Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
http://ziraatdergi.gop.edu.tr/

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2017) 34 (1), 223-228
doi:**10.13002/jafag826**

Precipitation Water Use Efficiency and Productivity of Dryland Safflower Cultivars under Different Intra-row Spacings

Ali Salek ZAMANI[1] Abolfazl NASSERI[1*]

[1]Department of Agricultural Engineering, East Azarbaijan Agricultural and Natural Resources Research and Education Center, AREEO, Tabriz, Iran
*e-mail: nasseri_ab@yahoo.com

Alındığı tarih (Received): 13.11.2014 Kabul tarihi (Accepted): 05.03.2017
Online Baskı tarihi (Printed Online): 22.04.2017 Yazılı baskı tarihi (Printed): 02.05.2017

Abstract: Safflower is grown in Iran as a traditional oilseed plant. However, up to now optimum intra-row spacing and response of new cultivars to dryland conditions have not been studied. Consequently, the present study was conducted to investigate the precipitation water use efficiency (PWUE) and production of safflower cultivars with different intra-row spacings under dryland conditions. Field experiments were conducted using three cultivars viz. Ns.1016, Isfahan and CH.65 sown with intra-row spacings 5, 10 and 15 cm in randomized complete block design with a factorial arrangement for two cropping years. Results showed that cultivars differed PWUE, seed yield, 1000-seed weight (TSW) and number of seeds in capitulum (NSC), however intra-row spacing only affected the number of capitulua in plant (NCP). The highest seed yield and PWUE were obtained from cultivar Isfahan with intra-row spacing of 5 cm.

Keywords: Safflower; Intra-row spacing; Safflower cultivars; Precipitation Water Use Efficiency.

1. Introduction

Safflower (*Carthamus tinctorius* L.) is one of the important crops, which is cultivated for oil. Total seed production of safflower in the world was approximately 733852 mt in 2014 (FAO, 2017). This crop was grown in Iran as a traditional oilseed because of its adaptability to dryland and irrigated conditions and its tolerance to cold, salt and alkali conditions with low demand for fertilizer (Mozaffari and Asadi, 2006; Arslan, 2007 and Yeilaghi et al., 2015). Safflower is grown as both irrigated, rainfed and dryland in Iran. Safflower yield depends on soil moisture storages and precipitation under dryland conditions (Doorenbos and Kassam, 1979). Mündel et al. (1994) reported that seeding rate and row spacing of safflower depdens on environmental conditions, production system and cultivar. A limited finding is currently available on the precipitation water use efficiency and productivity of safflower cultivars responses to different intra-row spacings under field conditions. Some important research findings is expressed as follows. Mündel et al. (1994) reported that row spacing of 15 and 30 cm at southern Alberta increased safflower yield with narrow rows. Oad et al. (2002) investigated three row spacing of 25, 35, and 45cm; and three plant spacing of 15, 22 and 30 cm effects on safflower production and concluded that the optimum row and distance were 45 × 30 cm to acquire the highest production from safflower cultivation. Abdolrahmani (2004) obtained the highest yield of 1219 kg ha^{-1} from plots with plant density of 33 m^{-2} for safflower cv. Arak 2811 under dryland conditions. Nakhzari Moghadam (2000) found that seed yields, number of seeds in capitulum (NSC) and number of capitulua in plant (NCP) were affected by plant density in safflower cv. Zarghan. However, row spaces did not affect these traits. Abdulhabip et al. (2004) indicated that the safflower spacing of 10 cm produced the highest 1000-seed weight under arid condition. Recently, Emami et al. (2011) reported that safflower spacing affected 1000-seed weight, seed yield, biological yield and harvest index. They reported 12.5 cm row-spacing produced the highest 1000-seed weight (43g), seed yield (1911

kg ha^{-1}) and harvest index (49%). Sharifmoghaddasi and Omidi (2009) the optimum row spacing and plant density of safflower were invstigated. They concluded that a significant effect on the seed yields was observed due to an decrease in row spacing from50 to 25 cm and inter row spacing from 15 to 5 cm.

