Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jls.htm
2014 Vol. 4 (3) July-September, pp. 50-54/Khalilvand and Herischi.
Research Article

EFFECT OF METHANOL FOLIAR APPLICATION ON SUNFLOWER (*HELIANTHUS ANNUUS* L.) PERFORMANCE UNDER DIFFERENT REGIMES OF IRRIGATION

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ABSTRACT
In order to evaluate the effect of methanol foliar application on sunflower (Helianthus annuus L.) performance under different regimes of irrigation, an experiment was conducted in the split plot form based on Completely Randomized Block Design with three replications during growing seasons of 2011-2012. Treatments were water deficit stress in four levels: a_1: severe stress (25% FC irrigation), a_2: mild stress (50% FC irrigation), a_3: fair stress (75% FC irrigation) and a_4: normal irrigation (100% FC irrigation) and the foliar application of methanol in six levels [b_1:0, b_2:7, b_3:14, b_4:21, b_5:28 and b_6:35 (v/v)]. The analysis of variance showed significant effect of interaction between water deficit stress and methanol foliar application on oil yield per plant, dry weight per unit area, Full and empty seeds percentage ($p<0.01$). 21% (v/v) Methanol foliar application and normal irrigation produced 69% more oil yield per plant, 2/4 times more dry weight. Besides, the results also proved that 21% (v/v) methanol foliar application in 100% FC had the lowest empty seeds percentage (4/07%). Furthermore, the highest full seeds percentage (95/92) was observed for 7% (v/v) methanol and normal irrigation.

Keywords: *Methanol, Sunflower, Water Deficit Stress*

INTRODUCTION
Water deficit is a major environmental factor restricting plant growth, development and productivity, particularly in arid regions more than any other single environmental factor (Huai-Fu *et al.*, 2014). Water stress reduces photosynthesis via reduction in leaf area, closing stomata and reduction of carbon fixation efficiency (Abbasi *et al.*, 2014). Photosynthesis is the substantial process for the production of organic matter in plants (Andres *et al.*, 1989).

Usually, the amount of the produced dry matter has a direct relationship with the photosynthesis efficiency of the plant and also the way in which CO2 fixation occurs in crops. Today, in order to achieve this goal, compounds such as methanol, ethanol, propanol, butanol and amino acids like glycine, glutamate and asparate are used. Recent investigation showed that C_3 crops yield and growth increased via methanol spray and methanol may act as C source for these crops. Therefore, Methanol spray is a method which increases crop CO_2 fixation in unit area (Hemming and Criddle, 1995).

Sadeghi-Shoae *et al.*, (2014) reported that methanol foliar application enhanced total dry matter (TDM), root yield (RY), sugar yield (SY) and white yield sugar.

Thus, methanol spraying results in increased production and reduces plants' water requirement in warm and dry conditions (Aslani *et al.*, 2011). Spraying with 25% volume level significantly increased in plant height, number of lateral root, root dry weight, tap root length, root area, root area to leaf area ratio, total root length, root to shoot ratio and leaf area compared with control (Hossinzadeh *et al.*, 2012).

Positive effects of methanol foliar application on growth of other plant have been confirmed in previous studies. Thus, the objectives of this study were to investigate the effects of methanol foliar application on sunflower performance under different regimes of irrigation.

MATERIALS AND METHODS

Field experiment

The field experiment was carried out in split plot form by Completely Randomized Block Design with three replicates at the Research Station of the Islamic Azad University, Tabriz Branch, north-western Iran, during the 2011 - 2012. The sunflower cultivar used was Record (a Romanian open-pollinated cultivar that is widely planted in Iran). The first factor was water deficit stress in four levels: a1: severe stress (25% FC irrigation), a2: mild stress (50% FC irrigation), a3: fair stress (75% FC irrigation) and a4: normal irrigation (100% FC irrigation). The second factor was the foliar application of methanol in six levels [b1:0, b2:7, b3:14, b4:21, b5:28 and b6:35 volumetric percentage (v/v)] that to prevent of methanol poisoning at light presence, 1 g lit-1 Glycine and 1 mg lit-1 Tetrahydrofolate (THF) were added to prepared solution (Bayat *et al.*, 2012). In all treatments, methanol spray was applied 4 times during stages of sunflower development contain: V-8 (determined by counting the number of true leaves at least 4 cm in length), R-4 (The inflorescence begins to open), R-6 (Flowering is complete and the ray flowers are wilting) and R-7 (The back of the head has started to turn a pale yellow colour). Flooding irrigation was conducted and all of treatments were irrigated completely prior to R-4 stage. Each plot consists of 5 rows, 60 cm row spacing and 20 cm plant interval. There were 2-5 seeds beside each other and they were thinned at three leaves stage to obtain plant density of 8 plants per m^2.

Statistical Analysis

In order to check the normality of data, analysis of variance, and mean comparison MSTAT-C software were used. The means of the treatments were compared using the least significant difference (LSD) test at $P < 0.05$.

RESULTS AND DISCUSSION

The analysis of variance showed significant effect of interaction between water deficit stress and methanol foliar application on oil yield, dry weight/unit area, Full and empty seeds percentage, ($p<0.01$), (table 1).

