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Original Research Article

Water Stress and Plant within Row Spacing Effects on Safflower Yield in Competition with Wild Oat

Ruhollah Naderi[1], Seyed Abdolreza Kazemeini[2*] and Majid Noroozi[2]

[1] Department of Agroecology, College of Agriculture and Natural Resources of Darab, Shiraz University, Shiraz, IRAN

[2] Department of Crop Production and Plant Breeding, College of Agriculture, Shiraz University Shiraz, IRAN

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ABSTRACT

A Two-year field experiment was carried out in 2009 and 2010 at Agricultural College of Shiraz University, Iran to evaluate the effects of different water stress and plant within row spacing on safflower yield and photosynthetic characteristics in weedy conditions. Results showed that drought stress at 75 % FC (field capacity) caused a reduction of 15 % in seed yield but this treatment had no significant difference with well watered. Yield reduction of 31 % was also observed at 50 % FC. The greatest seed yield was also found at plant within row spacing of 5 cm (302.6 ±23 kg m^{-2}). The yield reduction caused by weed competition was 57%. Compared to well water, at 75 % FC and 50 % FC Photosynthesis rate of safflower reduced 26.18 and 65.49 %, respectively. Weeds competition reduced safflower photosynthesis rate significantly about 25 %. Transpiration in weedy plots was also significantly lower than that of weed free plots (33%). Compared to well-watered, water stress at 75 % and 50 % FC reduced wild oat biomass by 29 % and 43 %, respectively. Increasing within row spacing from 5 cm to 10 cm and 20 cm caused an increase in wild oat biomass by 30% and 40%, respectively.

Keywords: Drought stress, Weed competition, Oil crop, Plant density, *Avena fatua*

Su Stresi ve Sıra Arası Mesafesinin Yabani Yulaf ile Rekabet Eden Aspir Bitkisinin Verimi Üzerine Etkisi

ÖZ

Şiraz Üniversitesi'nin Ziraat Okulu'nda 2009 ve 2010 yıllarını kapsayan 2 yıllık arazi çalışması yürütülmüş ve yabancı ot bulunan koşullarda su stresi ve sıra arası mesafesinin aspir verimi ve fotosentetik karakteristiklerine etkileri incelenmiştir. Sonuçlar incelendiğinde % 75 tarla kapasitesi tohum veriminde %15'lik bir kayba neden olmasına rağmen tam sulanmış arazilerden elde edilen verim ile arasında istatistiksel olarak bir fark bulunamamıştır. Buna ek olarak % 50 tarla kapasitesinde ise % 31'lik bir verim kaybı görülmüştür. En yüksek tohum verimi 5 cm sıra açıklığında elde edilmiştir (302.6 ±23 kg m^{-2}). Yabancı ot ile rekabet sonucunda oluşan verim kaybı % 57 olmuştur. Tam sulanmış araziye göre % 75 ve % 50 tarla kapasitelerinde aspir fotosentez oranı sırasıyla % 26.18 ve % 65.49'luk düşmüştür. Yabancı otlar ile rekabet aspir fotosentez oranını % 25 düşürmüştür. Yabancı ot bulunan parsellerde transpirasyon oranı temiz parsellere göre önemli ölçüde düşük olmuştur (% 33). Tam sulanmış araziler ile karşılaştırıldığında, % 75 ve % 50 tarla kapasitelerinde yaşanan su stresi, yabani yulafın biyokütlesinin sırasıyla % 29 ve % 43 azalmasını sağlamıştır. Sıra arasının 5 cm'den 10 ve 20 cm'ye çıkarılması sonucunda yabani yulaf biyokütlesi sırasıyla % 30 ve % 40 artmıştır.

Anahtar Kelimeler: Kuraklık Stresi, Bitki Rekabeti, Yağ Bitkisi, Bitki Yoğunluğu, *Avena fatua*

INTRODUCTION

Drought is known as one of the most important limiting factors affecting field crop yield, especially in arid regions. In southern areas of Iran with an arid climate, the portion of available water for agriculture is decreasing (Abbasi & Sepaskhah 2011). Therefore, cultivating crops that are well adapted to dryland conditions such as safflower is one of the main strategies for increasing crop production in these areas.

Safflower, a deep rooted oilseed crop, is grown in many areas of the world because it can be used as oil crop, vegetable, birdfeed and spices (Weiss 2000). For centuries in Iran, it has been cultivated for use in producing red and yellow dye for clothing and cooking (Oelke *et al.* 1990).

Safflower is also well adapted to salinity and drought stress possessing deep root which makes it to be able to meet its water requirements from a lower layer of soil (Knowles 1989; Weiss 2000). Although safflower

* Corresponding author: kazemin@shirazu.ac.ir

is a drought-tolerant crop and it can extract soil water down to a depth of 4 m under drought stress conditions (Knowles 1989), all reproductive stages of the crop are sensitive to water deficit (Saini & Westgate 2000). Jalali *et al.* (2012) reported that increasing the irrigation interval to 15 days at vegetative stage had no significant effects on grain yield, but grain yield decreased by 18 and29.8% with increases in the irrigation interval to 22 and 28 days, respectively.

