Menoufia J. Plant Prod., Vol. 2 February (2017): 81 - 95

EFFECT OF IRRIGATION INTERVALS AND SOME FOLIAR APPLICATION TREATMENTS ON DRY BEAN (*PHASEOLUS VULGARIS* . L) GROWTH, SEED YIELD AND QUALITY

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Received: Dec. 20 , 2016 Accepted: Jan. 2 , 2017

ABSTRACT: *Strategies such as foliar application of salicylic acid and potassium show particular possibilities for conserving irrigation water, aiding plant survival under dry conditions. In this study, two field experiments were carried out during the summer seasons of 2014 and 2015, to examine the response of bean (Phaseolus vulgaris .L) plants to the foliar application of salicylic acid (SA) at 10 and 20 ppm as well as potassium sulphate at 1 and 2% under three irrigation intervals i.e. 8, 12 or 16 days.*

The obtained results indicated that irrigation every 8 days improved vegetative growth in terms of plant height, number of leaves per plant and plant fresh and dry weights as well seed yield and quality i.e. germination percentage , mean germination time, seedling root length and seedling vigor index . All used foliar treatments i.e. salicylic acid at 10 and 20 ppm as well potassium sulphate at 1 and 2% improved vegetative growth ,seed yield and its quality. Foliar application with SA at 20 ppm was the best treatment in this regard. The interactions between irrigation every 8 days and foliar application with SA at 20 ppm gave the highest values of the studied vegetative, seed yield and quality characters.

For obtaining high seed yield and quality of bean plants it could be recommended that, irrigation should be done every 8 days and plants should be sprayed with salicylic acid at 20 ppm three times during the growing season at 3, 5 and 7 weeks after sowing. However, in case of water shortage it is possible to extend the irrigation interval up to 16 days with three times foliar application of salicylic acid at 20 ppm to ameliorate the drought stress without decreasing the yield.

Key words: *Bean, drought, irrigation, seed, germination.*

INTRODUCTION

River Nile which floods about 55.5 billion m^3 water a year is the most important water resources in Egypt for agricultural, industrial, and urban activities. Rainfall which is about 13 mm a year and occurs only in winter season is not sufficient even for an irrigation interval. Even though, most of ground water comes due to infiltrating and moving water from Nile or its irrigated fields. More than 85% of water consumption is due to agricultural related activities. In Egypt, water availability is considered the prime constraint that determines the addition of new cultivated areas. Agricultural expansion needs a huge amount of irrigation water which is already not sufficient to meet all the expected demands. There is a need to come up with strategies that will encourage sustainable agricultural production and also identify possible agricultural practices could integrate to save water.

The sustainable management of water resources is a priority for agriculture also for the temperate regions such as Egypt, where dry and hot summers usually occur (Tambussi and Bort, 2007), and drought events may have a large impact on both productivity and crop quality. It is necessary to get maximum yield in agriculture by using available water in order to get maximum profit per unit area because existing agricultural land and irrigation water are rapidly diminishing due to the rapid industrialization and urban development. Therefore, we need to know the right amount of water needed for the plants i.e. plant water consumption. Furthermore, it is essential to develop the most suitable irrigation schedule to get optimum plant yield for different ecological regions as plant water consumption depends mostly on plant growth, soil and climatic conditions (Ertek *et al.*, 2002).

Dry bean (*Phaseolus vulgaris* .L) is an important protein crop in Egypt grown mostly for human consumption. According to 2015 year statistics of Ministry of Agriculture and Land Reclamation , the average dry bean production in Egypt is about 128248 tons produced from 115498 feddan (1 feddan = 4200 m^2).