In irrigated lands, water use efficiency (WUE) is defined as the yield obtained per unit of water consumed as evapotranspiration (ET) by the crop under consideration (Wang et al., 2017; Zamani and Nasseri, 2008; Doorenbos and Kassam, 1979). Similarly, in dryland precipitation water use efficiency (PWUE) is the yield (kg ha^{-1}) acquired per mm of occurred precipitation over field (Zamani and Nasseri, 2008; Li and Wu, 2016). For safflower, water use efficiency ranges is from 0.2 to 0.5 kg m^{-3} (Doorenbos and Kassam, 1979).

In spite of importance and oldness of safflower cultivation in Iran, little research has been conducted on effect of intra-row spacing on precipitation water use efficiency and yield of safflower under dryland conditions and also optimum intra-row spacing and response of new cultivars to dryland conditions were not recognized. Consequently, the main objective of this study was to investigate responses of precipitation water use efficiency and production of safflower to intra-row spacing and cultivars under dryland conditions.

2. Materials and Methods

The field experiments were conducted at the Dryland Agricultural Research Institute (DARI) in Maragheh, Iran (37° 15' N, 46° 22' E and 1720 m level). The maximum and minimum air temperature averaged as 36.7 and 4.8 °C for long duration. Three-safflower cultivars viz. Ns.1016, Isfahan and CH.65 which currently is extensively cultivating in Iran and three intra-row spacing of 5, 10 and 15 cm with three replications were laid out in randomized complete block with factorial design for two cropping years ended up in 2001. Experimental plot size was 6×3 (=18) m^2. Planting depths and row spaces were 5-7 and 50 cm, respectively. All experimental plots were sown in last week March each year. In the sowing time, fertilizers as 50 kg N ha^{-1} through urea and 30 kg Pha^{-1} through triple superphosphate were applied to the soil. All plots had six rows with 50 cm space (Fig. 1). Field soil classified as clay loam and each year soil preparation was made normally for dryland farms. All treatments received precipitation water as 116 and 98 mm in the first and second growing season (Table 1). After maturity in June, seed yields, 1000-seeds weight (TSW), number of seeds in capitulum (NSC) and number of capitulua in plant (NCP) were measured in all plots. Analysis of variance techniques was applied to statistically analysis the experimental data. Duncan's multiple range tests was used to compare treatment means (Duncan, 1955). Similar to index of water use efficiency for crop production in irrigated lands, precipitation water use efficiency is the acquired yield from occurred precipitation over field in drylands. Therefore, precipitation (or rainfall) water use efficiency (PWUE) was estimated as (Guevara et al., 1996; Zamani and Nasseri, 2008; Li and Wu, 2016):

PWUE= Seed yield (kg ha^{-1})/ Seasonal precipitation (m^3 ha^{-1})

Table 1. Some meteorological factors in two growing seasons of safflower

Growing season months	Precipitation (mm)		Air temperature (°C)		Relative humidity (%)		Pan evaporation (mm)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
1st month	62.7	32.0	08.5	09.3	47.3	51.4	000.0	000.0
2nd month	53.0	34.0	12.7	12.1	52.3	46.7	227.0	223.3
3rd month	00.0	00.0	17.6	17.9	40.7	31.9	307.0	323.0
4th month	0.40	31.6	23.3	21.8	36.0	35.2	309.0	372.0

The 1st month was from 20 March to 20 April. The first and second years were 2000 and 2001, respectively.

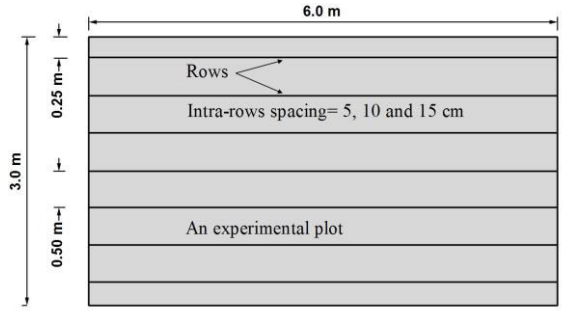

Figure 1. An experimental plot

3. Results and Discussion

3.1. Results

Seed yields averaged as 380.1±85.6 kg ha^{-1} for all cultivars and two cropping years. Seed yields were separately affected by cultivars and by cropping years but were not affected by intra-row spacing at 5% significant level (Table 2). In general, for all cultivars and two cropping years, precipitation water use efficiency averaged 0.353±0.07 kg m^{-3}. The cultivar effects and cropping years on PWUE were statistically significant (Table 2), but intra-row spacing effect was insignificant ($p<0.05$).