Safflower is not a strong competitor against weeds mainly during its early growth stages, when it has not started branching (Blackshaw 1993). Safflower yields can be reduced up to 75% by weeds depending on the weed species and density (Agyman *et al.* 2002). Jalali *et al.* (2012) also found that weed competition in safflower field caused a yield reduction of 29 %.

Wild oat (*Avena fatua*) is known as an annual grass and its control is difficult, since its seed shattering occurs before crop maturity. It is a dominant weed in most Iranian crop fields including safflower which can cause major yield loss as well as lower crop quality (Scursoni & Satorre 2005).

It is clear that water does not have anequal role in all crop-weed interactions. Weeds would compete for water and can lead to crop water stress. Weeds need as much or more water than crops and they are often more successful in acquiring it (Zimdahl 2004).Turner (2004) and Rjcan (2001) reported that weeds can deplete the stocks of soil water and thus, induce or intensify crop water stress. However, Massinga *et al.* (2003) found that soil water depletion and water status of root zone did not affected by weed competition in corn (*Zea mays* L.). Chauhan and Johnson (2010) reported that plant height and biomass production of jungle rice (*Echinochloa colona*) grown alone were reduced with increasing water stress. Additionally, when jungle rice and rice grown together under water stressed conditions, jungle rice was taller than rice.

Some studies have shown that increased rice density can suppress weed growth (Chauhan *et al.* 2011; Zhao 2007). A dense canopy can have positive effects on plant growth, especially in severe environmental conditions (Franks &Peterson 2003; Luo *et al.* 2010). Higher plant density might also facilitate plant acclimation to drought stress as a result of increased relative humidity and leaf wetness duration (Tu 1997; Asghari *et al.* 2009).

There is limited information on appropriate within row spacing of safflower in water stress conditions when fields are highly infested by wild oat in Southern Iran, Fars Province. Therefore, this research was carried out to evaluate the effects of different water stress and plant within row spacing on safflower yield and photosynthetic characteristics in competition with wild oat.

MATERIALS AND METHODS

A Two-season field experiment was carried out in 2009/2010 and 2010/2011 at the Research Field of Agricultural College of Shiraz University, Iran. Plots were located on a silty loam soil with 0.57% organic matter, 0.054% total N, 22.14 mg kg^{-1} phosphorus, 600 mg kg^{-1} potassium, pH of 7.56, and EC of 0.68 dSm^{-1} in the surface horizon (0-20 cm). Meteorological data are given in table 1.

Table 1. Mean monthly temperature and precipitation amount during 2009 and 2010 growing seasons.

Month	**2009/2010**		**2010/2011**	
	Mean temperature (°C)	Precipitation (mm)	Mean temperature (°C)	Precipitation (mm)
November	15.85	21	14.4	0
December	9.25	118	9	0
January	7.9	15	6.6	33
February	9.5	39	6.6	100
March	14.1	17	11.5	62
April	16.65	24	16.65	20
May	21.4	9	21.4	0
June	27.5	0	27.5	0
July	30	0	30	0
Total		**243**		**215**

Commercial safflower seeds, cultivar Sina, were sown on October 7, for both seasons in 3×4 m plots. Each plot consisted of 6 rows spaced 50 cm apart. Experimental design was split- split plot with three replications. Main plots consisted of water stress (100, 75 and50 % FC (field capacity), and sub plots consisted of weed control (weedy and weed free), and sub plots consisted of plant within row spacing (5, 10and 20cm). Since the experimental field in both years was highly infested by wild oat, in weedy plots all the weeds except wild oat was removed by hand. Weeds in weed-free plots were also removed by hand every 2 weeks during first month of the experiment and every week thereafter. No chemical herbicides were used in this experiment.

In order to determine soil depleted water from field capacity, before each irrigation, gravitational soil water content was measured at a profile depth of 0 to 90 cm using a spiral auger for soil sampling. Soil samples first weighed and then oven dried at 105 °C and weighed again. The Weight deference is equivalent to water weight. Gravitational water content calculated through dividing soil sample water weight by dried soil weight. Volumetric water content was gained by multiplying gravitational water content by soil bulk density of the experimental farm (1.4 g cm^{-3}). Net water requirement for each irrigation calculated using the following formula (Israelsen 1980).

$$dn = \frac{(FC - Pv) * \rho b * D}{100}$$

Where dn is net water requirement (cm), FC and P_v are volumetric water content for soil at field capacity (33%) and volumetric soil water content before irrigation, respectively. ρb is soil bulk density (1.4 g cm^{-3}) and D is soil depth (cm).

