Effect of water stress on agronomic traits of cactus pear (*Opuntia ficus indica* L.)

[1]Saeed Sharafi, [2]Soraya Ghasemi, [3]Zeinolabedin Jouyban and [4]Somaye Akhlaghi

1- Arak University, 2- Ilam Researches Center, 3- Young Researchers Club, Borujerd Branch, Islamic Azad University, Borujerd, Iran, and 4- Karaj Payamnoor University

Email:sharafi.saeed@gmail.com; Tell: 09183641420 fax: 0861-2761007

Abstract: Cactus pear (*Opuntia ficus indica* L.) is a xerophytic plant whose high moisture content is a very useful characteristic under water deficit conditions in arid regions. Therefore, given the consequences of climate change and global warming in recent years, it can substitute forage crops that have a high water use because of its slight water use. So, the present study was carried out in research station of Agricultural Research Center of Ilam, Iran (located in Mehran city) in two years in order to evaluate the possibility of cultivation of cactus pear under water stress conditions (rain-fed conditions and irrigation intervals of 7, 15 and 30 days starting from May 22, 2010). The studied traits included number of new pad on maternal pad (total pad number), number of pads emerged on each pad, pad length and width, and fresh and dry forage yield. It was found that irrigation treatment resulted in significant differences in most studied traits in the first year, so that the best treatment in terms of all studied traits was normal irrigation, i.e. once seven days, in the first year. But, given that this treatment was not economical, it was removed from the recommended treatments. In the first year, given the small size of the plants they were not harvested for measuring their fresh and dry forage yield since it was not economical. In the second year, following the treatment of normal irrigation, irrigation interval of 15 days resulted in the best fresh and dry yield of 35.15 and 3.67 t ha^{-1}, respectively. Considering that the soil of the study field was weak and inappropriate, it can be said by sure that irrigation interval of 15 days can result in yield higher than that obtained in the present study.

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INTRODUCTION

Grazing from pastures in an extent three times greater than their production capacity weakens and destroys the plants (forage loss) on one hand and decreases the production of protein and dairy products on the other hand; and finally, it causes soil erosion and water loss and its consequences (Sharif Abad and Torknejad, 2000). Following World War II, about 50% of arid and semi-arid pastures of the world lost their crop cover due to the population growth. Also, the population of sheep was increased by 75% during 1950-1989 and the ratio of sheep to plant cover fall from 0.25% per ha to 1. The contribution of pastures in feeding livestock has decreased from 80 to less than 25% during the last fifty years (Nefzaoui and Salem, 2001). One solution is cactus pear which is more efficient in converting water to dry matter than grasses and legumes, produces a great deal of forage, fruits and other useful products with high economical value, and has a high mean yield, so that it can produce 100 t ha^{-1} in regions with mean annual precipitation of 150, 200 and 400 mm. In Brazil, 400 000 ha (Nefzaoui and Salem, 2001) and in North Africa (Tunisia, Algeria and Morocco), up to 1 000 000 ha is devoted to the cultivation of cactus for forage supply (Domingues, 1993; Dos Santos, and Albuquerque. 2001). On the other hand, drought is a normal and natural attribute of arid zones. It has seriously damaged crops in the recent years. Hence, drought should not be confused with aridity because the latter is the mean long-term relationship between precipitation and evaporation. Such a drought occurs in arable fields, too. In these regions, mostly severe as well as seasonal droughts occur. Drought results in the loss of forage and consequent loss of many domestic livestock and injures dairy products to a large extent. One eminent attribute of cactus pear is its high capability in converting water to dry matter (Han and Felker, 1997; Nobel, 1991; Nobel, 1994) and its remarkable capability of producing high-quality dry matter in regions with water limitation (Felker et al, 2005). The only vitamin A source will be cactuses during drought period during which other crops are burned by the heat and drought. The point to note about cactuses is that their high moisture content is a very useful trait under water deficit conditions of arid regions because they lessen the water requirement of livestock to a large extent (Gathaara et al, 1987). Cactuses are of two kinds: thorny and unthorny. Some varieties of thorny cactuses are gourmet. They can be used in feeding of animals simply after burning their thorns which is done by special machines. Owing to these advantages of cactus pear and its high resistance to adverse environmental conditions like high temperature, long-time droughts and poor soils (DeKock, 1980), it can be regarded as an appropriate forage source in hot and arid regions especially in low-efficient as well as marginal fields. On the other hand, its high yield which is 20-100 t ha^{-1} can play an important role in supplying the forage required by animals in regions which face forage deficiency due to climatic limitations.

