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Effects of irrigation regimes at different growth stages on seed yield and yield components of two soybeans (*Glycine max* L. (Merr.)) varieties in semi-arid conditions

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Water stress is the most limiting abiotic stress factor for soybean growth, development and production in semi-arid regions. The development of new soybean cultivars with high efficiency and ability to drought resistance is very important. Field experiment was conducted to investigated the impact of irrigation regimes at different growth stages (Full irrigation, irrigation regimes at vegetable growth, flowering, and pod full stages) on yield and yield components of two soybean varieties (1448 and Egyptian) under semi-arid regions. The results indicated that irrigation regimes had significant effect on most of traits except the weight of plant. The pod full stage higher affected by the drought than other stages on most of parameters tested. Irrigation regimes at pod full stage reduced the number of pods plant^{-1} by 38.4 and 26.0%, weight of pods plant^{-1} by 23.7 and 53.6%, number of seeds plant^{-1} by 29.0 and 28.8%, seeds weight plant^{-1} by 17.2 and 38.8%, 100-seeds weight by 35.3 and 38.1% for 1488 and Egyptian respectively. While, irrigation regimes at flowering stage decreased the weight of plant for Egyptian by 57.5% and seed yield by 24.4 and 31.2% for 1448 and Egyptian respectively as compared with same variety at full irrigation. Varieties had significant differences on plant weight, number of pods plant^{-1}, number of seeds plant^{-1}, harvest index, and seeds yield. In conclusion, the soybean cultivars used in this study were very sensitive to water stress. The 448 cultivar is recommended due to having higher seed yield and yield components in the study conditions.

Key word: Grain yield, harvest index, legume crops, irrigation regimes, yield components.

INTRODUCTION

Abiotic stresses such as salinity and drought stresses remain one of the most significant constraints to crop production worldwide (Ali et al., 2019, 2020). The maximum decrease is of abiotic stresses including drought, salinity, heat, cold, light intensity, inadequate nutrients and soil acidity (Ali et al., 2021). Drought stress

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impairs plant morphological and physiological attributes related to growth and causes drastic reduction in grain yield (Sehgal et al., 2017). Drought stress in legumes elevates abscisic acid level and causes pollen sterility by impairing the ability of reproductive sinks to use starch and sucrose resulting in ovary abortion and poor pollen grain development, leading to fewer grains and reduced grain yield (Farooq et al., 2020a). Drought stress or drought badly affects the yield of different crops. It has been suggested that in many crops differences in sensitivity to drought stress occur at different growth stages (Abayomi, 2008). All the physiological processes of plant are directly or indirectly influenced by water status (Ali et al., 2009). All field crops respond differently at different phenological stages to changing water status of the soil under deficit irrigation, which means that plants are more sensitive to water deficit at some stages than at other stages (Kirda, 2002). Soybean (*Glycine max* (L.) Merrill) is one of the most important crops in the world. It has high nutritional qualities due to its high protein content of 40% by weight, 32% carbohydrate, 20% fat, 5% minerals and 3% fiber, and other trace substances Such as vitamins and diet fiber which are used for both human and animal consumption as well as for industrial purposes (Mentreddy et al., 2002; Singh, 2010; Comlekcioglu and Simsek, 2011). There are different varieties of soybean growth in the world. Consideration in the choice of varieties depends on yield, habit of growth, colors of seed ability to hold leaves, to shatter seed, length of growing season, disease resistance and oil and protein content. Whether it is grown for seed, forage, and green vegetable or for general purposes (Ali et al., 2009). The yield of soybean is highly affected by many factors among the soil water availability, cultivars and irrigation being the most important ones. Similarly, various soybean cultivars show varying sensitivity to drought at different developmental stages (Ali et al., 2009). Drought stress at any stage of soybean development can reduce seeds yield, but the extent and nature of damage, the capacity for recovery, and the impact on yield, timing of a stress episode vary (Ali et al., 2009). Generally, soybean water use is low during the germination and seedling stages; the water use is especially high during the reproductive stages and less than during the maturation stages (Liu, 2004). General field observation of drought stressed soybeans indicates that the amount of soil water available to the plants throughout all developmental stages exerts a major influence on plant growth Moisture stress in soybean reduced the number of pods per plant, pod weight, number of seeds per pod and seed weight (Farooq et al., 2009). Irrigation increased seed yield, 100 - seed weight and seed weight per plant. The final seed yield of soybean is highly affected by drought stress, particularly when the stress is occurring during the flowering and early pod expansion. The yield loss is due mainly to an increased rate of pod abortion resulting in a smaller number of seeds per plant, and ultimately decreases seed yield (Kokubun et al., 2001). Soybeans respond well to irrigation during later growth stages where water stress may lead to a decrease in yield. Therefore, knowledge on the irrigation schedule of soybean under deficit irrigation condition becomes more important. The most important times for soybean plants to have adequate water are during pod development and seed fill. These are the stages when water stress can lead to a significant decrease in seeds yield (Abd El-Mohsen et al., 2013). Keeping in view all these aspects, the objectives of this study were to investigate the impact of four different irrigation regimes on yield and yield component traits of two soybean cultivars at different growth stages under north Khartoum conditions. Also to determine relationship between yield and yield components by using different statistical methods to help soybean breeders how to determine the effect of yield components and what yield components could be efficiently used in breeding program.