Most dry bean production in the developing world occurs under conditions of recurring drought stress (Graham and Ranali, 1997). Drought stress has a considerable impact on dry bean growth and seed yield although the ranges of reductions are highly variable due to differences in the timing and intensity of the stress imposed and genotype used (Emam *et al*., 2012). Dry bean is very sensitive to drought stress during flowering because any type of stress during this stage can result in significant flower and pod abortion. (Graham and Ranalli, 1997). The impact of drought stress is determined by the severity of stress and the ability of plants to adapt to this stress (Rosales *et al*., 2012). Drought stress reduced bean dry matter production, leaf area index, number of pods per plant, number of seeds per plant, hundred seed weight and grain yield (Mathobo *et al.* 2017), reduced leaf area, chlorophyll content, dry matter and yield in two common bean cultivars (D81083 and Sayyard) in Iran (Emam *et al*., 2012). Post flowering drought stress resulted in a reduction in seed yield, pods per plant and 100 seed weight in small red seeded common bean (Rezene *et al.*, 2013). Also photosynthetic rate of bean plants was reduced due to stomatal conductance (Zlatev and Yordanov, 2004). Periods of drought stress during the reproductive phase of the common bean have been associated with a reduction in seed yield (Emam 1985). Molina *et al*. (2001) reported that drought stress reduced seed yield of common bean cultivars, by 50%. Shoot biomass accumulation is considered an important trait to attain high seed yield in grain legumes. Significant differences have been observed for shoot biomass accumulation among dry bean cultivars grown under severe drought stress conditions. Furthermore, differences in biomass accumulation and allocation have been detected among bean cultivars with different growth habits (Rosales-Serna *et al.* 2004).

A variety of strategies have been considered to avert the adverse effects of drought stress in plants. Among them foliar application of salicylic acid and potassium used to alleviate the harmful effects of drought on plants. In this connection, Dawa *et al.* 2015 indicated that foliar application of salicylic acid at 15 and 30 ppm and foliar potassium at 1% and 2% improved vegetative growth, photosynthetic pigments and yield of bean plant under both well watered and water stress conditions. Results of Sadeghipour and Aghaei (2012) showed that water stress reduced number of pods per plant, number of seeds per pod, 100-seeds weight and finally seed yield of common bean. Exogenous application of SA improved all measured traits under both well watered and water stress conditions, Results signify the role of SA in regulating drought response of plants and suggest that SA could be used as a potential growth regulator, for improving common bean growth under water stress conditions.

Potassium foliar application proved to be effective to improve yield of different legumes under water stress conditions Kassab and El-Zeiny (2004) on faba bean and Thalooth *et al.* (2006) on mung bean plants.

Therefore, the objective of this study was to determine whether the foliar application of salicylic acid or potassium sulphate can improve growth and yield of dry bean under prolonged irrigation intervals and to check the possibility of saving water without losing much yield.

MATERIALS AND METHODS

Two field experiments were carried out during two successive summer seasons of 2014 and 2015, at El- Baramoon Research Farm, Mansoura Horticulture Research Station, HRI, ARC. Egypt to investigate the response of bean plants to foliar application with salicylic acid and potassium under different irrigation intervals. The soil of the experimental plots was analyzed, using the methods described by Page *et al*. (1982), for the physical and chemical properties and the obtained data are shown in Table (1).

Common bean seeds (*Phaseolus vulgaris* L. c.v. Nebraska) were obtained from the Vegetable Crops Seed Production and Technology Department, Horticulture Research Institute. Sowing was done on 10 th and 11th of March in the two summer seasons of 2014 and 2015, respectively. The seeds were planted at 10 cm apart in a single row. Each row was 3 m long and 0.7 m wide. Each plot contains 6 rows. Thus, the area of each plot was 12.6 m ^{2}. Other agriculture practices such as fertilization, weeding, pest and insect control were carried out as recommended for the conventional common bean planting.

The studied factors were:

1- Irrigation intervals every 8, 12 and 16 days. The irrigation water amount added each time was at rate of 175 m^3 per feddan which calculated according to the equation of Israelson and Hansen (1962).

2- Foliar treatments : control (sprayed with distilled water), salicylic acid at 10 ppm, salicylic acid at 20 ppm , potassium sulphate at 1% and potassium sulphate at 2%. All foliar treatments were applied thrice at 3, 5 and 7 weeks after sowing.

A strip block system in complete randomized blocks design with three replicates was used. Irrigation intervals were assigned in the main plots (vertically) and foliar treatments were randomly distributed in sub-plots (horizontally).

Table 1: The main physical and chemical properties of the experimental site during the two growing seasons.