A water-discharge-calibrated tape irrigation pipe was used for irrigation of plots considering water requirement according to the treatments. An irrigation interval of 9 days was applied for all the plots. All plots were kept free from pests and diseases during the experimental period. Seedbed preparation was moldboard plowing and fall disking. The field was fertilized on the basis of soil test recommendations with 150 kg N ha^{-1} (as urea). Half of N fertilizer was hand-broadcasted at planting, and the remaining was applied at stem elongation.

At crop maturity, July 6th, the two middle rows from each plot were harvested for determination of safflower yield and its yield components. Additionally, weeds were harvested from a 2 m^2 area per plot and dried at 75°C for 48 h and weighed. Wild oat height and number of tillers were also measured. Photosynthetic rate and transpiration was taken at seed filling (reproductive stage) and measured using photosynthesis meter (LCi, UK). Percentage of oil in safflower seed was determined using the method of Agrawal & Daldani (1987).

Analysis of variance over years indicated that the effect of years was not significant ($p<0.05$). Thus, data collected from both years of the experiment were combined. Fisher's Protected LSD test was used to detect and compare mean treatment differences at the 5% level of probability by using SAS software (2002).

RESULTS AND DISCUSSION

Oil percentage

Results showed that water stress significantly reduced oil percentage of safflower ($p<0.05$). However, the reduction was only significant at 50 % FC (Figure1). Similarly, Ashrafi & Razmjoo (2010) reported that the amount and composition of safflower oil was affected by irrigation regimes. However, Ozturk *et al.* (2008) reported that irrigation regimes did not have an effect on oil contents of safflower. This could be because of reduced availability of carbohydrates for oil synthesis under drought stress conditions. Singh and Sinha (2005) also reported that decreasing oil content of crops under drought stress conditions might be because of the oxidation of some polyunsaturated fatty acids.

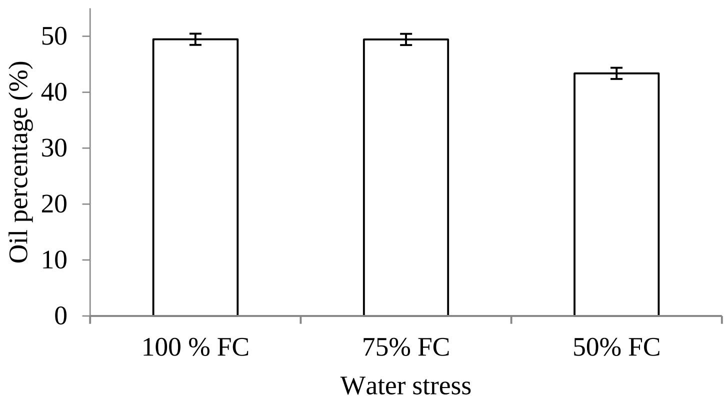

Figure 1. Effect of water stress on safflower oil percentage. Vertical bars indicate standard errors (data over two seasons).

Although oil percentage reduced in weedy plots (39 ± 3 %), it was not significantly different from weed free plots (41 ± 1 %). Our results are consistent with those of Jalali *et al.* (2012) in safflower. Naderi & Bijanzadeh (2014) also reported that oil percentage of rapeseed was not affected by weeds.

Plant within row spacing also did not have any significant effect on oil percentage. Elfadl *et al.* (2009) also found that plant density did not significantly affect oil content of safflower. Alessi *et al.*(1981) evaluating the effect of plant density on safflower in a 4-year trial under dryland conditions in North Dakota reported that oil content across all 4 years was not significantly affected by plant density. None of the interactions of the treatments were significant.

Safflower seed yield

Safflower seed yield was significantly affected by drought stress ($p<0.05$).Drought stress at 75 % FC caused a reduction of 15 % in seed yield. However, there was no significant difference between well watered and 75 % FC ($p>0.05$) (Figure 2). Jalali *et al.* (2012) also reported that safflower could tolerate moderate drought stress and its yield did not affect by moderate drought stress.

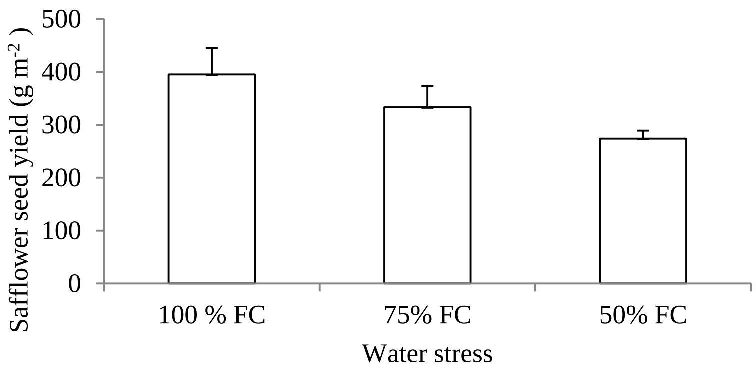

Figure 2. Effect of water stress on safflower seed yield. Vertical bars indicate standard errors (data over two seasons).