MATERIALS AND METHODS

Experimental site and experimental design

A field study was carried out on the Experimental Farm of Sudan University of Science and Technology, College of Agricultural Studies (32.35"E, 15.31"N, within the semi-desert region) (Adam, 2002), in the soybean growing seasons of 2011 and 2012. The soil of the site is described by Abdel-Hafeez (2001) as loam clay and it is characterized by a deep cracking, moderately alkaline clays, and low nitrogen content and pH 7.5 – 8, and high exchangeable sodium percentage (ESP) in subsoil.

The climate of this area is semi-arid and with low relative humidity, the annual rainfall is about 151.8 mm (Oliver, 1965). This field experiment was conducted as split plot arrangement in a randomized complete block design (RCBD) with four replications. Main plots included four irrigation regimes (Full irrigation, irrigation regimes at vegetable growth, flowering, and pod full stages), and subplots included two varieties (1448 and Egyptian). The two season experiments were sown on first June for 2011 and 2012 seasons.

Land preparation

The experimental unit was divided to plots (3.5 m long and 3.5 m wide), each plot had 6 ridges, each ridge measuring 5 meters and 70 cm between ridges. Soybean seeds were planted in hills spaced 25 cm on the one side of the ridge, each hill received 6 seeds. Seedlings were thinned at three weeks after sowing to secure three plants per hill.

The plots were irrigated using a furrow irrigation method and subsequent irrigations were applied every 10 days during plant development, up to 3 weeks before final harvest. Nitrogen fertilizer in the form of Urea (46% N) was added at the rate of 90 kg N ha^{-1} was divided into two doses prior to the first and second irrigations. Potassium sulfate (70 kg ha^{-1}, 48% K_2O) was applied at two days after planting. Calcium superphosphate (180 kg ha^{-1}, 15.5% P_2O_5) was applied during seed bed preparation. All cultural operations were kept normal and uniform except water regime levels. Before conducting the experiment, land was prepared by applying two dry ploughings.

Seeds varieties and sowing data

Pure quality seeds of two varieties including Egyptian and 1448 were obtained from Agricultural Research center in Khartoum (Shambata) was used in this study. Seeds within a variety were selected for uniform size, shape, and color. All seeds were less than five months old and were previously stored in paper bags under laboratory conditions (RH 40-60% at 15-20 °C) to maintain good germination ability. Before planting, seeds were sterilized using sodium hypochlorite solution (1%) for 3 min, washed with distilled water three times, and then air-dried. Seeds rate was four seeds per hole spaced at 30 cm between holes. Sowing was carried out on the July 21th, 2011. Thinning was carried out three weeks after sowing to raise two plants per hill. Weeding was done twice using hand hoeing. These seeds were planted carefully by following the methodology generally recommended for the region.

Experimental treatments

The crop during growing seasons received full irrigations (control) every 10 days including planting irrigation (D0). Irrigation regimes treatments were applied by skipping two irrigations at three critical stages; irrigation regimes at vegetable growth (D1), flowering (D2) and pod filling stages (D3). Four treatments were defined by the water irrigation at three different growth stages. For this purpose, the life cycle of soybean was divided into three stages, namely vegetative, flowering, and pod filling. According to the classification of developmental stages of soybean (Fehr et al., 1971).

Sampling and data collection

Yield components parameters

At maturity stage, for assessing the relationship between yield and its components, according to Yoshida et al. (1971), the yield components were recorded at the time of harvest. Five plants were selected randomly from each experimental unit and average values were calculated for traits such as fresh weight of plant, number of pods per plant, number of seeds per plant and weight of seeds per plant and was calculated by using the number of pods per plant and number of seeds per plant as follows:

$$\text{Number of seeds per pod} = \frac{\text{Number of seeds per plant}}{\text{Number of pods per plant}}$$

100-seed weight (g)

A sample of 100-seed was taken randomly from the yield of each plot, and then weighed to determine the 100 seed weight for each treatment.

Seeds yield (kg/ha)

Plants on the one-meter length from middle of each plot of each treatment were harvested, sun-dried, weighed to obtain the biological yield. The pods of the harvested plants were threshed, and seeds were collected. The seed yield per unit area was converted into kg ha^{-1} at 14% moisture content.

Harvest index

It was estimated using the data of grain yield and biological yield as follows:

$$\text{Harvest index} = \frac{\text{Final Seed Yield weight}}{\text{Biological Yield}} \times 100$$

Statistical Analysis

Analysis of variance was performed using MSTAT-C Statistical Package software with season and replication as random and irrigation regimes and varieties as field effects (Abdelgadir et al., 2010). Dependent variables included plant weight, number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds plant^{-1}, weight of seeds plant^{-1}, 100 seeds weight, seeds yield, and harvest index, and were analyzed across the 2 seasons. The procedure of analysis of variance and mean separation were followed according to the description of Gomez and Gomez (1984). When *F* values were significant, each parameter's means were compared by the LSD test ($P \leq 0.05$).

RESULTS

ANOVA analysis

Effects of variables of season and irrigation regimes on number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds plant^{-1}, weight of seeds plant^{-1}, 100 seeds, seeds yield, and harvest index were analyzed for significance at the $P < 0.05$, $P < 0.01$ or $P < 0.001$ levels. Significant effects of season and varieties were each observed on all parameters except number of seeds plant^{-1} and harvest index, while only irrigation regimes exerted not significant effects on plant weight. However, no significant effects were exerted by varieties on either number of pods plant^{-1}, weight of pods plant^{-1}, weight of seeds plant^{-1}, 100 seeds, and harvest index. Significant effects of varieties on plant weight, number of seeds plant^{-1} and seeds yield. The interaction of season × varieties revealed significant effects on plant weight, number of pods plant^{-1} and seeds yield ($P < 0.05$), while the irrigation regimes × varieties interaction exerted significant effects on all parameters ($P < 0.05$). Significant effects of the season × varieties × irrigation regimes interaction had a significant effect ($p < 0.05$) on all traits except number of pods plant^{-1} and harvest index (Table 1).

