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EFFECTS OF SUPPLEMENTAL IRRIGATION ON YIELD AND YIELD COMPONENTS OF SPRING SAFFLOWER GENOTYPES

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Abstract
In order to evaluate the effect of supplemental irrigation on yield and yield components of spring safflower genotypes, an experiment was conducted with four irrigation levels (none irrigation, irrigation at heading, flowering and heading + flowering stages) and three safflower genotypes (Gilla, Isfahan land race and PI-537636) in a split plot experiment based on complete block design with three replications in Agricultural Research Station of Ardabil in 2008. In this study effects of irrigation levels and genotypes on plant height, number of seed per head, 1000-grain weight, kernel to seed coat ratio, biological yield, harvest index, oil and seed yield was significant. Irrigation at heading and flowering stages were most efficient. Also there was significantly interaction between irrigation and genotypes in kernel / seed coat ratio and seed yield. Isfahan land race genotype with irrigation at heading and flowering stages had the best treatment combination.

Key Words: Supplemental Irrigation; Safflower; Genotype; Harvest Index.

Introduction

Iran in terms of exposure at semi-arid areas of the world has limited rainfall, so different tools and methods that reduce the risk of possible crop production stability and durability should be consider. In this regard irrigation and supplemental irrigation management can be applied with selecting appropriate variety for yield increment (Tavakoli, 2001; Tavakoli et al, 2000). The mean of supplemental irrigation is the limited amount of water supply at the end of rainfall season to sustain plant growth and increase yield (Oweis et al, 1999). Optimum supplemental irrigation in dry land farming is based on three aspects (Oweis, 1997): 1- water is used only for improving the crop yield of dry land farming (and without irrigation had common yield). 2- When the rainfall is the most important source of water supply, supplemental irrigation will be used when the rain fails can not improve the water necessary to sustain yield and its stability. 3- Rate and time of supplementary irrigation is planned to achieve optimal yield by minimum available water in the sensitive stages of crop growth (rather than maximum yield). Safflower (*Cartamus tinctorius* L.) is an oil crop that has good compatibility to semi-arid areas. Safflower is grown in world wide including Iran, Afghanistan, Pakistan, India, and many other areas (Nasr et al, 1978). Safflower is annual and broadleaf plant witch produced with different goals such as oilseed crop, poultry and bird's feed or pharmaceutical applications and flowers as a source of dyeing usage (Khan et al, 2003). The leaves, petals and seeds of safflower contain excellent pharmaceutical materials and widely used in pharmacology and drug production, specific extracts from petals and used to dying clothes and food (Zhaoma and Lijie, 2001; Carvalho etal,2006). Currently, only about 7 percent of needed oil produced in our country and the rest is imported (Tavakoli, 2001). Safflower has potential of 4 tons per hectare yield and the high yield of 2 tons per hectare is favorable. The average yield of safflower in Iran is 700 kg per ha, which is near the global average (Forouzan, 1999). Rainfall limitation, high evapotranspiration and other limiting factors in safflower production needs more study on reducing the drought effect by using existing water resources and drought resistant cultivars. Therefore, the aim of this research was to achieve high yield, determining the best irrigation time and its effects on grain yield of three safflower genotypes.

Materials and Methods

This study was performed in the field of Ardabil Agricultural Research Station of Ardabil, Iran (1350 meters elevation, 38º 15' latitude and 48º 15' longitude) in 2008. Soil texture was clay loam. A split plot experiment was conducted in randomized complete block design with three replications. Irrigation treatments included 4-levels, based on plant phonological stages (Tanaka et al 2002), including: $I_{1=}$ control (non- irrigation), $I_{2=}$ Irrigation at heading stage, $I_{3=}$ Irrigation at flowering stage and $I_{4=}$ irrigation at both the heading and flowering stages and sub-plots included three safflower genotypes (Gilla, Isfahan land race and PI-537636). Each sub-plots, was including 6 rows by 25 and 10 cm inter and intra row spacing and 4 m row length. This field was used before by bean witch plowed in the autumn of 2007. Seeds planted manually in late March, weeds controlled with hand-weeding and Diazinon applied against pests. The final harvest was performed of each square meter to evaluate the yield and yield components. The results analyzed by SAS 2003 software and mean compared with LSD and Excel software used for figures.

