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Yield and some morphological traits of the medicinal herb desert indianwheat (*Plantago ovata* Forssk.) in Jiroft, Iran as affected by water deficit stress and manure

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Abstract

In order to study the effect of water deficit stress and manure application on seed yield and morphological traits of desert indianwheat (*Plantago ovata* Forssk.), a split-plot experiment was conducted in greenhouse of Islamic Azad University, Jiroft Branch, Iran in spring 2009 based on a Randomized Complete Block Design with three replications. The treatment of water deficit was the main plot at three levels of irrigation when soil moisture reached 75, 50 and 25% of field capacity (mild, moderate and severe stress, respectively). Also, manure application formed the sub-plot at five levels of 0, 10, 20, 30 and 40 t/ha. The results showed that water deficit significantly affected seed yield and other related traits including plant height, spike length, spike number per plant, root dry weight and hay yield except 1000-seed weight. The treatment of manure did not significantly affect plant height and 1000-seed weight. The treatment of mild water deficit stress with the application of 20 t manure/ha produced the highest seed yield (232.3 kg/ha) which showed no significant difference with the treatment of moderate water deficit stress at the same manure level. Thus, the application of 20 t manure/ha is recommended in the cultivation of desert indianwheat in climatic conditions of Jiroft, Iran, when there is a relative water deficiency.

Keywords: desert indianwheat; water deficit stress; manure; seed yield; field capacity.

Introduction

Desert indianwheat (*Plantago ovata* Forssk.), belonging to the family of Plantaginaceae, is traditionally used as a medicine in South Asia, but nowadays it is widely used throughout the world as a medication. Being native to Mediterranean regions including North Africa, Europe and Pakistan, desert indianwheat is able to grow in a wide range of agroclimates; however, it is limited to arid zones because of its low water demand (Zahoor *et al*., 2004). Its seeds are useful in healing dysentery, enteritis and gastritis (Dagar *et al*., 2006). As a result of growing demand for medicinal herbs in traditional medicine and pharmaceutics industries, some medicinal herbs are cultivated at a commercial level, but soil moisture deficit is a serious threat to their cultivation (Abdul Jaleel *et al*., 2007). Abiotic stresses are the major cause of yield loss throughout the world so that on average, they, particularly drought and salt stresses, cause 50% loss of staple crops (Valliy and Nguyen, 2006). Supplying enough water is an important cultural practice for realizing optimum growing conditions for a plant population and their optimum yield by avoiding the occurrence of moisture stress during sensitive growth stages (Stone *et al*., 2001). Optimization of irrigation management is accompanied with planting appropriate crops in arid and semi-arid zones. Therefore, inadequate irrigation water capacity

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and limited water resources are among the factors forcing the farmers of these zones to reduce irrigation, but it is well known that the effects of water stress on growth and yield depends on species and cultivar (Cakir, 2004). Nowadays, water deficit is an important limiting factor of yield increase in arid and semi-arid regions and the yield loss caused by drought stress is much greater than that caused by other environmental stresses (Rodriguez, 2006). The growth potential of herbs under water deficit and their economical value have made them suitable alternative crops in arid agro-ecosystems (Koocheki and Nadjafi, 2003). Planting drought-resistant crops with lower water demand is a technique of agronomical management for optimal usage of these resources in arid climates. Using organic farming helps the persistence of sustainable agriculture and environmental quality (Poudel *et al*., 2002). In a study on the effects of different drought stress levels (100, 75, 50 and 25% of field capacity) on desert indianwheat, yarrow, sage, calendula and chamomile, Lebaschy and Sharifi Ashoorabadi (2004) reported that shoot weight and the height of the studied crops started to decrease with drought stress intensification. Nadjafi and Rezvani (2002) showed that irrigation had significant effect on grain yield, hay yield, spike number per plant, plant height and spike length of desert indianwheat. They reported that the highest grain and hay yield was observed with irrigation interval of 7 days. In a study on calendula, Shubhra *et al*. (2004) found that grain yield, oil yield, plant height and flower number per plant severely decreased under drought stress. Organic cultivation of medicinal herbs ensures their quality, so that it reduces the likely adverse effects on their medicinal quality and yield (Griffe *et al*., 2003). Organic fertilizers are desirable nutrition resources for crop production and they improve soil physical and chemical properties (Ewulo, 2005). Application of manure and biofertilizers decreases the demand for application of chemical fertilizers, helps the conservation of environment and improves soil fertility and crop yield. Most researchers believe that manures increase soil porosity and make it spongy by increasing its organic matter and humus content and hence, they decrease apparent specific weight of soil. These factors in turn improve root growth and development in soil and increase water and nutrient uptake rate of crops (Singh *et al*., 2003; Ghosh *et al*., 2004; Blaise *et al*., 2005). Yadav *et al*. (2002) applied manure with N fertilizer and farmyard manure (FYM) in psyllium cultivation and found that tiller number per plant, plant height, dry matter accumulation, spike number per plant, grain number per spike and grain yield were increased which was associated with the effect of FYM in enhancing nutrient supply and hence improving photosynthesis and partitioning of materials in source. Lotfi *et al*. (2009) studied the effect of water deficit stress and manure on quantitative and qualitative characteristics of psyllium and observed that manure significantly affected all traits except plant height and 1000-seed weight, so that the highest seed yield was obtained by the application of 40 t manure/ha. Therefore, the current experiment studied the effect of water deficit stress and manure and their interaction on seed yield and morphological traits of desert indianwheat for realizing higher yield in Jiroft Region, Iran.

