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Effect of Different Irrigation Regimes on the Yield and Qualitative Characteristics of Different Cultivars of Soybean (*Glycine max* L.) in Jiroft

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ABSTRACT

Background: Identification and development of new varieties are important elements of improving and sustaining soybean yield, especially in arid and semi-arid regions, including Iran.

Methods: The study aims to investigate the effect of different levels of low irrigation on yield and qualitative characteristics of different soybean cultivars (Dezful 504, Sahar, Telar, Tekavar, Zan and Sari) under water stress (90%, 70% and 50% of the field capacity), under the climatic conditions of Jiroft during two years (2020 and 2021). This experiment was carried out as a split plot based on a randomized complete block design with 18 treatments and 3 replications at the farm of South Kerman Agricultural Research and Training Center and Natural Resources.

Result: The highest qualitative characteristics and performance were in the cultivar 504 Dezful. Examining the results related to the interaction effect of irrigation × variety showed that the variety 504 Dezful under the conditions of 90% of the field capacity has the highest amount of grain yield (3748 kg/ha), oil yield (916.41 kg/ha) and protein yield (1351.53 kg/ha). Also, this cultivar was superior to cultivars in all levels of low irrigation. In general, and according to the obtained results, Dezful cultivar 504 was identified as the most resistant cultivar and Sari cultivar as the most sensitive cultivar to drought stress.

Key words: Drought stress, Oil yield, Proline content, Southern Kerman, Variety.

INTRODUCTION

Soybean, with the botanical name *Glycine max* L., is a plant with high economic value, which has about 20% oil and 40% protein among oilseeds in the world, and has the largest cultivated area (120 million hectares) (FAO, 2021; Szpunar-Krok and Wondolowska-Graboweska, 2022). In Iran, it is known as Suja and is an annual plant, which grows in the form of a firm and relatively leafy bush (Kochaky and Sarmadnya, 2011). The growth and development of agricultural plants are permanently affected by various environmental factors, and environmental stress is one of the most important factors that reduce the yield of agricultural products in the world (Franklin *et al*., 2010). Drought and the resulting stress is one of the most important and common non-living environmental stresses that limit agricultural production and affect almost every aspect of plant growth (Aslam *et al*., 2006; Manna *et al*., 2021). According to some researchers, mild irrigation stress in some leguminous plants such as *Lathyrus satius* L. increases water use efficiency, and the varieties have different resistance to water stress (Alizadeh *et al*., 2014; Bahramnejad *et al*., 2021). One of the factor affecting the slow rate of supply is climate change and the phenomenon of global warming, which has faced arid and semi-arid areas with a decrease in rainfall and continuous droughts and has caused a significant increase in the areas affected by drought stress (Qiu *et al*., 2023). The best way to improve its performance and stability under stress conditions is to use physiological methods, which are among the fastest ways to develop new tolerant varieties.

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One of the methods that can be used to expand the area under soybean cultivation in such conditions and save on irrigation water consumption is to use the low irrigation method and promote drought-tolerant cultivars. This research was conducted to investigate the effect of different levels of low irrigation on the yield and quality characteristics of different soybean cultivars under the climatic conditions of Jiroft city, Kerman province as an arid and semi-arid region.

MATERIALS AND METHODS

To investigate the impact of different levels of irrigation on the yield and quality characteristics of different soybean cultivars in the Jiroft, experiment was conducted during two consecutive cropping year 2020 and 2021 with 18 different treatments with 3 replication under split plot design. The main factor was the irrigation 90, 70 and 50 per cent of water requirement and the second factor was six soybean varieties including Sari, Sahar, 504 Dezful, Tekavar, Telar and Zan. The distance between the rows and between the bushes on the row was 50 and 5 cm, respectively and the amount of seed used per hectare was 70 kg/ha. The buffer zone of 3 meter was kept between main and secondary plot to prevent the effect of irrigated water.

