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DETERMINATION OF OPTIMUM ROW-SPACING AND PLANT DENSITY IN GOLDASHT SAFFLOWER VARIETY

Mohammad SHARRIF MOGHADDASI[1], A.H. OMIDI[2]

[1]Islamic Azad University/Savehbranch, felestin esq. 39137-366, Saveh, Iran
[2]Seed and Plant Improvement Institute (SPII), Karaj, Iran

Corresponding author email: memo1340@yahoo.com

Abstract

In this study optimum row-spacing and plant density of new safflower cultivar, Goldasht were evaluated during a two-year period (2007-2009) in Saveh University in Iran. The experimental design was set up as strip-plot in a randomized complete block with four replication Rows were arranged at varying spaces of 25, 30, 50, 60 cm while the plants were adopted horizontally at 5, 10 and 15 cm. In this way, plants density ranged from 111111 to 800000 plant/ha. Combined analysis of two years, demonstrated that a significant effect on the seed and oil yields due to a decrease in row spacing from 50-25 cm and inter-row spacing from 15 to 5 cm. This decrease in row spacing from 50 to 25 cm and inter-row spacing from 15 to 5 cm could also increase 100SW from 27 gr to 31 gr, and seed and oil yields from 1010 and 361 kg/ha to 1399 and 422 kg/ha respectively. Moreover, an increase in plant spacing from 50 to 25 cm and inter-row spacing from 15 to 5 cm caused decreasing in the number of head/plant from 15 to 5, number of branches from 19 to 9. Correlation among the traits showed that the grain yield is significantly correlated with oil yield, number of heads and number of secondary branches. It can be concluded that the higher number of heads per plot caused more seed yield, comparing with high number of heads per plant.

Key words: *safflower, row spacing, plant density, variety.*

INTRODUCTION

Safflower, *Carthamus tinctorius* L., is a member of the family Compositae or Asteraceae, cultivated mainly for its seed, which is used as edible oil and as birdseed (Ashri, 1976). Traditionally, the crop was grown for its flowers, used for coloring and flavoring foods and making dyes, especially before cheaper aniline dyes became available, and in medicines. Safflower is a highly branched, herbaceous, thistle-like annual or winter annual, usually with many long sharp spines on the leaves (Li and Mündel, 1996).

Plants are 30-150 cm tall with globular flower heads (head) and, commonly, brilliant yellow, orange or red flowers. Achenes are smooth, four-sided and generally lack pappus.

The plant has a strong taproot which enables it to thrive in dry climates. Depending on condition varieties grow from about 0.75 to 1.5 m tall. Some have spiny, others do not.

In China, safflower is grown almost exclusively for its flowers, which are used in treatment of many illnesses as well as in tonic tea. Safflower has a bitter herbal taste, but the Institute of Botany of the Chinese Academy of Sciences in Beijing has developed a non bitter, sweet-smelling tea which contains amino acids, minerals and vitamins B1, B2, B12, C and E. Safflower preparations should be stored in light-resistant containers (Weiss, 1971).

India is the biggest safflower producing country, following by the USA and Mexico (Li and Mündel, 1996). Safflower has tolerance to drought and is suitable for growing in dry and marginal areas.

Safflower has been cultivated in Iran for centuries on limited areas for dye extraction from its florets. Its importance as an oil seed crop has only been realized since 1970 in Iran (Ahmadi and Omidi, 1997). Iran is one of the richest germplasm sources of safflower. For instance, out of the 2042 safflower genotypes deposited at the Western Regional Plant Introduction Station, Pullman, WA, USA, 199 are from Iran (De Haro et al., 1991).

Safflower is being grown in over 60 countries but India is contributing about 50% of production. In Iran the area safflower cropped area has increased over the last few years reaching about 7500 ha in 2001 whereas in 1997 it was 200-300 ha (Omidi, 2001).