Materials and Methods

The present study was carried out as a split plot experiment based on a Randomized Complete Block Design with three replications in greenhouse of Islamic Azad University, Jiroft Branch, Iran in spring 2009. The water deficit stress was the main plot at three levels including irrigation when soil moisture reached 75, 50 and 25% of field capacity (mild, moderate and severe stress, respectively). The sub-plot was the application of cattle manure at five levels of 0, 10, 20, 30 and 40 t/ha. The pots were 20 cm in diameter and 20 cm in height with average soil amount of 6 kg (the amount of manure which was 6 kg in each pot was determined by calculating the weight of the soil of 1 ha with the depth of 30 cm with an apparent specific weight of 1.5 g/cm^3 after the relevant conversions, e.g. approximately 133 g manure was added to 6-kg pots to have the treatment of 10 t manure/ha). Ten pots were watered so long as to reach their saturation; then, they were covered by plastic and after 24 hours during which the soil moisture drained from the holes at the bottom of the pots, their soil was sampled and oven dried at 100°C for 24 hours. The amount of manure to be added to the pots was calculated on the basis of soil analysis and properties (Table 1), plant fertilizer demand and pot surface area.

After pots preparation, the seeds were manually planted in furrows with the depth of 0.5 cm. After emergence, they were thinned twice in one month and then, four plants were kept in

Table 1. The characteristics of the soil used in the experimental pots

Soil depth (cm)	Soil texture	pH	EC × 10^6 (μmos.cm^{-1})	SP (%)	Field capacity (%)	Total N percentage	Absorbable P (ppm)	Absorbable K (ppm)
0-15	Loom-sandy	7.9	1.2	2.9	20	0.02	8	240

each pot. Also, the weeds were regularly removed. The treatments of water deficit stress were applied after full establishment of seedlings at 3-4-leaf stage and were continued until physiological maturity. Moisture meter (ECH2O CHECK, USA) was used for determining the time of irrigation and applying the water deficit stress treatments. The pots were irrigated when their moisture reached the desired field capacity. The harvest date was determined on the basis of such visual marks of maturity as yellowing and drying of leaves, pinking of seeds and browning of spikes (Gupta *et al*., 1994). The measured traits included seed yield, 1000-seed weight, plant height, spike length, spike number per plant, seed number per spike, root dry weight and hay yield. Root dry weight was measured after oven drying at 70°C for 48 hours. All data were analyzed by software MSTAT-C and the means were compared by Duncan's multiple rande Test.

Results and Discussion

The results of analysis of variance showed that the effect of water deficit stress was significant on seed yield, plant height, spike length, root dry weight and hay yield at 1% probability level and on seed number per spike and spike number per plant at 5% probability level. 1000-seed weight was not affected by water deficit stress. On the other hand, different manure levels significantly affected seed yield, spike number per plant, seed number per spike, root dry weight and hay yield at 1% level and spike length at 5% level. Plant height and 1000-seed weight were not affected by manure levels. The interaction between water deficit stress and manure level significantly affected seed yield, spike length, spike number per plant, root dry weight and hay yield at 1% level and seed number per spike and 1000-seed weight at 5% level. Plant height was not affected the interaction of the two factors.

The highest seed yield (232.3 kg/ha) was produced under the treatment of mild water deficit stress and the application of 20 t manure/ha which did not show significant difference with that produced under the treatment of moderate water deficit stress and the application of 20 t manure/ha. Also, the treatment of severe water deficit stress with no manure application had the lowest seed yield (9.2 kg/ha). This can be related to the fact that manure improves soil physical and chemical properties and its water holding capacity by which it increases seed yield (Blaise *et al*., 2005). In a study on the effect of irrigation frequency and manure on cumin, Ghanbari *et al*. (2005) reported that by application of manure, irrigation frequency can be lowered without putting the yield in stake which is in agreement with the results of the present study. Singh *et al*. (2003) reported the increase in seed yield of isabgol when manure was accompanied with some soil mineral amendments.

