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Effects of Different Plant Densities on the Yield and Quality of Second Crop Sesame

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Abstract**—**Sesame is one of the oldest and most important oil crops as main crop and second crop agriculture. This study was carried out to determine the effects of different inter- and intra-row spacings on the yield and yield components on second crop sesame; was set up in Antalya West Mediterranean Agricultural Research Institue in 2009. Muganlı 57 sesame cultivar was used as plant material. The field experiment was set up in a split plot design and row spacings (30, 40, 50, 60 and 70 cm) were assigned to the main plots and and intra-row spacings (5, 10, 20 and 30 cm) were assigned to the subplots. Seed yield, oil ratio, oil yield, protein ratio and protein yield were investigated. In general, wided inter row spacings and intra-row spacings, resulted in decreased seed yield, oil yield and protein yield. The highest seed yield, oil yield and protein yield (respectively, 1115.0 kg ha^{-1}, 551.3 kg ha^{-1}, 224.7 kg ha^{-1}) were obtained from 30x5 cm plant density while the lowest seed yield, oil yield and protein yield (respectively, 677.0 kg ha^{-1}, 327.0 kg ha^{-1}, 130.0 kg ha^{-1}) were recorded from 70x30 cm plant density. As a result, in terms of oil yield for second crop sesame agriculture, 30 cm row spacing, and 5 cm intra row spacing are the most suitable plant densities.

Keywords**—***Sesamum indicum* L., oil ratio, oil yield, protein ratio, protein yield

I. Introduction

SESAME (*Sesamum indicum* L.) is one of the oldest crops in the world, and is under cultivation in Asia for over 5000 years [1] . The crop has early origins in East Africa and in India [2, 3]. Today, India and China are the world's largest producers of sesame, followed by Myanmar, Sudan, Uganda, Nigeria, Pakistan, Tanzania, Ethiopia, Guatemala and Turkey. World production fluctuates due to local economic, crop production disturbance and weather conditions. The crop is highly drought tolerant, grows well in most kind of soils, regions and is well suited to different crop rotations. In reality, sesame is mostly grown under moisture stress with low management input by small holders [4]. However, the sesame production is below expectation and the potential could be considerably higher. The low production is due to a number of reasons such as low inputs and poor management (e.g low or non-fertilization, irrigation, pest control etc), occurrence of biotic and abiotic stresses and more importantly, a lack of an appropriate breeding program [5].

Nowadays, many sesame varieties are ready in the worldmarket. There are including local varieties and commercial varieties. However, the cultivation of improved varieties is limited due to insufficient variety information. The farmers continue to grow local varieties with low yields.

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Therefore, adequate knowledge of morphology as well as phylogenetic relationship among sesame varieties will help the breeder to improve high yielding of sesame, good quality cultivars that will increase sesame production in Turkey. In 2010, Turkey grew about 31804 ha of sesame with seed production was 23460 metric tons [6]. The average seed yield of sesame in Turkey was about 738 kg ha^{-1}, which is quite low in comparison with most other sesame producing countries. Cultivation of sesame in special large scales is fixed especially in the Southeastern, Mediterranean and Aegean areas of the Turkey. Due to short period of maturation, relatively low production costs and possibility that can be cultivated with other crops [7]. The importance of sesame lies in its high content of oil, protein, calcium, iron and methionine [8]. Its seed contains about 51% edible oil of high quality, 17 - 19% protein and 16 - 18 % carbohydrate [9]. Sesame oil is used for the manufacture of margarine, salad oil, cooking oil, soap, paints, lubricants and lamp fuel. Ryu et al. [10] reported that sesame oil contains sesamoline and sesamine which is used as synergist for insecticides. The sesame oil does not turn rancid unlike other edible oils because of the presence of antioxidant `Sesamol' [11]. Its oil has high oleic and linoleic oil contents.