Istanbulluoglu *et al.* (2009) in a study on water stress on the yield of both winter and summer safflower reported that the effect of water stress at any stage of crop development on grain yield was significant and the highest yield was achieved in fully irrigation control treatment.

Seed yield reduction of 31 % was also observed at 50 % FC. This level of drought stress was significantly different from the other irrigation treatments ($p<0.05$) (Figure 2). Water stress imposed on crops would lead to decrease yield via reducing grain set (Al-Ghzawi *et al.*2009). This could also be attributed to shorter grain filling period and lower accumulation of dry matter in the growing grains (Garcia 2003; Samarah *et al.* 2009). It has been reported that severe drought stress can sharply decrease seed and oil yields of safflower (Lovelli *et al.* 2007).

Plant density had also a significant effect on safflower seed yield ($p<0.05$). The greatest seed yield was found at plant within row spacing of 5 cm (302.6 ±23 kg m^{-2}). The lowest seed yield was gained at plant within row spacing of 20 cm (117.1 ±18 kg m^{-2}). Our results are similar with the findings of irrigated safflower in India in which seed yield increased as plant density increased from 7.5 to 22.5 plantsm^{-2} (Mane & Jadhav 1994). However, Elfadl (2009) reported that plant density did not show any significant variation in seed yield of safflower.

Weeds competition had a significant effect on seed yield ($p<0.05$). The yield reduction caused by weed competition was 57% (Figure 3). Similar results were also found by Jalali *et al.* (2012). Safflower is a poor competitor against weeds (Blackshaw 1993) and its yield can be reduced up to 75% by weeds (Agyman *et al.* 2002).Weeds might compete with the crops for different resources and they might also reduce available soil water (Zimdahl 2004).

There were no significant differences among any of the treatments ($p>0.05$).

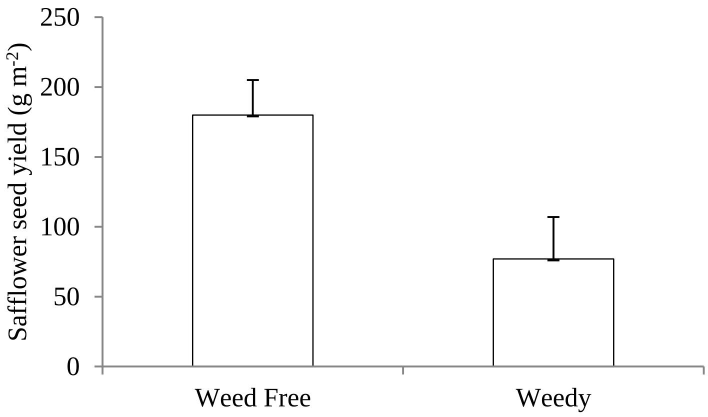

Figure 3. Effect of weeds competition on safflower seed yield. Vertical bars indicate standard errors(data over two seasons).

Photosynthetic characteristics of safflower

Water stress affected photosynthesis rate of safflower significantly so that compared to well water at 75 % FC and 50 % FC, photosynthetic rate reduced 26.18 and 65.49 %, respectively (Figure 4). Water stress had also a significant effect on transpiration. Compared to well water, transpiration at 75 % and 50 % FC reduced by 24.95 and 64.91 %, respectively (Figure 5). Similarly, Chastain *et al.* (2014) in a study on water stress in cotton reported that under water deficit, net photosynthesis is limited by decreased gross photosynthesis, resulting from declines in stomatal conductivity and an increase in photorespiration. Kumar *et al.* (1994) also found that water stress caused an increase in *Brassica juncea* L. as a result of decrease in crop photosynthesis. Drought stress can inhibit the gas exchange parameters of crops due to decrease in leaf expansion, impaired photosynthetic machinery, premature leaf senescence, oxidation of chloroplast lipids and changes in structure of pigments and proteins (Menconi *et al.*,1995). Additionally, water stress can inhibit the photosynthetic processes and as a result reduction in nutrient supply to the reproductive organs (Campbell 1996). Therefore, an inadequate supply can block the development of reproductive structures and cause grain abortion (Westgate and Boyer 1986).

