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SAFFLOWER YIELD RESPONSE TO IRRIGATION AND GAMMA IRRADIATION

SUMMARY

Safflower (*Carthamus tinctorius* L.) is drought resistant plant, but the adequate irrigation is important for the increasing of safflower yield. The effects of drip irrigation associated with pre-sowing gamma irradiation of seeds on plant growth and yield were investigated. The seeds were irradiated by gamma rays (^{60}Co) at various doses (50, 100, 150Gy). The safflower plants were grown under drip irrigation and rainfed conditions of the Republic of Moldova in season of 2017. Modifications of bio-morphological (height, number of secondary branch, developed and undeveloped inflorescence) and yield attributing (number of seeds per head and per plant, weight of seeds per plant and 1000-seed weight) characters of safflower were studied. The results showed that the drip irrigation influenced positive and statistically significant ($p \leq 0.001$) on all studied characters of safflower. The plant grown under irrigation had the number of developed inflorescences, the number of seeds and the weight of seeds per plant, respectively 1.83, 1.81 and 2.50 times more than rainfed plants; as well as undeveloped inflorescence less 2.47 times. The contribution of pre-sowing irradiation was not so pronounced. The impact of factors (irradiation, irrigation) and their interaction for the improvement of bio-morphological and yield attributing characters were determined. The significant impact of growing condition on the number of seeds per plant at $p \leq 0.01$, weight of seeds per plant and 1000-seeds weight at $p \leq 0.01$ was established. The gamma radiation had the contribution to changes in 1000-seeds weight but the contribution of growing condition on this character was 15.7 times stronger.

Keywords: safflower, seed yield, pre-sowing seed irradiation, rainfed, irrigation.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is characterized as drought tolerant plant which could be cultivated under arid and semi-arid conditions (Beyyavas et al., 2011). According to pedoclimatical conditions the Republic of Moldova is not considered as arid or semi-arid area, but during last three-five years it was observed the rising of mean summer temperatures by 2.2…3.3ºC and amount decreasing of precipitation by 100…200 mm. Previous studies (Ivanova, 2016*;*

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Ivanova et al., 2017) showed that the safflower is a new crop for Republic of Moldova as it easily adapted to these conditions. However, the safflower plants depend on an adequate water supply for optimum growth, development and for improvement of seed and oil yield. Numerous studies have examined the effects of irrigation on plant height, number of secondary branches, number of head, head diameter, number of seed per head, 100-seed or 1000-seed weight, seed and oil yields of safflower as well as the relationships between seed yield and some morphological traits (Ozturk et al., 2008; Istanbulluoglu et al., 2009; Khalili et al., 2013; Feyzollahzadeh et al., 2014; Shahrokhnia & Sepaskhah, 2017).

The bio-morphological and yield attributing characters of safflower plants could also be improved by pre-sowing treatment of seed with natural bioregulators (Ivanova et al., 2017) and gamma irradiation (Patil et al., 2001; Parameshwarappa & Meghannavar, 2001). Only several publications focus on the impact of combined abiotic factors such as irrigated or non-irrigated conditions with the pre-sowing treatment of seeds by different doses of γ-radiation on biological potentials of safflower (Mozaffari et al., 2009; Kaya et al., 2009).

This study was initiated to evaluate the effects of drip irrigation associated with pre-sowing gamma irradiation of seeds on growth and seed yield of safflower plant, cultivated in the Republic of Moldova.

MATERIAL AND METHODS

Plant materials were obtained on the experimental fields of the Institute of Genetics, Physiology and Plant Protection in Chisinau area of Republic of Moldova (lat. 47°01', long. 28°75', alt. 85 m above sea level), in the season of 2017. Safflower seeds were treated with three doses of γ-radiation (50, 100, 150Gy) using gamma RXM-V-20 system, the radiation source - ^{60}Co. Irradiated seeds were sown in rainfed and drip irrigation plots in first decade of April. The row spacing of plantation was 50cm and intra-row spacing - 15cm. Each row consisted of 50 seeds, in triplicate. The plants grown from intact (untreated with gamma radiation) seeds served as control.

T**he bio-morphological and yield attributing characters of safflower plants** were studied according to Ahmadzadeh (2013), namely plant height (cm), number of secondary branches, number of inflorescences per plant, number of seeds per plant, number of seeds per head, 1000-seed weight (g), seed yield (g).