The crop is grown under a range of environments, which probably affects its performance. The environmental factors that influence sesame productivity include climatic factors such as temperature, rainfall and day length, soil types and management practices such as plant densities, time of sowing, irrigation, fertilizers, herbicides and fungicides, some of which may partially mitigate others [12,13]. In particular, population density plays a cardinal role in determining seed yield. Above or below the threshold level of plant population it would lead to intra species competition among plants for scarce resources which cause sub normal sesame seed yield. Adoption of suitable and optimum spacing would fulfil the objective of maximizing the yield of sesame [14]. Hence, identification of optimum population for each variety being tested become vital. The effect of plant population on yield and yield components have been reported by several workers. For example, seed yield per unit area increases with increased population density from 80 000 to 160 000 plants ha^{-1} and beyond this density it becomes counter productive [15]. Also, increased number of seeds per capsule, number of capsules per plant, and dry matter production increased when the intra–row spacing increased from 30 to 90 cm [16,17]. As regards weed control, row planting is superior to broadcasting, resulting in increased yield [18], while wide spacing favour higher weed competition in crops [19]. Adeyemo et al. [20] reported that optimal population of sesame is between 133 333 and 266 667 plants ha^{-1}. Tiwari et al. [21] found that the average yields of four sesame varieties planted as 30x15 and 10x10 cm spacings were 2.05 and 3.00 t ha^{-1}, respectively. Mandal et al. [22] investigated the relationship between plant density and the yield of B-67 sesame variety and reported that increase in plant density from 110 000 plants per hectare to 166 000 and 222 000 plants per hectare resulted in 0.77, 0.89 and 1.08 ton ha^{-1} yield increases, respectively.

Ahmad et al. [23] sowing sesame at spaces 30, 45 and 60 cm between plants and reported that 45 cm apart was the best distance for plant height and seed yield ha^{-1}. Rahnama and Bakhshandeh [24] revealed that planting sesame at 37.5, 50 and 60 cm space between plants than number of capsules/plant, seed index, seed weight/plant and oil concentration were increased by increment plant distance up to 60 cm. Karaaslan et al. [25] used the four row spacing were alternating rows of 50x30, 70x30, 80x40 cm in 6 row-plots and 70x70 cm in 4 row- plots and found that decreasing row spacing increased seed yield ha^{-1}, but number of capsules/plant was decreased. Roy et al. [26] sowed sesame at 15, 30 and 45 cm between plants and observed that seed yield ha^{-1} and yield components were increased by raising planting space from 15 to 30 cm.Sesame production areas in Turkey have remained generally stable over the years. Competition from more remunerative crops, low yield potential, poor filled establishment, problem of harvesting and high labour cost have pushed sesame to less fertile fields and to areas of higher risk, if left unchecked, production may decrease in the foreseeable future. The influence of population density on the performance of high-yielding sesame genotypes in Turkey is, however, unknown. The objectives of this study, therefore, were to investigate the influence of population densities on seed yield, and yield components of sesame.

II. Materials and Method

Field experiment was conducted during the late cropping seasons in 2009 at the West Mediterranean Agricultural Research Instıtue, Antalya (36^{0}52' N, 30^{0}50' E) located in the Southern Turkey at an altitude of about 15 metres above sea level. The site was previously cropped to wheat. The climate is typical Mediterranean, with mild and rainy winter season and hot and dry summer season. Rainfall is concentrated between late autumn and spring.

Based on meteorological statistics (Table 1), the total rainfall for the experimental period of June through October was 92.8 mm, mean air temperature was 26.8°C, mean relative humidity was 5 7.6%. The soil had 26.7 % $CaCO_3$, 68.0 % silt, 24.0 % clay and 8% sand with a pH of 7.8, 2.10 % organic matter, 31.0 ppm available P and 218.0 ppm available K (Table 2).

Muganlı 57 sesame cultivar was used as plant material. The field experiment was set up in a split plot design with three replications and inter rows (30, 40, 50, 60 and 70 cm) were assigned to the main plots and and intra rows (5, 10, 20 and 30 cm) were assigned to the subplots. The experimental sub plots were sown in 6 rows 5 m long on 20 June 2009 by hand. 60 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} nitrogen and 60 kg ha^{-1} potassium applied to each plot. Routine management practices were followed. The plots were irrigated one times using flood irrigation.