The recommended range of planting density for spring and winter types is from 200 to 400 thousand plants per hectare; this will vary depending on germination rate, soil type and availability of irrigation (Omidi et al., 2009).
Omidi (2000) concluded that in winter safflower type seed number per head, head number per plant showed a decrease against increasing of plant density from 111 thousand to 800 thousand plants per hectare.
Salera (1996) conducted an experiment on safflower cultivars for best plant density in 25, 30, 50 and 60 cm. Results showed a remarkable rise in the seed yield against plant density which rose from 25 to 75 cm.
Uslu (1997) had run an experiment on two safflower over 3 varying plant rows spacing of 20, 40 and 60 cm. His conclusion revealed that the highest seed yield was belonging to 20 cm row space.
Evaluating yield components and their interrelationships and detecting suitable selection indexes is also very important in safflower breeding programme,
Omidi (1994) reported that the number of seeds per head is associated with the increase of seed yield in safflower. Uslu et al. (1994) concluded that selection for number of head per plant was effective for the improvement of the yield. Consentino et al. (1980) showed that the number of head per plant and seeds per head were significantly and positively correlated.
Yazdi-Samadi and Abd-Mishani (1989) grouped all 1618 Iranian and American safflower genotypes into 5 clusters according to their similarities and reported that the of lines from USA and Iran and other eastern countries were classified into same cluster, as they had similar genetic base.
Zongwen Zhang (2001) in a classification of 89 accessions of safflower reported that accessions from India possessed high diversity and accessions from Turkey were closely related to those from the other Middle East countries.
Bagawan and Ravikumar (2001) studied 10 safflower populations from F2 and M2 generation and reported that the number of head per plant is the most important character contributing to grain yield per plant and the number of head recorded the highest positive correlation with grain yield.
Johnson et al. (2001) indicated that grain yield was positively correlated with seed weight, and plant height.
Thus this study was planned to evaluate determination of optimum row-spacing and plant density for safflower varieties.

MATERIALS AND METHODS

This experiment was carried out over a two - year period in Saveh University at 48°26’’ and 32°16’’ with an altitude of 1000 m above sea level. Based on meteorological statistics, the annual rainfall is 350 mm, mean annual air temperature are +35^{o}C, maximum and minimum absolute annual temperature are +35^{o}C and -9^{o}C respectively. The pilot farm indicated a silty clay loam texture, the table 1 shows to the soil farm trial characters.
The experiment was conducted in four replications using statistical strip plots. The vertical plots were arranged in rows at 25, 30, 50 and 60 cm and plant intervals of 5, 10 and 15 cm. Table 2 shows the various densities in different cultivation patterns. Each plot was composed of four lines of 10m long. The new safflower variety Goldasht was planted in October 2008. After emergence, manual thinning was used to obtain normal density. For the experiment, 70 kg/ha of P_2O_5 as ammonium phosphate and 25 kg/ha of nitrogen as urea were supplied prior to sowing and 30 kg/ha of nitrogen as urea at the start of stem elongation. Weeds were controlled by manual weeding before stem elongation. Irrigation was applied at 7 stages:

- after emergence;
- stem elongation;
- bud formation;
- beginning of flowering;
- 50% of flowering;
- finishing of flowering;
- seed filling.

Data on yield per plant and yield components and other agronomic traits were recorded on plants randomly selected from the two middle rows. The harvesting areas for determination of seed yield, after deletion of the plot sides, were from two middle rows. The data for each experiment were analysed by MSTATC software for comparison of the mean values by the Duncan test at the 1% level.

Table 1. Soil farm trial characters at two depths

Soil depth Cm	N %	p %	K %	PH	EC Ds/cm	Soil Texture
0-30	0.77	14.1	111	7.1	2.2	Silty clay Loam,
30-60	0.70	11.3	99	7	3.1	Silty Loam

Table 2. Plant numbers per square meter at different row spacing and plant distances

Plant distance (cm) / Row spacing (cm)	5	10	15
25	800	400	266
30	666	333	222
50	400	200	133
60	333	166	111

RESULTS AND DISCUSSIONS

In this investigation the impact of plant density over 12 growing patterns, ranging from 111111 up to 800000 plants per unit area were monitored on the seed and oil yields and their components. After homogeneity test for error variances, combined analysis of variance was performed. F test of different sources of variation revealed that the effect of row space x year, plant distance x year and row space x plant distance x year interaction were not significant. Analysis of the grain and oil yields and some traits showed significant difference for the main effects of row space, plant distance and row space x plant distance (Table 3).

There were significantly different results values between plant heights on the rows spacing treatments but, as well as plant distance being increased, plant height became decreased, it means that inter-plant competition was decreased.

The results of Yield and yield components comparison for different row spacing and densities are shown in table 4 and 5. The highest plant height belong to 25x5 cm, because in this situation, relative humidity is high and there is no direct sun shine, and also there is desirable temperature, they cause to Auxin reduction especially in some parts of stem in shadow, Auxin as a class of plant growth substance that have an essential role in coordination of many growth and behavioral processes in the plant life cycle.

Also, the results showed that, by spacing the rows more widely from 25 to 60 cm, and by distancing the plants from 5 to 15 cm led to increase in number of head from 13 to 20 cm and 11 to 14.5 respectively.