Weight of plant (g per plant)

The results in Table (1) indicated that, the weight of plant had a significant change during the seasons of study and the highest weight of plant was observed in the second season (41.5 g per plant). The mean comparison of the interaction between seasons and varieties revealed that the both varieties in the second season of study had the highest value of weight of plant (45.7 g per plant for Egyptian and 37.3 g per plant for 1448 variety) (Table 2). The flowering stage was highly affected by the drought stress than pod full and vegetative growth stages. Therefore, as a result of the interaction between irrigation regimes with varieties, variety 1448 at pod full stage was

Table 1. Summary of the analysis of variance (ANOVA) of egpytion and 1448 for the season (Y), drought stress (D), variety (V), and their possible interactions on plant weight, number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds plant^{-1}, weight of seeds plant^{-1}, 100 seeds, harvest Index, and seeds yield in 2011 and 2012.

Source	F value							
	Weight of plant	Number of pods plant^{-1}	Weight of Pods plant^{-1}	Number of seeds plant^{-1}	Weightof seeds plant^{-1}	100 Seeds weight	Harvest index	Final seeds yield
Seasons (Y)	4.68**	64.95***	95.73***	0.23^{ns}	10.37**	21.95**	0.02^{ns}	20.12***
Irrigation Regimes (D)	1.69^{ns}	52.34**	22.73**	10.20**	20.54***	67.24**	6.13**	65.70***
Y × D	0.58^{ns}	18.77**	19.08**	3.20*	6.83**	111.60***	2.61*	58.30***
Varieties (V)	3.37*	1.17*	0.02^{ns}	7.44*	0.03^{ns}	1.36^{ns}	12.43**	0.19*
Y × V	6.78*	1.68^{ns}	0.32^{ns}	0.01^{ns}	2.26^{ns}	0.60^{ns}	4.88*	0.41^{ns}
D × V	5.95**	13.09**	5.48**	6.14**	3.80*	29.75***	8.01**	5.70**
Y × D × V	11.07**	2.37^{ns}	3.07*	6.16**	7.83**	43.12**	1.71^{ns}	5.91**
Seasons								
2011	27.1 ±6.60^{b}	92.8 ±33.1^{a}	25.3 ±9.7^{a}	153.41 ± 28.1 ^{a}	15.2 ± 6.8^{a}	10.9 ±4.0^{b}	34.21 ± 17.4^{a}	1126.8 ±18.90^{b}
2012	41.5 ±25.0^{a}	75.5 ±22.2^{b}	15.3 ±4.0^{b}	151.25 ± 27.7 ^{ab}	12.9 ± 2.7^{b}	12.0 ±2.4^{a}	34.59 ± 16.8^{a}	1273.4 ±335.4^{a}
CV (%)	19.05	16.79	20.99	12.75	24.79	6.62	25.47	8.26

Note: ns: No significant effects. *,** and *** Significant effect at P < 0.05, P < 0.01 and P < 0.001 level. The means with the same letters indicate non-significant differences at p ≤ 0.05 between parameters in the same column.

Table 2. Interaction of seasons × varieties on weight of plant (g per plant) and harvest index two growing seasons of two varieties of soybean.

Seasons	Varieties	Parameter	
		Weight of plant (g per plant)	Harvest index
2011	Egyptian	26.45 ± 5.91^{c}	27.08 ± 8.45^{c}
	1448	27.83 ±7.32^{bc}	41.54 ± 21.25^{a}
2012	Egyptian	45.77 ± 19.35^{a}	23.25 ± 10.56^{d}
	1448	37.38 ± 29.95^{b}	36.36 ± 11.85^{b}

Values represent mean ± SD values of three biological replicates per treatment. The means with the same letters indicate non-significant differences at p ≤ 0.05 between parameters in the same column.

more affected by the other stages, it was decreased by 37.7% as compared with same variety at full irrigation. While, Egyptian variety at the flowering stage was more affected, it was reduced by 57.5% as compared with same variety at full irrigation (Figure 1a).

Number of pods per plant

As a result of the interaction between varieties with drought stress, both varieties at flowering and pod full stages were more affected than vegetable growth stage, and the Egyptian variety was sensitive to drought stress than 1448. As comparison with 1448 variety at full irrigation, the