Some Physical properties	**V**		**Some Chemical Properties**	**Val**	
	1st	**2nd**		**1st**	**2nd season**
Sand (%)	28.1	27.9	**pH* value (1:25)**	8.0	7.9
Silt (%)	31.8	31.6	**EC dSm^{-1}**	0.9	0.9
Clay (%)	40.1	40.5	**Total N (%)**	0.03	0.04
Texture class	Clay-loam	Clay-loam	**Available N (ppm)**		
			NH_4-N	23.37	23.00
			NO_2-N	0.162	0.126
			NO_3-N	13.21	13.12
$CaCO_3$ (%)	3.2	3.0	**Available P (ppm)**	13.3	12.6
Organic matter (%)	1.8	1.6	**Available K (ppm)**	304	302

Data recorded

1-Vegetative growth characters

At flowering stage, ten random plants from each treatment were taken to measure: Plant height (cm), number of leaves/ plant, fresh weight/ plant (g), and dry weight/ plant (g).

2-Seed yield and its components

At harvest stage (after ripening and pods drying), samples of fifteen random plants from each treatment were collected and used for recording seed yield parameters i.e number of seeds per pod, seeds yield per plant(g),weight of 100 seeds (seed index) (g) and total seed yield per feddan (kg).

3-Seed quality

Germination percentage and rate were carried out according to ISTA rules (ISTA, 2011).

Shoot length (cm) and root length of seedling (cm) were also determined at the end of germination test.

Seedling vigor index (SVI) was calculated according to the equation of Abdul-Baki and Anderson (1973).

SVI= Seedling length (cm) x Germination percentage

4- Chemical analysis of leaf

At flowering stage, top fourth leaf from five random plants were picked up and subjected for determining total chlorophyll. A digital chlorophyll meter, Minolta SPAD-502 (Minolta Company, Japan) was used. The same leaves were dried, grinded and prepared for measuring nitrogen, phosphorus and potassium according to methods described in Cottenie *et al.,* 1982.

Statistical analysis:

All the collected data were tabulated and statistically analyzed by Statistical Analysis of variance using MSTAT-C version 4, 1987 software and the treatments means were compared using the LSD test according to Gomez and Gomez 1984

RESULTS AND DISCUSSION

1-Vegetative growth characters

Data presented in Table 2 indicated that all vegetative growth characters in terms of plant height, number of leaves per plant as well plant fresh and dry weights were significantly affected by irrigation intervals. Short irrigation interval every eight days recorded the highest values of all studied characters followed by irrigation every 12 days and finally irrigation every 16 days. Irrigation every 8 days increased plant height by 12.39 and 19.33 % over irrigation every 12 and 16 days respectively, for the first season. While, this increment was 12.06 and 19.24 % in the second season, for the same periods. The same trend was observed for number of leaves and fresh and dry weights/ plant.

Concerning the effect of foliar application either by salicylic acid or potassium sulphate, data in the same table showed that, either salicylic acid or potassium sulphate at all used concentration improved the vegetative growth of bean regardless the irrigation intervals. Foliar application with salicylic acid at 20 ppm recorded the highest values of the studied characters. It increased plant height by 24.41 and 24.33 % ; number of leaves by 44.11 and 40 % ; plant fresh weight by 21.65 and 21.59% and plant dry weight by 20.63 and 20.67% over control treatment for the first and the second seasons, respectively.

As regards the effect of interaction between irrigation intervals and foliar application of salicylic acid and potassium sulphate on bean vegetative growth, Table 2 indicated that, in both seasons of study, irrigation bean plant every 8 days and spraying them with salicylic acid at 20 ppm recorded the highest values of all vegetative growth characters followed by irrigation every 8 days and spraying with salicylic acid at 10 ppm. While increasing the irrigation intervals up to 16 days without applying any of salicylic acid or potassium sulphate significantly decreased the all characters. Prolonged irrigation interval to 12 or 16 days with applying salicylic acid or potassium sulphate as foliar protective treatments improved the values of different characters to reach more or less near to the values when irrigation was done every 8 days without applying any foliar treatment.

Table (2): Effect of irrigation intervals, foliar application treatments with SA and K_2SO_4 and their interaction on bean vegetative growth during 2014 and2015 seasons.

