J. Glob. Innov. Agric. Soc. Sci., 2017, 5(1): 5-9.
ISSN (Online): 2311-3839; ISSN (Print): 2312-5225
DOI: https://doi.org/10.22194/JGIASS/5.1.774
http://www.jgiass.com

EFFECTS OF DIFFERENT GIBBERELLIC ACID DOSES ON SEED YIELD, OIL CONTENT AND SOME QUALITY TRAITS OF SAFFLOWER (*Carthamus tinctorius* L.)

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The aim of this study was to determine the effects of gibberellic acid (GA_3) on some yield and quality components of safflower (*Carthamus tinctorius* L.). Research was conducted at Applying Research Field, Faculty of Agriculture, Namık Kemal University, Tekirdağ in spring of 2014 and 2015. The experiment was laid out as a split plot design based on Randomized Complete Block Design with three replications, in which cultivars constituted the main plot with two cultivars (Dinçer and Balcı), and gibberellic acid constituted the sub-plot with four doses (0 ppm, 100 ppm, 200 ppm and 300 ppm). Results showed that variation in doses of gibberellic acid had a significant effect on seeds per capsule, capsule diameter, 1000 seed weight, hull ratio, seed yield and oil ratio of safflower. In this study, results showed that applications of GA_3 significantly changed seed yield, oil ratio, hull ratio and 1000 seed weight of safflower. Especially, seed yield and hull ratio were affected negatively. But, increasing doses of GA_3 (200 and 300 ppm) increased the oil ratio and 1000 seed weight. More research are required to determine effects of growth regulators (PGRs) on safflower and other oil crops.
Keywords: *Carthamus tinctorius* L., gibberellic acid, safflower, quality, yield

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an annual oilseed crop that is adapted to hot and dry environments (Li and Mundel, 1996). Due to the fact that safflower has been cultivated on small area in the world, it is considered as one of alternative oil crops among the other oil crops. The importance of safflower as oilseed crop has increased in recent years, especially with the increasing interest in the production of biofuels (Dordas and Sioulas, 2008). In 2014, total production of safflower seed was 867,659 t in the world. The highest amount of production was in Kazakhstan with 196,000 t (539 kg ha^{-1}); 144,411 t in Mexico (1260 kg ha^{-1}); 113,000 t in India (535 kg ha^{-1}); 94,640 t in USA (1374 kg ha^{-1}) and 87,093 t in Russia (710 kg ha^{-1}). Also, the production of safflower seed was 62,000 t and yield was 1411 kg ha^{-1} in Turkey, 2014. (FAOSTAT, 2016). In Turkey, the main oil seed crops are sunflower, canola and soybean, but farmers don't cultivate safflower in a large area because its seed yield and oil content are low. However, safflower can be a potential oilseed crop for arid and fallow areas. Therefore, research must be done in order to increase seed yield and oil content of safflower. Plant growth regulators are the chemical substances which, when applied in small amounts, modify the growth of plants usually by stimulating part of natural growth regulatory system (Tamilselvi and Vijayaraghavan, 2014). Use of the growth regulators (PGRs) might be a useful alternative to increase crop production. Recently, there has been global realization of the important role of PGRs in increasing crop yield. Gibberellic acid (GA_3) is an important growth regulator that may have many uses to modify the growth, yield and yield contributing characters of plant (Rafeekher *et al.,* 2002). Plant growth regulators are used widely to improve plant performance. Gibberellic acid is one of those growth regulators that have positive effect on plant as enhancing vegetative growth and plant yield and increasing dry weight (Islam *et al.,* 2007). Baydar (2000) reported that although fatty acid syntheses of safflower did not change with any application, oil synthesis increased significantly from 33.8 % to 38.8 % with the application of 300 ppm GA_3 at the budding stage. Potter *et al.,* (1993) observed that GA_3 increased total stem weight, but decreased leaf weight, flower bud number and seed yield of safflower. In another study, applying GA_3 doses increased capsule and seed yield and decreased pollen viability in poppy (Sarıhan, 2004; Khan *et al.,* 2007). Also, Bibi *et al.,* (2003) indicated that increasing concentrations of GA_3 gradually improved oil content of sunflower.

The aim of this study was to find out suitable gibberellic acid doses for increasing the seed yield and some quality characteristics in safflower.