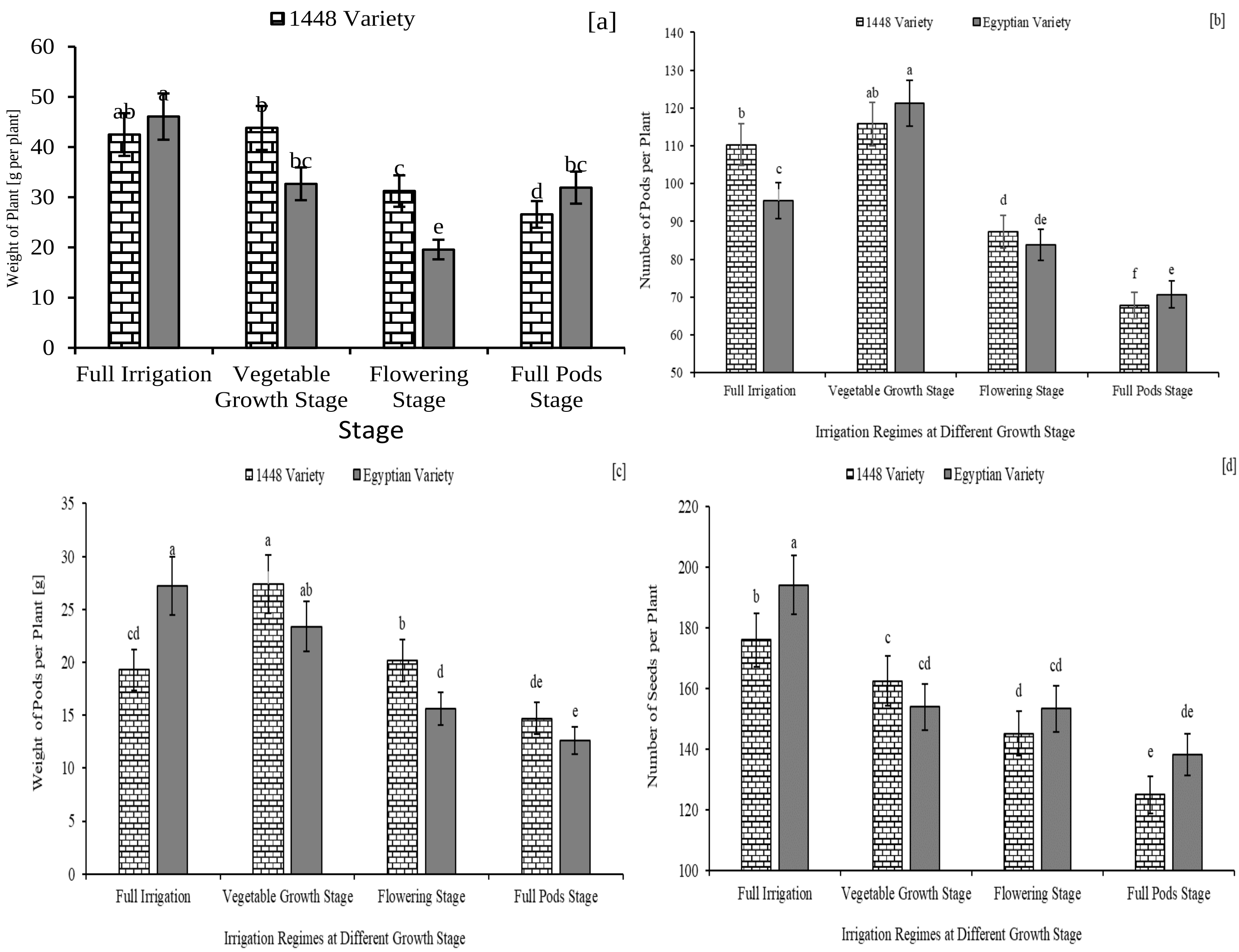

Figure 1. Plant weight (a), number of pods per plant (b), weight of pods per plant (c) and number of seeds per plant (d) of two soybean varieties 1448 and Egyptian variety as influenced by the combination between varieties and irrigation regimes at different stages. Bars with different letters are significantly different at the 0.05 probability. Means were separated by the LSD test.

number of pods per plant was reduced by 20.8 and 38.4% at the flowering and pod full stages respectively, but increased by 5.0% at the vegetative growth stage (Figure 1b). In addition, the number of pods per plant was increased at vegetative growth stage by 26.9%, and reduced by 12.2 and 26.0% at the flowering and pod full stages respectively for the Egyptian variety as comparison with the same variety at full irrigation (Figure 1b). The mean comparison of the seasons and irrigation regimes interaction revealed that the vegetative growth stage in both seasons was not impacted by the drought stress than other stages. As compared with full irrigation at first and second season, the number of pods per plant increased by 26.3 and 37.0% respectively, over the control, but drought stress at the flowering and pods full stages decreased by 19.1 and 20.6% respectively, for the first season, and 28.0 and 18.8% respectively for the second season (Table 3).

Weight of pods per plant (g per plant)

The results in Table (1) indicated that, the weight of pods per plant had a significant change during the seasons of study, and the highest weight of pods per plant was observed in the first season. The mean comparison of the weight of pods per plant affected by the interaction between irrigation regimes and seasons showed that, as compared with control at the same season, irrigation regimes at the vegetative growth, flowering and pods full stages were decreased by 30.5, 37.3 and 56.1% respectively, for first season and were reduced by 33.3, 39.1 and 37.1% respectively, for second season (Table 3). Therefore, in the interaction between irrigation

Table 3. Impacts of interaction of seasons × irrigation regimes on number of pods per plan, weight of pods per plant, number of seeds per plant, weight of seeds per plant, 100 seeds weight, harvest index and final seeds yield in two growing seasons of two soybean verities.