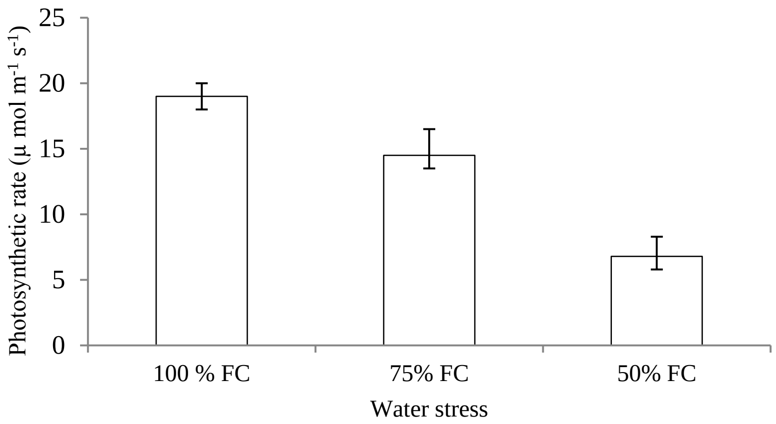

Figure 4. Effect of water stress on safflower photosynthetic rate. Vertical bars indicate standard errors (data over two seasons)

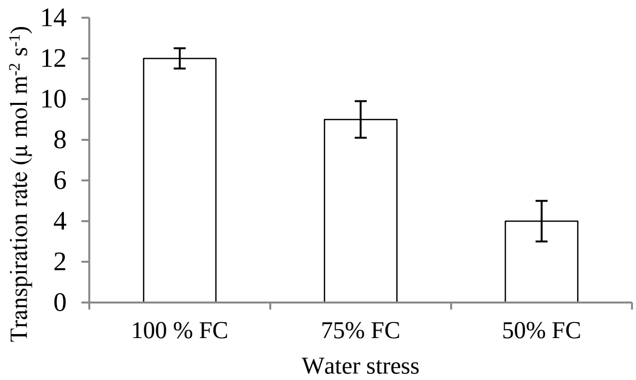

Figure 5. Effect of water stress on safflower transpiration rate. Vertical bars indicate standard errors (data over two seasons).

Weeds competition reduced safflower photosynthesis rate significantly approximate to 25 %. Transpiration in weedy plots (6 µ mol m^{-2} s^{-1}) was also significantly lower than in weed free plots (9.2 µ mol m^{-2} s^{-1}) (33%). Our results are in accordance with Iqbal and Wright (1999) who have found that competition of *Phalaris minor, Chenopodium album* and *Sinapis arvensis* led to a decrease in flag leaf photosynthesis of spring wheat. Naderi and Ghariri (2013) also reported that photosynthesis of corn showed a significant decrease in weedy plots.

Plant density had no significant effect on photosynthesis rate and transpiration. There were no significant interactions among any of the treatments for both photosynthesis rate and transpiration.

Wild oat height

Wild oat height was affected by water stress significantly ($P<0.05$). Wild oat height at 75 % FC and 50 % FC compared to well-watered treatment reduced 5.28 and 12.98 %, respectively (Figure 6).Wright *et al.* (1999) reported that water stress decreased height of *Sinapis arvensis* in wheat field. Chauhan and Johnson (2010) in a greenhouse study reported that Plant height, biomass, and seed production of jungle rice grown alone reduced with increasing water stress.

Plant density had no effect on wild oat height. This is likely because of rapid growth of wild oat compared to safflower. Irrespective of both water stress and plant within spacing, wild oat height was greater than the safflower plants (data not shown). This indicated that wild oat would grow taller than safflower and it can take advantage of the higher light intensity above the safflower canopy. No interaction of the treatments was found.

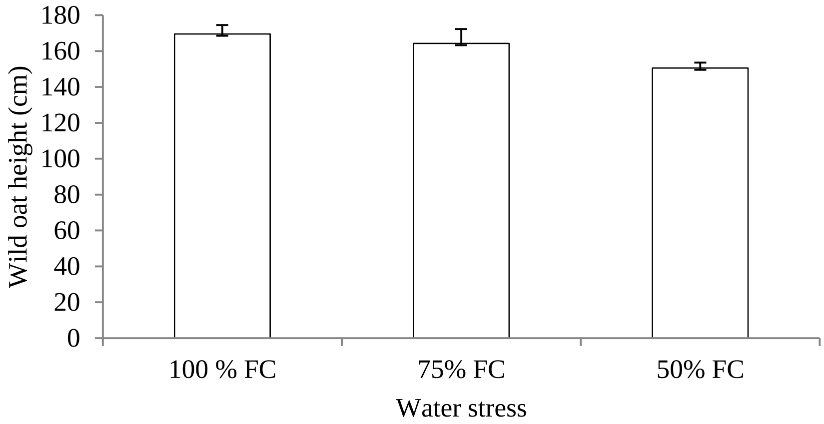

Figure 6. Effect of water stress on wild oat height. Vertical bars indicate standard errors (data over two seasons).