Plots were harvested by hand at the stage of full ripeness on 5 October 2009 after removing two outer rows at each plot. In this research, seed yield, oil ratio, oil yield, protein ratio and protein yield were investigated. Seed yield (kg ha^{-1}) was determined from the plants of the four ridges in each plot and the yield per hectare was calculated. Seed oil content (%) was determined by using Soxhlet continuous extraction apparatus with petroleum either as an organic solvent according to A.O.A.C. [27] and seed protein content was determined by using Khejdal method (% protein = % nitrogen in seedx6.25). Seed oil yield (kg ha^{-1}) and protein yield (kg ha^{-1}) were calculated by multiplying oil and protein percentage with seed yield per ha. Analysis of variance was used to test the significance of treatment effects. Least Significant Difference (LSD) Test was used to compare treatment means using the computer program MSTAT-C [28].

TABLE I
Meteorological Data of the Experimental Region in 2009

Month	Temperature (^{0}C)	Rainfall (mm)	Relative Humidity (%)
June	26.8	0.3	56.4
July	29.4	0.6	57.0
August	29.2	0.0	55.3
September	25.4	60.6	58.9
October	23.0	31.3	60.3
Mean	26.8	-	57.6
Total	-	92.8	-

TABLE II
Result of Some Chemical And Physical Analysis of Experimental Field Soil

Depth (cm)	pH	$CaCO_3$ (%)	Available P_2O_5 (ppm)	Available K_2O (ppm)
0-30	7.8	26.7	31.0	218.0
	Organic matter (%)	Sand (%)	Clay (%)	Silt (%)
	2.1	8	24	68

III. Results and Discussion

A. Seed Yield

There was significant difference in seed yield between intra row spacings (Table 3). Average seed yield ranged from 989.1 kg ha^{-1} (5 cm) to 711.6 kg ha^{-1} (30 cm). Effect of inter row spacing on seed yield was not significant. However, it was found that wided row spacings decreased seed yield. The highest seed yield (865.5 kg ha^{-1}) was obtained from the narrow row spacing (30 cm) whereas the lowest seed yield (767.3 kg ha^{-1}) was determined from the widest row spacing (70 cm). Data in (Table 3) shows that there was insignificant interaction effect between row spacing and intra row spacing on seed yield. However, as can be seen in Fig.1, the highest seed yield (1135.3 kg ha^{-1}) was obtained 30x5 cm (666 666 plants ha^{-1}) and lowest seed yield (677.1 kg ha^{-1}) was obtained 70x30 cm (47 619 plants ha^{-1}) plant densities.

Many researchers observed that sesame yields were generally higher at high plant density. Channabasavanna and Setty [29] reported that plant density of 666 000 plants ha^{-1} produced 15.72 per cent, higher seed yield over plant density of 222 000 plants ha^{-1} (655 kg ha^{-1}). Similar reports were also reported by Adeyemo et al. [19], Chimanshette and Dhoble [30], Tiwari et al. [21], Basavaraj et al. [31], Imayavaramban et al. [32], Çalışkan et al. [33] and Ojikpond et al.[34], wherein they observed increased seed yield with increased plant density. On the contrary, Arunachalam [35] reported that gradual reduction in seed yield of sesame from 279 kg ha^{-1} to 184 kg ha^{-1} with increase in plant density from 200 000 plants ha^{-1} to 400 000 plants ha^{-1}. Whereas, Sharma et al. [36] and Dixit et al. [37] reported that seed yield of sesame was not significantly influenced by change in plant density.

It is worthy to mention that increases in seed yield per ha at highest plant population density might be due to that the greater number of sesame plants per unit area in narrow distance between hills could compensate that reduction in yield attributes of the individual plants such as number of capsules/plant, 1000-seed weight and seed weight/ plant. It is important that the unit land area not the individual plant, produces its maximum yield [38]. These results are in harmony with those reported by Ahmad et al. [23], Rahnama and Bakhshandeh [24], who found that the highest seed yield ha^{-1} was produced with planting distance of 45 cm and 30 cm between hills, respectively. The seed yield results of this investigation would therefore favour the adoption of 30x5 cm spacing for Muganlı-87 variety of sesame in Southern Turkey.