Seasons	Irrigation regimes	Parameter						
		Number of pods per plant	Weight of pods per plant	Number of seeds per plant	Weight of seeds per plant	Weight of 100 seeds	Harvest index	Final seeds yield
2011	DS1	96.00 ± 41.8^{b}	36.7 ± 7.2^{a}	169.0 ± 36.5^{ab}	16.6 ± 7.2^{b}	15.3 ± 2.0^{a}	26.2 ± 9.5^{e}	1140.1 ± 10.6^{c}
	DS2	121.2 ± 36.5^{a}	25.5 ± 9.7^{b}	156.7 ± 23.0^{cd}	21.6 ± 7.7^{a}	13.7 ± 1.2^{ab}	35.9 ± 6.4^{c}	1137.1 ± 24.0^{cd}
	DS3	77.7 ± 16.1^{cd}	23.0 ± 4.4^{bc}	152.1 ± 31.0^{d}	12.5 ± 2.4^{cd}	7.9 ± 0.7^{d}	51.3 ± 25.3^{a}	1116.6 ± 14.8^{de}
	DS4	76.2 ± 10.9^{cd}	16.11 ± 1.6^{d}	135.9 ± 10.7^{f}	10.0 ± 2.0	6.8 ± 1.7^{cd}	23.4 ± 7.5^{f}	1113.1 ± 6.70^{e}
2012	DS1	74.30 ± 8.70^{d}	21.0 ± 2.1^{c}	171.2 ± 19.4^{a}	13.5 ± 2.1^{c}	12.3 ± 1.3^{b}	32.0 ± 5.5^{d}	1756.3 ± 255.6^{a}
	DS2	101.8 ± 11.0^{ab}	14.0 ± 1.8^{de}	159.8 ± 28.4^{c}	14.6 ± 3.2^{bc}	10.4 ± 0.7^{c}	33.9 ± 4.5^{cd}	1160.5 ± 97.4^{b}
	DS3	53.50 ± 9.80^{f}	12.8 ± 1.2^{e}	126.3 ± 9.50g	11.5 ± 1.7^{cd}	13.5 ± 3.4^{b}	38.8 ± 15.4^{b}	1043.3 ± 129.4^{f}
	DS4	60.30 ± 17.90^{e}	13.2 ± 3.5^{de}	147.7 ± 30.6^{e}	11.8 ± 2.7^{d}	11.9 ± 2.6^{bc}	33.7 ± 14.7^{cd}	1133.4 ± 209.0^{d}

Values represent mean ± SD values of 3 biological replicates per treatment. The means with the same letters indicate non-significant differences at $p \leq 0.05$ between parameters in the same column. DS1: Full irrigation, DS2: irrigation regimes at vegetative growth stage, DS3: irrigation regimes at flowering stage and DS4: irrigation regimes at seed formatting stage.

regimes with varieties, both varieties at pod full stage was more affected by the other sages. Variety 1448 did not affected by the irrigation regimes at the vegetative growth and flowering stages, it was increased by 42.0 and 4.6%, while reduced by 23.7% at the pods full stage as compared with same variety with full irrigation, while, variety Egyptian was affected by the irrigation regimes at all stages, as compared with variety 1448 with full irrigation, the weight of pods per plant decreased by 14.1, 42.6 and 53.6% at the vegetative growth, flowering and pods full stages respectively (Figure 1c).

Number of seeds per plant

In the interaction between irrigation regimes with varieties, both varieties were affected by the irrigation regimes at all stages. The pod full stage was more affected by the other stages, and the variety Egyptian was more affected by irrigation regimes than 1448. As comparison with 1448 variety at full irrigation, the number of seeds per plant was reduced by 7.7, 17.5 and 29.0% at the vegetable growth, flowering and pod full stages respectively (Figure 1d). However, the number of seeds per plant was reduced at the same stages by 20.7, 21.0 and 28.8% respectively, for the Egyptian variety as compared with the same variety at full irrigation (Figure 1d). In the interaction between season and irrigation regimes revealed that the number of seeds per plant at the first season higher than second season. Meanwhile, as compared with full irrigation at first and second season, the number of seeds per plant at the vegetable growth stage were decreased by 7.3 and 6.7% respectively, at the flowering stage were reduced by 10.0 and 26.2% respectively, and at the pod full stage decreased by 19.6 and 13.7% respectively, (Table 3).

Weight of seeds per plant

Averaged across the seasons and irrigation regimes, in both seasons, irrigation regimes at flowering stage and pods full stage decreased the weight of seeds per plant by 24.7 and 39.8% respectively for first season, and reduced by 14.8 and 12.6% respectively, for second season. While, soybean plant supplied to irrigation regimes at the vegetable growth stage was not affected, it was increased by 8.2 and 30.1% for first and second season respectively as compared with full irrigation at the same seasons (Table 3). Averaged across all the irrigation regimes and both varieties, irrigation regimes exhibited weight of seeds per plant at different plant growth stage except vegetative growth stage. Variety 1448