Wild oat tillers

Water stress had a significant effect on wild oat tillers (p<0.05). A decrease in water supply from well water to 75 % and 50 % FC decreased number of wild oat's tillers 20.6 and 38.35 %, respectively. This might show that the ability of wild oat to compete with the safflower was remarkably reduced under water stress. Peters (1982) also found that when parent plants of wild oat were subjected to moisture stress, seed production was reduced. Plant within row spacing had also a significant effect on wild oat tillers so that plant within row spacing of 20 cm led to the highest number of tillers of wild oat (21±3) compared to plant within row spacing of 5 cm which caused the lowest number of tillers of wild oat (12.22±1). Chauhan and Abugho (2013) also reported that seed production of *Echinochloa crus-galli* declined markedly with increasing crop density.

Interaction of water stress and plant within row spacing was significant for wild oat tillers. Maximum number of wild oat tillers was gained at well water and plant within row spacing of 20 cm (27.31±3) and minimum number of wild oat's tillers was attained at 50 % FC and at plant within row spacing of 5 cm (9±2) (Figure 7).

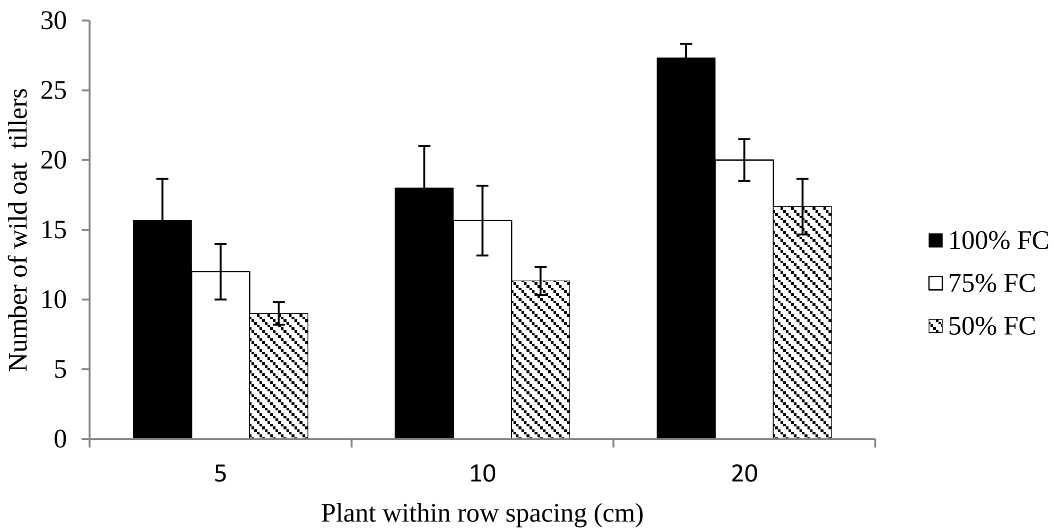

Figure 7. Effect of water stress and safflower plant within row spacing on number of wild oat tillers. Vertical bars indicate standard errors (data over two seasons).

Wild oat biomass

Water stress affected wild oat biomass significantly ($p<0.05$). Increasing drought stress decreased wild oat biomass but there was no significant difference between 75 % FC and 50 % FC. Compared to well water (137±12), drought stress at 75 % (96±7) and 50 % FC (78±5) reduced wild oat biomass by 29 % and 43 %, respectively. These results are in agreement with those of Chauhan and Abugho (2013) in *Echinochloa crus-galli*, Peters (1982) in wild oat and Wright *et al.* (1999) in wild mustard.

Plant within row spacing had a significant effect on wild oat biomass ($p<0.05$). Increasing within row spacing from 5 cm to 10 and 20 cm caused an increase in wild oat biomass by 30 % and 40 %, respectively. Chauhan *et al.* (2012) Rao *et al.* (2007) Zhao (2006) also suggested that cultivating rice densely in narrower rows could help to suppress weed biomass.

Interaction of irrigation regimes and within row spacing was significant ($p<0.05$). The greatest wild oat biomass was found at well watered and within row spacing of 20 cm and the lowest was gained at 50 % FC and within row spacing of 5 cm (Figure 8). Chauhan and Abugho (2013) also found that biomass of *Echinochloa crus-galli* decreased as crop density increased in soil moisture stress.