Treatments		Plant height (cm)		No. of leaves/plant		Plant fresh weight (g)		Plant dry weight (g)	
Irrigation Intervals	Foliar Application	2014	2015	2014	2015	2014	2015	2014	2015
A: Irrigation Intervals									
Irrigation every 8		38.64	39.78	12.15	12.40	49.64	51.14	5.460	5.566
Irrigation every 12		34.38	35.5	11.60	12.20	46.22	47.16	5.300	5.508
Irrigation every 16		32.38	33.36	10.60	11.40	36.76	38.2	4.070	4.190
LSD 5%		0.97	0.92	0.34	0.43	0.18	0.23	0.24	0.18
B: Foliar Application									
Control		30.85	31.77	9.25	10.00	39.73	40.90	4.460	4.597
SA 10 ppm		37.66	38.77	12.67	12.67	46.30	47.67	5.170	5.323
SA 20 ppm		38.38	39.50	13.33	14.00	48.33	49.73	5.380	5.547
K_2SO_4 1%		34.60	35.67	11.33	11.67	43.67	44.97	4.880	5.027
K_2SO_4 2%		34.34	35.37	10.67	11.67	43.00	44.23	4.800	4.947
LSD 5%		1.21	1.13	1.02	0.95	0.96	0.70	0.29	0.24
C: The interaction									
Irrigation every 8 days	**Control**	35.15	36.20	10.75	11.00	45.20	46.60	4.970	5.070
	SA 10 ppm	41.18	42.40	13.00	13.00	52.30	53.90	5.750	5.870
	SA 20 ppm	42.25	43.50	14.00	14.00	53.50	55.10	5.860	5.980
	K_2SO_4 1%	37.50	38.60	12.00	12.00	49.00	50.50	5.390	5.500
	K_2SO_4 2%	37.12	38.20	11.00	12.00	48.20	49.60	5.300	5.410
Irrigation every 12 days	**Control**	30.20	31.10	09.00	10.00	41.20	42.00	4.720	4.910
	SA 10 ppm	37.30	38.40	13.00	13.00	48.40	49.40	5.550	5.770
	SA 20 ppm	38.10	39.20	13.00	14.00	49.60	50.60	5.710	5.940
	K_2SO_4 1%	33.50	34.50	12.00	12.00	46.10	47.10	5.300	5.510
	K_2SO_4 2%	33.30	34.30	11.00	12.00	45.80	46.70	5.200	5.410
Irrigation every 16 days	**Control**	27.20	28.00	08.00	09.00	32.80	34.10	3.700	3.810
	SA 10 ppm	34.50	35.50	12.00	12.00	38.20	39.70	4.200	4.330
	SA 20 ppm	34.80	35.80	13.00	14.00	41.90	43.50	4.580	4.720
	K_2SO_4 1%	32.80	33.90	10.00	11.00	35.90	37.30	3.950	4.070
	K_2SO_4 2%	32.60	33.60	10.00	11.00	35.00	36.40	3.900	4.020
LSD 5%		2.10	1.96	1.77	1.64	1.66	1.21	0.50	0.42

Under water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells (Nonami, 1998). Drought caused impaired mitosis; cell elongation and expansion resulted in reduced growth traits (Hussain *et al.* 2008). Similar to our results, Dawa *et al.* (2015) reported that, drought stress decreased vegetative growth of bean but application of SA or potassium improved these traits in both drought and control conditions. Reduction of dry bean leaf area under drought stress conditions during vegetative growth stage has been reported in many studies (Emam *et al.* 2012; Nielsen and Nelson, 1998).

Role of SA in improving plant height under water stress may be due to improving mitosis and cell elongation process. Water deficit stress mostly reduces leaf growth and in turns the leaf areas in many species of plants (Jaleel *et al.* 2009). Exogenous application of potassium salts improved the growth, enhanced water use efficiency, leaf turgor and relative water content of stressed sunflower (Akram *et al*., 2009). Obtained results are in agreement with those of Dawa *et al.,* 2015; Ghanbari *et al.* 2013 and Emam *et al*. 2012, who all worked on bean.