MATERIALS AND METHODS

Climate and Soil Characteristics of Research Field: This research was conducted at Applying Research Field, Faculty of Agriculture, Namık Kemal University in 2014 and 2015. The experimental field was situated in a subtropical area of Suleymanpasa town at the longitude of 27° 34´ E. and the

latitude of 40° 59´ N. with an altitude of 10 meter above sea level. The annual rainfall is about 585 mm with average monthly temperatures of 19.2 °C and 18.8 °C and relative humidity of 74.2 % and 78.1 % over growing season (March to August) for 2014 and 2015, respectively. The soil was clay loam with pH of 7.06, OM of 1.1 % and EC of 4 µS/cm.

Plant Material: The two cultivars of safflower (Dinçer and Balcı) was used as a material of this research. Seeds of a local cultivar of safflower Dinçer and Balcı were obtained from Transitional Zone Agricultural Research Institute, Eskisehir in 2014.

The experiment was conducted as a split plot design based on Randomized Complete Block Design with three replications, in which cultivars constituted the main plot and doses of gibberellic acid constituted the sub-plot. The seeds were sown with the rate of 60 kg ha^{-1} on plots with 6 rows of 5 m long and 20 cm apart in March of two years. Nitrogen and phosphorous were applied at the rate of 120 kg urea and 60 kg diammonium phosphate per hectare, respectively. All phosphorus and half of the nitrogen were applied prior to seed sowing, and the remaining nitrogen was applied in stem elongation stage (45-50 days after planting). In this research different doses of gibberellic acid (0, 100, 200 and 300 ppm) were used. The doses of GA_3 were applied by spraying to plants before flowering stage. In the study, number of seeds per capsule, capsule diameter (cm), 1000 seed weight (g), hull ratio (%), seed yield (kg ha^{-1}) and oil ratio (%) were investigated.

Statistical Analysis: Results of both years were analyzed using MSTAT-C (MSTAT, 1989) statistical software for analysis of variance. Least Significant Difference (LSD) test was used to compare the means of the obtained results in this research ($p < 0.05$).

RESULTS AND DISCUSSION

Number of seeds per capsule: The results of the first year variance analysis showed that significant effect doses of GA_3 and also the interaction effect of the doses of GA_3 and cultivar on number of seeds per capsule were at a level one percent ($p < 0.01$). The results of doses means showed that the highest number of seeds per capsule was in the control plot with 29.483 seeds. Interactions between doses of GA_3 and cultivar showed that the highest number of seeds per capsule in both cultivars were control treatments with 29.200, 29.767 seeds respectively (Dinçer, Balcı) (Table 1). The results of the second year variance analysis showed that significant effect doses of GA_3 on number of seeds per capsule were at a level

Table 1: The effects of different gibberellic acid doses on some yield components of safflower in 2014

Characters	Cultivars	Doses				Means
		0 ppm	100 ppm	200 ppm	300 ppm	
Number of seeds per capsule	Dinçer	29.200 a	17.800 bc	11.500 d	14.500 cd	18.250
	Balcı	29.767 a	14.833 cd	19.900 b	10.933 d	18.858
	Means	29.483 a	16.317 b	15.700 bc	12.717 c	
	$LSD_{0,05}$:	Dose: 3,264	Cultivar x Dose: 4,615			
Capsule diameter (cm)	Dinçer	2.290	2.113	2.097	2.130	2.157
	Balcı	2.390	2.117	2.000	2.070	2.144
	Means	2.340 a	2.115 b	2.048 b	2.100 b	
	$LSD_{0,05}$:	Dose: 0,136				
1000 seed weight (g)	Dinçer	45.825	48.758	53.917	54.548	50.762
	Balcı	45.000	53.025	55.885	54.475	52.096
	Means	45.413 c	50.892 b	54.901 a	54.512 a	
	$LSD_{0,05}$:	Dose: 2,718				
Hull ratio (%)	Dinçer	47.913	51.667	51.507	51.840	50.732 a
	Balcı	40.127	42.067	43.200	44.247	42.410 b
	Means	44.020 b	46.867 a	47.353 a	48.043 a	
	$LSD_{0,05}$:	Cultivar:3,147	Dose: 1,922			
Seed yield (kg ha^{-1})	Dinçer	1,624.2 a	816.0 bc	577.0 cd	491.2 d	877.1
	Balcı	916.6 b	435.2 d	455.4 d	397.2 d	551.1
	Means	1,270.4 a	625.6 b	516.2 b	444.2 b	
	$LSD_{0,05}$:	Dose:19,691	Cultivar x Dose: 26,684			
Oil ratio (%)	Dinçer	31.727 c	31.227 c	30.580 c	40.450 ab	33.496 b
	Balcı	36.853 b	36.743 b	41.053 a	41.993 a	39.161 a
	Means	34.290 b	33.985 b	35.817 b	41.222 a	
	$LSD_{0,05}$:	Cultivar:1,703	Dose: 2,626	Cultivar x Dose: 3,713		