The statistical analysis were done using software package Statgraphics Plus 2.1. The ANOVA test was applied for variance analysis of bio-morphological and yield attributing characters, Student test in assessment of statistically significant differences between plots (Raudonius, 2017).

RESULTS AND DISCUSSION

Bio-morphological characters of safflower plants grown in irrigation and rainfed conditions are given in Figure 1.

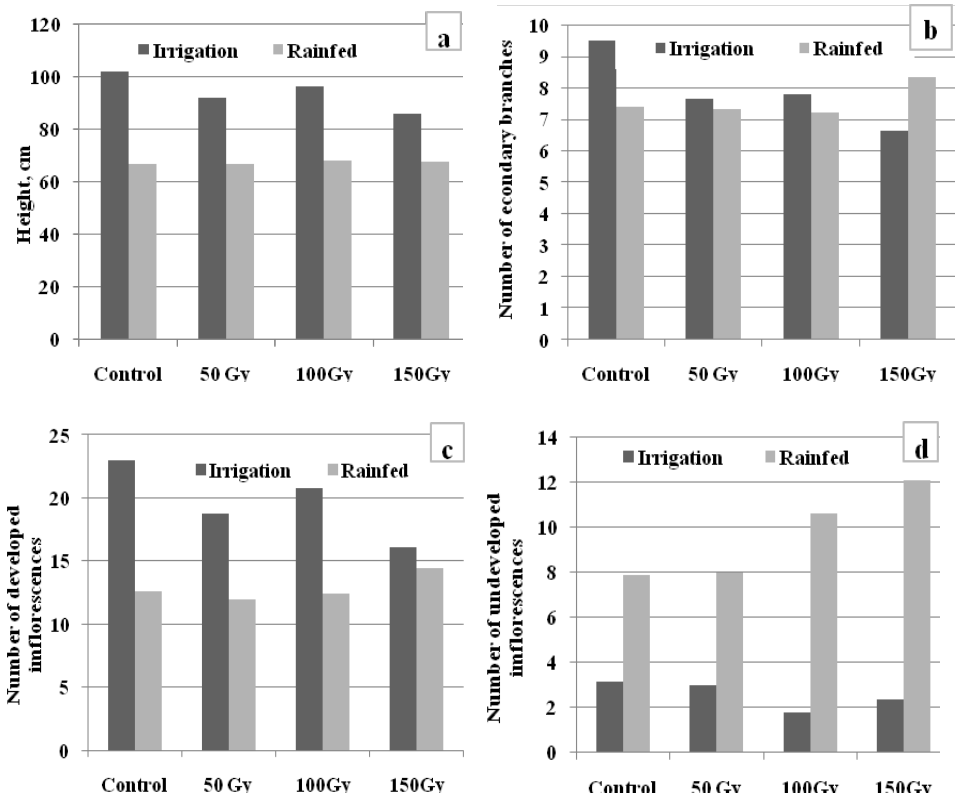

Figure 1. Bio-morphological characters: height (a), number of secondary branches (b), developed (c) and undeveloped (d) inflorescences of safflower grown in different conditions

It was observed that the intact seeds that were not exposed to pre-sowing treatment by gamma radiation under different growth conditions (control) give the plants of dissimilar characters.

Under irrigation conditions (Fig. 1a), in the control plot the plant height varied from 64.0 to 130.0cm (101.80±2.54cm), however under rainfed condition it was 41.0 - 95.0cm (66.86±1.47cm). Similar differences of height between irrigated and non-irrigated plants equal to 8.23 - 33.85cm were evaluated on various genotypes of safflower during two growing seasons (Ozturk et al., 2008).

Additionally, the irrigated safflower were more ramified, with the mean of two secondary branches per plant (Fig.1b); and had 2.0 times more developed inflorescences (Fig. 1c) and 2.5 times less undeveloped inflorescences than the rainfed plants (Fig. 1d). Thus irrigated safflower plants are characterized by better bio-morphological values than plants growing under rainfed conditions.

Pre-sowing irradiation of seeds and subsequent cultivation under irrigation condition led to decreasing in bio-morphological values of safflower plant (Fig.1). A statistically significant difference in comparison with control was

observed on plant height at 50Gy ($p \leq 0.05$) and 150Gy ($p \leq 0.001$) as well as on number of secondary branches at 150Gy ($p \leq 0.01$). Gamma irradiation did not affect the height of rainfed plants. Moreover doses of 50 and 100Gy did not influence on number of secondary branches and developed inflorescences of rainfed safflower. Dose effects of 150Gy were detected as an increase in the number of secondary branches and developed inflorescences as well as, in number of undeveloped inflorescences (Fig. 1).

