American-Eurasian J. Agric. & Environ. Sci., 10 (6): 947-953, 2011
ISSN 1818-6769

Response of Yield, Yield Component and Oil Content of Safflower (*cv.* Sina) to Planting Date and Plant Spacing on Row in Rainfed Conditions of Western Iran

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Abstract: In order to evaluate of planting date and plant spacing on yield, yield components of safflower (*cv.* Sina) in western Iran, an experiment was conducted in Research Farm of Ilam Province Agricultural-Jihad Researches Center, located in Sarableh during 2007-2008. The experiment was conducted as factorial with randomized complete block design and four levels of planting date (5 November, 5 December, 4 January and 3 February) and plant spacing was in four levels (5, 7.5, 10 and 12.5 cm) by four replications. The results showed that planting date affected on head per plant, seeds per head, 1000-seeds weight, seed yield, biological yield, harvest index and oil content. The sowing date 5th November had the highest heads per plant (20.9 head), seeds per head (23.6 seeds), 1000-seed weight (39.9 g), seed yield (1877.7 kg/ha), biological yield (3850 kg/ha), harvest index (48.7 %) and oil content (30.9 %) than other traits. Plant spacing affected heads per plant, seeds per head, 1000-seed weight, seed yield, biological yield and harvest index. 12.5 cm plant spacing had the highest heads per plant (21.02 head), 1000-seed weight (43.1 g), seed yield (1911.1 kg/ha), biological yield (3911 kg/ha), harvest index (48.7 %). Seed yield had the highest correlation with heads per plant, 1000-seeds weigh biological yield and harvest index.

Key words: Seed yield · Planting date · Plant density · Safflower · Sina cultivar

INTRODUCTION

Safflower is an oil seed plant that use in industry and as food. This plant is tolerant against drought and saltiness stresses and grows in the country dry regions (Iran). Planting date is very important in agricultural production management decisions, especially at region having environmental restrictions such as sooner or later coldness and severs. Hot at middle. Of summer equal plants distributing/m^2 effect is significant on desired distributing absorbed sunlight across canopy. Thus main effect of planting pattern and plant density on crop is mainly due to difference. In distributing sunlight and increasing sunlight absorbing resulted in improving yield [1]. Various studies on safflower shown that germination, rosette duration, grain yield, grain filling duration, grains per head, plant height, weight and heads per plant of safflower affected by planting date [2-5]. Desired planting time is when plant grown, stabled and adopted with environmental conditions. Hocking [6] reported that later planting caused to shortening vegetative period and as a result period between flowering and maturity would be shorten. Mackinnon and Fettel [7] reported that planting date and cultivar had significant affection yield and oil content and delaying planting caused to decrease in yield. Bilgili *et al.* [8] and Lythgoe *et al.* [9] indicated that different safflower cultivars yielded low yield in thinner densities under dry farming condition, but thicker densities caused to not only high yield but also to reducing weeds. Oad *et al.* [10] suggested that plant density caused to belonging maturity duration and thickening density caused to increasing grain yield. Abdulhabib *et al.* [11] also indicated that under dry farming culture. 10 cm plant spacing produces the highest 1000-seed weight in compare with other spaces. This study conducted in order to investigating planting date

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and plant spacing on row effects on yield, grain yield and oil content of safflower under dry farming conditions in Ilam, Iran.

MATERIALS AND METHODS

This experiment was conducted as factorial in form of randomized complete design in four replications in Agricultural Research Station of Sarableh, Shirvan Chardavol located at 30 km east of Ilam, with 33° 47′ northern altitude and 49° 36′ eastern longitude and 975 m height Sea. Experiment factors included planting date (5 November, 5 December, 4 January and 3 February) and plant spacing on row (5, 7.5, 10 and 12.5 cm). Soil texture was loamy-clay and pH was 7.8 that were not limiting factors for plant growth (Table 1). Annual rainfall was 500-550 mm and rainfall rate was 240 mm in the year with experiment conducted (Table 2). Used cultivars was Sina that is first cultivar introduced by agricultural research center in Iran to dry farming conditions. Any plot included, lines with 6m long. 70 and 50 kg Nitrogen and phosphorus fertilizers manure to soil based on soil test (Nitrogen from urea source and phosphorus from super-phosphate). Harvest operation done manually. Studied attributes that selected using 10 plants randomized form middle rows and omitting 50 cm of end and beginning of any plat, included: Seed yield, heads per plant, seeds per head, 1000-seed weight, biological yield, harvest index, plant height and oil content. Entire plot harvested manually to estimating grain yield and oil content measured using NMR method and NMR set. Data anglicized statistically using SAS, MSTAT-c software. Mean treatments compared using Dunken test.