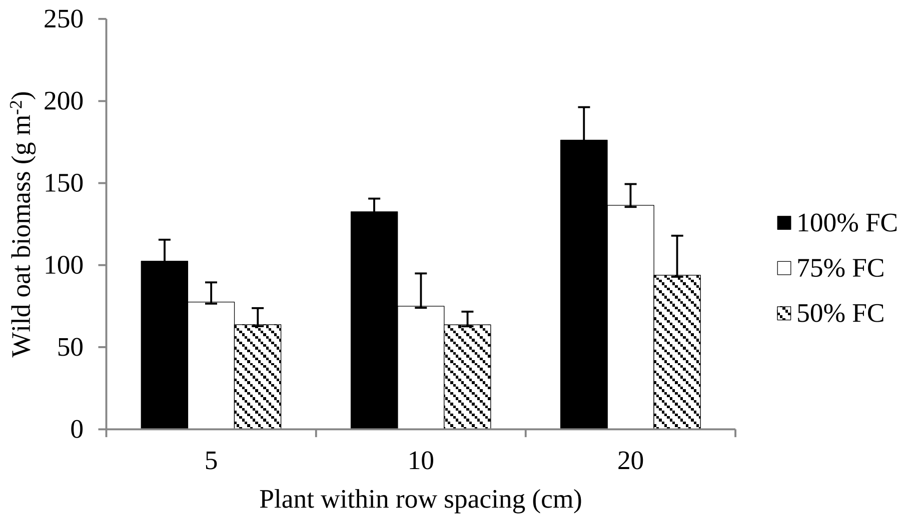

Figure 8. Effect of water stress and safflower plant within row spacing on wild oat biomass. Vertical bars indicate standard errors (data over two seasons).

CONCLUSIONS

The results of this experiment suggest that safflower can tolerate moderate water stress. However, even moderate water stress caused about 15 % yield loss. Water stress also decreased wild oat growth mostly in narrower within plant spacing. It is also concluded that weed control and water supply are important factors for increasing grain yield in safflower. The knowledge gained in the present study focusing on the growth response of crop and weed to environmental factors and their competition might help in designing a better weed management strategy.

REFERENCES

Abbasi MR, Sepaskhah, AR. 2011. Response of different rice cultivars (*Oryza sativa* L.) to water-saving irrigation in greenhouse conditions. Int J Plant Produc. 5: 35-43.

Abel GH. 1975. Effects of irrigation regimes, planting dates, nitrogen levels, and row spacing on safflower cultivars. Agron J. 68:448–451.

Agrawal PK, Daldani M. 1987. Techniques in Seed Science and Technology, fourth ed. South Asian Publishers, India, 344 pp.

Agyman GA, Loiland L, Karow R, Hang AN. 2002. Safflower. Dry land cropping systems

Agyman GA, Loiland L, Karow R, Hang AN. 2002. Safflower.Dry land cropping systems [internet].Oregon State University. Available from: http:/www.eesc.oregonstate.edu

Alessi J, Power JF, Zimmerman DC. 1981. Effects of seeding date and population on water-use efficiency and safflower yield. Agron J. 73: 783–787.

Al-Ghzawi AA, Zaitoun S, Gosheh HZ, Alqudah AM.2009. The impacts of drought stress on bee attractively and flower pollination of *Trigonell amoabitica* (*fabaceae*). Arch Agron Soil Sci. 55: 683–692.

Asghari MT, Daneshian J, Farahani HA. 2009. Effects of drought stress and planting density on quantity and morphological characteristics of chicory (*Cichorium intybus* L.). Asian J Agric Sci. 1: 12–14.

Ashrafi E, Razmjoo K. 2010. Effect of irrigation regimes on oil content and composition of safflower (*Carthamus tinctorius* L.) cultivars. J Am Oil Chemist Soc. 87:499–506.

Blackshaw RE. 1993. Safflower (*Carthamus tinctorius*) density and row spacing effects on competition with green foxtail (*Setaria viridis*). Weed Sci. 41:403–408.

Campbell DR. 1996. Evolution of floral traits in a hermaphroditic plant: field measurements of heritability and genetic correlations. Evolution. 50:1442–1453.

Chastain DR, Snider JL, Collins GD, Perry CD, Whitaker J, Byrd SA.2014. Water deficit in field-grown *Gossypium hirsutum* primarily limits net photosynthesis by decreasing stomatal conductance, increasing photorespiration, and increasing the ratio of dark respiration to gross photosynthesis. J Plant Physiol. 171: 1576–1585

Chauhan BS, Abugho SB. 2013. Effects of water regime, nitrogen fertilization, and rice plant density on growth and reproduction of lowland weed *Echinochloacrus-galli*.. Crop Prot. 54: 142-147.

Chauhan BS, Johnson DE. 2010. Growth and reproduction of Junglerice (*Echinochloa colona*) in response to water stress. Weed Sci. 58: 132-135.

Chauhan BS, Johnson DE. 2010. Response of rice flatsedge (*Cyperus iria*) and barnyardgrass (*Echinochloa crus-galli*) to rice interference. Weed Sci. 58, 204-208.

Chauhan BS, Singh VP, Kumar A, Johnson DE. 2011. Relations of rice seeding rates to crop and weed growth in aerobic rice. Field Crops Res. 121: 105-115.

Elfadl E, Reinbrecht C, Frick C, Claupein W. 2009. Optimization of nitrogen rate and seed density for safflower (*Carthamus tinctorius* L.) production under low-input farming conditions in temperate climate. Field Crops Res. 114: 2–13.

Franks SJ, Peterson CJ. 2003. Burial disturbance leads to facilitation among coastal dune plants. Plant Ecol. 168: 13–21.

Garcia L. 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean condition. Agron J. 95:266–274.