When compare the factors impact in following mode: radiation and growing conditions such as with or without irrigation, it was detected that the condition had the statistically significant ($p \leq 0.001$) influence on height of safflower, number of developed and undeveloped inflorescences per plant (Tab. 1).

The interaction between radiation and growing condition factors had major contributions at $p \leq 0.01$ to changes in number of secondary branches per plant. Thus, it could be suggested that the bio-morphological characters of safflower plants depends on cultivation conditions more than on gamma radiation doses applied to seeds in pre-sowing time.

The study of growing conditions influence on yield attributing characters of safflower indicated that the seed number per head of control plants was practical equal for irrigated (23.50±1.50) and non-irrigated (21.62±1.16) safflower (Fig.2a). No significant differences of seed number per head between irrigated and non-irrigated plants were also reported (Ozturk et al., 2008). It was shown that this character depends significantly at $p \leq 0.01$ on genotype of safflower and growing season

However, the number of seeds obtained from one control plant cultivated under drip irrigation (536.60±60.22) and rainfed (295.41±29.05) condition varied significantly (Fig. 2b). In addition, the weight of seeds harvested from one irrigated plant was 2.5 times greater than the seeds weight from rainfed plant (Fig. 2c). The seeds of irrigated plants were 1.5 times heavier compared to the seeds of non irrigated safflower; 1000-seed weight was equal 36.67±1.45g for irrigated plants and 25.47±0.97g for plants from rainfed condition (Fig. 2d). The minimum and maximum values of this character in our experiments varied from 10.70 to 60.30g, and our data is in excellent agreement with the results presented by other scientists (Beyyavas et al., 2011; Ahmadzadeh, 2013).

The character 1000-seed weight significant depends on genotype of safflower and interaction between genotype and growing season. Ozturk et al. (2008) reported that seven studied genotypes had higher 1000-seed weight in non-irrigated and three genotypes – in irrigated condition.

According to obtained results, the safflower plants grown under irrigation conditions had better yield attributing characters. Previous studies also reported that the irrigation during safflower grown cycle increased in seeds yield (Lovelli et al., 2007: Istanbulluoglu et al., 2009) and conditions of water stress in safflower reduced its productivity (Eslam, 2011; Singh et al., 2016). In Brazil the seed yield of safflower under irrigation regime was 1,552.1 kg/ha and the mean

value of seed yield under water deficit followed by rehydration regime - 1,144.9 kg/ha (Bortolheiro & Silva, 2017). It was observed (Feyzollahzadeh et al., 2014) that weight of one safflower seed within the various irrigation regimes was significantly different at ($p \leq 0.01$) and modified into the range of 0.040 - 0.055 g. The most direct effect on seed yield was obtained from 1000-seed weight of safflower under irrigation.

Table 1.Impact of radiation and conditions of growth on bio-morphological characters

Factor	**Sum of squares**	**Df**	**Mean square**	**F-ratio**	**P-value**	**Contribution of factor, %**
Height of plant, cm						
Radiation (R)	1764.79	3	588.26	4.71**	0.0033	2.51
Condition (C)	24304.70	1	24304.70	194.50***	0.0000	34.66
Interactions R-C	1938.17	3	646.06	5.17**	0.0018	2.76
Total	70121.90	233				
Secondary branches						
Radiation (R)	42.83	3	14.28	1.83	0.1422	ns
Condition (C)	3.99	1	3.99	0.51	0.4749	ns
Interactions R-C	92.66	3	30.89	3.96**	0.0088	4.86
Total	1904.65	233				
Developed inflorescence per plant						
Radiation (R)	265.75	3	88.58	1.08	0.3573	ns
Condition (C)	1601.19	1	1601.19	19.57***	0.0000	7.29
Interactions R-C	489.06	3	163.02	1.99	0.1160	ns
Total	21964.30	233				
Undeveloped inflorescence per plant						
Radiation (R)	87.52	3	29.17	1.01	0.3883	ns
Condition (C)	1694.14	1	1694.14	58.76***	0.0000	19.28
Interactions R-C	208.40	3	69.47	2.41	0.0679	ns
Total	8789.12	233				

Note: **; *** - denotes the statistically significant difference at p≤0.01; p≤0.001

Pre-sowing irradiation of seeds resulted in some fluctuation of yield attributing characters of plants (Fig. 2). Concerning to irrigated plants the number of seeds per head (Fig. 2a) decreased significantly ($p \leq 0.05$) from 23.50±1.50 (control) to 16.88±1.46 (150Gy). Number and weight of seeds harvested from one plant were also 1.58-1.74 times reduced (Fig. 2b, c), control plant produced a mean of 536.60±60.22 seeds, and safflower from seeds irradiated by 150Gy dose

- 308.0±76.13 seeds ($p \leq 0.1$). On the contrary, the weight of 1000 seeds from irrigated plants augmented depending on the rising of radiation doses (Fig. 2 d).

