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Physiologic and agronomic traits in safflower under various irrigation strategies, planting methods and nitrogen fertilization

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ABSTRACT

Drought and limited supplies of water in many areas of the world have created serious concerns about agricultural production and global food security. Hence, application of more efficient management strategies in fields has been favourably developed in arid and semi-arid regions. In this respect, physiological and agronomic behaviour of a crop can be an advantageous index for identification of its response to different management policies. The objective of this study is to investigate the effects of partial root drying (PRD) irrigation, planting methods and nitrogen fertilization on some agronomic and physiologic behaviour of safflower (*Carthamus tinctorius* L.). The experiment was designed as split–split plot that arranged in randomized complete blocks with irrigation strategy as the main plot, planting method as the subplot and nitrogen levels as the sub-subplot in three replications. The irrigation strategies consisted of ordinary furrow irrigation (OFI) and variable alternate furrow irrigation (VAFI) as a PRD technique. The planting methods included of on-ridge planting (P1) and in-furrow planting (P2) methods The fertilizer levels were 0 (N_0), 100 (N_1) and 200 (N_2) kg ha^{-1} of urea as 0, 46 and 92 kg ha^{-1} of nitrogen. Results of this study indicated that VAFI strategy can be an alternative irrigation policy for safflower farms in which certain irrigation water saving, low yield reduction and more drought adaptation in crop is provided. Furthermore, it was shown that safflower is relatively drought-tolerant to water stress in which the stem elongation stage was more sensitive to drought than the heading and flowering stages. Since, photosynthesis rate (A_n) was strongly correlated with heads formation (number of heads per plant, NHP) and seeds accumulation (number of seeds per plant, NSH) in safflower, the photosynthesis deficiency by water stress resulted in decrease of safflower seed yield mainly thorough the reduction in NHP and NSH than other components such as number of branch per plant (NBP) and thousand seeds weight (TSW). Based on findings, in-furrow planting method can be another favourable strategy due to its influence on enhancement of yields, photosynthesis, stomatal conductance (g_s), transpiration rate (T_r), leaf area index (LAI) and vegetative growth of safflower. Besides, nitrogen fertilization at rate of 46 kg ha^{-1} is recommended for improving the agronomic and physiologic traits of safflower.

1. Introduction

Drought and scarce resources of water have stimulated the water scientists to seek for more efficient strategies in application of irrigation water. Deficit irrigation (DI) as a water saving strategy is commonly used in arid and semi-arid regions in order to decrease applied irrigation water and increase water productivity. The partial root-zone drying irrigation (PRD) is a version of DI in which half of the root zone receives water in one irrigation event and the other half receives water in the next irrigation event (Ahmadi et al., 2010). The variable alternate furrow irrigation (VAFI) is an approach of PRD technique in surface irrigation. The changing of the irrigation sides in VAFI induces production of root-originated ABA from the dry side that regulates the stomatal conductance (g_s) and net photosynthesis (A_n) (Ahmadi et al., 2010). Application of PRD irrigation may also impose some restrictions on the crop physiological parameters depending on the severity and timing of the drought stress (Ahmadi et al., 2010). Drought stress, particularly at its mild intensity, can inhibit leaf photosynthesis and stomatal conductance in most green plants (Medrano et al., 2002). Therefore, photosynthesis can be used to monitor plant response to abiotic stress and its association with plant growth has been observed in some crops like sunflower (Ashraf, 1999). The control of water loss through stomatal regulation has been recognized as an early plant

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Table 1
Physico-chemical properties of the soil and water at experimental site.

Characteristic	Unit	Soil Depth	(cm)			Irrigation water
		0–30	30–60	60–90	0–90	
Sand	%	35	23	21	–	–
Silt	%	35	38	39	–	–
Clay	%	30	39	40	–	–
BD	$g\,cm^{-1}$	1.39	1.44	1.47	–	–
FC	$cm^3\,cm^{-3}$	0.32	0.34	0.36	–	–
PWP	$cm^3\,cm^{-3}$	0.11	0.14	0.16	–	–
EC	$dS\,m^{-1}$	–	–	–	0.64	0.718
pH	–	–	–	–	7.54	7.58
Cl^-	($meq\,l^{-1}$)	–	–	–	1.2	0.9
Na^+	($meq\,l^{-1}$)	–	–	–	1.0	0.62
K^+	($meq\,l^{-1}$)	–	–	–	0.03	0.03
Ca^{2+}	($meq\,l^{-1}$)	–	–	–	4.5	4.0
Mg^{2+}	($meq\,l^{-1}$)	–	–	–	2.1	3.0
HCO_3^-	($meq\,l^{-1}$)	–	–	–	4.0	4.0
SO_4^{2-}	($meq\,l^{-1}$)	–	–	–	2.4	2.5