RESULTS AND DISCUSSION

Heads per Plant: Heads per plant is most important yield component of safflower and is more to improving yield [12]. Planting date effect was significant on heads per plant at $P<0.01$. Delaying planting decreased these traits (Heads per plant). The highest and lowest heads per plant were obtained from 5 November and 3 February planting dates, respectively. Positive effect of planting date on fertile heads number also showed that longer growth duration cause to forming and inoculating more heads in secondary situations. Also sooner planting would cause to hens forming and flowing period hadn't encounter with summer middle hot. A study showed that heads per plant was decreased significantly due to delaying in planting [13]. Plant spacing on row effect on heads per plant was significant at $P<0.01$ (Table 1). The highest heads per plant obtained using 12.5 cm spacing with mean 21.02 heads and the lowest obtained in 5cm spacing with mean 9.9 heads. Such reduction with decreasing plant spacing may be due to the plants competition to uptake nutrients, sunlight, shadowing leave and branches of upper parts and decreasing fruit fullness of side branches. Similar results based on decreasing branching power due to thickening density reported by Leitch and Sahi [14] and Gubbles and Kenaschuk [15]. Results of correlation analysis indicated that there is significant and positive correlation between heads per plant with seed yield, biological yield and harvest index (Table 4). Positive correlation between heads per plant and seed yield is an obvious fact, the more heads per plant, the more seed yield, biological yield and harvest index. Gonzales *et al.* [16] also reported the reducing heads per plant due to

Table 1: Soil physical and chemical properties of experimental area

Soil texture	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Total N (%)	Organic Carbon (%)	E.C(dS/m)	pH
clay loam	4.8	305	0.09	1.01	0.60	7.8

Table 2: Monthly mean value of precipitation and relative humidity in Sarableh, Ilam station in 2007-2008

Month	Min temp (°C)	Max temp (°C)	Precipitation (mm)	Min. RH (%)	Max. RH (%)
Oct.	18.1	36.9	0.4	14	46
Nov.	15.4	27.5	21.0	34	70
Dec.	8.9	19.5	24.6	48	88
Jan.	9.7	20.9	15.7	40	80
Feb.	8.6	20.2	31.7	34	78
Mar.	14.1	26.0	27.2	25	62
Apr.	15.2	29.1	34.0	20	61
May	21.5	35.0	22.7	14	47
Jun.	27.1	44.0	0.0	7	23
Jul.	29.5	45.7	0.0	8	23

Table 3: Result of variance analysis of studies traits in safflower

		MS						
S.O.V	df	Heads per plant	Seeds per head	1000- seed weight	Seed yield	Biological yield	Harvest index	Oil content
Replication	3	0.6	73.8	29.5	13322.4	59518.6	14.2	12.3
Planting date	3	5.5**	68.3**	56.1**	129094.8**	399729.5*	192.7*	105.6*
Plant spacing	13	3.1**	197.7**	266.9**	1333111.1**	1333111.6**	96.09*	69.1ns
Interaction	19	0.05ns	4.5 ns	1.7 ns	13950.5 ns	127869.03ns	24.2ns	24.2ns
Error	45	0.2	9.6	8.1	29813.8	126683.8	129.7	31.7
CV%	-	12.05	14.9	17.4	10.3	9.8	11.8	6.5

ns, * and ** showed non-significant and significant in 5% and 1%, respectively.

Table 4: Mean comparison of studies traits in safflower as affected by planting date

Treatment	Heads per plant	Seeds per head	1000- seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Oil content (%)
5 November	20.9a	23.6a	39.9a	1877.7a	3850a	48.7a	30.9a
5 December	15.4b	20.3b	35.5b	1721.6ab	3720.6bc	46.4ab	29.1b
4 January	14.5c	20.3b	32.4c	1616.4bc	3470.6bc	46.4ab	128.6c
3 February	12.4d	18.7b	31.02c	1436.09c	3350c	42.8b	26.2d

The same letter (letters) showed non differences between treatments

Table 5: Mean comparison of studies traits in safflower as affected by plant spacing on row