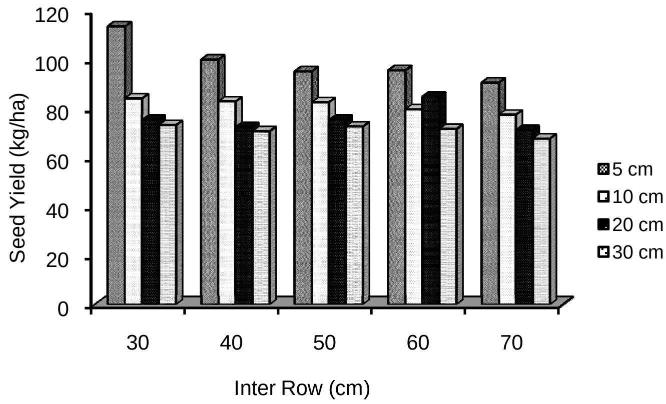

Fig. 1 Effect of the interaction between inter and intra row spacings on seed yield (kg ha^{-1}) of sesame

TABLE III
Effect of Inter- and Intra- Row Spacing on Seed Yield (Kg Ha^{-1}) of Sesame

Intra Row (cm)	Seed Yield (kg ha^{-1}) Inter Row (cm) 30	40	50	60	70	Mean
5	1135.3	998.5	951.2	955.2	905.1	989.1a**
10	841.0	827.5	825.2	796.1	774.4	812.8b
20	753.3	724.0	753.3	747.1	712.5	738.1b
30	723.3	706.7	725.7	716.0	677.1	711.6b
Mean	865.5	814.2	813.8	803.6	767.3	812.9
			$LSD_{intra\ row}$: 11.69			

*** P<0.01*

B. Oil Content

Effect of inter rows, intra rows and the interaction between inter and intra row spacing on seed oil content were significant.

The highest seed oil content was noticed in 50 cm (52.18 %) as compared to 40 cm (48.06 %) row spacing. The intra row spacing of 30 cm produced the highest oil content (50.95 %) while 10 cm produced the lowest oil content (47.99 %; Table 4).

The highest oil content (55.71 %) was obtained from 50x20 cm (100 000 plants ha^{-1}) while the lowest oil content (45.73 %) was obtained from 60x10 cm (166 666 plants ha^{-1}) plant density (Fig.2).

May be the lack of the number of plants per unit area helps the growth of plants that are good for the availability of fertilizer nutrients, water and air, thereby increasing the accumulation of food ingredients in seeds as part of the economic yield and oil content of seeds [38]. These results are in agreement with those recorded by Rahnama and Bakhshandeh [24] who found that seed oil percentage increased by increment in planting distance up to 60 cm.

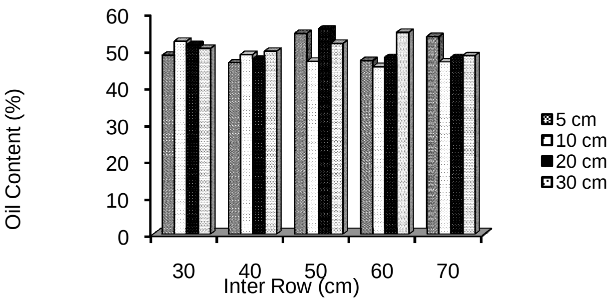

Fig. 2 Effect of the interaction between inter and intra row spacing on oil content (%) of sesame

TABLE IV
EFFECT OF INTER- AND INTRA- ROW SPACING ON OIL CONTENT (%) OF SESAME

Intra Row (cm)	Oil Content (%) Inter Row (cm)					Mean
	30	40	50	60	70	
5	48.45f-ı**	46.45ıj	54.38abc	47.08hıj	53.64bcd	50.00b**
10	52.29de	48.65fgh	46.92hıj	45.43j	46.66hıj	47.99c
20	52.35cde	47.54ghı	55.71a	47.90ghı	47.87ghı	50.27ab
30	50.36ef	49.61fg	51.70de	54.68ab	48.41f-ı	50.95a
Mean	50.86a**	48.06b	52.18a	48.77b	49.14b	49.80

$LSD_{inter\ row}$: 1.37;$LSD_{intra\ row}$: 0.92; $LSD_{inter\ rowxintra\ row}$: 2.06

*** P<0.01*

C. Oil Yield

As can be seen in Table 5, significant difference in oil yield (kg ha^{-1}) was recorded between intra row spacing. The highest oil yield (493.7 kg ha^{-1}) was obtained at the closest intra row of 5 cm while the least value (358.4 kg ha^{-1}) was obtained with the widest spacing of 30 cm.