The same agricultural management system was applied to all treatment as per the recommendation of the Agricultural Research Center and regional customs. The land used was plowed and disked before cultivation. To know the physical and chemical properties of the soil, two composite samples from the depth of 0-25 and 25-50 cm of the soil profile were taken and sent to the laboratory of the Agricultural Research Center. While performing the soil analysis (Table 1 and 2), The required chemical fertilizers were used according to the soil test and fertilizer recommendation and for all the studied treatments. hand weeding was done to remove the weeds from experimental field. The seeds of genotypes and cultivars were obtained from Karaj Seedling and Seed Breeding Institute and planting was done on August 7 of every year.

Irrigation scheduling

The values of water with constant irrigation interval of seven days were obtained using the following formula:

Amount of water (m^3 water ha^{-1}):

mm evaporation during 7 days in class A pan × 75% (class A pan coefficient) × coefficient for each treatment × 10

The amount of water per plot using water cubic meters per hectare (m^3 water ha^{-1}) and the level of each plot is specified and each treatment was provided using a discharge tube (Bahramnejad *et al.,* 2021). Irrigation of each plot was done by drip and using standard tape. Irrigation treatments were carried out after plant emergence. The traits were measured at the physiological ripening stage and include traits (the amount of chlorophyll a, b and total, carotenoid, leaf proline, protein percentage and seed oil percentage) and seed yield.

The amount of chlorophyll was estimated according to the formulas of Arnon and Mackinney, respectively, to estimate the amount of chlorophyll a, b, total and carotenoids (Mackinney, 1941; Arnon, 1949).

$$\text{Chl a (mg/g FW)} = \frac{[12.25A(663)-2.55A(646)]\times V}{W} \times 1000$$

$$\text{Chl b (mg/g FW)} = \frac{[22.31A(646)-4.91A(663)]\times V}{W} \times 1000$$

$$\text{Chl a+b (mg/g FW)} = \frac{[17.76A(646)+7.34(663)]\times V}{W} \times 1000$$

$$\text{Car (mg/g FW)} = \frac{[4.96(440)-0.267(\text{chl a + b}] \times V}{W} \times 1000$$

The method of Lowry *et al.* (1951) was used to measure protein and the Kjeldahl method was used to measure the percentage of seed protein. The oil (%) in the seed was determined by separating the oil with hexane solvent using a Soxhlet apparatus (AOAC, 1990). The method of Irigoyen *et al*. (1992) was used to measure proline. Before data analysis, the data normality tested and Bartlett's test were performed and data were analyzed using SAS software (ver. 9.2) and Duncan's multiple range test, the means were compared at the probability level of 1 and 5%.

RESULTS AND DISCUSSION

Seed yield

The interaction effect of Low irrigation treatment × variety on the seed yield was significant at the probability level of 1% (Table 3). The cultivar 504 Dezful showed increased in traits while cultivar Sari showed decreased in traits in different f irrigation levels. Thus, the seed yield in 90% water requirement supply in the variety 504 Dezful was 3748.01 kg/ha and in the irrigation condition of 50% water requirement supply it was 1281.06 kg/ha (Table 3).

The final performance of each crop plant genotype is determined by the mutual effects of the plant genotype and the growing environment. Bahramnejad *et al.* (2021) reported drought stress by 50% of irrigation water reduces the yield of *Lathyrus sativus* L. Under drought stress, the reduction in photosynthesis is due to the increase of free radicals in the plant and the destruction of the photosynthetic system (Liu *et al.,* 2015; Mouradi *et al.,* 2016; Zegaoui *et al.,* 2017).

Table 1: Soil analysis of the studied farm in 1st year.

Texture	A.O.K (ppm)	A.O.P (ppm)	Total N (%)	O.M (%)	EC (ds/m)	pH	Soil depth (cm)
S-L	210	8	0.003	0.22	2.28	8.1	0-25
S-L	170	6	0.002	0.19	1.95	8	25-50

Table 2: Soil analysis of the studied farm in 2nd year.