Results and Discussion

Irrigation had significantly effects on plant height (Table 1). These differences were between heading and flowering stages and control treatment. Although plant height in irrigation at both the heading and flowering stages was more than two others (Table 2). Such results reported before by naderi et al (2005) and Hang and Evans (1985). Consequently reduced plant height by increasing stress intensity can be related to turgor potential reduction and reduced cell growth and impaired photosynthesis and photosynthate transfer to developing plant parts (Ehdaei and Noor Mohammadi 1984). There was significantly difference between Genotypes on plant height (Table 1). Maximum (66/22 cm) and minimum height (58/9 cm) obtained from Isfahan land race and Gilla genotypes respectively (Table 2). Such results reported befor by Naderi et al. (2005). Irrigation schedules had significantly effects on Seed number per head (Table 1). Theis differences were between the irrigation versus non irrigation treatments, so there was no significantly difference (Table 2) among the irrigation treatments (irrigation at the heading, flowering and irrigation in both the heading and flowering stages). Tavakoli (2002) stated that water withholding of safflower before flowering reduces number of seed per head and imposing stress nearby the flowering had more effects on seed number. Abolhassani and Saeedi (2006) also reported similar results about seed number per head. There was significantly difference between Genotypes on seed number per head (Table 1). Maximum (26.86) and minimum (18.26) number of seed per head obtained from Isfahan land race and Gilla genotypes respectively (Table 2). Such results have reported by Arsalan et al. (1997) and Cassato et al. (1997). Irrigation had significantly effect on 1000-grain weight (Table 1). Irrigation in both of the heading and flowering stages had highest (41.01 g) and without irrigation lowest (31.5 g) 1000-grain weight (Table 2). Nabi Pur et al. (2002) observed that supplemental irrigation of wheat was very efficient on grain weight. There were significantly differences between genotypes on 1000-grain weight (Table 1), so Gilla had higher 1000-grain weight (38.09 g) relative to others, whereas 1000-grain weight of Isfahan land race and PI-537636 genotypes were equal (Table 2). Variation in 1000 seed weight between genotypes of safflower has reported by Khidir (1974) and Pascual et al. (1996). Theses results also conform with findings by Rashed mohassel and Behdani (1994) and Dadashi and Khajehpour (2004). Kernel to seed coat ratio was significantly different between irrigation treatments (Table 1), Irrigation in both heading and flowering stages was significantly different with other irrigated treatments (Table 2). It seems that the drought stress affects photo assimilates partitioning between the seed coat and kernel, So Ravishavkar et al. (1990) on sunflower stated that: drought stress increase the seed coat weight and reduce the kernel to seed coat ratio. There were significantly difference on kernel to seed coat ratio between the Genotypes (Table 1), and PI-537636 genotype had the highest response (1.17) and the Gilla lowest (1.11) kernel to seed coat ratio, whereas no significant differences were observed between the PI-537636 and Isfahan land race genotypes (Table 2). Also there was significantly interaction between irrigation levels and genotypes on kernel to seed coat proportion(Table 1), Isfahan land race genotype with irrigation in both heading and flowering stages reflected the highest responses (1.33) and Gilla by without irrigation displayed the lowest (1.02) kernel to seed coat ratio (Fig. 1).

Fig. 1. Interaction between irrigation and genotypes on kernel to seed coat ratio

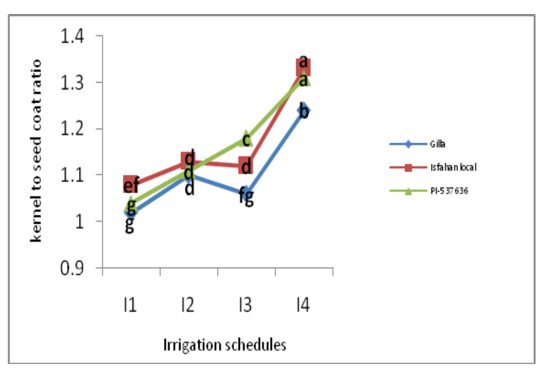


Table 1- ANOVA of yield and yield components of safflower genotypes under irrigation schedules

s.o.v	df	Plant height	Seed per head	1000-grain weight	Kernel to seed coat	Biological yield	Harvest index	Oil yield	Seed yield
Replication	2	7.9	31.55	17.19	0.0007	2.679	0.04	10273.2	28790.1
Irrigation	3	326.29**	380.2**	142.01**	0.095**	192.9**	57.78**	419496.1**	4319413.2**
R*I	6	22.25	25.54	2.58	0.0007	3.148	16.64	24277.1	86542.5
Genotype	2	163.84**	224.8**	26.12*	0/011**	18.09**	24.32*	44908.5*	457605.7**
G*I	6	4.65	24.58	6.32	0.0025**	5.281	10.25	26317.8	161623.9*
Errore	35	6.01	13.73	2.36	0.0003	2.51	8.58	12348.2	56017.8
Cv(%)	-	4	16.6	4.2	1.4	9.2	10.4	12.9	10.7

* , ** significant levels at 5% and1%

Table 2- Means comparison of yield and yield components of safflower genotypes under irrigation schedules

treatment	Plant height	Seed per head	1000-grain weight	Kernel to seed coat	Biological yield	Harvest index	Oil yield	Seed yield
Irrigation levels								
None irrigation	53.86 b	12.60 b	31.5 d	1.05 c	10.84 c	24.98 b	372.35 c	1330.3 d
Irrigation at heading	63.24 a	24.75 a	37.03 c	1.11 b	16.78 b	28.02 ab	592.81 b	2048.4 c
Irrigation at flowering	63.77 a	25.18 a	38.02 b	1.12 b	20.12 a	28.29 ab	744.2 b	2519.3 b
Irrigation at heading and flowering	68.17 a	26.56 a	41.01 a	1.29 a	21.09 a	31.18 a	908.18 a	2947.7 a
Genotype								
Gilla	58.9 c	18.26 c	38.09 a	1.11 b	15.97 b	26.5 b	570.1 b	1988.4 b
Isfahan local	66.22 a	26.86 a	36.2 b	1.16 a	18.42 a	28.68 ab	689.9 a	2351.4 a
PI-537636	61.66 b	21.73 b	36.38 b	1.17 a	17.23 ab	29.18 a	987.46 a	2294.6 a

