as influenced by phosphorus levels under different row spacing. J. Environ. Earth Sci., 4: 150-155.
2. Ahmad, R., T. Mahmood, M.F. Saleem and S. Ahmad, 2002. Comparative performance of two sesame (*Sesamum indicum* L.) varieties under different row spacings. Asian J. Plant Sci., 1: 546-547.
3. Golla, W.N., 2020. Yield performance of sesame (*Sesamum indicum* L.) varieties at different levels of plant population in optimum moisture areas of Western Tigray, Northern Ethiopia. J. Biol. Agric. Healthcare., 10: 16-21.
4. Idoko, J.A., P.D. Baba and T.R. Ugoo, 2018. Effect of inter-row and intra-row spacing on the growth and yield of sesame (*Sesamum indicum* L.) in Makurdi, Nigeria. Int. J. Agron. Agri. Res., 12: 69-76..
5. El-Naim, A.M., E.M. EL day and A.A. Ahmed, 2010. Effect of plant density on the performance of some sesame (*Sesamum Indicum* L) cultivars under rain fed. Res. J. Agric. Biol. Sci., 6: 498- 504.
6. Kanton, R.A.L., J. Yirzagla, P.A. Asungre, S. Lamini, E. Ansoba, C. Kuukaraa and M. Alebkia, 2013. Contribution of plant spacing and n fertilizer application to growth and yield of sesame (*Sesamum indicum* L.). J. Adv. Agric. Sci. Technol., 1: 9-13.
7. El Naim, A.M., E.M. El dey, A.A. Jabereldar, S.E. Ahmed and A.A. Ahmed, 2012. Determination of suitable variety and seed rate of sesame (*Sesamum indicum* L) in sandy dunes of Kordofan, Sudan. Int. J. Agric. For., 2: 175-179.
8. Nadeem, A., S. Kashani, N. Ahmed, M. Buriro, Z. Saeed, F. Mohammad and S. Ahmed, 2015. Growth and yield of sesame (*Sesamum indicum* L.) under the influence of planting geometry and irrigation regimes. Am. J. Plant Sci., 6: 980-986.
9. Valiki, S.R.H., S. Ghanbari, S. Golmohammadzadeh and K.R. Kiasari, 2015. Effect of different plant density on growth and yield of three cultivars of sesame (*Sesamum indicum* L.). Biol. Forum Int. J., 7: 1524-1528.
10. Naorka, I.R., S.I. Hafiz and M.A.S. El-Bramawy, 2011. Response of sesame to population densities and nitrogen fertilization on newly reclaimed sandy soils. Pak. J. Bot., 43: 1953-1958.
11. Ngala, A.L., I.Y. Dugje and H. Yakubu, 2013. Effects of inter-row spacing and plant density on performance of Sesame (*Sesamum indicum* L.) in a Nigerian Sudan Savanna. Sci. Int., 25: 513-519.
12. Ndor, E. and I.U. Nasir, 2019. Response of sesame (*Sesamum indicum* L) to sowing methods and fertilizer types on degraded soil of Southern Guinea Savanna Agro Ecological Zone, Nigeria. East Afr. Scholars J. Agric. Life Sci., Vol. 2. 10.36349/easjals.2019.v02i06.004.
13. Ozturk, O. and O. Saman, 2012. Effects of different plant densities on the yield and quality of second crop sesame. Int. J. Agric. Biosyst. Eng., 6: 644-649.
14. Rahnama, A. and A. Bakhshandeh, 2006. Determination of optimum row spacing and plant density for uni-branched sesame in Khuzestan province. J. Agric. Sci. Tech., 8: 25-33.
15. Adebisi, M.A., M.O. Ajala, D.K. Ojo and A.W. Salau, 2005. Influence of population density and season on seed yield and its components in Nigerian sesame genotypes. J. Trop. Agric., 43: 13-18.
16. Bhardwaj, H.L., A.A. Hamama, M.E. Kraemer and D.R. Langham, 2015. Characterization of oil yield and quality in shatter-resistant dwarf sesame produced in Virginia, USA. J. Agric. Sci., 7: 87-94.
17. Ehsanullah, N. Akbar, A. Iqbal and M.R. Mohsin, 2007. Effect of different planting patterns on the growth and yield of two varieties of sesame. Pak. J. Agri. Sci., 44: 584-585.
18. AOAC., 2005. Official Methods of Analysis of AOAC International. 18th Edn., Association of Analytical Chemist, Washington DC., USA., ISBN: 9780935584752 Pages: 26.
19. Steel, R.G.D., J.H. Torrie and D.A. Dickey, 1997. Principles and Procedures of Statistics: A Biometrical Approach. 3rd Edn., McGraw-Hill Co., New York, USA., ISBN: 9780070610286, Pages: 666.

20. Caliskan, S., M. Arslan, H. Arioglu and N. Isler, 2004. Effect of planting method and plant population on growth and yield of sesame (*Sesamum indicum* L.) in a Mediterranean type of environment. Asian J. Plant Sci., 3: 610-613.
21. Shahidi, F., 2005. Bailey's Industrial Oil and Fat Products. 6th Edn., John Wiley and Sons, Inc., UK, ISBN: 978-0-471-38460-1, Pages: 3616.
22. Baydar, H., I. Turgut and K. Turgut, 1999. Variation of certain characters and line selection for yield, oil, oleic and linoleic acids in the Turkish sesame (*Sesamum indicum* L.) populations. Turk. J. Agric. For., 23: 431-441.