The safflower cultivars and two cropping years produced different 1000-seeds weight ($p<0.01$). Overall, 1000-seeds weight ranged from 21.3±2.2 to 35.2±0.80g for conducted experiments (Table 2). Interactive effects of cultivar and cropping year on number of seeds in capitulum were significant ($p<0.05$). The effect of intra-row spacing on number of capitula in plant was statistically significant ($p<0.01$). However, safflower cultivars and precipitation changes in two years did not affect number of capitulua in plant.

3.2. Discussion

Seed yields ranged from 246.3±126.3 (year 2 with precipitation of 98mm, CH.65 with plant space of 15cm) to 483.3±28.9 kg ha^{-1} (year 1 with precipitation of 116mm, Isfahan with plant space of 5cm). In the present study, the highest seed yields obtained from Isfahan cultivar with intra-row spacing of 5 cm (Table 2). Abdolrahmani (2004) also reported that the highest seed yields acquired from plant spaces of 10 cm for cv. Arak 2811. Isfahan produced the highest mean (=405.2 kg ha^{-1}) and CH.65 produced the lowest mean (=349 kg ha^{-1}) seed yields (Table 3). On the other hand our findings on similarity in seed yields values were not in accordance with report of Nakhzari Moghadam (2000). Precipitation is one of the main factors that affect safflower yield (Doorenbos and Kassam, 1979) similar to wheat production (Zamani and Nasseri, 2008). Therefore, precipitation as 116 and 98 mm in two consecutive growing seasons was the main reason for yield difference in two years.

Precipitation water use efficiency ranged from 0.25±0.13 to 0.42±0.2 kg m^{-3} (Table 2). The average value is in accordance with those reported by Doorenbos and Kassam (1979). The highest PWUE acquired from Isfahan with intra-row spacing of 5 cm. The highest mean for PWUE (= 0.38 kg m^{-3}) produced by Isfahan and the lowest ones (=0.32 kg m^{-3}) was from CH.65 (Table 3). Intra-row spacing of 5, 10 and 15 cm produced PWUE as 0.35, 0.37 and 0.34 kg m^{-3}, respectively. Precipitation water use efficiency averaged 0.38 and 0.33 kg m^{-3} in the first and second cropping years. Although precipitation values in the first and second years were 116 and 98 mm, respectively. However, low yield caused a low PWUE in the second year.

The highest (=32.5g) and lowest (=24.2g) mean for 1000-seeds weight were acquired from NS.1016 and Isfahan, respectively (Table 3). On the other hand, the first and second years produced 26.1 and 30.0g for 1000-seeds weight. Overall, 1000-seeds weight ranged from 21.3±2.2 to 35.2±0.80g for conducted experiments (Table 2). The different 1000-seeds weight was probably due to genetic diversity of safflower cultivars of NS.1016 and Isfahan.

Table 2. Seed yields, Precipitation water use efficiency, 1000-seeds weight, Number of seeds in capitulum and Number of capitulua in plant of three safflower cultivars for different intra-row spacing.

Intra-row spacing	5 cm			10 cm			15 cm		
2000/2001	Seed yields	PWUE	TSW	Seed yields	PWUE	TSW	Seed yields	PWUE	TSW
Year 1 NS. 1016	423.3±40.4	0.36±0.03	29.4±2.0	443.3±40.4	0.38±0.03	31.2±0.2	423.3±46.2	0.36±0.04	30.3±2.9
Isfahan	483.3±28.9	0.42±0.02	23.9±2.0	480.0±43.6	0.41±0.04	21.3±2.2	460.0±60.8	0.40±0.05	22.5±0.8
CH.65	410.0±26.5	0.35±0.02	24.2±4.0	386.7±85.0	0.33±0.07	26.2±0.5	420.0±30.0	0.36±0.03	25.5±2.2
Year 2 NS. 1016	357.3±89.0	0.36±0.09	35.2±0.8	339.0±60.3	0.35±0.06	34.0±1.7	331.3±48.3	0.34±0.05	34.7±0.8
Isfahan	287.0±98.8	0.29±0.10	26.0±1.0	413.0±25.1	0.42±0.03	26.7±0.8	307.7±42.2	0.31±0.04	25.0±1.0
CH.65	318.3±79.0	0.32±0.08	29.5±1.8	311.3±19.6	0.32±0.02	30.3±0.6	246.3±126.3	0.25±0.13	28.3±0.3
PWUE= Precipitation water use efficiency, TSW=1000-seed weight, NSC = Number of seeds in capitulum and NCP =Number of capitulua in plant.									