The highest plant height (16.67 cm) was obtained under the treatment of mild water deficit stress with the application of 40 t manure/ha which did not show significant difference with that under the treatment of mild water deficit stress with the application of 20 and 30 t manure/ha. In a study on the effect of moisture

Table 2. Means comparison of seed yield and other studied traits of Desert Indianwheat as affected by water-deficit stress and manure

Source of variations	df	Mean of squares							
		Seed yield	Plant height	Spike length	Spike no./plant	Seed no./spike	1000-seed eight	Root dry weight	Hay yield
Replication	2	1247.224^{ns}	2.156^{ns}	0.039^{ns}	12.356^{ns}	12.055^{ns}	0.009^{ns}	0.0001^{ns}	988.356^{ns}
Water-deficit stress	2	17272.668**	129.626**	7.222**	104.154*	227.712*	0.021^{ns}	0.055**	220722.754**
Error *a*	4	197.426	0.956	0.039	18.889	20.117	0.141	0.0001	6612.889
Manure	4	20991.809**	4.533^{ns}	1.139*	315.744**	161.524**	0.109^{ns}	0.042**	127119.911**
Manure × water-deficit stress	8	7438.296**	4.317^{ns}	1.056**	122.378**	54.918*	0.112*	0.024**	24600.478**
Error *b*	24	399.032	7.856	0.296	6.267	20.328	0.049	0.002	3855.572
C.V. (%)		17	24	31	11	26	17	23	21

*, ** and ^{ns} show statistically significance at 5 and 1% probability level and non-significance.

Table 3. Means of interactions between water-deficit stress and manure for seed yield and morphological traits of Desert Indianwheat

Treatments		Seed yield (kg/ha)	Plant height (cm)	Spike length (cm)	Spike no./plant	Seed no./spike	1000-seed weight (g)	Root dry weight (g)	Hay yield (kg/ha)
75% of FC	0 t manure/ha	54.4hij	13.67abcd	1.333cde	18.00ef	11.61cd	1.350ab	0.1533cde	146.3de
	10 t manure/ha	182.5bc	14.00abc	1.667bcde	22.67cde	27.88a	1.400ab	0.1133def	492.3ab
	20 t manure/ha	232.3a	15.33ab	2.667b	34.67a	22.40abc	1.153bc	0.4867a	626.7a
	30 t manure/ha	147.2cde	15.33ab	2.333bc	26.67bcd	17.72abcd	1.407ab	0.2867b	397.0bc
	40 t manure/ha	160.2cd	16.67a	3.667a	23.00cde	25.06ab	1.297ab	0.2867b	432.3bc
50% of FC	0 t manure/ha	70.5ghi	11.67abcd	2.333bc	15.67f	14.45bcd	0.8533c	0.3000f	162.0de
	10 t manure/ha	37.4ij	11.33abcd	1.833bcde	13.00f	16.72abcd	1.390ab	0.2333bc	299.3cd
	20 t manure/ha	224.6ab	13.00abcd	2.500b	31.33ab	26.25ab	1.637a	0.1267cdef	516.0ab
	30 t manure/ha	102.7efgh	9.000cd	1.333cde	25.33bcd	12.97cd	1.350ab	0.1967bcde	236.0d
	40 t manure/ha	131.1def	11.33abcd	2.000bcd	27.33bcd	16.09bcd	1.217abc	0.1533cde	301.1cd
25% of FC	0 t manure/ha	9.2j	9.000cd	1.000de	6.66c	6.222d	1.167bc	0.0933ef	18.0e
	10 t manure/ha	118.8defg	10.33bcd	1.000de	22.00de	17.53abcd	1.120bc	0.2167bcd	237.3d
	20 t manure/ha	78.9ghi	10.00bcd	1.333cde	14.00f	14.91bcd	1.283ab	0.2233bcd	160.0de
	30 t manure/ha	144.9cde	8.33d	0.8333e	27.33bcd	16.52abcd	1.460ab	0.1967bcde	2189.3cd
	40 t manure/ha	88.9fgh	8.33d	0.833e	28.67bc	10.56cd	1.203abc	0.1767bcde	177.3d
LSD		45.62	4.723	0.9168	5.717	10.30	0.3730	0.1021	141.8

Figures with the same letter(s) in each column show statistically non-significance at 5% level.

stress and manure on *Plantago psyllium* yield and yield components, Koocheki *et al*. (2004) reported that the highest plant height was produced under the treatment of irrigation interval of 10 days and that manure treatments did not affect plant height.