Treatment	Heads per plant	Seeds per head	1000- seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Oil content (%)
5cm	9.9c	24.6a	33.9d	1450.3d	3320c	43.6c	28.4a
7.5cm	12.2bc	22.2b	39.5b	1577.6c	3538.6bc	44.5b	28.1a
10cm	15.6b	19.8c	36.4c	1706.7b	13597.6bc	47.4b	28.6a
12.5cm	21.02a	16.3d	43.1a	1911.1a	3911a	48.8a	28.7a

The same letter (letters) showed non differences between treatments

Table 6: Mean comparison of interaction effect of planting date × plant spacing on row on seed yield and agronomic traits

	Treatment	Heads per plant	Seeds per head	1000- seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Oil content (%)
5 November	5	13.4e	25.1a	35.6f	1450.1ef	3650d	39.7f	31.4a
	7.5	18.9cd	22.8b	37.8d	1532.2 def	3734.9cdef	41.02ef	29.1bc
	10	21.4bc	20.9bc	42.1b	1674.2d	3853.7c	43.4d	29.6b
	12.5	25.07a	18.6 c	45.2a	2100.1a	4181.4a	50.2a	28.7c
5 December	5	12.9cd	23.1b	31.2hi	1350.3f	3550.3de	38.02ghi	28.6c
	7.5	17.5d	20.8bc	34.2fg	1432.3efg	363.84d	39.4fe	28.2d
	10	20.3bcd	18.9 c	36.5def	1610.4d	3753.6cde	42.8de	28.3cd
	12.5	22.05b	16.6 de	40.4c	1960.5b	4081.7b	48.02b	28.4cd
4 January	5	10.9e	22.1bc	32.01h	1296g	3450.4e	37.3h	28.7c
	7.5	16.5de	19.8bcd	36.7e	1352.7f	3534.8def	38.2gh	28.2d
	10	20.3bcd	17.9cd	38.01cd	1590.9de	3653.7d	43.5f	28.6c
	12.5	21.05bc	16.1 d	39.6c	1810c	3950.9bc	45.8c	28.7c
3 February	5	8.9f	21.9b	30.8i	1290.6gh	3350.6f	38.6gh	28.4cd
	7.5	13.5e	19.6bcd	34.3fg	1334.1fg	3434.6ef	38.8g	28.1d
	10	16.3de	17.4cde	36.5def	1499.2e	3583.3de	41.8e	28.6c
	12.5	19.05cd	16.01def	37.3de	1637.3d	3760.2cd	43.5d	28.7c

The same letter (letters) showed non differences between treatments

Table 7: Correlation coefficient among planting date and plant spacing on row in safflower

Traits		1	2	3	4	5	6	7
1	Head per plant	1						
2	Seeds per head	0.46*-	1					
3	1000- seeds weight	0.56*	0.32*-	1				
4	Seed yield	0.6*	-0.35*	0.51*	1			
5	Biological yield	0.69*	0.26ns	0.56**	0.76**	1		
6	Harvest index	0.61*	0.19ns	0.43*	0.63**	0.65**	1	
7	Oil content	0.49*	0.14ns	0.26ns	0.56**	0.63**	0.16ns	1

ns, * and ** showed non-significant and significant in 5% and 1%, respectively.

thickening density. Interaction effect of planting date and plant spacing were not significant on plant height (Table 3). Nevertheless, the highest and lowest heads per plant were obtained from 5 November planting date ×12.5 cm, plant spacing and 3 February planting date ×5 cm plant spacing, respectively (Table 6).

Seeds per Head: According on data variance analysis, planting date and plant spacing on row had significant difference on seeds per head at $P<0.01$ (Table 3). In this experiment, delaying planting date reduced seeds per head. The highest seeds per head was obtained at 5 November planting date, averagely 23.6% and the lowest was obtained at fourth planting date (3 February), averagely 18.7, about 21% reduction. Able [13] also confirmed decreasing in seeds per head due to delaying planting date. Zimmerman [17] also suggested that safflower yield is affected by cultivar and environmental conditions during flowering period and after it so that increasing temperature and relative humidity during flowering period, yield would decrease due to reducing seed numbers per head. 5.5 cm planting yielded the highest seeds per head, averagely 24.6 seeds and the lowest was obtained at 12.5 cm plant spacing averagely 16.3 seeds. As seed forming is depend on supplying necessary nutrients and desired environmental conditions during productive to generative growth transforming period and later under experimental conditions, seeds per head was increased due to the reduction of heads per plant but head size is greater in high seed application to control, so 5cm spacing induced more seeds per head. Similar results were reported by Hoag *et al.* [18], Zope *et al.* [19] and Sing *et al.* [20]. Correlation analysis results showed that there was significant and negative correlation between seeds per head and heads per plant and 1000- seed weight (Table 7).

