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# Effect of Irrigation Methods and Row Spacing on Yield and Yield Components of Sesame [*Sesamum indicum* (L.)]

[1]S. Gerçek [2]E. Boydak and [1]M. Şimşek
[1]Department of Structures and Irrigation,
[2]Department of Field Crops,
Faculty of Agriculture, University of Harran, 63200 Sanliurfa, Turkey

**Abstract:** The objective of this study was to determine the effect of irrigation method and row spacing on yield and several yield components of Local dark sesame in Sanliurfa (Turkey) in 1998 and 1999. Experiments were designed in a split plot. The main plots were two irrigation methods (sprinkle and drip) and the split plots were four row spacings (500-300, 700-300, 800-400 and 700-700 mm) with three replications. The results showed that the yield, plant height and number of capsules per plant were significantly affected by irrigation methods and row spacing. Means of sesame yields in two years were 1440 and 1732 kg ha$^{-1}$ sprinkle and drip irrigation, respectively. The highest yield was observed at 500-300 mm (1913 kg ha$^{-1}$) treatment of plant density and the lowest yield was at 700 mm (1220 kg ha$^{-1}$) row space.

**Key words:** Sesame, row spacing, irrigation methods

## INTRODUCTION

For high production, the importance of irrigation is beyond the question. The efficiency and economy of irrigation depend upon minimising of water loss due to the evaporation onto surface and into deep soil. To minimize the water loss, the pressurized irrigation (drip and sprinkle irrigation) techniques are strongly recommended. Although the initial investments of these techniques are high, both methods are becoming more popular today[1].

Many factors, such as the length of growing season, climate (temperature, rainfall, humidity, evaporation and wind speed), the humidity of soil topography and soil structure determine the water requirement of the plants.

The amount of water uptake including through evaporation from the soil and transpiration from the plant is under the strong influence of environmental conditions. The transpiration from the plant tissues depends on canopy size, wind and water potential and other leaf characteristics that offer for resistance around the plant root. Thus, if the plants are planted wide apart, the soil surface per unit area is high and, in contrast, if the plants are planted density, the leaf area index per unit area is higher normally.

It is possible to meet plant's water requirement by determining the plant density. The water usage efficiency and rate affected by row spacing are the main factors for sesame production especially in relatively arid regions[2].

Majumdar and Roy[3] reported that irrigation caused an increase in yield and there was no significant difference between 30 and 40 cm row spacings. That 50 cm row spacing led to a decrease in the yield and the highest yield was obtained from 30 cm row spacing (1620 kg ha$^{-1}$) and from planting density of 333 000 plants ha$^{-1}$.

Efforts have been made to increase the yield per unit area by raising the number of plants per unit area. The seed yield of sesame can be calculated by using the following equation:

Number of plants per m$^2$ x number of seeds per capsule x number of capsules x weight of 1000 seeds (g)[4].

With the increase in plant density in sesame, the leaf area index and dry matter contents are affected positively[5,6]; the height of plant, first capsule height, number of capsules and height of capsule are not influenced significantly[5]; number of capsules[7] and the number of branches[5] decline and, finally, the seed yield increases[5-8].

It has been reported that the yield of sesame went up with the decrease in row spacing. Tiwari *et al.*[9] 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. In a study in which T85 and JLT7 sesame varieties were planted as 45x10 cm, 15 and 25 cm, the yield was found to be increased with the plant density.

**Corresponding Author:** Sinan Gercek, Department of Structure and Irrigation, Faculty of Agriculture, Harran University, Sanliurfa, Turkey Tel: +90 0414 247 03 84 E-mail: sinangercek@yahoo.com

Tomar *et al.*[9] planted the NP-6, TMW and selection-R sesame varieties as 30x30 cm, 30x20 cm and 30x10 cm spacings and recorded the seed yields as 0.71, 0.93 and 0.74 t $ha^{-1}$, respectively. Mandal *et al.*[11] investigated the relationship between plant density and the yield of B-67 variety and found that with the increase in plant density from 110 000 plants $ha^{-1}$ to 166 000 and 222 000 plants $ha^{-1}$, the yield increased accordingly (0.77, 0.89 and 1.08 t $ha^{-1}$, respectively).

## MATERIALS AND METHODS

In this study, a local dark sesame was grown in June of 1998 and 1999 in the Faculty of Agriculture, Department of Field Crops, Harran University, Turkey. The experimental design for irrigation methods and row space trials was a split-plot with three replications. The research field is located in an arid climate which the summer is hot and dry and the winter is warm and dry. The altitude of the research field is approximately 464-467 m. The field is located at $37^0$-08 N and $38^0$-46 E.