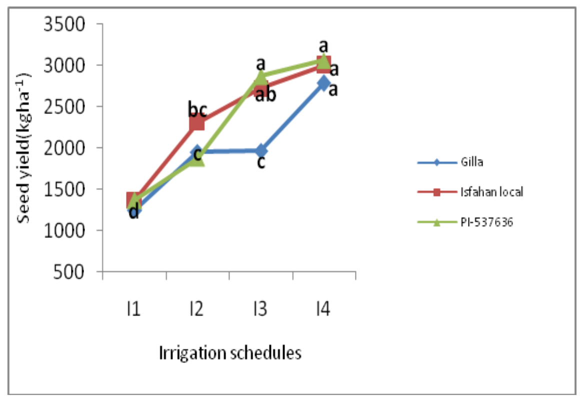
Biological yield affected from Irrigation schedules (Table 1). Irrigation in both heading and flowering stages had the highest (21.09) and without irrigation the lowest (10.84 g plant^{-1}) biological yield (Table 2). Water withholding during plant growth reduced growth stage, leaf area duration and ultimately reduced biological yield. The biological yield was significantly different between genotypes (Table 1), and Isfahan land race genotype had the highest (18.42) and Gilla the lowest (15.97 g per plant) biological yield (Table 2).

Harvest index affected by irrigation regimes (Table 1). Irrigation in both heading and flowering stages had highest (31.18 percent) and without irrigation was the lowest (24.98 percent) harvest index (Table 2). Reducing harvest index in drought conditions is due to more effects of drought stress on vegetative growth in comparison to generative growth stage. Results of this research were similar to pandy et al. (2001) findings. Also the significant differences were observed via genotypes on harvest index (Table 1), so that PI-537636 genotype showed the highest (29.18 percent) and Gilla the lowest (26.5 percent) harvest index (Table 2). Similar results reported already by Bagheri (1995).

Irrigation had significant effects on oil yield (Table 1). Irrigation in both heading and flowering stages had maximum (908.18) and without irrigation was minimum (372.35 kg ha^{-1}) oil yield, and no significantly differences were observed between irrigation at heading and flowering stages (Table 2). According to the reducing of yield in non-irrigated conditions in addition as oil yield is depended to the seed yield, we observed reduction oil yield by the seed yield reduction, thus sufficient irrigation is useful to increase the seed and oil yield (Roshdi et al., 2006). These results are also confirmed with founding's by Naderi et al. (2005). Between the genotypes there were significantly differences on oil yield (Table 1). Isfahan land race genotype had maximum (689.9) and Gilla the minimum (570.1 kg ha^{-1}) oil yield (Table 2). Naderi et al. (2005) also reported the existing differences between genotypes.

Irrigation methods had effects on seed yield (Table 1). Irrigation in both heading and flowering stages showed highest (2947.7) and withholding irrigation showed lowest (1330.3 kg ha^{-1}) seed yield (Table 2). Water restriction reduce the photosynthesis and yield components such as the number of the seed per head and 1000-seed weight so finally reduce seed yield (Bonari et al., 1992). Water deficiency causes stomata closer so reduced photosynthesis and finally reduces the seed yield (Tezara et al, 1999). Jafarzadeh et al. (1997) reported more reduction in sunflower yield under drought stress; because of reduction in photosynthesis and photo assimilate translocation during grain filling. Results of this research also confirmed with Naderi et al. (2005). Seed yield had significantly differences between genotypes (Table 1), so that Isfahan land race genotype had the highest (2351.4) and Gilla the lowest (1988.4 kg ha^{-1}) seed yield. There was no significantly difference between Isfahan land race genotype and PI-537636, but yield of these genotypes differed with Gilla genotype (Table 2). Gonzalez et al. (1994) also reported significant effects differences between safflower genotypes. Interaction between irrigation and genotypes on seed yield was significant (Table 1), and PI-537636 genotype with irrigation in both heading and flowering stages had maximum (3059.5) and Gilla by non irrigation had the minimum (1250.1 kg ha^{-1}) seed yield (Fig. 2).

Fig. 2. Seed yield as affected by irrigation and genotypes of safflower



Conclusion

Although safflower is drought tolerant plants, supplemental irrigation showed significant increase on seed yield. The major difference was between non irrigation and irrigation on heading stage (54 percent increase in yield) and non irrigation and irrigation at flowering stage (89.4 percent increase in yield), respectively. According to increasing the environmental stresses, due to reducing the relative humidity and temperature raising irrigation at flowering stage had greater effects on seed yield. Since the lack of water is the most important concern of this area, irrigation at flowering stage achieve economic yields. Also some differences among the genotypes were observed. The Isfahan land race genotype was recognized as the most superior cultivar, because of its superior such as plant height and number of seeds per head relative to other cultivars.

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