Iqbal J, Wright D. 1999. Effects of weed competition on flag leaf photosynthesis and grain yield of spring wheat. J Agric Sci. 132: 23-30.

IsraelsenOW. 1980. Irrigation Principles and Practices. 4th edition. John Wiley & Sons Inc.. 430p.

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.). Agr Water Manage. 96: 1429–1434.

Jalali A, Salehi F, Bahrani M. 2012. Effects of different irrigation intervals and weed control on yield and yield components of safflower (*Carthamus tinctorius* L.). Arch Agron Soil Sci. 58:11, 1621-1269

Knowles PF. 1989. Safflower. In: Robbelen G, Downey RK, Ashri A, editors. Oil crops of the world. New York: McGraw Hill. p. 363–374.

Kumar A, Singh DP, SinghP. 1994. Influence of water stress on photosynthesis, transpiration, water-use efficiency and yield of *Brassica juncea* L. Field Crops Res. 37: 95–101.

Lovelli SM, Perniola AF, Ferrara A, Di Tommaso T. 2007. Response factor to water and water use efficiency of *Carthamus tinctorius* L. and *Solanum melongena* L. Agr Water Manage. 92:73–80.

Luo WB, Xie YH, Chen XS, Li F, Qin XY. 2010. Competition and facilitation in three marsh plants in response to a water level gradient. Wetlands 30: 525–530.

Mane VS, Jadhav AS. 1994. Effects of fertilizers and plant densities on growth and yield of irrigated safflower (*Carthamus tinctorius*). Indian J Agron. 39: 79-82.

Massinga RF, Currie RS, Trooien TP. 2003. Water use and light interception under Palmer amaranth (*Amaranthus palmeri*) and corn competition. Weed Sci. 51: 523–531.

Menconi M, Sgherri CLM, Pinzino C, Navari-Izzo F. 1995.Activated oxygen production and detoxification in wheat plants subjected to a water deficit programme. J Exp Bot. 46: 11-23.

Naderi R, Ghadiri H. 2013. Nitrogen, manure and municipal waste compost effects on yield and photosynthetic characteristics of corn (*Zea mays* L.) under weedy conditions. J Biol Environ Sci. 7: 141-151.

Naderi R, Bijanzadeh E. 2014. Chemical, mechanical and integrated weed management under two phosphorous fertilizer application methods in rapeseed. Arch Agron Soil Sci. http://dx.doi.org/10.1080/03650340.2014.941287. [Internet]. [cited 2014 Jul 22]. Available from: http://www.tandfonline.html

Oelke EA, Oplinger ES, Teynor TM, Putnam DH, Doll JD, Kelling KA, Durgan BR, Noetzel DM. 1990. Safflower alternative field crop manual.Ext. Univ. of Minnesota ext. Plant and Animal Products and Minnesota ext. p. 65.

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. 54:453–460.

Peters NCB. 1982. The dormancy of wild oat seed (*Avena fatua* L.) from plants grown under various temperature and soil moisture conditions. Weed Res. 22: 205-212.

Rajcan I, Swanton CJ. 2001. Understanding maize–weed competition: resource competition, light quality and the whole plant. Field Crops Res. 71: 139–150.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK, Mortimer AM. 2007. Weed management in direct-seeded rice. Adv Agron. 93: 153-255.

Saini HS, Westgate ME. 2000. Reproductive development in grain crops during drought. Adv Agron. 68:59–96.

Samarah NH, Alqudah A, Amayreh J, McAndrews G. 2009. The effect of late-terminal drought stress on yield components of four barley cultivars. J Agron Crop Sci. 195:427–441.

Scursoni JA. Satorre EH. 2005. Barley (*Hordeum vulgare*) and wild oat (*Avena fatua*) competition is affected by crop and weed density. WeedTechnol. 19: 790–795.

Tu JC. 1997. An integrated control of white mold (*Sclerotinia sclerotiorum*) of beans, with emphasis on recent advances in biological control. J Bot. 38: 73–76.

Turner NC. 2004. Agronomic options for improving rainfall-use efficiency of crops in dryland farming systems. J Exp Bot. 55: 2413–2425.

Weiss EA. 2000. Oil seed Crops. Blackwell Publishing Limited, London, UK.

Westgate ME, Boyer JS. 1986. Reproduction at low silk and pollen water potentials in maize. Crop Sci. 26:951–956.

Wright KJ, Seavers GP, Peters NCB, Marshall MA. 1999. Influence of soil moisture on the competitive ability and seed dormancy of *Sinapis arvensis* in spring wheat. Weed Res. 39: 309-317.

Zhao D. 2006. Weed Competitiveness and Yielding Ability of Aerobic Rice Genotypes (PhD thesis). Wageningen University, The Netherlands.

Zimdahl RL. 2007. Weed–Crop Competition. A Review, 2nd ed. Blackwell Publishing, IA, USA.