1000-Seed Weight: Planting date and plant spacing on row had significant effect on 1000-seed weight at $P<0.01$ (Table 3). The highest 1000-seed weight was obtained from first planting date (5 November), averagely 39.9 g and the lowest was obtained at fourth planting date (3 February), averagely 31.02g that was 22% lower than other dates. Results of the study showed that delaying planting to 5 December decreased the 1000-seed weight and after it, delaying planting date hadn't effect on 1000-seed weight. Horn and Burnside [21] showed that delaying planting reduced seed weight due to low moisture in the end of growth season. Nanda *et al.* [22] contributed the reduction in seed yield at late planting to 1000-seed weight. The highest 1000-seed weight was obtained at 12.5 cm plant spacing on row, averagely 43.19 and the lowest 1000-seed weight was obtained using 5cm spacing averagely 33.9 g, that was 22% lower (Table 3). Theses results are in agreement with those obtained by Gonzales *et al.* [16]. According to Table 7, 1000-seed-weight was correlated negatively with heads per plant, seed yield, biological yield and harvest index. There was negative correlation between 1000-seed weight and seeds per head. Many researchers reported that there was negative and significant correlation between 1000-seeds weight and heads per plant and also between seeds number and primary branch numbers, it seems that compensating role of seed weight was effective in balancing nutrients distributing among formed seeds [23].

Seed Yield: Planting date and plant spacing on row effect was significant at $P<0.01$ (Table 3). Due attention to Table 2, The highest mean seed yield was belonged to first planting date (5 November), mean 1877.7 kg/ha, while the lowest was obtained at fourth date (3 February), averagely 1436.09 kg/ha, that was 23.5 lower than other dates. The results of this study indicated that in later planning date, some matters used by useless branches due to crop growth stability and thus seed yield was reduced. Such reduction in seed yield may be due the reduction in heads per plant, seeds per head and 1000-seeds weight at later dates. This is in agreement with

those obtained by Lueble *et al.* [4] and Hadjchristodoulau [24]. The results also indicated that at late planting date, plant height was reduced and the period between planting and flowering was reduced lead to the reductionin crop yield [13]. Lueble *et al.* [4] studied planting date on seed yield and reported that by 4-6 week delaying in planting date reduced 260 kg/ha seed yield. Johnson *et al.* [25] compared various planting date and suggested that delaying planting date significantly decreased seed yield. Siddique et al. [26] reported that seed yield was decreased due to delaying planting date. The highest seed yield was recorded by using 12.5cm spacing, averagely 1911.1 kg/ha and the lowest at 5cm spacing, mean 1450.3 kg/ha. Many researchers studied plant density effect by changing plants spacing on row in safflower and indicated that low to medium densities (80000 to 175000 plants/ha) produced more yield but in very thick densities, yield reduced due to increasing competing to uptake water, nutrients and light. But many researchers found that plant size and yield components decreased due to increasing plant density in safflower, but increasing plants/m^2 compensated plant yield and seed yield remained constant or slightly reduced. Also researchers showed that low density of safflower caused to longer maturity period and lower density improved seed yield [10]. Correlation analysis results showed that there was positive and significant correlation between seed yield and heads per plant (Table 7). This correlation is obvious because more branches due to more heads resulted in biological yield. The interaction effect of planting date and plant spacing were not significant on seed yield (Table 3). Nevertheless, the highest and lowest seed yield were obtained from 5 November planting date ×12.5 cm, plant spacing and 3 February planting date × 5 cm plant spacing, respectively (Table 6).