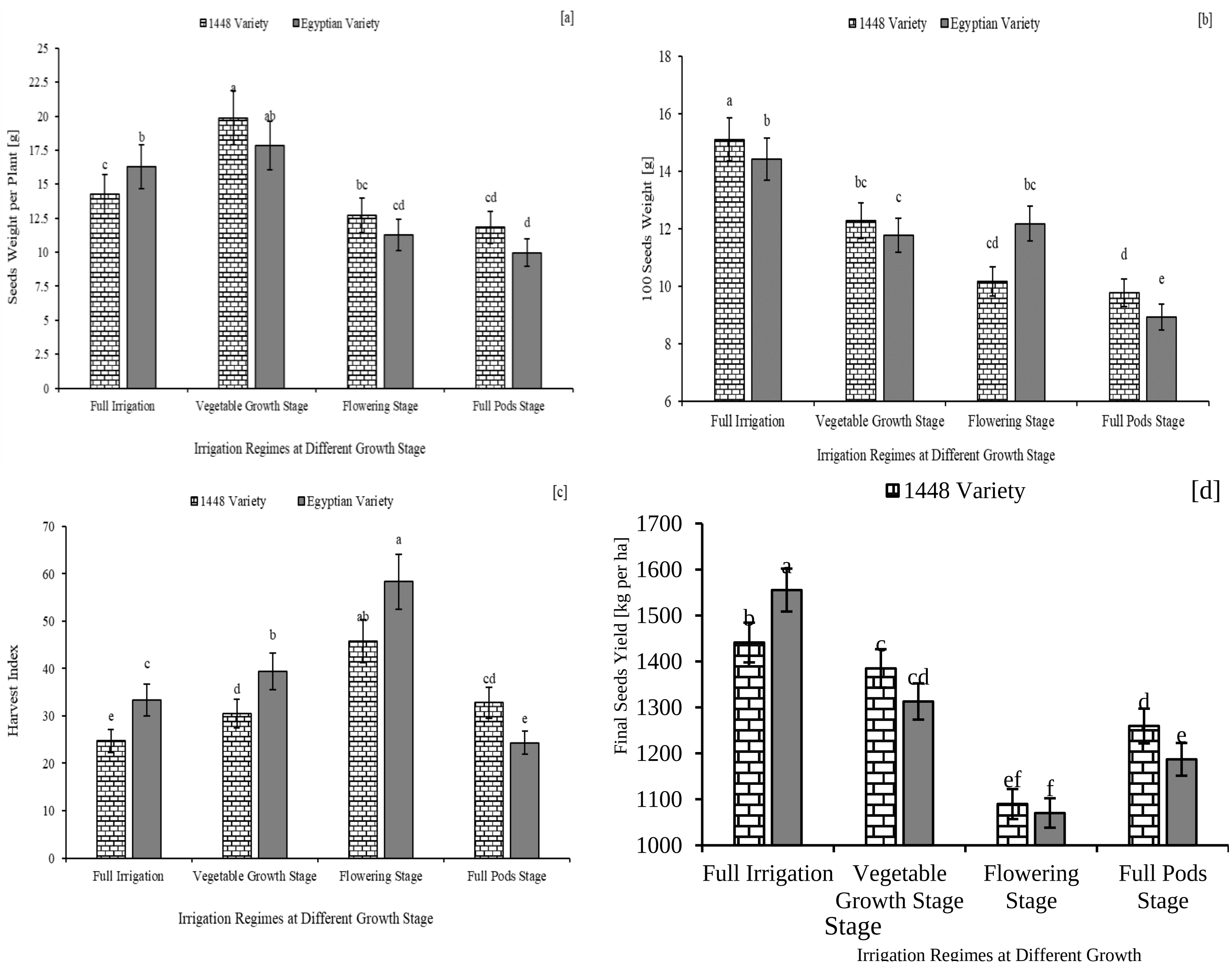

Figure 2. The weight of seeds per plant (a), 100 seeds weight (b), harvest index (c) and final seeds yield (d) of two soybean varieties 1448 and Egyptian variety as influenced by the combination between varieties and irrigation regimes at different stages. Bars with different letters are significantly different at the 0.05 probability. Means were separated by the LSD test.

recoded the high number of seeds per plant at all drought stress than variety Egyptian (Figure 2a). irrigation regimes decreased the seeds weight per plant for 1488 and Egyptian varieties at flowering stage by 10.9 and 30.8% respectively, and decreased by 17.2 and 38.8% respectively at pods full stage, while, at the vegetative growth stage, 1448 and Egyptian varieties were increased the seeds weight per plant by 39.2 and 9.5% respectively, as compared with the same varieties at the full irrigation (Figure 2a).

100 seeds weight

The 100 seeds weight values averaged of two soybean varieties exhibited and decreasing with irrigation regimes at the different plant growth stage at both seasons (Table 3). Regarding the interaction between irrigation regimes and seasons, irrigation regimes exhibited 100 seeds weight at different plant growth stage. The 100 seeds weight was decreased by 10.5 and 55.6% for first season and reduced by 15.5 and 3.3% for second season for vegetative growth and pods full stages as compared with same variety at full irrigation (Table 3). In the interaction between irrigation regimes and varieties, the annual average of 100 seeds weight value at the vegetative growth and pod full stages, 1448 variety were slightly increased by 4.2 and 9.2% respectively, relative to Egyptian variety at the same irrigation regime, while at the flowering stage Egyptian variety was increased by

19.9 relative to 1448 (Figure 2b).

Harvest Index

For each soybean varieties and within each season, variety 1448 was observed the highest value for harvest index with the increased by 53.5 and 56.3% for first and second season respectively, as compared with Egyptian variety at the same season (Table 2). Irrigation regimes increased the harvest index at all growth stages, the highest value at the first and second seasons recorded at the flowering stage (51.3 ± 25.3 and 38.8 ± 15.4 respectively), following the vegetative growth and pod full stages (Table 3). Variety Egyptian was more tolerance to drought stress than 1448 variety. In the interaction between irrigation regimes and varieties, at the vegetative growth, flowering, and pods full stages, the harvest index increased by 29.4, 27.4 and 35.0% respectively, for Egyptian variety relative to 1448 variety at the same irrigation regime (Figure 2c).