Table 2. Continued

Intra-row spacing	5 cm		10 cm		15 cm	
	NSC	NCP	NSC	NCP	NSC	NCP
Year 1 (2000) NS. 1016	21.7±9.5	3±1	25.3±6.0	4±1	23.7±2.1	4±0
Isfahan	32.7±2.1	4±1	21.0±4.4	5±0	23.7±8.0	5±1
CH.65	26.0±5.3	4±1	24.7±2.1	5±0	23.7±1.5	5±1
Year 2 (2001) NS. 1016	17.7±2.1	5±1	25.7±10.8	8±3	15.3±9.1	9±1
Isfahan	25.7±7.0	6±1	28.7±5.1	8±4	24.7±8.3	10±3
CH.65	14.7±5.0	6±2	17.0±3.6	8±3	17.7±4.2	11±2

Table 3. Mean seeds yields, PWUE, 1000-seeds weight, NSC and NCP for three safflower cultivars

	Seed yields (kg ha^{-1})	PWUE (kg m^{-3})	1000-seeds weight (g)	NSC	NCP
NS. 1016	386.3 ab	0.36 ab	32.5 a	21.6 b	5.6 a
Isfahan	405.2 a	0.38 a	24.2 c	26.1 a	6.3 a
CH. 65	348.8 b	0.32 b	27.4 b	20.6 b	6.3 a

PWUE= Precipitation water use efficiency, NSC= Number of seeds in capitulum and NCP=Number of capitulua in plant.

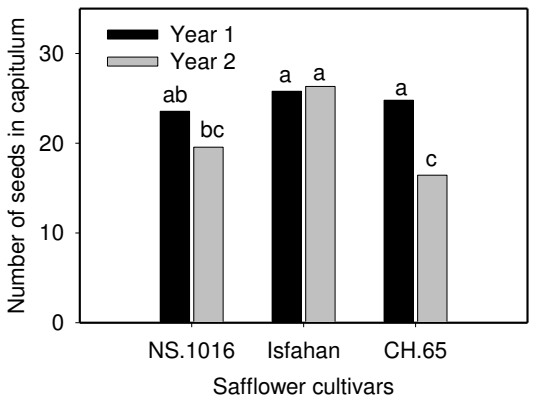

Figure 2. Interactive effects of safflower cultivars and cropping year on number of seeds in capitulum.

In general, Isfahan produced the highest number of seeds in capitulum (NSC) in two years. Also, CH.65 produced the lowest NSC (=16) in the second year (Fig. 2). It can be said the produced NSC in the first year (with precipitation of 116mm) was higher than those produced in the second year (with precipitation of 98mm). It seems decrease in precipitation values decreased number of seeds in capitulum for NS.1016 and CH.65. However, NSC of Isfahan was approximately constant with changes in precipitation in two years. The highest and lowest number of seeds in capitulum were as 32.7±2.1 and 14.7±5.0 that were acquired from Isfahan (in the first year) and CH.65 (in the second year) with plant space of 5cm (Table 2). It seems the different number of seeds in capitulum was probably acquired from genetic diversity of safflower cultivars and effective precipitation in two cropping years.

Our finding on the relation of number of capitula in plant with intra-row spacing is in accordance with that find by Nakhzari Moghadam (2000) and Ghasemi *et al.* (2006).

In the present study, produced NCP by intra-row spacing treatments had similar mean and equaled to six. It can be said that safflower cultivars and precipitation changes in two years did not affect number of capitulua in plant. The highest and lowest numbers of capitula in plant were as 11±2 and 3±1 that were acquired from CH.65 with space of 15 cm (in the second year) and NS. 1016 (in the first year) with space of 5cm (Table 2).

