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Effect of drought stress on the damage of safflower weevils, on three cultivars of *Carthamus tinctorius* L.

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Abstract. In this study, effect of drought stress on the damage of safflower weevils was evaluated on three cultivars of safflower, *Carthamus tinctorius* L. during 2011. The experimental design was split plot arrangement in completely randomized design. Where levels of irrigation including complete irrigation during whole growing season (S1), cutting irrigation at flowering (S2) and cutting irrigation at heading bud formatting (S3) as main plot, and safflower cultivars including Goldasht, Padidih and C44 as subplot. Percentage of infested boll and seed weight were sampled in the experimental plots. Results indicated that there was significant difference among drought stresses in 5% level in percentage of infested bolls. Also, percentage of infested bolls and 1000-seed weight in healthy boll had significant difference between cultivars. The highest and lowest percentage of infested bolls was belonged to non-stress conditions (11.33%) and stress S2 (6.45%), respectively. The highest and lowest percentage of infested bolls was related to Goldasht (13.68%) and Padideh cultivars (3.43%), respectively.

Key words: safflower, cultivars, weevils, drought stress.

Introduction

Safflower, *Carthamus tinctorius* L. is an annual plant from the composite family, Asteraceae and has vertical roots that can tolerate against environmental stresses such as salinity and water (Lovelli et al. 2007, Bassil & Kaffka 2002, Bassiri et al. 1977). Thisis an oil plant that its oil has been considered as valuable oil due to having more than 90% unsaturated fatty acids, especially linoleic and oleic acids (Mundel et al. 1995). Safflower has potential to produce yield about 4 tons per hectare and the yield of 2 tons per hectare is considered as good yield (Omidi Tabrizi et al. 2000). The average of safflower yield is about 700 kg per hectare in Iran which is close to the average in the world (Foruzan 1999). Two species of weevil including *Larinus flavescens* Gemar and *L. liliputanus* Fst. (Col.: Curculionidae) caused damage to safflower farms of Tehran (Iran). This pest by attacking to safflower seeds and feeding of safflower lower bolls is reducing product. *L. flavescens* has caused damage to plant up to 16 percent in Australia and France (Grace1 et al. 2002). This species is also seen in Turkey, Mediterranean countries and Spain (Pehlivan et al. 2005, Sanz Benito et al. 1996, Alonso-Zarazaga et al. 2006). *Larinus flavescens* has caused damage on safflower in Kohgiluyeh and Boyer-Ahmad province of Iran (Saeidi & Adam 2011). Another species, *L. liliputanus* is caused to reduce quality of safflower yield in Isfahan province of Iran (Nematollahi 2010). Use of resistant cultivars has many advantages in integrated pest management (IPM). Resistant cultivars reduce pest damage with the least cost for the farmer (Reagan et al. 1997). Resistant cultivars according to the type of resistance mechanism could influenced pest population in a short term or long term and or despite pest not seen the yield reduction in the product (Nuri- ghonblani 1995). In some plants such as cauliflower, use of resistant cultivars reduces pest density and increases efficiency of different parasitoids (Hasanshahi 2012, Hasanshahi et al. 2012c). Use of suitable plant species and improved cultivars that having desirable performance and tolerant to moisture stress conditions, provides possible better use of available water resources and is causes to development of area under cultivation and increase production efficiency (Miladi 2010). Safflower provides part of seed yield (65 to 95%) by the transfer of carbohydrate reserves before pollination to seed during water deficit in late season (Koutroubas et al. 2004). Safflower is sensitive to drought stress in reproductive sub phases and drought stress during early reproductive growth stages and reduces capitulum and seed numbers per capitulum (Saini & Westgate 2000). Many researchers have pointed to effects of drought stress on safflower yield reduction (Mozaffari & Asadi 2006, Effatdoust et al. 2004, Kar et al. 2007, Hayashi & Hanada 1985, Mosallayi et al. 2011, Tarighi et al. 2012). Some of cultural methods such as irrigation can be effective on population and the amount of damages to safflower, so that drought might be effective in amount of pest damages. For example, drought has adverse impact on maize crop production in 2003 in France and reduced its yield (Faure et al. 2004). Therefore drought stress can be affect on population density of safflower pests including *Uroleucon carthami* Hille Ris Lambers, *Empoasca decipiens* Paoli, *Acanthophilus helianthi* Rossi, *Heliothis peltigera* Den and Shi, *Agrotis segetum* Schiff, *Oxycarenus pallens* H. Sch and *Tetranychus urticae* Koch. Several studies in relation with effect of drought stress on pest population of different plants have been done. Previous study showed that the weevils are major pest of safflower in south of Tehran. So, this research was aims to study the drought stress effect on weevil damage in different cultivars and for the first time in south of Tehran.