Cultivar means and cultivar x dose interaction with different letter for the same column(s) are significantly different ($p < 0.05$), dose means with different letter for the same row are are significantly different ($p < 0.05$)

Table 2: The effects of different gibberellic acid doses on some yield components of safflower in 2015

Characters	Cultivars	Doses				Means
		0 ppm	100 ppm	200 ppm	300 ppm	
Number of seeds per capsule	Dinçer	26.167	13.967	16.600	13.167	17.475
	Balcı	22.167	18.433	18.033	15.800	18.608
	Means	24.167 a	16.200 b	17.317 b	14.483 b	
	$LSD_{0,05}$:	Dose: 5,846				
Capsule diameter (cm)	Dinçer	2.277	2.087	2.133	2.083	2.145
	Balcı	2.193	2.073	2.173	2.103	2.136
	Means	2.235 a	2.080 b	2.153 ab	2.093 b	
	$LSD_{0,05}$:	Dose: 0,088				
1000 seed weight (g)	Dinçer	52.727	55.120	58.143	58.060	56.012
	Balcı	44.867	49.910	55.900	59.147	52.456
	Means	48.797 c	52.515 b	57.022 a	58.603 a	
	$LSD_{0,05}$:	Dose: 3,400				
Hull ratio (%)	Dinçer	48.747	52.267	52.230	52.280	51.381 a
	Balcı	40.563	41.777	43.523	44.623	42.622 b
	Means	44.655 b	47.022 a	47.877 a	48.452 a	
	$LSD_{0,05}$:	Cultivar:2,870	Dose: 1,763			
Seed yield (kg ha^{-1})	Dinçer	1,715.2	874.0	625.3	606.8	955.3 a
	Balcı	876.9	431.7	318.5	377.7	501.2 b
	Means	1,296.2 a	652.9 b	471.9 b	492.3 b	
	$LSD_{0,05}$:	Cultivar: 30,828 Dose: 25,067				
Oil ratio (%)	Dinçer	38.160 b	35.457 bc	35.710 bc	37.563 bc	36.723
	Balcı	34.763 c	37.403 bc	37.393 bc	41.847 a	37.852
	Means	36.462 b	36.430 b	36.552 b	39.705 a	
	$LSD_{0,05}$:	Dose: 2,051	Cultivar x Dose: 2,900			

Cultivar means and cultivar x dose interaction with different letter for the same column(s) are significantly different ($p < 0.05$), dose means with different letter for the same row are are significantly different ($p < 0.05$)

5 % ($p < 0.05$). The results of doses means showed that the highest number of seeds per capsule was in the control plot with 24.167 seeds (Table 2). Increasing doses of GA_3 decreased the number of seeds per capsule in both years. Number of seeds per capsule had the maximum direct and positive effect on seed yield per plant (Hamid and Saeidi, 2004). Therefore, decrease in number of seeds per capsule can cause seed yield losses as well.

Capsule diameter (cm): The results of both years variance analysis showed that significant effect doses of GA_3 on capsule diameter were at a level 1 % ($p < 0.01$). The results of doses means showed that the highest capsule diameter was in the control plot with 2.340, 2.235 cm respectively (2014, 2015) (Table 1, Table 2). Increasing doses of GA_3 decreased the capsule diameter in both 2014 and 2015. Camas *et al.*, (2005) reported that seed yield, number of seeds per capsule, 1000 seed weight and oil content positively and significantly correlated with capsule diameter.

1000 seed weight (g): The results of both years variance analysis showed that significant effect doses of GA_3 on 1000 seed weight were at a level 1 % ($p < 0.01$). In the first year, the highest 1000 seed weight was obtained by applications 200 and 300 ppm GA_3 respectively (54.901, 54.512 g) (Table 1). In the second year, the highest 1000 seed weight was obtained by applications 200 and 300 ppm GA_3 respectively (57.022, 58.603 g) (Table 2). Results showed that 1000 seed weight increased with increasing doses of GA_3 from 0 to 300 ppm. Jafri *et al.,* (2015) and Naghashzadeh *et al.,* (2009) found the similar results for 1000 seed weight.