Trials were conducted on a silted-clay soil[12] at pH 7.5[13] and lime content of 99000 ppm[14] without salinity problem (620 ppm)[15] which was deficient in organic matter (11200 ppm)[16]. Modify potassium was 78 kg $da^{-1}$[17].

Field capacity between (32.71-33.19%), permanent wilting point (21.18-22.55%) and bulk density of experiment soils were changed. Irrigation water was determinated in $C_2S_1$ soil classification. Soil moisture changing in 0-30 cm layers was determinated by gravimetric method. Sprinkle irrigation was applied. Twelve sprinkles were laid down in 6x6 m interval as square for per sprinkle irrigation plot. In drip irrigation a lateral pipe was laid down to per 700 mm row spacing. The meteorological data were recorded from planting date to the harvest of each treatment in Table 1.

All treatments were fertilized with 100 kg $ha^{-1}$ nitrogen (50% after planting) and 60 kg $ha^{-1}$ phosphorus in each year. Seeds were planted between seeds with 20 cm in 4 m rows. Germination percentage was 100%. The four row spacings were alternating rows of 500-300 mm, 700-300 and 800-400 mm in 6 row-plots and 700-700 mm in 4 row-plots.

| | |
|---|---|
| 500-300-500-300-500-300 mm | = 12.5 seeds/$m^2$ or 125,000 seeds/ha |
| 700-300-700-300-700-300 mm | = 10.0 seeds/$m^2$ or 100,000 seeds/ha |
| 800-400-800-400-800-400 mm | = 8.33 seeds/$m^2$ or 83,300 seeds/ha |
| 700-700-700-700 mm | = 7.13 seeds/$m^2$ or 71,300 seeds/ha |

Planting and harvesting dates were given in Table 2. Twenty plants per plot were randomly sampled at harvest to determine capsules number, branches number and plant height. For capsules number and branches number values were obtained counting on the 20 plants. Plant height was observed with measurement between soil surface and top of plants. For seed yield, plants were harvested from middle two rows of six rows per plot treatment. Harvest was done by hand.

The following equation was used to determine changes in soil water content at 0-30 cm soil depths using gravimetric method[18]. Water was applied to bring the soil at 0-90 cm to the field capacity in the first irrigation. The amount of required irrigation water was calculated by Class A evaporation pan every day. Experiment was irrigated at 12 days interval. Total water level, measured by using a manual limnimeter with 0.1 mm accuracy, was multiplied by area to calculate volume of water evaporated. These measurements were checked with the readings obtained from flow meters mounted in each plot.

$$\text{Eq. } ET = P + I - R - D_p \pm \Delta S$$

Where, ET is crop water consumption, P is rainfall, I is irrigation water, R surface flow, Dp is deep percolation, dS soil water content variation in crop root depth.

Table 1: Monthly mean temperatures and rainfall during the growing season for sesame (June-October) in 1998 and 1999 in Şanliurfa of Turkey

| | Mean temp. (°C) | | Minimum temp. (°C) | | Maximum temp. (°C) | | Total rainfall (mm) | |
|---|---|---|---|---|---|---|---|---|
| Months | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 |
| June | 29.4 | 28.8 | 17.8 | 18.8 | 41.2 | 40.0 | 0.6 | 1.6 |
| July | 33.0 | 32.5 | 19.8 | 21.5 | 45.4 | 43.2 | NR | NR |
| August | 33.4 | 31.2 | 22.6 | 20.5 | 43.0 | 43.0 | NR | 26.0 |
| September | 27.0 | 26.2 | 15.1 | 17.0 | 39.6 | 36.6 | 0.0 | NR |
| October | 21.5 | 21.0 | 10.2 | 11.3 | 34.1 | 35.6 | 0.1 | 8.4 |

* NR, no rainfall

Table 2: Planting and harvesting dates for the different row spacings for sesame at Şanliurfa, Turkey in 1998 and 1999

| Row spacings (mm) | Harvest dates 1998* | Row spacings (mm) | Harvest dates 1999** |
|---|---|---|---|
| 500-300 | 10 November | 500-300 | 13 November |
| 700-300 | 05 November | 700-300 | 07 November |
| 800-400 | 01 November | 800-400 | 03 November |
| 700-700 | 25 October | 700 | 28 October |

* Planted June 15, 1998, ** Planted June 19, 1999

Amount of water given to plots were calculated based on class-A-pan evaporation. Since high sprinkle irrigation rate causes soil and water losses, a 80% of accumulated evaporation was applied based on soil infiltration rate. Water was supplied from a well located in the experimental area. The space between the in-line type of drippers was 33 cm and flow rate of it was 2,5 L $h^{-1}$ for 1 atmosphere. The lateral with a 16 mm diameter was placed in the centre of two rows.