4. Conclusions

The present study was to investigate responses of precipitation water use efficiency (PWUE) and production of safflower to intra-row spacing and cultivars under dryland conditions. Results showed that precipitation water use efficiency, seed yields, 1000-seeds weight and number of seeds in capitulum were affected by cultivars. The highest seed yield and PWUE was obtained from Isfahan cultivar with intra-row spacing of 5 cm. It can be said that under dryland conditions, increase in precipitation increased number of seeds in capitulum, decreased 1000-seeds weight, consequently increased seed yields and precipitation water use efficiency. It is recommended to use safflower cv. Isfahan with plant space of 5 cm to have the high seed yields for Maragheh or similar climate conditions in Iran.

References

Abdulhabip O, Demirbilek T, Gur MA and Copur O (2004). Effects of different sowing date intra row spacing on yield and some agronomic traits of safflower (*Carthamus tinctorius* L.) under Harran Plian arid condition. Turkish Journal of Agriculture and Forestry, 28(6):413-419.

Abdolrahmani B (2004). Effect of plant density on grain and oil yield of safflower cv. Arak 2811 in dryland conditions. Seed and Plant Research, 20: 417-428.

Arslan B (2007). The path analysis of yield and its components in safflower (*Carthamus tinctorius* L.). Journal of Biological Sciences, 7:668-672

Doorenbos J and Kassam AH (1979). Yield response to water, Irrigation and Drainage Paper 33. Food and Agricultural Organization of the United Nations. Rome, Italy.

Duncan DB (1955). Multiple range and multiple F tests. Biometrics, 11(1):1-42.

Emami T, Naseri R, Falahi H and Kazemi E (2011). 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. American-Eurasian J. Agric. and Environ. Sci., 10(6): 947-953.

FAO (2012). Statistical database. http://www.fao.org/faostat/en/#data/QC. Accessed at: Jan. 2017.

Ghasemi Sh, Bahrani MJ, Motalebipour SH and Kheradnam M (2006). Effect of row and plant spacing on yield and yield components of two spring safflower cultivars. Iranian Journal of Agricultural Sciences, 37(1):585-591.

Guevara JC, Estevez OR and Torres ER (1996). Utilization of the rain-use efficiency factor for determining potential cattle production in the Mendoza plain, Argentina. Journal of Arid Environments, 33(3): 347-353.

Li S and Wu J (2016). Community assembly and functional leaf traits mediate precipitation use efficiency of alpine grasslands along environmental gradients on the Tibetan Plateau. Peer J, 4:1-20

Mozaffari K and Asadi AA (2006). Relationships among traits using correlation, principal components, and path analysis in safflower mutants sown in irrigated and drought stress conditions. Asian Journal of Plant Sciences, 5(6): 977-983.

Mündel HH, Morrison RJ, Entz T, Blackshaw R E, Roth BT, Kiehn F and Vandenberg A (1994). Row spacing and seeding rates to optimize safflower yield on the Canadian prairies. Canadian journal of plant science, 74(2):319-321.

Nakhzari Moghadam A (2000). Effect of plant density on yield and yield components of safflower cv. Zarghan. *Iranian 6th congress on Plant Breeding and Agronomy*. Mazandaran University, Bablsar, Iran. pp:120

Oad C, Samo M A, Qayyum SM, and Oad NL (2002). Inter and Intra Row Spacing Effect on the Growth, Seed Yield and Oil Content of Safflower Carthamus tinctorius L. F. Asian Journal of Plant Sciences, 1(1):18-19.

Sharifmoghaddasi MR and Omidi AH (2009). Determination of optimum row-spacing and plant density in Goldasht safflower variety. Advances in Environmental Biology, 233-239.

Yeilaghi H, Arzani A, and Ghaderian M (2015). Evaluating the contribution of ionic and agronomic components toward salinity tolerance in safflower. Agronomy Journal, 107(6): 2205-2212.

Wang Y, Janz B, Engedal T and de Neergaard A (2017). Effect of irrigation regimes and nitrogen rates on water use efficiency and nitrogen uptake in maize. Agricultural Water Management, 179: 271-276.

Zamani AS and Nasseri A (2008). Response of dryland wheat production and precipitation water productivity to planting date. Asian Journal of Plant Sciences, 7(3): 323-326.