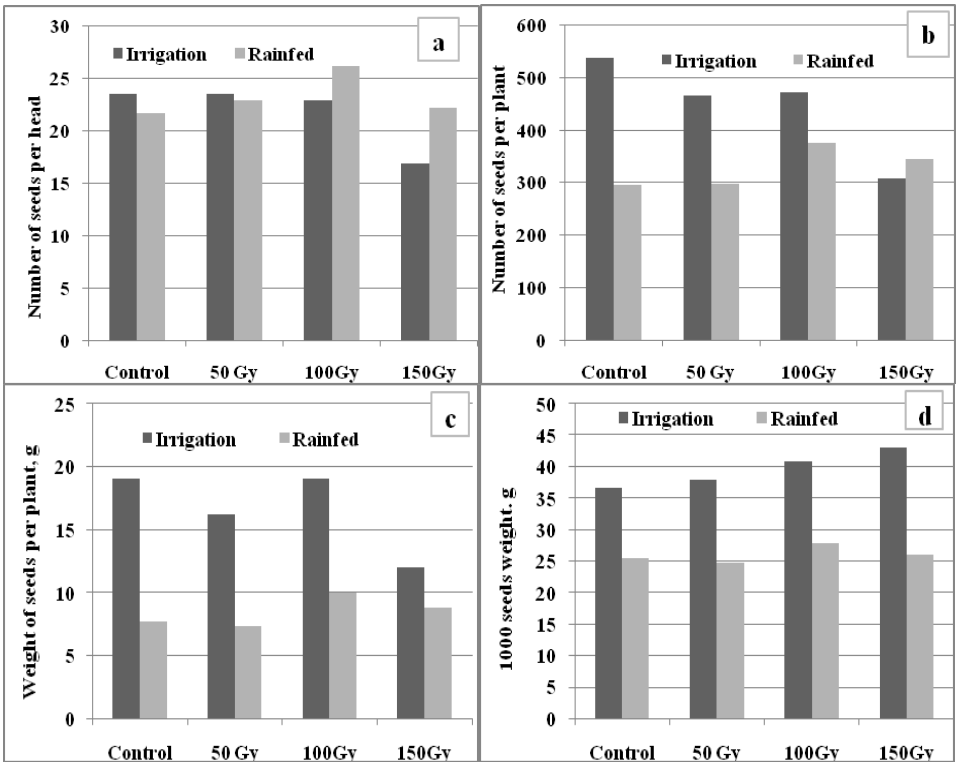

Figure 2. Yield attributing characters: number of seeds per head (a) and per plant (b), weight of seeds per plant (c) and 1000 seeds weight (d) of safflower grown in different conditions

More advantageous influence of gamma radiation was observed on yield attributing characters of safflower grown in rainfed conditions. All studied characters of these plants tended to increase in comparison with the control. The safflower germinated from seeds irradiated by 100Gy and cultivated in rainfed condition possessed the higher values of yield attributed characters (Fig. 2a-d), namely: 26.08±2.10 seeds per head; 374.61±60.63 seeds per plant; 9.94±1.68 g of seeds weight per plant and 27.77±1.42 of 1000-seeds weight. Thus, it was shown that the values of safflower yield attributing characters modified under both factors: the growing condition and pre-sowing gamma irradiation.

The contribution of these factors was evaluated by statistical analysis of the data (Tab. 2). The significant impact of growing condition was observed on the number of seeds per plant at $p \leq 0.01$, weight of seeds per plant and 1000-seeds weight at $p \leq 0.01$. The factor of radiation had the contribution to changes in

1000-seeds weight but the contribution of cultivation condition on this character was 15.7 times stronger.