Effect of inter row on yield ha^{-1} was not significant. Interaction between inter- and intra- row spacing with respect to oil yield ha^{-1} was not significant. However, sesame grown at higher plant density produced higher oil yield ha^{-1}. The closer spacing of 30x5 cm (666 666 plants ha^{-1}) gave oil yield (551.3 kg ha^{-1}) was higher than the yields obtained at other densities. The lowest oil yield (327.0 kg ha^{-1}) was determined from 70x30 cm (47 919 plants ha^{-1}) densities (Fig.3).

The increase in oil yield/ha with higher plant population density are mainly due to the increase in seed yield per ha confirming results reported by Rahnama and Bakhshandeh [24] and Noorka et al. [38].

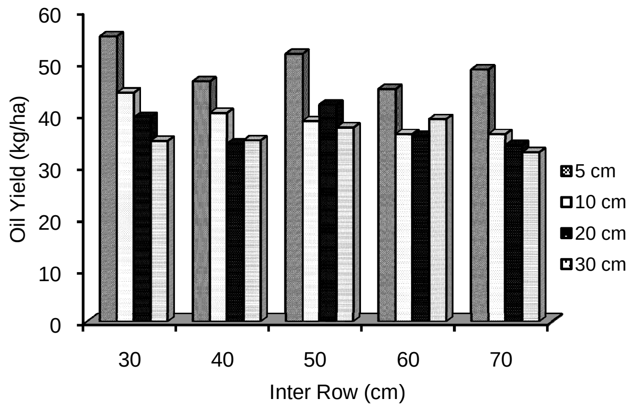

Fig. 3 Effect of the interaction between inter and intra row spacings on oil yield (kg ha^{-1}) of sesame

TABLE V
EFFECT OF INTER- AND INTRA- ROW SPACING ON OIL YIELD (KG HA^{-1}) OF SESAME

Intra Row (cm)	Oil Yield (kg ha^{-1}) Inter Row (cm)					Mean
	30	40	50	60	70	
5	551.3	464.0	517.0	449.3	486.7	493.7a**
10	441.7	402.7	387.0	362.0	361.7	391.0b
20	395.3	344.3	419.0	358.3	341.0	371.6b
30	349.0	349.7	375.3	391.0	327.0	358.4b
Mean	434.3	390.2	424.6	390.2	379.1	403.7

$LSD_{intra\ row}$: : 6.24

*** P<0.01*

D. Protein Content

Protein content of sesame was not influenced by change in inter- and intra row spacing and interaction between them (Table 6). However, 50 cm inter row, 5 cm intra row and 50x10 cm (200 000 plants ha^{-1}, Fig.4) recorded higher seed protein content (19.93 %, 19.79 % and 20.33 %, respectively) as compared to others. Weiss [16] reported that protein content in sesame seed was 18.6 % on average. As some researches [39,40] stated, although protein content may be affected by environmental conditions, they vary to a great extent depending on the genetic properties of variety.

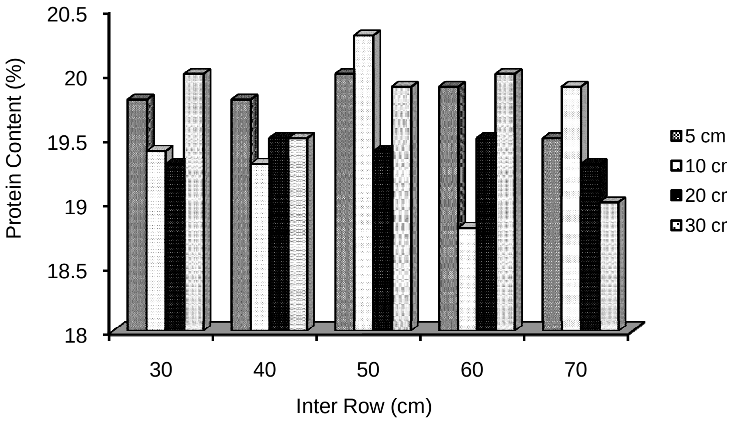

Fig. 4 Effect of the interaction between inter and intra row spacings on protein content (%) of sesame