The average head number per plant in interaction effects between row spacing with plant distance was also significant and revealed that widening distance between the plants, which caused competition decrease among the variety, also increased the head number of plant. The greatest number of plant heads was recorded as 19 in 60x15 cm pattern. Whereas the least, recorded as 8 was detected in 5x25 cm pattern. The seed number of the head as another component of yield was effected by the plant distance applied. Although no significance was identified between the seed number of the heads at varying plant spacing. The significant interaction effects of row and plant spacing were indicated that in increasing plant distance each row spacing would increase the seed content of the head. The least quantity of the head seeds at 10 was seen in its highest density in 25x5 cm pattern, while the greatest content was reported equal to 16 in the 60x15 cm growing arrangement.

Significantly effect of the number of branches trait was observed in different row spacing. The highest number of plant branches was recorded as 19 in 60 cm. Study of plant row spacing and plant distance interaction showed the highest number of branches (21) was belonging to 60x15 cm pattern. High plant density produced more biomass compared to low plant density. The thousand seed weight was also affected by the above spacing, so that the greatest weight was yielded at 60 cm wide. The mean seed weight interaction effects significant different. The range of thousand seed weight in the treatments was 37 to 42 grams. It is because of high Net photosynthetic rates, in this case, the leaves and seeds work as source and sink respectively. The highest seed and oil yields were obtained at the highest plant density .The 25 and 5 cm row and plant spacing possibly due to excessive competition, and the row and plant spacing of 60 and 15 cm, for their lower plant density per unit area, demonstrated less yield. Also, the planting density of 800000 plants per unit area resulted in the highest seed yield. Having the higher the all treatments at a 25 cm row spacing, as well as with the preferred 5 cm, plant distance for all row spacing, a growing pattern of 25x5 cm is

therefore recommended .The pattern is available easily, by planting two lines in 50 cm row spacing, prepared by seed planter.
It can be concluded that the higher number of heads per plot caused more seed yield, comparing with high number of heads per plant.
The relationship between seed yield and row spacing, plant distance and plant density represented a linear character and followed the equation y=-9.79 x +1692.5, y=-4.99. x +1324.5 and y=0.0007 x +1040.5 respectively, which means a falling trend of seed yield against row spacing, plant distance and plant density. According to the above equations, the highest seed yield was obtained in the highest plant population. The planting density of 111111 to 800000 plants per unit area resulted in the highest seed yield (Figures 1-3).
The results of phenotypic correlations showed that the grain yield is significantly correlated with oil yield (0.84), biomass (0.71) coefficient and number of head per plant (0.97).

Table 3. Mean squares for yield and yield component

S.OV	df	ms							
		Seed yield (kg/ha)	Oil yield (kg/ha)	Head per plant	Seed per head	Thousand Grain weight	Number of branches	Biomass (kg/ha)	Height (cm)
Year	1	13380.22 ns	7440 ns	221.88 ns	847.87 ns	724.1 ns	933.5 ns	144506 ns	9855.8 ns
E1	6	8920.33	3270.32	401.77	422.8	499.8	577.8	111158.1	7039
R.S	3	18960.66**	5611.47**	398.38**	998.11**	395.88**	407.11**	104409.1**	5877.46**
Rs×Y	3	964.33 ns	3981.01 ns	100.06 ns	411.40 ns	222.2 ns	99.77 ns	9999.8 ns	1510.5 ns
E2	18	2106.33	561.42	36.88	155.8	88.79	37.3	9494.33	839.8
P.d	2	8222.0. ns	1165.78 ns	81.2 ns	101.63 ns	108.68 ns	99.68 ns	13254.88 ns	1741.6 ns
P.d×Y	2	1478.66 ns	1121 ns	88.87 ns	107.11 ns	111.2 ns	88.87 ns	25688.2 ns	1054.10 ns
E3	12	7475.33	604.21	31.4	95.11	88.8	58.99	17839.8	1456.55
R.S×Pb	6	27084.77**	2599.77**	774.568**	2010.02**	477.47**	659.7**	132547.8**	9984.98**
R.S×Pb×Y	6	4129.33 ns	911.33 ns	99.90 ns	233.11 ns	100.2 ns	147.17 ns	98.74.9 ns	990.8 ns
E4	36	2608.88	256.66	59.61	313.48	53.11	99.55	12801.57	1426.14

Table 4. Yield and yield components comparison for different row spacing and densities