2-Seed yield and its components

Data in Table 3 revealed that all seed yield and its components were significantly and negatively affected by increasing the irrigation intervals up to 16 days which recorded the lowest values. Irrigation every 8 days gave the highest values of all studied characters, i.e. 5.6 and 5.85 seeds per pod; seed index of 47.98 and 48.92 g of 100 seeds and 1079 and 1101 kg per feddan as total yield for the first and the second seasons, respectively. Irrigation every 12 days came in the second rank while irrigation every 16 days exhibited the last rank in this regard.

Foliar application of salicylic acid (10 or 20 ppm) or potassium sulphate (1 or 2%) significantly improved seed yield and its components in bean Table 3. All foliar treatments significantly increased number of seeds per pod over control without significant differences between those treatments in both seasons. Seed index was positively affected by foliar application of SA at 20 ppm which recorded the highest values (47.92 and 47.88 gm) in the first and the second seasons, respectively. Seed yield per plant and total seed yield per feddan had the same trend in their response to foliar application treatment .Salicylic acid at 20 ppm was the superior treatment in this regard as it increased seed yield per feddan by 35.42 % over control treatment as an average of the two seasons. Salicylic acid at 10 ppm recoded an increment of 31.97 % over control and came in the second order while potassium sulphate at 1% ranked third with 24.9 % and lastly potassium sulphate at 2% recorded 20.81 % increment over control plants.

Concerning the interaction between the three used irrigation intervals and foliar application treatments, Data in Table 3 indicated that the highest seed yield and its components recorded when irrigation done every 8 days with foliar application of SA at 20 ppm then SA at 10 ppm under the 8 days of irrigation. Medium irrigation interval of 12 days with using SA or potassium sulphate improved yield considerably and gave total seed yield higher than irrigation every 8 days without using SA or potassium. When irrigation period extended up to 16 days with applying SA at 20 ppm , SA at 10 ppm or potassium sulphate at 1% , plants still produce seed yield higher than when irrigation done every 8 days without applying any foliar treatments. The lowest values of all studied seed yield characters were obtained when irrigation done every 16 days without applying SA or potassium.

Table (3): Seed yield and its components of bean as affected by irrigation intervals , foliar application treatments with SA and K_2SO_4 and their interaction during 2014 and 2015 seasons

Treatments		No. of seeds/pod		Seed index (g)		Seed yield/plant (g)		Seed yield/fed. (kg)	
Irrigation Intervals	Foliar Application	2014	2015	2014	2015	2014	2015	2014	2015
A: Irrigation Intervals									
Irrigation every 8 days		5.600	5.850	47.98	48.92	19.92	20.32	1079	1101
Irrigation every 12 days		5.200	5.400	46.15	47.05	18.18	18.58	998	1015
Irrigation every 16 days		4.400	4.200	41.19	40.18	16.78	17.11	944	962
LSD 5%		0.82	0.77	0.32	0.55	0.73	0.65	6.00	12.00
B: Foliar Application									
Control		4.000	4.083	39.04	39.80	14.73	15.02	821	837
SA 10 ppm		5.667	5.667	46.95	47.88	19.98	20.38	1084	1104
SA 20 ppm		5.667	5.667	47.92	45.81	20.49	20.90	1114	1133
K_2SO_4 1%		5.000	5.333	46.18	47.10	18.51	18.88	1026	1045
K_2SO_4 2%		5.000	5.000	45.44	46.32	17.79	18.17	992	1011
LSD 5%		0.73	0.75	0.82	0.95	0.89	0.75	10.00	16.00
C: The interaction									
Irrigation every 8 days	Control	5.000	5.250	42.83	43.70	17.22	17.56	970.0	990.0
	SA 10 ppm	6.000	6.000	49.34	50.29	21.54	21.97	1150	1175
	SA 20 ppm	6.000	6.000	50.82	51.82	21.93	22.37	1169	1190
	K_2SO_4 1%	5.000	6.000	48.84	49.80	19.81	20.21	1075	1100
	K_2SO_4 2%	6.000	6.000	48.09	48.96	19.12	19.50	1030	1050
Irrigation every 12 days	Control	4.000	4.000	39.39	40.09	14.83	15.13	840.0	858.0
	SA 10 ppm	6.000	6.000	48.29	49.26	20.42	20.83	1108	1122
	SA 20 ppm	6.000	6.000	49.34	50.33	20.18	20.60	1053	1071
	K_2SO_4 1%	5.000	6.000	47.20	48.14	18.21	18.57	1008	1025
	K_2SO_4 2%	5.000	5.000	46.52	47.45	17.35	17.77	983.0	999.0
Irrigation every 16 days	Control	3.000	3.000	34.91	35.61	12.13	12.37	652.0	663.0
	SA 10 ppm	5.000	5.000	43.22	44.08	19.12	19.50	1083	1101
	SA 20 ppm	5.000	5.000	43.59	35.28	18.22	18.58	1031	1051
	K_2SO_4 1%	5.000	4.000	42.51	43.36	17.52	17.87	994.0	1009
	K_2SO_4 2%	4.000	4.000	41.72	42.55	16.91	17.23	962.0	985.0
LSD 5%		1.26	1.30	1.42	1.65	1.54	1.29	18.00	28.00