Texture	A.O.K (ppm)	A.O.P (ppm)	Total N (%)	O.M (%)	EC (ds/m)	pH	Soil depth (cm)
S-L	180	5	0.003	0.22	2.28	8.0	0-25
S-L	140	4	0.003	0.19	1.95	8.1	25-50

Table 3: Interaction effects of lack of irrigation × variety on yield and quality characteristics of soybean.

Studied treatments		Chlorophyll a ($mg.g^{-1}$ fresh wt).	Chlorophyll b ($mg.g^{-1}$ fresh. wt)	Total chlorophyll ($mg.g^{-1}$ Fw)	Carotenoid ($mg.g^{-1}$ Fw)	Leaf proline (mg/gr fresh weight)	Protein yield ($kg.ha^{-1}$)	Seed oil yield ($kg.ha^{-1}$)	Seed yield (kg/ha^{-1})
90% FC	504 Dezful	2.93a	1.68cd	4.61a	2.98a	0.142efgh	1351.53a	916.41a	3748.01a
	Sahar	2.91ab	1.96a	4.87a	2.92a	0.141fgh	1131.12b	645.55b	3199.85b
	Telar	2.85ab	1.79be	4.64a	2.79b	0.140fgh	929.19c	649.02b	2746.65c
	Takavar	2.81ab	1.81b	4.62a	2.78bc	0.137h	795.37d	566.31b	2416.82d
	Zan	2.74bc	1.64de	4.38ab	2.56d	0.141fgh	672.39e	479.36c	2043.76c
	Sari	2.78bc	1.78bc	4.53ab	2.54d	0.138fgh	622.13ef	463.45c	2019.92e
70% FC	504 Dezful	2.58c	1.86ab	4.44b	2.68c	0.158d	557.36f	477.38c	1980.83e
	Sahar	2.21d	1.69cd	3.90c	2.46de	0.149e	472.09g	396.28de	1698.26f
	Telar	2.16d	1.61de	3.77c	2.42e	0.145efg	440.56g	349.91ed	1515.56fg
	Takavar	2.27d	1.59de	3.86c	2.36ef	0.146ef	406.54gh	328.74ed	1429.56gh
	Zan	2.21d	1.58de	3.75c	2.28fg	0.149e	351.24hi	314.69def	1356.24gh
	Sari	2.24d	1.54ef	3.78c	2.23gh	0.139fgh	331.92i	283.18ef	1252.92h
50% FC	504 Dezful	2.12d	1.45fg	3.57c	2.35ef	0.192a	259.06j	292.57ef	1281.06h
	Sahar	1.82e	1.45fg	3.20d	2.13hi	0.168bc	207.08j	230.48fy	1026.08i
	Telar	1.78e	1.42g	3.20d	2.06i	0.163cd	207.31jk	185.43g	857.31ij
	Takavar	1.87e	1.40g	3.20d	1.89j	0.169bc	179.62k	159.81gh	758.62j
	Zan	1.83e	1.37g	3.20d	1.76k	0.173b	158.82k	151.08gh	672.82j
	Sari	1.84e	1.34g	3.18d	1.68k	0.165c	99.95l	91.62h	449.95j
Mean square		0.030*	0.048*	0.055*	0.023**	0.0001**	72671.39**	21162.35*	349138.01**
LSR	0.0027	0.068	0.418	0.34	0.235	159.40	135.70	482.56	
CV(%)	6.0	5.78	7.94	6.62	10.4	11.53	17.58	10.9	

Mean within columns followed by different letter are significantly different (Duncan's multiple test, P≤0.05).
n.s.: Non-significant; *:significant at 5% probability levels; **significant at 1% probability levels.