Materials and methods

This study was conducted at the Shahed University research field (south of Tehran) during 2011. Effect of three type of irrigation stress including 50 mL evaporation from evaporation pan (S1), 100 ml evaporation from evaporation pan or almost every 5 days irrigation

Table 1. Climatic and soil characteristics of experimental area, Shahed University, Tehran, Iran.

Height from sea surface (m)	Annual average rainfall (mm)	Annual average temperature (C°)	Soil texture	K (mg.kg-1)	P (mg.kg-1)	Percent Nitrogen	Organic Matter	Electrical conductiv-ity	Acidity (PH)
1500	216	17.1	Loam	170	7.6	0.05	0.57	1.2	7.71

Table 2. Analysis of variance of different characteristics in split plot design.

	Source	df	Mean of Square	F
percentage of infested boll	Stress effect	2	0.01	3.39*
	Cultivar effect	2	0.03	8.62**
	Interaction effect	4	0.01	8.08**
healthy 1000-seed weight in infested boll	Stress effect	2	107.04	4.49*
	Cultivar effect	2	184.32	9.62**
	Interaction effect	4	101.95	14.87**
infested 1000-seed weight in infested boll	Stress effect	2	144.98	9.36**
	Cultivar effect	2	42.90	1.98ns
	Interaction effect	4	80.03	13.46**
healthy 1000-seed weight in healthy boll	Stress effect	2	272.88	6.58**
	Cultivar effect	2	494.93	17.69**
	Interaction effect	4	204.88	20.19**

** Significant at 1% probability level;* Significant at 5% probability level

Table 3. Comparison of mean (±SE) of different characteristics on three safflower cultivars with Duncan Multiple Range test.

Cultivars	percentage of infested boll	healthy 1000-seed weight in infested boll	infested 1000-seed weight in infested boll	healthy 1000-seed weight in healthy boll
Goldasht	13.85±2.04a	33.69±1.01b	18.99±0.52a	31.99±0.91c
Padideh	3.43±1.18b	41.31±1.31a	21.04±0.61a	44.77±1.67a
C44	9.11±1.57a	35.93±1.43b	17.26±2.18a	37.35±1.82b

100 ml evaporation from evaporation pan or almost every 5 days irrigation (S2) and 150 mL evaporation from evaporation pan (S3); The same letters in each column shows no significant difference

(S2) and 150 mL evaporation from evaporation pan (S3) was evaluated on weevil damage on three cultivars: Goldasht, Padide and C44 with a split plot arrangement in completely randomized design with six replications. Different drought stress was applied at flowering time. Each plot was composed of six lines of 8m long for every cultivar spacing was considered between the rows 25 cm and spacing on rows 5 cm and spacing between the each plot 50 cm. Four middle rows were selected for determine traits and two lateral rows were considered as marginal. Sampling was done at the end of the season (last week of July). So that 15 bolls were selected randomly from each row and for each cultivar in each drought, then they were transferred to the laboratory. Pollution status was studied with boll fission in lab and percentage of infested bolls was calculated. To obtain healthy 1000- seeds weight in healthy bolls, seeds of healthy bolls were separated. Healthy seeds and infected seeds were separated from the infected bolls, separately. Then the seeds were dried in shadow condition and seeds were weighed by using digital scale with a precision of 0.0001 gr, separately.

Statistical analysis was carried using SAS Institute software (1997). The means of different characteristics on cultivars were compared using Duncan Multiple Range Test (DMRT, α = 0.05 and mean comparison of the main plot (stress) was performed using LSD test.

Results

Water retention in different soils was differed due to the texture and other physical characteristics of the soil. Also climatic and wealthy conditions is effective on soil moisture and water retention in the soil. Therefore climatic characteristics and soil profile of Shahed University research field is given in Table 1.

Results of data analysis of different characteristics on different cultivars are given in Table 2. Statistical analysis showed that there were significant differences between percentage of infested bolls in different cultivars (P<0.01). According to Table 3, percentage of infested bolls by weevils on Goldasht and C44 cultivars was higher than Padide cultivar and showed a significant difference. In this study, percentage of infested bolls in different cultivars was estimated about 8% that showed high populations of pest in the region. Result of infested 1000-seed weight in infested bolls in different cultivars showed that there are not significant differences. Also healthy 1000-seed weight in healthy bolls in different cultivars have significant differences (P<0.01). So that this attribute in Goldasht and C44 cultivars is less than Padide cultivar. 1000-seed weight was increased in infested bolls of Goldasht cultivar. Probably a compensation phenomenon has occurred in Goldasht cultivar. According to these results, infested 1000-seed weight reduced sharply. By comparing the mean of healthy 1000-seed weight in healthy bolls three cultivars were placed in separate groups. Healthy 1000-seed weight in healthy bolls in Goldasht cultivar was less than two other cultivars and Padide cultivar had the highest healthy 1000-seed weight. According to Table 2, in-

Table 4. Analysis of variance of different characteristics on three irrigation stress.