Treatment		Seed yield (kg/ha)	Oil yield (kg/ha)	Head per pant	Seed per head	Thousand Grain weight	Number of branches	Biomass (kg/ha)	Height (cm)
Row spacing	25	1477 a	315 a	13 a	11.3 b	42.6 a	13.3 a	6530 a	147 a
	30	1362 ab	295 b	13 a	12.3 b	39.6 b	15.6 b	6110 ab	131 a
	50	1210 b	266 b	12.3 a	12.3 b	38 b	15.3 b	5629 b	126 a
	60	1036 c	234 b	20.6 b	15.3 a	37.6 b	19 b	4710 c	117 b
Plant distance	5	1351 a	300 a	11 a	12 a	39.5 a	13.75 a	5893 a	128 a
	10	1252 a	271 a	13.5 a	13.5 a	38.75 a	12.75 a	5653 a	127 a
	15	1211 a	262 a	14.75 a	13 a	38.7 a	16 a	5688 a	127 a

Means followed by similar letters in each column for each main row or plant distance are not significantly different at the 1% level

Table 5. Yield and yield components comparison for different row spacing and densities

Row spacing (cm)	Plant distance (cm)	Seed yield (kg/ha)	Oil yield (kg/ha)	Head per plant	Seed per head	Thousand Grain weight	Number of branches	Biomass (kg/ha)	Height (cm)
25	5	1605 a	353 a	8 b	10b	42 a	11 b	7295 a	139 a
	10	1421 a	298 a	15 a	13a	40 a	18 a	6178 a	135 a
	15	1407 a	295 a	9 b	11b	40 a	11 b	6117 a	139 a
30	5	1390 a	319 a	9 b	11b	40 a	11 b	5791 b	121 b
	10	1376 a	275 a	17 a	14a	39 a	20 a	6254 a	119 b
	15	1320 b	290 a	13 a	12a	40 a	16 a	6258 a	117 b
50	5	1300 b	286 a	13 a	12a	38 b	16 a	5652 b	128 a
	10	1212 b	278 a	11 a	12a	38 b	14 a	5637 b	138 a
	15	1120 b	235 b	13 a	13a	38 b	16 a	5600 b	135 a
60	5	1112 b	244 b	14 a	15a	38 b	17 a	4833 c	115 b
	10	1000 b	230 b	16 a	15a	38 b	19 a	4545 c	119 b
	15	998 b	229 b	19 a	16a	37 b	21 a	4752 c	120 b

Means followed by similar letters in each column for each main row or plant distance are not significantly different at the 1% level

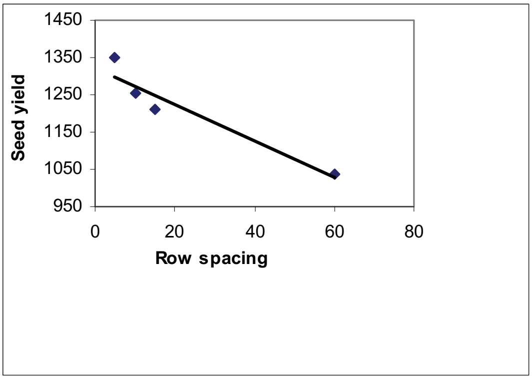

Figure 1. The relation between row spacing and seed yield which follows the linear equation: of y=-9.79 x +1692.5 representing yield decrease yield decrease against row space increase

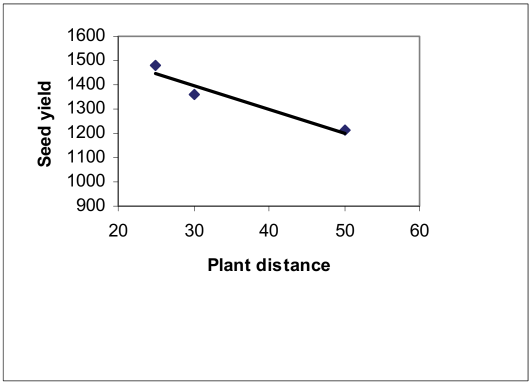

Figure 2. The relation between plant distance and seed yield which follows the linear equation: of y=-4.99. x +1324.5 representing yield decrease yield decrease against plant distance increase

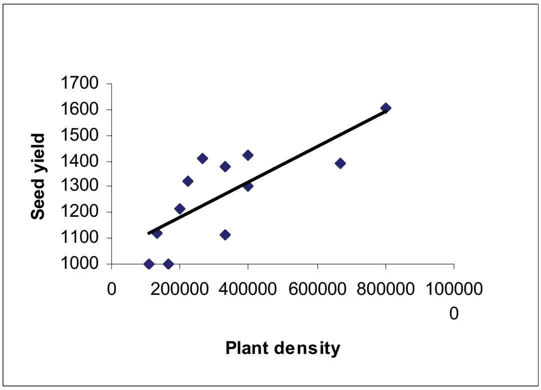

Figure 3. The relation between plant density and seed yield which follows the linear equation: of y=0.0007 x +1040.5 representing yield decrease yield decrease against plant distance increase

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