Biological Yield: Biological yield was significant affected ($P<0.01$) with planting date and spacing on row (Table 3). According Table 3 the highest biological yield was obtained at first planting date (5 November), with 3850 kg/ha and the lowest yield was in fourth date (3 February), with 33350 kg/ha, that was 13% lower than other dates. Under desired conditions, 5 November was a desirable vegetative period and dry matter was increased significantly during forming reproductive organs and inoculation because temperature perfectly correspond with optimized condition to inculcating. Planting date at 3 February, in addition to reducing vegetative growth, biological yield also decreased due to undesired environmental conditions and lack of suitable transforming preserved matters to seeds as a result of increasing temperature at the end of growth season. Plant spacing on row had significant effect on biological yield at $P<0.01$ (Table 3). The highest biological yield was obtained by using 12.5 cm spacing, on average 3911 kg/ha and the lowest yielded by using 5cm spacing, on average 3320 kg/ha, that was 15% lower than other spacing (Table 5). Severe competition due to more spacing between plants caused to minimizing useful effects of rapid growth and lower density could used perfectly environmental factors and produced more dry weight. In closer spacing, fewer flowers transformed to seeds due to severe competition and as a result fewer seeds per head formed. The experiment results shown that due to rainfall deficit, more spacing was useful because plants grown better and as a result dry weight increased and in closer spacing, plants hadn't grown adequately due to moisture deficit. Correlation analysis results showed that biological yield correlated significantly and positively with grain yield (Table 7). Because seed yield is followed by biological yield, thus it is expected that there is positive correlation among them. This correlation is obvious because more branches, due to more heads result in increasing seed yield and biological yield.

Harvest Index: Harvest index indicating transforming percent photosynthetic matters from vegetative organs (source) to seeds (sink). Planting date affected significantly harvest index at $P<0.05$ (Table 3). The highest harvest index was obtained with first planting date (5 November) on average 47.8% and the lowest yielded in fourth date (3 February) on average 43.3% (Table 3). Increasing harvest index at first date indicating that temperature was optimum to transforming photosynthetic matters from source to sink, but in fourth date (3 February), transforming photosynthetic matters done hardly due to lack of suitable producing yield components in vegetative growth period and as a result, harvest index reduced. Plant spacing on row effect was significant on harvest index at $P<0.05$ (Table 3). The highest and lowest harvest index was obtained by using 12.5 and 5cm spacing, respectively (Table 5). Harvest index is depend on the manner by with photosynthetic matters transforms to vegetative and reproductive organs and plan spacing cause to increasing harvest index by affecting photosynthetic matters and transforming them to grains. Many researcher indicated that although increasing density cause to increasing dry matter yield, thinking density cause to increasing vegetative sinks (stem, leaf, etc) to reproductive sinks (grains) ratio and as

a result harvest index reduced [27]. Other researchers also confirmed these results [23-28]. Correlation analyzing results showed that harvest index correlated positively and significantly with heads per plant, 1000-seeds weight and seed yield (Table 7). In safflower, head and external brackets are below closest photosynthetic organs of plants to sink (seeds) and also seed organs are involved in seed forming period and as retransforming preserved matters forming 25% total seed yield, thus it play key role in determining seed yield [23].

Oil Content: According to analysis of variance (Table 3), planting date affected significantly oil content ($P<0.05$). Data indicated that delaying planting date reduced oil content. The highest oil content was obtained at 5 November planting date. Delaying planting date decreased oil by 3.8% (Table 4). In fourth date (3 February) oil content was reduced due to increasing temperature. Robertson *et al.* [29] indicated that increasing the temperature by 1°C lead to decrease oil content by 1.7 %. Rajput *et al.* [30] contributed decreasing oil content and increasing protein content to delaying planting date. In this study, plant spacing on row hadn't significant effect on oil content. It is obvious that oil content wouldn't affected by environmental factors such as plant spacing on row, but more affected by cultivar and genotype [1-31-32].

CONCLUSION

Results indicated that planting date affected significantly quantities and qualities attributes of safflower. Delay of cultivation induced significant reduction of seed yield. Planting date at 5 November or 3 February date produced the highest and lowest seed yield, 1877.7 kg/ha and 1436.09 kg/ha, respectively and seed yield was reduced about 23.5%. Main cause to increasing seed yield in sooner dates was favorable weather in November that caused to plants grow quickly and more and finally produce more components and stronger plants. The highest seed yield was produced by 12.5 cm plant spacing treatment, with 1911 kg/ha, indicating the importance of this spacing on seed yield. Subsequently, as most safflower farms are as dry farming in this region and to optimum using water and soil sources and to improving production in autumn safflower planting, 5 November planting date and 12.5 cm plant spacing on row recommend in the studied region.

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