Treatments	percentage of infested boll		healthy 1000-seed weight in infested boll		infested 1000-seed weight in infested boll		healthy 1000-seed weight in healthy boll	
	Mean of Square	F	Mean of Square	F	Mean of Square	F	Mean of Square	F
50 mL evaporation from evaporation pan (S1)	0.02	12.46**	5.59	2.19ns	37.94	7.71*	105.97	14.03**
100 ml evaporation from evaporation pan or almost irrigation every 5 days (S2)	0.01	5.86*	96.39	27.44**	33.44	4.62*	266.70	30.21**
150 mL evaporation from evaporation pan (S3)	0.01	4.49*	198.77	13.70**	103.76	18.26**	12.37	0.01**

** Significant at 1% probability level; ns Non significant

Table 5. Mean (±SE) of different characteristics on three irrigation stress with LSD test.

Treatments	Percentage of infested boll	Healthy 1000-seed weight in infested boll	Infested 1000-seed weight in infested boll	Healthy 1000-seed weight in healthy boll
50 mL evaporation from evaporation pan (S1)	11.33±2.35a	36.86±1.78ab	18.73±0.95b	32.71±1.45b
100 ml evaporation from evaporation pan or almost irrigation every 5 days (S2)	6.45±1.61b	40.02±1.30a	22.74±0.99a	41.91±2.15a
150 mL evaporation from evaporation pan (S3)	6.15±1.45b	34.05±2.00b	15.82±1.39b	39.48±1.89a

The same letters in each column shows no significant difference

Table 6. Mean (±SE) of different characteristics on cultivars with LSD test in each the stress.

Treatments	Cultivar	Percentage of infested boll	Healthy 1000-seed weight in infested boll	Infested 1000-seed weight in infested boll	Healthy 1000-seed weight in healthy boll
50 mL evaporation from evaporation pan (S1)	Goldasht	22.29±2.62a	35.85±0.96a	18.53±0.74ab	29.45±1.43b
	Padideh	4.34±2.08c	36.58±0.35a	21.91±1.09a	38.65±0.89a
	C44	14.07±2.08b	38.16±0.92a	15.76±1.38c	30.05±1.67b
100 ml evaporation from evaporation pan or almost every 5 days irrigation (S2)	Goldasht	14.05±2.06a	35.40±1.46c	20.53±0.65b	33.07±1.92c
	Padideh	4.34±2.08b	45.17±0.60a	21.68±0.49b	49.16±1.25a
	C44	4.40±2.09b	39.49±0.35b	26.01±2.17a	43.52±1.15b
150 mL evaporation from evaporation pan (S3)	Goldasht	8.33±0.01ab	29.81±0.84b	17.91±0.92a	33.45±0.29b
	Padideh	2.06±2.40b	42.19±2.33a	19.53±1.22a	46.52±2.95a
	C44	11.86±2.41a	30.15±2.16b	10.01±1.38b	38.48±1.32b

The same letters in each column shows no significant difference

teraction effects of different stress and cultivars showed significant differences in all studied traits. In other words, the studied traits of each cultivar changed with the change of different stress and these changes showed significant difference. According to Table 4, there is a significant difference between all measured traits except healthy 1000-seed weight in infested bolls of three cultivars in different type of stress. According to Table 2 stress effects on all measured traits showed significant difference (P<0.01). Mean comparison of main treatment (different stress) is given in Table 5. The lowest percentage of infested bolls was calculated in S2 and S3. The highest percentage of infested bolls was calculated in S1 and this treatment showed significant difference with two other stress type.

Healthy 1000-seed weight in infested bolls in S2 was higher than other treatments. Healthy 1000-seed weight in infested bolls in S3 due to excessive drought was lowest than other treatments.