Hull ratio (%): The results of both years variance analysis showed significant effect doses of GA_3 and cultivars on hull ratio were at a level one percent ($p < 0.01$). In the first year, the result of mean compared showed that the highest hull ratio obtained from cultivar Dinçer (50.732 %). Also, the highest hull ratio was obtained by applications 100, 200 and 300 ppm GA_3 respectively (46.867, 47.353 and 48.043 %) (Table 1). In the second year, the result of mean compared showed that the highest hull ratio obtained from again cultivar Dinçer (51.381 %). Also, the highest hull ratio was obtained by applications 100, 200 and 300 ppm GA_3 respectively (47.022, 47.877 and 48.452 %) (Table 2). According to results, hull ratio showed a significant difference due to applications of GA_3. Results showed that hull ratio increased with increasing doses of GA_3 from 0 to 300 ppm. Hull content showed significant positive association with seed weight but was negatively related to oil content (Ranga Roa *et al.,* 1977; Mandal, 1990). Baydar

(2002) reported that seeds from GA_3 treated plants had more hull ratio than seeds from the non-GA_3 treated plants. This result is associated with our results.

Seed yield (kg ha^{-1}): The results of the first year variance analysis showed that significant effect doses of GA_3 ($p < 0.01$), and also the interaction effect of the doses of GA_3 and cultivar on seed yield were at a level 5 % ($p < 0.05$). The results of doses means showed that the highest seed yield was in the control plot with 1,270.4 kg ha^{-1}. Interactions between doses of GA_3 and cultivar the highest seed yield were obtained control treatments in Dinçer cultivar with 1,624.2 kg ha^{-1} (Table 1). The results of the second year variance analysis showed that significant effect doses of GA_3 and cultivars on seed yield were at a level 1 % and level 5 % respectively ($p < 0.01$, $p < 0.05$). The results of cultivars means showed that the highest seed yield obtained from cultivar Dinçer (955,3 kg ha^{-1}). Also, the results of doses means showed that the highest seed yield was in the control plot with 1,296.2 kg ha^{-1} (Table 2). According to the path analysis, seed yield was determined by head diameter, capsules/plant and seeds/capsule, because these characters had highly positive significant direct effects on seed yield (Arslan, 2007). Results showed that GA_3 applications affected significantly seed yield. Seed yield decreased with increasing GA_3 doses from 0 to 300 ppm. Potter *et al.*, (1993) reported that GA_3 decreased leaf weight, flower bud number and seed yield of safflower. Also, Baydar (2000) indicated that GA_3 applications significantly decreased the seed yield per plant in safflower. These results are associated with our results.

Oil ratio (%): The results of the first year variance analysis showed that significant effect doses of GA_3 and cultivars ($p < 0.01$), and also the interaction effect of the doses of GA_3 and cultivar on oil ratio were at a level 5 % ($p < 0.05$). The results of cultivars means showed that the highest oil ratio obtained from cultivar Balcı (39.161 %). Interactions between doses of GA_3 and cultivar the highest oil ratio were obtained in Balcı cultivar by applications 200 and 300 ppm GA_3 respectively (41.053 and 41.993 %). Also, the results of doses means showed that the highest oil ratio was obtained by applications 300 ppm GA_3 with 41.222 % (Table 1). The results of the second year variance analysis showed that significant effect doses of GA_3 and also the interaction effect of the doses of GA_3 and cultivar on oil ratio were at a level 5 % ($p < 0.05$). Interactions between doses of GA_3 and cultivar the highest oil ratio were obtained in Balcı cultivar by applications 300 ppm GA_3 (41.847 %). Also, the results of doses means showed the highest oil ratio was obtained by applications 300 ppm GA_3 with 39.705 % (Table 2). Results showed that increasing doses of GA_3 increased the oil ratio in both 2014 and 2015. Baydar (2000) reported that oil content increased significantly from 33.8 % to 38.8 % with the application of 300 ppm GA_3 at the budding stage. Also, Bibi *et al.*, (2003) indicated that increasing concentrations of GA_3 gradually improved oil content of sunflower. This result is associated with our results.

Conclusions: The above review of literature generally establishes that growth regulators (PGRs) and especially GA_3 have stimulant effect on growth and development of plants. From the findings of the present study, results showed that applications of GA_3 significantly changed seed yield, oil ratio, hull ratio and 1000 seed weight of safflower. Especially, seed yield and hull ratio were affected negatively. But, increasing doses of GA_3 increased the oil ratio and 1000 seed weight. However, it was not sufficient to increase the oil yield per decare. Further studies as application of GA_3 in other development stages (emergence, stem elongation etc.) are required to determine effects of plant growth regulators (PGRs) on safflower.

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