Neither growing conditions nor irradiation significantly influence on the number of seeds per head (Tab. 2). Thus it could be concluded that the seed yield of safflower predicted by number of heads or number of developed inflorescences per plant. Khalilli et al. (2013) reported that under irrigation the most direct effect of characters on seed yield of safflower was from head diameter and 100-seed weight, and under rainfed condition – from number of head per plant. The results of path analysis reported by Bahmankar et al. (2014) strongly suggested that 1000-seed weight; heads per plants and main head diameter contain positive direct effect on seed yield.

Table 2.Impact of radiation and growing conditions on safflower seed yield

Factor	Sum of squares	Df	Mean square	F-ratio	P-value	Contribution of factor, %
Number of seeds per plant						
Radiation (R)	220720.00	3	73573.20	1.08	0.3580	ns
Condition (C)	470923.00	1	470923.00	6.92**	0.0091	2.78
Interactions R-C	491921.00	3	163974.00	2.41*	0.0679	2.91
Total	1.69288E7	230				
Weight of seeds per plant						
Radiation (R)	310.05	3	103.35	1.67	0.1743	ns
Condition (C)	2262.07	1	2262.07	36.55***	0.0000	12.43
Interactions R-C	416.19	3	138.73	2.24*	0.0843	2.29
Total	18198.70	230				
Weight of 1000 seeds						
Radiation (R)	401.718	3	133.91	2.47*	0.0629	1.92
Condition (C)	6316.02	1	6316.02	116.40***	0.0000	30.20
Interactions R-C	209.20	3	69.73	1.29	0.2803	ns
Total	20915.30	230				
Number of seeds per head						
Radiation (R)	410.77	3	136.93	2.00	0.1149	ns
Condition (C)	75.53	1	75.53	1.10	0.2947	ns
Interactions R-C	360.50	3	120.17	1.76	0.1566	ns
Total	16108.80	230				

Note: *; **; ***- denotes the statistically significant difference at $p \leq 0.1$; $p \leq 0.01$; $p \leq 0.001$ respectively

The strong direct proportional dependences between the developed inflorescences and number of seeds per plant were observed in this study (Tab. 3). The high correlation coefficients (>0.75) of these dependences were detected in all experimental plots of safflower plants. The safflower yield was significantly correlated with number of heads (R^2=0,916) and number of secondary branches (R^2=0,639) per plant (Tabrizi, 2001). The correlation between the number of secondary branches and developed inflorescences of different safflower cultivars also was determined (Beyyavas et al. 2011). Concerning to direct selection of safflower characters for improvement of the seed yield the author opinions differ. Ahmadzadeh et al. (2012) suggested that the improvement of the seed yield will immensely be efficient via 100-seed weight based selection in both conditions. Moreover direct selection could be made for plant height under irrigated conditions and number of seeds per head under non-irrigated conditions. Khalili et al. (2013) concluded that under rainfed conditions selection could be made for number of head per plant which confirm the results of the present study.

Table3. Correlation coefficient between developed inflorescences and seeds per plant

Variant	Control	50Gy	100Gy	150Gy
Irrigation	0.8660	0.8949	0.9552	0.9733
Rainfed	0.9252	0.8781	0.9440	0.7596

CONCLUSIONS

It was observed that the bio-morphological and yield attributing characters of safflower plant could be improved under adequate drip irrigation. The response of safflower growth and yield to pre-sowing treatment of seeds by gamma radiation with doses 50.100.150Gy was various (negative or positive) and depended on subsequent condition of cultivation. The cultivation conditions contributed more for plant growth and seed yield of safflower than the pre-sowing gamma irradiation. The number of head per plant is the most suitable selection character for improving seeds yield in safflower.

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REFERENCES

Ahmadzadeh A. (2013). Genetic diversity and classification of spring safflower (Carthamus tinctorius) cultivars using morphological characters. Advances in Bioresearch. 14 (4), 125-131.

Ahmadzadeh A.R., Alizadeh B., Aghdam Shahryar H., Narimani-Rad M. (2012). Path analysis of the relationships between grain yield and some morphological characters in spring safflower (Carthamus tinctorius) under normal irrigation and drought stress condition. Journal of Medicinal Plant Research. 6 (7), 1268-1271.

Bahmankar M., Nabati D.A., Dehdari M. (2014). Correlation, multiple regression and path analysis for some yield-related traits in safflower. Journal of Biodiversity and Environmental Sciences. 4 (2), 111-118. http://www.innspub.net.