BD: Bulk density.
FC: Field capacity.
PWP: Permanent wilting point.
EC: Electrical conductivity.

response to drought (Jia and Zhang, 2008; Harb et al., 2010). Stomatal limitation that is generally considered as the major factor of photosynthesis reduction in water deficit conditions (Galmés et al., 2007; Bousba et al., 2009) has been attributed to a decline in sub-stomatal CO_2 concentration (Ci). The reduction of carbon assimilation rate and water loss in drought conditions resulted in maintenance of the carbon assimilation at the cost of low water availability (Brock and Galen, 2005; Sausen and Rosa, 2010; Pan et al., 2011). On the other hand, stomata closure is known to have a more inhibitory effect on transpiration of water than that on CO_2 diffusion into the leaf tissues (Chaves et al., 2009; Sikuku et al., 2010). Consequently, low transpiration may also impact the various agronomic and physiologic components of crops that essentially contribute in the quantity and quality of productions.

Proper planting methods can be another strategy to have more water saving in areas with limited water supplies. In this respect, better conditions for plant growth may be provided by in-furrow planting due to higher soil water and temperature (Shabani et al., 2013b; Yarami and Sepaskhah, 2015b). In addition, in-furrow planting has recognized as an appropriate strategy by Shahrokhnia (2016) in order to reduce downward fertilizer leaching and other relevant environmental concerns. Regarding to the chosen planting method, the components of crop growth or yield production can also be affected by the situation. In the investigations by Yarami and Sepaskhah (2015a) and Shabani et al. (2013a) the leaf area index, dry matter, photosynthesis rate and stomatal conductance have been influenced by in-furrow planting for saffron (*Crocus sativus* L.).and rapeseed (*Brassica napus* L.), respectively.

Nitrogen is one of the most important nutrients for crop production because it affects dry matter production by influencing leaf area development and maintenance as well as photosynthetic efficiency. Under N deficiency, growth is inhibited and shoot–root ratio is decreased (Steer and Harrigan, 1986). Besides, N deficiency reduces the radiation interception, radiation use efficiency, dry matter partitioning to reproductive organs, leaf area index, and protein concentration of seeds (Marschner, 2012). Meanwhile, N deficiency delays both vegetative and reproductive phenological development, reduces leaf emergence rate, yield, and yield components such as the number of heads per plant, the number of seeds per head, the single seed weight, and the number of seeds per plant (Gilbert and Tucker, 1967; Jones and Tucker, 1968; Steer and Harrigan, 1986).

It is interesting to identify the effects of applied management strategies on factors that contribute as base factors in crop growth and yield production and it is favourable for proper decision making in farms. Safflower (*Carthamus tinctorius* L.) as a multipurpose crop is grown in many areas of the world however, researchers has shown fewer interests to this crop rather than the others. The various uses of safflower are included as edible oil, food colouring and flavouring, dyes making, pharmaceutical applications, livestock and poultry feed and biofuels. In this respect, the objectives of this study were to evaluate the effects of various irrigation strategies, planting methods and N application rates on some agronomic, physiologic and gas exchange parameters of safflower that was grown in a semi-arid and water restricted area.

2. Materials and methods

2.1. Experimental site

This study was conducted in the Experimental Research Station of the Agricultural College, Shiraz University in Iran during the 2012–2013 and 2013–2014 growing seasons. The station was located in Badjgah valley at 29°56′N latitude, 52°02′E longitude and 1810 m above mean sea level in a semi-arid area. There was a weather station located near the site for daily recording of the climatic parameters (rainfall, maximum and minimum temperatures, maximum and minimum relative humidity, wind velocity, sunshine hours, pan evaporation). The mean monthly climatic data for the two years of experiment have reported in Fig. 1. Rainfall events were mostly occurred from November to May for both years of study as 433 and 276 mm for first and second year, respectively. Higher depths of precipitation were observed in November, December and April of 2012–2013 and November and January of 2013–2014. The average of minimum temperature was below zero from December to February of both years and it was in lower value in second year of experiment due to snowfall in comparison with the first year. The mean relative humidity was about 45% during the experiment and it was lower in second year compared with the first year of study. The soil and irrigation water characteristics presented in Table 1 according to methods detailed in Sparks et al. (1996) and the physical properties of soil (Table 1) were taken from the study of Barzegari (2012).