Protein yield and seed oil yield

The interaction effect of low irrigation stress × variety on protein yield and seed oil was significant (Table 3). The highest protein yield (1351.53 kg/ha) was observed in Dezful 504 variety under normal conditions (90% FC), which had a significant difference from other studied treatments. While, the lowest protein yield (99.95 kg/ha) was observed in the Sari variety under severe water stress conditions (50% FC). The highest oil yield under 90% FC treatment was obtained for the Dezful 504 variety (914.41 kg/ha), while the lowest oil yield under high stress conditions (50% FC) was obtained in Sari variety (91.62 kg/ha). Drought stress during seed filling causes a significant decrease in soybean oil yield the production of smaller seeds, which often have more protein, and the reason for this is the less effect of stress on protein accumulation than other main components such as oil (Rotundo and Westgate, 2010). As the intensity of water stress increases, the oil percentage of the seeds will decrease and the protein percentage of the seeds will increase (Pourmusoi *et al.* (2008). It has been reported that the percentage of oil had a negative and significant correlation with the percentage of protein (Sabak Dast Nodhi *et al*., 2017). A decrease in oil percentage and an increase in seed protein percentage with increasing water stress have also been reported (Behtari *et al*., 2008).

Leaf proline

The interaction effect of low irrigation treatment × variety on the proline of soybean leaves was significant (Table 3). The amount of proline in leaves increased significantly with increase in severity of drought stress. So, the highest amount of leaf proline was observed under severe water stress conditions and in cultivar 504 Dezful (0.192 μg/g fresh weight). While, the lowest amount of leaf proline was estimated in Tekavar cultivar under stress-free conditions, which was not significantly different from at par with other cultivars under stress-free conditions (Table 3). Some plants protect their cell structures against radicals produced under stress conditions by producing antioxidant compounds such as phenolic compounds and carotenoids, and others lead to adaptation in plants by accumulating osmolytes such as proline (Bettaieb *et al.*, 2010).

Chlorophyll a, b and total and carotenoids

The interaction effect of low irrigation treatment × cultivar on the studied traits (Chlorophyll a, b and total and carotenoids) was significant (Table 3). The amount of carotenoids a was maximum in Dezful 504 and Sahar cultivars in 90% water requirement supply conditions respectively 2.98 and 2.92 mg/gram of fresh weight of leaves) and minimum in Zan and Sari cultivars in 50% water requirement supply conditions 1.67 and 1.78 mg per gram of leaf wet weight, respectively. The amount of chlorophyll a was maximum in Dezful 504, Sahar, Telar and Tekavar cultivars in 90% water requirement supply conditions and minimum in Sahar, Telar, Tekavar, Zan and Sari cultivars in 50% water requirement supply conditions. Similar results were obtained in relation to total chlorophyll. The highest amount of total chlorophyll was observed in non-stress conditions and the lowest amount was observed in Sahar, Tekavar, Telar, Zan and Sari cultivars under severe drought stress conditions. (Table 3). The stress of dehydration significantly reduced the amount of pigments and the relative water content of the leaves. These results were consistent with the reports of other researchers in this field. Fateh *et al.* (2012) in the study of the effect of drought stress on the physiological traits of soybean reported that drought stress caused a significant decrease in photosynthesis and seed yield. It has been reported that under the influence of stress, the amount of chlorophyll a and b and carotenoids changes (Chéour *et al.,* 2014). Studies show that the lack of decomposition of chlorophyll may increase the amount of active oxygen produced to such an extent that it destroys the detoxification ability of antioxidant systems (Sinha *et al*., 2003). Some plants protect their cell structures against radicals produced under stress conditions by producing antioxidant compounds such as phenolic compounds and carotenoids, and others lead to adaptation in plants by accumulating osmolytes such as proline accumulation (Bettaieb *et al*., 2010).

CONCLUSION

According to the results of this research, it was determined that the use of 504 Dezful cultivar can be a management solution to improve soybean yield in arid and semi-arid regions, so it is possible to increase productivity by choosing this cultivar.

Conflict of interest: None.

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