Materials and Methods

order to evaluate the possibility of cultivation of cactus pear (*Opuntia ficus indica* L.) under stress conditions, an experiment was carried out in Mohsenabad Research Station (Long. 46°16′34′′ E., Lat. 33°05′50′′ N.) in 2010-2011 in which the effect of irrigation treatments (rain-fed conditions and irrigation intervals of 7, 15 and 30 days starting from May 22, 2010) on agronomic traits of cactus pear was studied on the basis of a Randomized Complete Block Design with three replications. The field preparation started with 25-30-cm-deep plow. Then, the soil was sampled from the depth of 0-30 cm to measure its macronutrients and micronutrients content. The experimental plots were composed of two planting rows spaced 2 m apart with the length of 16 m. The treatments, main plots and replications were spaced 2, 2 and 3 m apart, respectively. The proliferation organ of cactus pear is its pads. In order to have successful cultivation and optimum establishment and rooting of the plants, two-third of their pads were placed under the ground. The field was fertilized with 100 t ha^{-1} manure before the planting to improve its fertility. Also, it was enclosed by fence to prevent the damages of grazing or rodents. After planting, the field was not irrigated until the onset of irrigation treatments (i.e. May 22). Three and seven days after the planting of pads, they were sprayed by iprodione+carbendazim (2:1000). Given the type of the experiment, the precise time of the emergence of new shoots and fruits was recorded during their growth. Moreover, to calculate the rate of the growth, the length and width of the pads were measured once a month. At harvest time, the plots were sampled to determine fresh and dry forage yield. The data were statistically analyzed – including simple and combined analysis of variance – by MS-TATC software and the means were compared by Duncan Multiple Range Test. Then, the effects of the studied factors were specified.

Results and Discussion

Results of analysis of variance revealed that irrigation interval significantly influenced the measured traits at 1% probability level (Table 1). The irrigation intervals of 7, 15 and 30 days resulted in the production of 6.12, 3.67 and 1.65 t ha^{-1} dry matter yield, respectively; and irrigation interval of 7 days was ranked in group *a*, irrigation intervals and 15 and 30 days were ranked in groups *b* and *c*, respectively, and rain-fed treatment was ranked in group *d* (Fig. 1a). It should be noted that dry yield of cactus is affected by its biomass weight which is, in turn, highly influenced by irrigation (Gathaara et al, 1987; Felker and Russell, 1987).

Rodngues et al (2010) obtained the highest annual biomass weight of 226 t ha^{-1} and dry matter yield of 13.9 t ha^{-1} under drip irrigation. Harnandezeton (2004), reported biomass weight and dry matter yield as to be 108 and 21 t ha^{-1}, respectively. CAM photosynthesis system is a system by which evapotranspiration is reduced by absorbing CO_2 at night, thick cuticle and lower number of stomata. Water storage system allows CAM plants to tolerate drought stress periods during which soil available water content decreases (Nobel, 1994; Smith, 1997). The biomass weights obtained under the irrigation intervals of 7, 15 and 30 days were 64.88, 35.16 and 16.11 t ha^{-1}, respectively (Fig. 1b). The highest number of pads on maternal pad was 15.73 obtained under the irrigation interval of 7 days following by the irrigation interval of 15 days which was ranked second. The latter treatment did not show significant difference with the irrigation interval of 30 days. No pad was produced under rain-fed conditions (Fig. 1c). The newly produced pads increased the sensitivity of maternal pads to drought because they had C3 photosynthesis system as well as open stomata during day (Osmond, 1978). Since then, the water in maternal pad would be needed (Nobel, 1994; Wang et al, 1996). Agronomic species of Opuntia produce pad under stress too, whereby weak pads produced under stress disappear (Pimienta et al, 2002), whereas the wild species lack this mechanism and in fact, they do not produce new pads to avoid stress. Under appropriate irrigation conditions, newly produced pads increase the photosynthesis for maternal pad (Gifford and Evans 1981; Wang et al, 1996). The number of pads produced on maternal pad deeply influences net CO_2 absorption rate (Nobel and Hartsock 1984; Pimienta et al, 2001). The irrigation intervals of 15, 30 and 7 produced 2.83, 2.5 and 2.11 new pads on each pad and were ranked in group *a*. Under rain-fed conditions, no new pad was produced on each pad and was ranked in group *b* (Fig. 1d). The longest pads (with the average length of 22.49 cm) was obtained from the irrigation interval of 7 days which showed no significant difference with the irrigation interval of 15 days (with the average length of 20.48 cm) and the lowest one was observed under rain-fed conditions (due to the complete ruin of the pads) and so, it was ranked in group *c* (Fig. 1e). The average pad width was 20.07, 17.95 and 16.20 cm under the irrigation intervals of 7, 15 and 30 days and showed significant differences with each other and with that under control (rain-fed conditions) at 1% level (Fig. 1f).

Table 1. The results of square means for *Opuntia ficus indica* L.

SOV	df	Pad on mother pad	Pad on pad	Pad length	Pad width	Biomass	Dry matter
Block	2	0.726	0.073	1.009	0.146	3.162	0.28
Irrigation	3	119.95**	2.435**	309.35**	10.492**	2297.6**	18**
Error	6	0.86	0.117	0.755	0.163	6.967	0.07
CV		12.6	18.882	5.55	4.29	9.03	8.94

n.s: not significant, * probability 5% and ** probability 1%.