The treatment of mild water deficit stress with the application of 40 t manure/ha had the highest spike length (3.667 cm). Carrubba *et al*. (2002) and Chatterjee (2002) reported similar results, too. The treatment of mild water deficit stress with the application of 20 t manure/ha had the highest spike number per plant (34.67) which did not show significant difference with the treatment of moderate water deficit stress and the application of 20 t manure/ha. It might be due to the supply of macro and micro elements by manure which subsequently, increased plants potential in producing spike per plant. Also, Ganpat *et al*. (1992) stated that the application of manure had positive and significant effect on spike number per plant in blond psyllium which is in agreement with the results of the current study.

Various studies on blond psyllium in India showed the increase in spike number per plant in response to the increase in irrigation frequency and manure application (Patel *et al*., 1996). In the present study, the highest seed number per spike (27.88) was produced under the treatment of mild water deficit stress with the application of 10 t manure/ha which showed no significant difference with that under the treatment of moderate water deficit stress with the application of 20 t manure/ha. Koocheki *et al*. (2004) reported similar results, too.

Thousand-seed weight was not significantly affected by the treatments of water deficit and manure which is in agreement with some other studies (Ehteramian, 2002; Koocheki *et al*., 2004; Lotfi *et al*., 2009). Since 1000-seed weight is an indicator of the status and the length of reproductive period in plants and after the flowering initiation and the establishment of seed number per plant, the seeds become an important destination for receiving and storing some assimilates, 1000-seed weight of the stressed plants with 1000-seed weight of the normal plants should be distinguished. However, because of the dependence of 1000-seed weight on genetic factors rather than environmental factors, environmental stresses seemingly can only reduce desert indianwheat seed weight down to a certain point because the plant supplies the minimum material required for developed seeds through decreasing seed number. Some reports show that frequent irrigations decrease 1000-seed weight which is due to the increased number of spikes per plant because of the availability of the inputs for producing more assimilates and as a result, the share of assimilates partitioned to each spike decreases and leads to the decrease in 1000-seed weight (Ahmadian *et al*., 2004).

The treatment of mild water deficit stress with the application of 20 t manure/ha produced the highest root dry weight (0.486 g/plant) and hay yield (626.7 kg/ha).

Table 4. Coefficients of correlation between the measured traits in Desert Indianwheat

	Spike number	1000-seed weight	Spike length	Plant height	Hay yield	Root dry weight	Seed number	Seed yield
Spike number	1							
1000-seed weight	0.816**	1						
Spike length	0.303ns	-0.261ns	1					
Plant height	-0.345ns	-0.292ns	0.836**	1				
Hay yield	-0.375ns	0.019ns	0.645**	0.687**	1			
Root dry weight	0.278ns	0.135ns	0.356ns	0.430*	0.573**	1		
Seed number	0.275ns	0.396ns	0.640**	0.671**	0.894**	0.299ns	1	
Seed yield	0.720**	0.097ns	0.513*	0.534**	0.916**	0.462*	0.839**	1

*, ** and ns show statistically significance at 5% and 1% level and non-significance, respectively.

In total, root is the first organ which encounters drought stress and so, its efficiency for providing nutrients and water to other organs is reduced and these factors all may cause the decrease in root dry weight (El Nadi *et al*., 1969). Singh *et al*. (2003) reported the increase in hay yield of isabgol with the application of different combinations of organic and inorganic amendments. Also, Scheffer *et al*. (1993) indicated that organic fertilizer increased biomass production and their extracted compounds in the cultivation of medicinal herbs. Nadjafi (2002) reported the increase in hay yield with the increase in irrigation frequency, too. In a study on the effect of irrigation interval and manure on yield of okra/pepper intercrops, Lawal and Rahman (2007) recommended the application of 5 t manure and 10-day irrigation intervals (i.e. moderate stress) in an economical sense, although they applied 400 kg chemical fertilizer/ha whose results are partly in agreement with the results of the present study.

The coefficients of correlation between the studied traits are shown in Table 4. Spike number per plant, plant height, hay yield and seed number per spike had high correlations with seed yield at 1% probability level and the correlation of root dry weight and spike length with seed yield was significant at 5% probability level. In addition, no significant correlation was observed between 1000-seed weight and seed yield. The highest correlation was found between hay yield and seed number per spike.

Conclusion

According to the results of the current study and given that desert indianwheat is a quite drought resistant plant and has a short growing period, it can be an appropriate crop for Jiroft Region, Iran. Therefore, moderate water deficit stress accompanied with the application of 20 t manure/ha is appropriate for realizing the maximum yield in an economical sense.

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