Table1: **The analysis of variance of measured traits in experiment**

S.O.V	df	Oil yield	Dry weight /unit area	Full seeds percentage	Empty seeds percentage
Rep	2	20/44ns	184190757ns	7/87ns	2959ns
WDS	3	116/77 ns	304500048 ns	6/57ns	14211ns
Error	6	118	154859865	40/155	5199
MFA	5	212/4 ns	62348892ns	6/27ns	8210ns
MFA×WDS	15	1005**	147869282**	27/95**	14570**
Error	40	782	47997538	8/517	3959
CV		10/13	25/42	14/09	41/86

** and ** significant at 5% &1% respectively, WDS: Water Deficit Stress, FA: Foliar application*

Oil Yield

In normal irrigation (100% FC), methanol foliar application with 21% (v/v) indicated the highest oil yield per plant (53/34 g) and severe stress (25% FC) at 0% methanol application produced the lowest oil yield per plant (31/42 g) (table 2). Since water deficit stress was exerted from the R-4 stage, 25% and 50% FC irrigation treatments received less water than other treatments and water deficit stress decreased yield component such as biomass and seed yield. However, this study showed that levels of methanol effected all characteristics and methanol spraying decreased the negative effects of water deficit stress.

Interestingly, water deficit stress condition, oil yield was reduced with increase in amount of methanol from 28- 35 [v/v] so that their yield were less than 7-21 [v/v] probably because of the decrease in seed yield. Mirakhori *et al.*, (2009) and Bayat *et al.*, (2012) demonstrated that 21% (v/v) methanol spraying under water deficit stress had the greatest effect on yield, and other physiological traits. Paknejad *et al.*, (2012) indicated that under deficit irrigation, methanol spray every 7 days in the morning and foliar application of methanol every 21 days presented the uppermost (573.29 kg ha-1) and least (364.30 kg ha-1) oil yield, respectively.

Dry Weight/Unit Area

21% (v/v) methanol foliar application in 100% FC and 7%(v/v) methanol foliar application in 25% FC had the highest (3723 gm^{-2}) and the lowest (1532 gm^{-2}) dry weight respectively (table 2). Dry matter production per unit area is the first Condition for achieving high yield per unit area, because about 90% of the dry weight is due to the CO2 assimilation by photosynthesis, therefore strategies that increase CO2 fixation in crops can be considered as options to enhance their yield (Abdel-Latif *et al.*, 1996). Sadeghi-Shoae *et al.*, (2014) reported that methanol foliar application enhanced total dry matter. Several studies have been shown that foliar application of methanol can prevent of biomass reduction (Paknejad *et al.*, 2009; Abbasi *et al.*, 2014; Hossinzadeh *et al.*, 2012).

Table 2: **Mean comparison of interaction between methanol foliar application and deferent regimes of irrigation**

WDS	MFA	Oil Yield (g/plant)	Dry weight (gm^{-2})	Full seeds percentage	Empty seeds percentage
25% FC	0	31/42	2637	82/09	28/43
	7	42/91	1532	91/22	17/36
	14	41/38	2036	83/37	16/62
	21	33/94	2857	89/05	10/95
	28	40/26	1778	88/27	11/72
	35	43/41	2170	86/00	17/90
50% FC	0	42/07	2519	83/65	8/800
	7	46/07	3628	91/19	16/34
	14	47/57	2669	92/33	7/660
	21	44/03	329	90/43	9/553
	28	42/82	2994	90/20	5/800
	35	40/6	2447	84/79	15/20
75% FC	0	40/08	3266	85/76	14/23
	7	44/01	3723	88/55	11/44
	14	47/17	2451	93/98	13/99
	21	46/83	2422	94/19	12/16
	28	49/81	2682	86/97	13/02
	35	42/33	3522	87/83	8/770
100% FC	0	39/89	1801	82/64	6/010
	7	52/48	2714	95/92	6/700
	14	52/75	3395	93/30	7/680
	21	53/34	3723	92/32	4/073
	28	38/4	2651	90/69	9/793
	35	46/99	1701	71/57	9/310
LSD5%		5/84	990/1	7/657	7/658

WDS: Water Deficit Stress, MFA: Methanol Foliar application

Full Seeds Percentage

The results showed that the highest (3723 g) and the lowest (82/09) Full seeds percentage were for 7% (v/v) methanol foliar application in 100% FC and 0%(v/v) methanol foliar application in 25% FC respectively (table 2).

Empty Seeds Percentage

A comparison of mean empty seed percentage revealed that the highest (28/43) and lowest (4/07) means were for 0% (v/v) methanol foliar application in 25% FC and 21%(v/v) methanol foliar application in 100% FC respectively (table 2). Moghadas *et al.*, (2013) reported that 15 % (v/v) methanol foliar application on barley had significant effect on number of seeds per spike. Spraying of methanol decreased damage from water stress and yield was affected by the stage of methanol application, which is in agreement with the findings of Paknejad (2012) observations.

Methanol foliar application increased Oil yield per plant, Dry weight per m^2, Full seeds percentage and Empty seeds percentage, so that application of 21 % (v/v) methanol had the best performance on the above traits.

ACKNOWLEDGEMENT

The authors would like to thank Tabriz Branch, Islamic Azad University for the financial support of this research, which is based on a research project contract.

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