As regards effect of stress with type of cultivar have significant interaction effect, therefore stress effects on pest damage and plant yield was different in each cultivar and stress effects for each cultivar should be evaluated separately. Mean of each trait in different cultivars and different stress separately is given in Table 6. Padide cultivar is resistant cultivar against weevil damage with 4.34 percentage of infested bolls in S1. Goldasht cultivar is susceptible cultivar to weevil damage with 22.29 percentage of infested S1. As shown in Table 6, padide cultivar is resistant cultivars against weevil damage in term of normal irrigation (S1). But healthy 1000-seed weight in infested bolls is more than healthy 1000-seed weight in healthy bolls in Goldasht and C44 cultivars. Padide cultivar is resistant cultivar against weevil damage S2 and S3. Goldasht cultivar is susceptible cultivar to weevil damage in all stresses. But this cultivar has compensation power of weevil damage and can be compensated some of weevil damage.

Discussion

It seems that infestation of number of seeds in the boll is caused to reduce healthy 1000-seed weight in healthy bolls and healthy 1000-seed weight in infested bolls is more than healthy 1000-seed weight in healthy bolls and compensation phenomena has occurred in Goldasht cultivar. This trend is observed in Goldasht cultivar S2. Due to excess drought in S3 compensation phenomenon is not observed. In such conditions, plant nutritional deficiencies due to inadequate absorption of nutrients by the plant reduces the strength of structural and physical of plant (Luna 1988). Therefore drought stress value increases pest resistance but severe drought stress increases pest population. The main reason for pest population increase under drought stress is changes in plant gene expression and increasing sugars and nitrogen compounds in plants (Caldeira et al 2002). In this regard, several studies showed that high stress is caused to increase pest population, including aphids. For example, Hatami et al. (2008) were observed that the highest population density of *Uroleucon carthami* (H.R.L.) on safflower was occurred in severe drought. Also walker (1954) was reported that drought periods can strengthen outbreak of *Toxoptera gramiunum* Rond. So that the density of *T. gramiunum* increases on plants under drought stress. Drought stress is caused to increase healthy 1000-seed weight in healthy bolls as compared to control. But by increasing drought stress, healthy 1000-seed weight in healthy bolls was reduced. Increasing 1000-seed weight under drought stress has been reported in another experiment, including Abulhashem et al. (1998), Haydari & Asad (1998), Hasanshahi et al. (2012a) and Ehdaei & Nourmohamadi (1983). Studies showed that percentage of infested bolls to Safflower fly is variable from 5 to 35% in Kuse cultivar in different drought stress (Hatami et al. 2008). Damage of safflower weevil in S3 is less than S1. It seems that this stress is caused plant resistance to weevil. Of course different stresses are caused to reduce somewhat pest damage and if this stress partially increased, pest damage as safflower fly was increased (Hasanshahi & Askarianzadeh 2012). In general, by increasing severity of drought stress more damage rate of number of pests is occurred. Severe pest damage on safflower yield reduction is due to stress effect in increasing pest population and plant intolerance in pest damage under stress. Imbalances of nutrient elements in plants increases population of safflower fly under drought stress conditions. Usually the balance of nutrient elements can increase resistance to insects (Luna 1988). So that less or more absorption of elements under drought stress can change the primary or secondary metabolism of plant and is caused to dysfunction in resistance or tolerance to insect damage in plant (Hatami et al. 2008). As regards to seed yield (healthy 1000-seed weight in healthy bolls) S2 produce more than seed yield in compare to S3, and so moderate drought stress can be recommended to decrease pest damage and increase safflower yield. Amount of damages of safflower fly on different safflower cultivars according to reports of different researchers was calculated 69.5, 96.7 to 3.99, 6.3 and 32.6 to 100%, respectively (Jakhmola & Yadav 1980, Al-Ali et al. 1977, Vaishampayan & Kapoor 1970, Verma 1974). Hasanshahi & Askarianzadeh (2012) reported that amount of damages of safflower fly in different cultivars is more than 50%. On crops like safflower, different pest attack including safflower fly is caused direct damage of pests with reduce the amount of seed production and reducing amount of oil in infected seeds compared with healthy seeds is reached to 37.8% (Jakhmola & Yadav 1980).

Hasanshahi et al. (2012b) calculated direct damage of Safflower fly in Goldasht, Padide and C44 cultivars equal to 50.09, 68.05 and 66.66%, respectively. Hasanshahi & Askarianzadeh (2012) were observed compensation phenomenon of Goldasht cultivar in amount of damage by safflower fly. Severe drought stress conditions will provide condition for safflower fly damage and is caused to increase pest damage. However slight drought stress will significant difference in the reduction of percentage of infested bolls of safflower fly and increasing of healthy 1000-seed weight in healthy bolls. Also are caused savings in water consumption (Hasanshahi & Askarianzadeh 2012).

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