Drought stress affects crop growth and yield during all developmental stages. The effect of drought on yield is highly complex and involves processes as diverse as reproductive organs, gametogenesis, fertilization, embryogenesis, and seed development stress (Barnabas *et al*. 2008). Reproductive development at the time of flowering is especially sensitive to drought stress (Samarah *et al.* 2009a,). Drought stress is a main abiotic stress that limits crop pollination by reducing pollen grain availability (Trueman and Wallace 1999), increasing pollen grain sterility (Al-Ghzawi *et al.* 2009), decreasing pollen grain germination and pollen tube growth (Lee 1988). Drought stress can also reduce megagametophyte fertility (Young *et al.* 2004), inhibit the differentiation of young microspores (Satake 1991), lower the number of dehisced anthers (Sawada 1987), repress anther development (Nishiyama 1984), and decrease seed set and seed development (Al-Ghzawi *et al.* 2009). Drought stress occurring during flowering and early pod development significantly increased the rate of pod abortion and consequently decreased final seed yield of soybeans (Westgate and Peterson 1993; Liu *et al.* 2003). In soybean, Liu *et al.* (2004) showed that ABA in flowers and pods was increased by drought stress and was associated with a reduction in pod set. These studies suggest that drought stress leads to increase ABA concentration causing pod abortion. Liu *et al.* (2004) found that ABA affected pod set directly via the processes within the ovary (i.e. cell division) or indirectly via influencing the availability of photosynthate sugar. Loss and Siddique (1997) reported that water deficits imposed during the reproductive development of faba beans can decrease number of flowers and pods per plant and number of seeds per pod. Same results were obtained in our study by decreasing seed yield with prolonged the irrigation intervals (Table 3).

3-Seed quality

Data presented in Table 4 showed that seed quality of beans was significantly affected by different irrigation intervals. When irrigation intervals increased, the different seed quality parameters i.e. germination percentage, mean germination time, seedling root length and seedling vigor index were decline. The highest values of these parameters reached their maximum when bean plants were irrigated every 8 days (91.1 % for germination; 2.455 day for mean germination time and 12.4 cm for seedling root length as an average of the two experimental seasons.).

Germination percentage was improved by applying salicylic acid (10 or 20 ppm) or potassium sulphate (1 or 2%) over the control treatment and SA at 20 ppm had the higher germination percentage. Mean germination time had a progressive reduction as a result of applying salicylic acid or potassium sulphate at any concentration and SA at 10 ppm was the best treatment in this regard. Seedling root length responded positively also to foliar treatment and SA at 10 or 20 ppm were the best treatments followed by potassium sulphate at 2% then potassium sulphate at 1% . Control treatment recoded the lowest value. Seedling vigor index increased with applying salicylic acid or potassium sulphate compared with control. SA at 20 ppm recoded the highest values then SA at 10 ppm followed by potassium sulphate at 2% then potassium sulphate at 1% and control treatments.