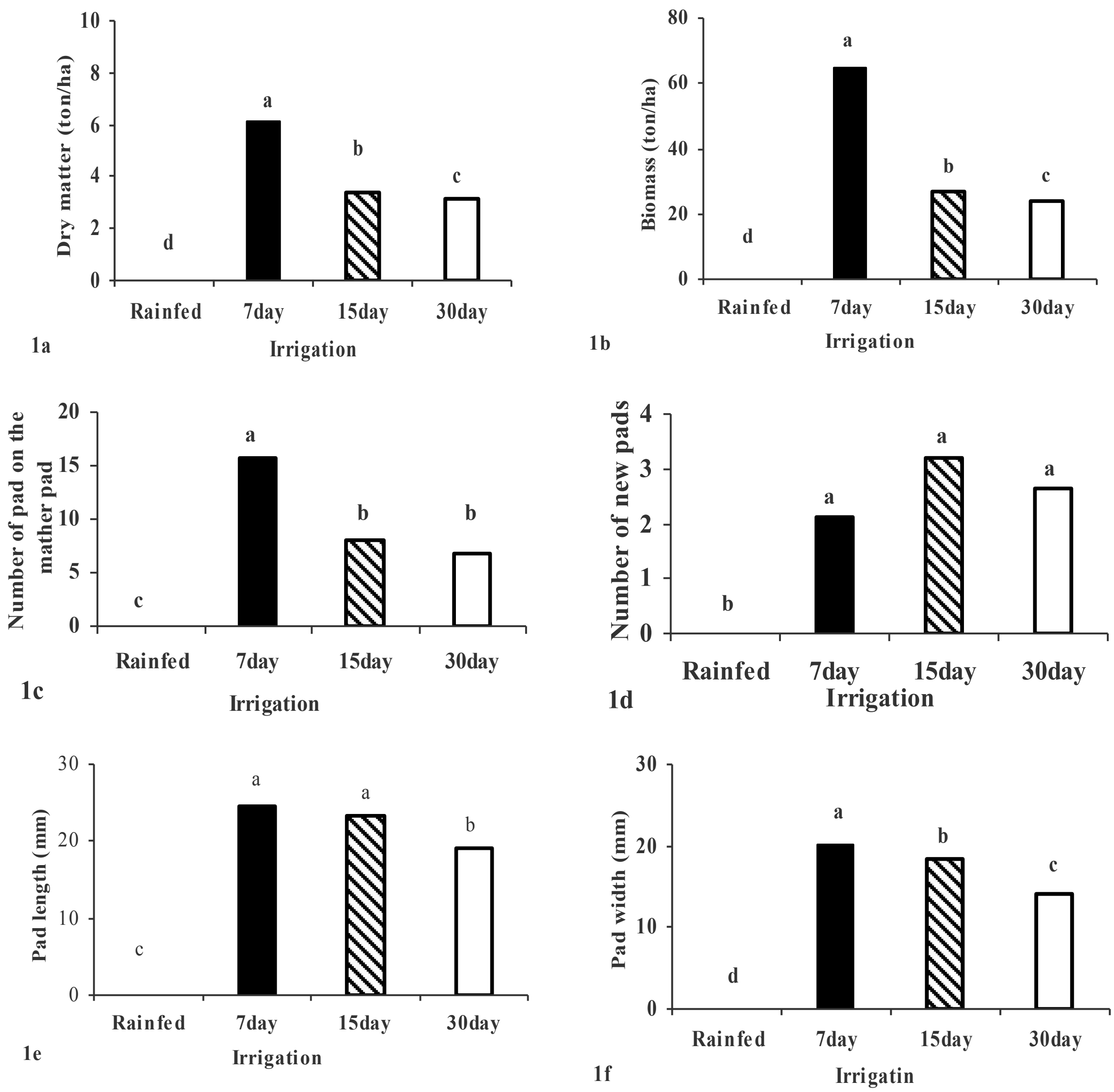

Figure 1. The effect of irrigation levels on a) Dry matter, b) Biomass, c) Number of pad on mother pad, d) Number of new pads, e) pad length and f) pad width.

Net CO_2 absorption rate of maternal pads with new pads is significantly lower under drought stress than under optimum irrigation conditions. On the other hand, more number of young pads acts as an adverse factor for the survival of the plant under stress. The regular norm of the increase in sinks (new pads) among other C4 and C3 plants does not lead to the increase source photosynthesis capacity of maternal pad in cactus pears (Gifford and Evans 1981; Wang et al, 1996). Optimum level of irrigation of cactus pears results in optimum net CO_2 absorption rate during date and night via a combination of CAM (maternal pad) and C3 (new pads) photosynthesis pathways as well as optimum water use efficiency, carbon balance of the plant and radiation use under appropriate and inappropriate conditions (Dodd et al, 2002). As a result of C3 pathway, CAM plants have the best carbon translocation chain when abundant water is available (Kitao et al, 2003). Daily photosynthesis of C3 and C4 plants is affected by stomata closure under water stress conditions (Chaves, 1991; Yordanov et al, 2000) which reduces the amount of CO_2 required in mesophyll (Warren, 2004; Kitao et al, 2003). Since CAM plants have open stomata during night, they can absorb CO_2 under high temperature and conditions which are regarded as stress for C3 and C4 plants (Pimienta et al, 2002).

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