The area of experimental plot for each row space was:

For 500–300 mm row space: 2.5x4 m
For 700–300 mm row space: 3.0x4 m
For 800–400 mm row space: 3.6x4 m
For 700–700 mm row space: 2.8x4 m

The total prowing area for each plot was calculated as 47.2 $m^2$.

Statistical analysis was carried out using Statistical Analysis System (TARIST, version 1)[19] with General Linear Mode (GLM). Significant differences were determined using LSD (Least Significant Difference) Multiple Range Test at $p<0.05$.

## RESULTS AND DISCUSSION

**Water use:** Total applied water was 971 mm and evapotranspiration rate of the sesame was 995 mm (sprinkle), 1102 mm (drip) in 1998, respectively. Total applied water was 1037 mm and evapotranspiration rate was 1111 mm (sprinkle), 1135 mm (drip) in 1999, respectively growing period. There was a similar trend for applied water and water use of sesame in both years. Since precipitation was higher in 1998 compared to 1999, soil moisture storage was higher in 1998 according to soil moisture in 1999. These results are in agreement with the findings of Sepaskhah and Andam[20].

**Agronomic traits:** In 1998 and 1999, the number of branch and capsules were significantly affected by the methods of irrigation and row spacing; however, the effects of these factors on the plant height were not-significant (Table 3 and 4).

According to the results obtained it was noted that while plant height (112 cm) was obtained from sprinkle irrigation, the highest number of branches (4.62 per plant) and capsules (103 per plant) were obtained from drip irrigation method. The possible cause of this difference may be that since the period of irrigation was longer in the drip irrigation method, because the plants are able to uptake more plant nutrients and water regularly. Although the plant height was not significantly affected by row spacing, the narrow rows produced slightly better results. This may be due to that when the plants are planted in narrow rows, since they are not able to receive sunlight sufficiently, they tend to compete with each other to have more sunlight. Furthermore, weed density in sprinkle irrigation was higher compared to drip irrigation. This might be due to fully irrigation of the field, stimulating weed density and development of the weeds in sprinkle irrigation. In our experiment, weed density, in particular johnsongrass (*Sorghum halepense* L.), was more in sprinkle irrigation than in drip irrigation and this, in turn, caused a competition for light between weeds and sesame plants resulting in increased plant height to utilize the light. On the other hand, in drip irrigation, weed development and density has been less intensive due to irrigation of plant canopy region only. As a result of this, number of branches and number of capsules per plant increased and yield increased as well. According to the results obtained, the plants planted in broader rows had higher number of branches than the ones planted in narrow rows. Even with broadening of the rows, a linear increase was noted in the number of branches. The reason of this is probably that the plants in broader rows had larger growth area and eventually better benefited from nutrients for per unit area. Similar results were recorded for the number of capsules as well. Since the capsules develop on the branches, the plants having higher number of branches had a higher number of capsules too. The factors causing an increase in the number of branches were found to be effective on the number of capsules. This is because of that the plants in broader rows were less competitive for plant nutrients. The results are similar to results of Avila *et al.*[8], Ghosh and Patra[5], Torres and Velasquez-Silva[7].

Regarding plant height and number of branches, the sprinkle irrigation obtained better results than the drip irrigation (Table 5). While the highest plant height (114 cm) was obtained from sprinkle irrigation method, the lowest plant height was noted from the drip irrigation method (97 cm). In terms of the number of branches, while the highest values was obtained from the drip irrigation method (4.90 branches per plant), the lowest number of branches was obtained from the sprinkle irrigation method (3.77 branches per plant). With the exception of 700 mm row spacing in drip irrigation method, both in sprinkle and drip irrigation methods, the plantings on broader rows gave better results than the ones planted on narrow rows. With regard to the number of capsules, the drip irrigation method produced better results than the sprinkle irrigation method and with the reduction in row spacing the number of capsules became lesser in both methods of irrigation. While the highest number of capsules was obtained from drip irrigation (124 capsules per plant), the lowest figure