Final seeds weight (kg per ha^{-1})

The results in Table 3 indicated that, the final seeds weight had a significant change during the seasons of study and the highest value was observed in the second season (1273.4 g per ha^{-1}) (Table 1). The mean comparison of the final seeds weight was affected by the irrigation regimes and seasons. At the first and second season, irrigation regimes reduced the final seeds weight. As compared with full irrigation at the same season, irrigation regimes at the vegetative growth, flowering and pods full stages were decreased by 0.3, 2.06 and 2.4% respectively, for first season and were decreased by 33.9, 40.6 and 35.4% respectively for second season (Table 3). Therefore, as a result of the interaction between irrigation regimes with varieties, both varieties at flowering stage was more affected by the other sages, it was decreased by 24.4 and 31.2% for 1448 and Egyptian variety as compared with same variety at full irrigation (Figure 2d). Variety 1448 recoded the highest value of final seed yield at all irrigation regimes, that means 1448 variety was more tolerance to irrigation regimes (Figure 2d).

DISCUSSION

Among abiotic factors, drought stress is probably the most limiting for crop quality and productivity. Drought stress is a multidimensional stress affecting plants at various levels of their organization (Farooq et al., 2020b). Thus, the effects of drought stress are often manifested at morphological, physiological, biochemical and molecular level, such as inhibition of growth, accumulation of compatible organic solutes, changes in plant hormones endogenous contents (Aimar et al., 2011). In addition, drought stress causes alternations in physiology, growth and plant metabolism by disturbing plant water relations, enzyme activities, photosynthesis, membrane integrity and enhanced oxidative stress (Farooq et al., 2020b). The number of pods per plant is an important variable for determining seed yield crops performance in leguminous plants. Drought stress especially at pod formation stage plays an important role for high yield and desired quality and it can gravely decrease the seeds yield (Mirzaei et al., 2013). The number of pods per plant more sensitive affect by the drought stress at any stage of crop especially at flowering stage, water stress at flowering stage has more effect on the seed yield through affecting and decreasing the number of pod per plant (Kobraee et al., 2011). In this study, irrigation regimes at flowering and seed development stages caused reducing in number of pods per plant, but water stress at vegetable growth stage was did not effected on this trait, the highest number of pods per plant were observed in vegetable growth stage following by full irrigation. The reduction in number of pods per plant is the result of water deficiency which has adverse effect on the development of reproductive parts of plants. Stress at vegetative stage results in less development of fruit bearing branches, which ultimately affect the number of pods per plant (Farooq et al., 2020b). This results agreement with Abd El-Mohsen et al. (2013), who reported that water stress nearer to flowering stage; its effect was increased on number of pods and finally the seed yield, it is concluded that drought stress had most effect on non-inoculation flowers and their falling. Increasing water irrigation caused to fertile flowers and finally growing pods this lead to increasing the number of pods per plant and seed yield (Abd El-Mohsen et al., 2013). Ma et al. (2006) reported that the drought stress had little effect on the seed growth and yield of the tested varieties during the vegetative growth and stem elongation stages.

The number of seeds per pod was remarkably affected by the water stress at any stage of soybean plant resulted in decreased. This fact reflects the environmental changes and genetic effects on the studied trait. In this study, the higher value of number of seeds per plant recorded at the full irrigation. These results are in agreement with the findings of Masoud (2007) and Mirzaei et al. (2013) who pointed out the increase in number of seeds per plant under water shortage during the vegetable growth, flowering and pods formation stages. By increasing the assimilate production, the stress can cause a decrease in seed yields through seed and pod shattering (Deloche, 1980). In addition, these findings are supported by those of Jones et al. (1984) and Siag and Verma (1990) indicated drought stress during any stage of soybean crop influenced significantly the number of seeds, and reported the higher number of seeds per plant and number of pods per plant at higher irrigation frequencies. Drought stress caused decreasing of photosynthesis and consuming of photosynthesis matters by growing leaves and decrease the phloem photosynthesis materials and finally assimilation amount which lead to increasing vulnerability of seed formatting under deficit water conditions (Mirzaei et al., 2013). However, water stress by decreasing the number of pod per plant and number of seed per pod reduced the rapeseed yield during the pollination and seed filling stages. However, the mustard was not affected by it seriously. In this study, the cause of seeds decreasing number per pod under deficit water condition is that (irrigation regimes) drought stress at different growth stages caused to produce preserved extract, this state caused to aborting reproductive organs (flowers) and as a result increasing vulnerability of seed formation in pods under drought stress condition (Mirzaei et al., 2013). Weight of seeds per plant and number of seeds per plant is an important factor for determining the yield of leguminous crops. Seed weight per plant has direct impact on the final yield of any crop. Severe drought stress seed forming stage results in significant reduction of weight of seed and pods per plant. Drought stress at any stages of plant at the end of growing period, all different parts of plant send all their stored photosynthesis matters to seed, this lead to increase the weight of seeds and pods. In this study, drought stress decreased the weight of seeds per plant (Aimar et al., 2011). The reduction in seed weight per plant during drought stress might be due to less development of seeds under stress conditions, and a reduction indirectly of the photosynthesis and consumption of photosynthesis matters by increased the growing of the leaves compared with growing of seeds and pods (Mirzaei et al., 2013). Positive and significant correlation between seed yield, weight of seeds and pods per plant indicated that change of these traits caused the change in seed yield (Mirzaei et al., 2013). In this study, irrigation regimes (drought stress) at flowering and pod formatting stage influenced mainly weight of pod per plant, weight of seeds per plant and 1000-seed weight and resulted in decreasing all these parameters. Same results reported by Ma et al. (2006) indicated that concurrency of reproductive stage during drought stress causes the reduction of most attributes related to seeds yield such as weight of seeds and pods per plant, reducing seed yield is mostly due to reducing this parameters. Environmental stresses such as water stress especially at seed forming and filling stage decrease the seed filling speed and duration and finally its weight of seeds and pods due to photosynthesis reduction (Mirzaei et al., 2013). This results are in line with findings of Poma et al. (1999) who observed that all seed yield components were decreased in drought stress condition. Pandey et al. (2001) and Keatinge and Cooper (1983) indicated that during water stress at flowering stage, the final grain yield reduces due to decreasing the seed weigh, resulting from harmful effect of drought on producing biomass and drought stress caused to reducing seed weight. Deloche (1980) showed that drought stress at pod filling stage caused to producing faded seeds.