TABLE VI
EFFECT OF INTER- AND INTRA- ROW SPACING ON PROTEIN CONTENT (%) OF SESAME

Intra Row (cm)	Protein Content (%)					Mean
	Inter Row (cm)					
	30	40	50	60	70	
5	19.79	19.76	20.01	19.91	19.51	19.79
10	19.38	19.27	20.33	18.83	19.93	19.55
20	19.27	19.49	19.44	19.45	19.27	19.38
30	19.95	19.45	19.94	19.99	19.01	19.67
Mean	19.60	19.49	19.93	19.55	19.43	19.60

E. Protein Yield

As shown in Table 7, the protein yield of sesame was significantly affected by intra row spacings. The highest protein yield was obtained from 5 cm with 195.9 kg ha^{-1}. Protein yield gradually decreased with the increasing intra row and the lowest value was obtained from 30 cm with 138.9 kg ha^{-1}. Inter row and inter- and intra-row spacing interaction did not clearly influence the protein yield. The closer spacing of 30x5 cm (666 666 plants ha^{-1}) gave oil yield (224.7 kg ha^{-1}) was higher than the yields obtained at other densities. The lowest oil yield (130.0 kg ha^{-1}) was determined from 70x30 cm (47 919 plants ha^{-1}) densities (Fig.5).

IV. CONCLUSION

As a result of this study, it was concluded that the population density affected yield and quality of sesame. Increasing plants population increased seed and oil yield per unit of area. Having the higher yield in all treatments at a 30 cm inter row spacing, as well as with the preferred 5 cm, plant distance for all row spacings, a growing pattern of 30x5 cm (666 666 plants ha^{-1}) is therefore recommended for high seed and oil yield in double crop sesame production under irrigated Mediterranean type environments.

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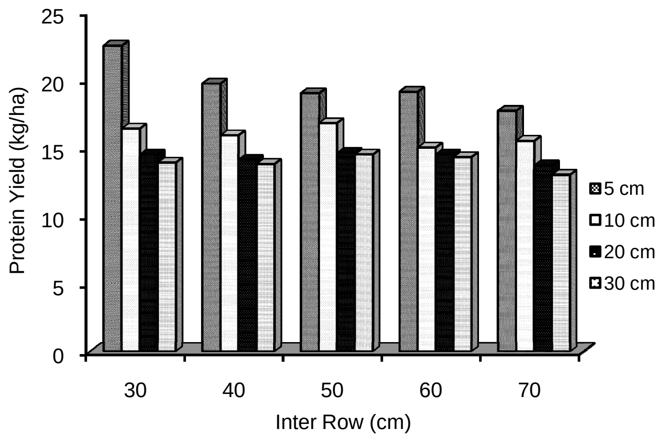

Fig. 5 Effect of the interaction between inter and intra row spacings on protein yield (kg ha^{-1}) of sesame

TABLE VII
EFFECT OF INTER- AND INTRA- ROW SPACING ON PROTEIN YIELD (KG HA^{-1}) OF SESAME

Intra Row (cm)	Protein Yield (kg ha^{-1}) Inter Row (cm)					Mean
	30	40	50	60	70	
5	224.7	197.0	190.0	191.0	176.7	195.9a**
10	163.7	159.3	168.0	150.0	154.7	159.1b
20	144.7	141.3	146.3	145.0	137.3	142.9b
30	139.0	137.7	145.0	143.0	130.0	138.9b
Mean	168.0	158.8	162.3	157.2	149.7	159.2

$LSD_{intra\ row}$:2.39

*** P<0.01*

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