Beyyavas V., Haliloglu H., Copur O., Yilmaz A. (2011). Determination of seed yield and yield components of some safflower (Carthamus tinctorius L.) cultivars, lines and populations under the semi-arid conditions. African Journal of Biotechnology. 10 (4), 527-534. DOI: 10.5897/AJB09.1395.

Bortolheiro F.P.A.P., Silva M.A. (2017). Physiological response and productivity of safflower lines under water deficit and rehydration. Anais da Academia Brasileira de Ciências ((Annals of the Brazilian Academy of Sciences), 89 (4), 3051-3066.

Eslam B.P. (2011). Evaluation of physiological indices for improving water deficit tolerance in spring safflower. J Agric Sci Technol. 13, 327-338.

Feyzollahzadeh M., Motlagh A.M., Nikbakhtt A.M. (2014). Effect of irrigation and nutrient on physical properties of safflower seeds. Int. Agrophys. 28, 7-14. DOI: 10.2478/intag-2013-0022.

Istanbulluoglu A., Gocmen E., Gezer E., Pasa C., Konukcu F. (2009). Effects of water stress at different development stages on yield and water productivity of winter and summer safflower (Carthamus tinctorius L.). Agric. Water Manage. 96, 1429-1434.

Ivanova R. (2016). Theoretical and practical aspects of the introduction of safflower (Carthamus tinctorius L.) in the Republic of Moldova. Studii şi comunicari. Stiintele Naturii. Muzeul Olteniei Craiova, Romania. 32 (2), 48-51.

Ivanova R., Mascenco N., Bejinari M. (2017). Influence of row spacing and bioregulators application on safflower yield. Scientific Papers. Series A. Agronomy, Bucharest, Romania. 60, 281-284

Kaya M.D., BayramİN S., KayaçetİN F., Katar D., Şenay A. (2009). Determination of proper gamma radiation (60Co) dose to induce variation in safflower. Ziraat Fakültesi Dergisi - Süleyman Demirel Üniversitesi. 4 (2), 28-33.

Khalili M., Aboughadareh A.P., Naghavi M.R., Rad H.N. (2013). Path analysis of the relationships between seed yield and some of morphological traits in safflower (Carthamus tinctorius L.) under normal irrigation and rainfed conditions. Technical Journal of Engineering and Applied Sciences. 15 (3), 1692-1696. www.tjeas.com

Lovelli S., Perniola M., Ferrara A., Di Tommaso T. (2007). Yield response factor to water (Ky) and water use efficiency of Carthamus tinctorius L. and Solanum melongena L. Agric. Water Manage. 92, 73–80.

Mozaffari K., Asadi A. A., Rahimi M. (2009).Investigation of yield and earliness traits in safflower mutants in irrigated and drought stress condition Journal of Nuclear Science and Technology. 46, 65-69

Ozturk E., Ozer H., Polat T. (2008). Growth and yield of safflower genotypes grown under irrigated and non-irrigated conditions in a highland environment. Plant Soil Environ. 54 (10), 453-460.

Patil S.A., Ravikumar R.L., Prabhu T.G., Parameshwarappa K.G. (2001). Gamma radiation induced polygenic variation homozygous and heterozygous genotypes of safflower. Reports of 5th International safflower conference, Williston, North Dakota and Sidney, USA. 99-101.

Raudonius S. (2017). Application of statistics in plant and crop research: important issues. Zemdirbyste-Agriculture. 104 (4), 377-382. DOI: 10.13080/z-a.2017.104.048.

Shahrokhnia M.H., Sepaskhah A.R. (2017). Safflower model for simulation of growth and yield under various irrigation strategies, planting methods and nitrogen

fertilization. International Journal of Plant Production. 11 (1), 167-192. http://ijpp.gau.ac.ir/article_3316_40d3bda947310b9e5439b20247b26ebe.pdf

Singh S., Angadi S.V., Grover K., Begna S., Auld D. (2016). Drought response and yield formation of spring safflower under different water regimes in the semiarid Southern High Plains. Agric Water Manage. 163, 354-362.

Tabrizi A.H.O. (2001). Correlation between traits and path analysis for grain and oil yield in spring safflower. Reports of Vth International safflower conferences, July 23-27, 2001. Williston, North Dakota and Sidney, Montana, USA. 95-98.

Parameshwarappa K.G., Meghannavar R.D. (2001). Combining hybridization and irradiation for enhancing genetic variability in early segregating generations of safflower crosses. Reports of 5th International safflower conference, Williston, North Dakota and Sidney, Montana, USA. 83-89