Table 3: Means for plant height and number of branches at different irrigation methods and row spacings at Şanliurfa, Turkey in 1998 and 1999

| | Plant height (cm) | | | Number of branches (per plant) | | |
|---|---|---|---|---|---|---|
| Years | 1998 | 1999 | Mean | 1998 | 1999 | Mean |
| Sprinkle | 116 | 109 | 112 | 4.05 | 4.72 | 4.39 |
| Drip | 95 | 105 | 100 | 3.70 | 5.54 | 4.62 |
| LSD (5%) | 19 | 12 | 7 | 0.78 | 0.98 | 0.40 |
| 500-300 mm | 106 | 107 | 106 | 3.80 | 4.32 | 4.06 |
| 700-300 mm | 103 | 108 | 106 | 4.08 | 5.02 | 4.55 |
| 800-400 mm | 109 | 107 | 108 | 3.85 | 5.45 | 4.65 |
| 700-700 mm | 104 | 105 | 105 | 3.77 | 5.73 | 4.75 |
| LSD (5%) | 8 | 5 | 4 | 0.84 | 0.82 | 0.56 |

Table 4: Means for number of capsules and seed yield at different irrigation methods and row spacings at Şanliurfa, Turkey in 1998 and 1999

| | Number of capsules (per plant) | | | Seed yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| Years | 1998 | 1999 | Mean | 1998 | 1999 | Mean |
| Sprinkle | 86 | 92 | 89 | 1402 | 1477 | 1440 |
| Drip | 87 | 119 | 103 | 1739 | 1725 | 1732 |
| LSD (5%) | 14 | 23 | 9 | 39 | 82 | 29 |
| 500-300 mm | 88 | 91 | 89 | 1905 | 1921 | 1913 |
| 700-300 mm | 81 | 100 | 91 | 1685 | 1717 | 1701 |
| 800-400 mm | 95 | 122 | 108 | 1507 | 1512 | 1510 |
| 700-700 mm | 81 | 110 | 95 | 1186 | 1253 | 1220 |
| LSD (5%) | 14 | 7 | 4 | 64 | 76 | 47 |

Table 5: Averages results of seed yield and yield components at row spacing according to irrigation methods

| | Plant height (cm) sprinkle | | | Number of branches (per plant) sprinkle | | |
|---|---|---|---|---|---|---|
| Row spacing/years | 1998 | 1999 | Mean | 1998 | 1999 | Mean |
| 500-300 mm | 120 | 105 | 112 | 3.80 | 3.73 | 3.77 |
| 700-300 mm | 115 | 108 | 111 | 4.17 | 4.97 | 4.57 |
| 800-400 mm | 117 | 111 | 114 | 3.70 | 5.10 | 4.40 |
| 700-700 mm | 112 | 112 | 112 | 4.53 | 5.07 | 4.80 |
| | | Drip | | | Drip | |
| 500-300 mm | 92 | 109 | 101 | 3.80 | 4.90 | 4.35 |
| 700-300 mm | 91 | 109 | 100 | 4.00 | 5.07 | 4.54 |
| 800-400 mm | 102 | 103 | 102 | 4.00 | 5.80 | 4.90 |
| 700-700 mm | 96 | 98 | 97 | 3.00 | 6.40 | 4.70 |
| LSD (5%) | 11 | 7 | 6 | 1.19 | 1.16 | 0.79 |
| | Number of capsules (per plant) sprinkle | | | Seed yield (kg ha$^{-1}$) sprinkle | | |
| Row spacing/years | 1998 | 1999 | Mean | 1998 | 1999 | Mean |
| 500-300 mm | 89 | 83 | 86 | 1570 | 1641 | 1606 |
| 700-300 mm | 77 | 84 | 80 | 1517 | 1552 | 1534 |
| 800-400 mm | 86 | 100 | 93 | 1231 | 1300 | 1266 |
| 700-700 mm | 92 | 100 | 96 | 1091 | 1214 | 1153 |
| | | Drip | | | Drip | |
| 500-300 mm | 87 | 98 | 92 | 2040 | 2000 | 2020 |
| 700-300 mm | 86 | 116 | 101 | 1852 | 1882 | 1863 |
| 800-400 mm | 103 | 144 | 124 | 1783 | 1723 | 1753 |
| 700-700 mm | 70 | 119 | 95 | 1282 | 1292 | 1287 |
| LSD (5%) | 20 | 6 | 10 | 90 | 108 | 66 |

was noted in sprinkle irrigation (80 capsules per plant) (Table 5).

**Seed yield:** Table 4 and Fig. 1 show that in 1998 and 1999, the methods of irrigation and row spacing (plant population) had a significant effect on the seed yield.