Final yield is the combined effect of various yield components under irrigation regimes. Thus, any variation in them is liable to bring about variation in seed yield. Water deficits have been shown to increase seed abortion, and the duration of the maturation period has been reduced by water stress during seed filling, leading to accelerated senescence, and decreased seed yield and yield components (Jaidee et al., 2012). Drought stress also significantly decreased soybean genotype seeds yield. In this study, drought stress at different growth stage also decreased seeds yield of soybean varieties. The highest and lowest seed yield was obtained at full irrigation and drought at flowering stage, respectively. Flowering and pod filling stages of soybean plant are most sensitive stages to drought stress. They are positive and significant correlation between final seed yield of soybean varieties in this study by the number of pods per plant, number of seeds per pod, weight of pods per plant, weight of seeds per plant and 1000-wight indicated that change of these parameters caused the change in seed yield. Similar result reported by Ma et al. (2006) indicated that water stress at any growth stages causes the reduction of yield component parameters such as number of pods per plant, number of seeds per pod, weight of pods per plant and weight of seeds per plant. In addition, Poma et al. (1999) observed that all yield components were reduced in deficit water condition as seed yield. It seems that in this study, Mirzaei et al. (2013) who noted that water stress at different growth stages caused the decrease in seed yield, but stress at flowering stage had more effect on decreasing the yield. These results are in line with the findings of Ardestani et al. (2011) they reported that the deficit irrigation treatments exhibited variable grain yield and biological yield. Cultivars had different response at different levels drought stress on yield component and seed yield. The results showed that Egyptian cultivar had highest seed yield using full irrigation and lowest seed yield obtained at flowering stag at same cultivar. High seed yield in Egyptian cultivar can attribute to high numbers of pods per plant, number of seeds per pod and 1000-seeds weight. The relative yield increased under fall irrigation and medium water stress. Similar results reported by Poma et al. (1999) and Rosadi et al. (2007). Demirtas et al. (2010) reported that fresh pod yield of ten vegetable soybean cultivars ranged from 11 to 15 t ha^{-1}. The possible reasons for such difference could be associated with their work which was conducted in different environmental conditions with other maturity groups of soybean (Comlekcioglu and Simsek, 2011).

Effect of soybean cultivars

The genetic differences among the varieties are involved in their efficiency to convert dry matter to the economic yield (Abd El-Mohsen et al., 2013). In this study, the highly significant difference existing among cultivars in term of all traits measured; thus, indicating that there is variability in cultivars studied (Abd El-Mohsen et al., 2013). Results suggested that the 1448 genotype produced the highest weight of seed per plant, weight of pod per plant and harvest index. While Egyptian genotype recorded the highest number of pods per plant, number of seeds per plant, 1000 seed weight and final seeds yield. The difference in the results might be due to the difference in genetic constitution of breeding material and environmental condition (Abd El-Mohsen et al., 2013). Abd Alla and Omran (2002) recorded that soybean cultivars had wide range of variation in growth and yield as well as its attributes. The results of present study are in line with those of Arshad et al. (2006) and Iqbal et al. (2010) and Sharief et al. (2010) who observed a wide range of variability for yield component parameters and seed yield. The difference in seed yield may be due to genetic nature of different cultivars. In addition, Kandil et al. (2012) found that soybean cultivars showed high difference in seed yield and its yield component. Other workers have reported significant yield differences among soybean genotypes (Rahman et al., 2011; El-Badawy and Mehasen, 2012). The difference in number of pods per plant can be attributed to differences in genetic makeup of the cultivars. El-Harty et al. (2010) had also reported the significant differences among cultivars for number of pods per plant.

Conclusion

Our study investigated the affects in yield and yield components characteristics of two varieties of soybean exposed to water stress. Water stress at any stage of soybean plant had significantly decreased plant weight, number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds plant^{-1}, weight of seeds plant^{-1}, 100 seeds, and seeds yield. More importantly, the highest seed yield would be achieved by full irrigation following by stress at vegetative growth stage, while the lowest seed yield recorded by water stress at flowering and pod filling stages. From the present study, it is concluded that the varieties exhibited a wide range of variability for most of the traits. In addition, the study demonstrated the existence of a high yield variation among soybean cultivars. From the results, it was observed that variety 1448 have the best performance for traits under different irrigation regime and hence its recommended as the most suitable commercial soybean varieties under the study conditions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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