The drip irrigation gave better results (1732 kg ha$^{-1}$) than the sprinkle irrigation (1440 kg ha$^{-1}$) (Table 4). This resulted from that since the period of irrigation was longer in drip irrigation method, the plants were able to uptake more plant nutrients and water regularly. Also, the insufficient irrigation due to surface flow in sprinkle irrigation and lodging of the plants may be other possible reasons of lower seed yield in the latter case. Furthermore, application of irrigation in rhizosphere or canopy region, effective use of water in drip irrigation and easy transpiration and photosynthesis of the plants are other likely seasons for higher yields in drip irrigation

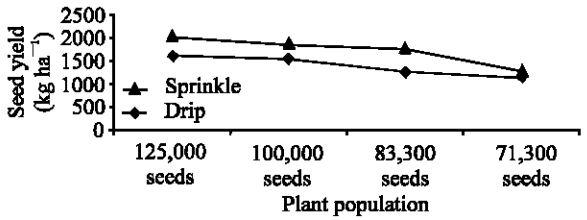


Fig. 1: According to averages of two years, between irrigation methods and plant population interaction in seed yield

method. Similar results for the characters being studied in this experiment, were reported in other studies[21], Glenn *et al.*[22], Paltineanu *et al.*[23], Greterol *et al.*[24] and Vearela[25] on soybean[26].

Results obtained showed that the highest seed yield was obtained from 500-300 mm row spacing with 1913 kg $ha^{-1}$. On the other hand, the lowest seed yield was obtained from 700 mm row spacing (1220 kg $ha^{-1}$) (Table 4). Overall, the yield of seed decreased relatively with the increase in row spacing.

This probably resulted from the fact that the increase in leaf unit index in a defined area caused an increase in the photosynthetic capacity of the plants in per area that would eventually lead to better uptake of plant nutrients. In addition, in narrow spacing, due to plant canopy the risk of water loss by evaporation could be less and the plants are less affected by atmospheric temperature. The increase in the number of plants in a narrow area provides a much better uptake from the soil. This naturally leads to an increase in the yield. The drip irrigation method caused higher yield per decare than the sprinkle irrigation. While the higher seed yield was obtained from the drip irrigation (2020 kg $ha^{-1}$), the lowest result was attained from the sprinkle irrigation method (1153 kg $ha^{-1}$) (Fig. 1). In both method of irrigation, the yield increased relatively with the decrease in row spacing. Our results are in similarity with some researches[3,5-11,27].

In this study, a local dark sesame was grown in June of 1998 and 1999. The experimental design for irrigation methods and row space trials was a split-plots with three replications. The research field is located in an arid climate in which the summer is hot and dry and The winter is warm and dry.

The highest seed yield was obtained from drip irrigation (1732 kg $ha^{-1}$). At row spacings the highest seed yield was observed from 500-300 mm with 1913 kg $ha^{-1}$ (Table 4). There was no difference between irrigation methods. In addition, increasing row distance decreased seed yield (sprinkle; 1153 kg $ha^{-1}$ and drip; 1287 kg $ha^{-1}$ in 700-700 mm row spacing) (Table 5).

Similar results were obtained in capsule and branches numbers. The highest number of capsule and branches numbers were observed from drip irrigation with 103 and 4.62 per plant, respectively. As row spacings, while the highest number of capsules were obtained from 800-400 mm row spacing with 108 per plant, the highest branches number was obtained from 700-700 mm with 4.75 per plant. But the lowest capsule and branches numbers were obtained from 500-300 mm row spacing with 89 and 4.06 per plant, respectively (Table 3 and 4). In addition, while the highest capsule numbers and branches numbers in sprinkle irrigation methods were obtained 700-700 mm with 96 and 4.86 per plant, respectively. In drip irrigation from 800-400 mm row spacing (124 and 4.90 per plant, respectively) (Table 5).

Plant height was observed from sprinkle irrigation with 112 cm. In row spacings the highest plant height (108 cm) was found from 800-400 mm. But results were not significant among row spacings in plant height (Table 3). In irrigation methods the highest plant height was observed from 800-400 mm in both sprinkle and drip irrigating (114 and 102 cm, respectively). The affect of irrigation methods and row spacings in plant height were not statistically significant (Table 3).

Overall, the results at this study indicated that obtaining the highest yield in sesame occurred when the crop was planted on rows as narrow as possible (up to 300 mm row spacing) and irrigated with a drip irrigation.

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