Concerning the effect of the interaction between irrigation intervals and foliar application treatments on bean seed quality, data in Table 4 showed that the best values of seed quality parameters were obtained by applying SA at 20 ppm under 8 days of irrigation interval. However, under the medium interval (12 days) or the long one (16 days) , SA acts efficiently to improve the quality parameters to record values exceeding the values exhibited when irrigation done every 8 days without applying any stimulating treatments.

Table (4): Effect of irrigation intervals, foliar application treatments with SA and K_2SO_4 and their interaction on bean seed quality during 2014 and 2015 seasons.

Treatments		Germination %		Mean Germination time (days)		Seedling root length (cm)		Seedling vigor index	
Irrigation Intervals	Foliar Application	2014	2015	2014	2015	2014	2015	2014	2015
A: Irrigation Intervals									
Irrigation every 8 days		90.80	91.40	2.442	2.468	12.28	12.52	3018	3101
Irrigation every 12 days		89.35	90.8	2.906	2.832	11.14	11.38	2857	2963
Irrigation every 16 days		85.6	85.8	3.258	3.309	8.94	9.06	2388	2443
LSD 5%		0.49	0.28	0.060	0.036	0.17	0.18	33.0	50.0
B: Foliar Application									
Control		82.00	83.00	3.589	3.647	9.20	9.40	2163	2238
SA 10 ppm		89.58	90.67	2.553	2.577	11.43	11.63	2947	3043
SA 20 ppm		92.33	92.33	2.653	2.680	11.57	11.80	3072	3138
K_2SO_4 1%		89.33	90.00	2.773	2.603	10.67	10.87	2741	2819
K_2SO_4 2%		89.67	90.67	2.773	2.840	11.07	11.23	2848	2940
LSD 5%		0.95	0.60	0.044	0.031	0.250	0.20	78.00	64.0
C: The interaction									
Irrigation every 8 days	Control	86.00	87.00	3.250	3.300	11.10	11.40	2589	2671
	SA 10 ppm	92.00	93.00	2.110	2.120	12.90	13.10	3211	3311
	SA 20 ppm	94.00	94.00	2.210	2.220	13.00	13.30	3309	3384
	K_2SO_4 1%	90.00	91.00	2.320	2.330	12.00	12.20	2907	3003
	K_2SO_4 2%	92.00	92.00	2.320	2.370	12.40	12.60	3073	3137
Irrigation every 12 days	Control	82.00	84.00	3.510	3.540	9.300	9.800	2237	2343
	SA 10 ppm	90.75	92.00	2.510	2.530	11.80	12.10	3076	3174
	SA 20 ppm	93.00	94.00	2.750	2.780	11.90	12.10	3161	3262
	K_2SO_4 1%	90.00	91.00	2.750	2.210	11.00	11.20	2835	2921
	K_2SO_4 2%	91.00	93.00	3.000	3.100	11.50	11.70	2985	3115
Irrigation every 16 days	Control	78.00	78.00	4.000	4.100	7.000	7.000	1662	1700
	SA 10 ppm	86.00	87.00	3.000	3.080	9.600	9.700	2563	2644
	SA 20 ppm	90.00	89.00	3.000	3.040	9.800	10.00	2744	2768
	K_2SO_4 1%	88.00	88.00	3.250	3.280	9.000	9.200	2482	2534
	K_2SO_4 2%	86.00	87.00	3.000	3.050	9.300	9.400	2487	2567
LSD 5%		1.65	1.04	0.077	0.054	0.43	0.35	134	111

Many researchers had similar conclusions to our results presented in table 4 and found that drought stress not only affects seed production, but also lowered seed germination and vigor found that drought stress during reproductive growth lowered seed germination and vigor, Drummond *et al.* 1983 ; Heatherly ,1993 and Samarah *et al, .* 2009b; increased electrical conductivity, Dornbos and Mullen 1985 or reduced seed vigor, as measured by the accelerated aging test Yaklich 1984 who all worked on soybean.

4-Chemical analysis

It is clear from the data in Table 5 that the mean values of total chlorophyll, nitrogen, phosphorus and potassium% in leaves of bean plants were significantly affected by different irrigation intervals, the highest values of chlorophyll, nitrogen and phosphorus were recorded with irrigation every 8 days followed by irrigation every 12 days however, the lowest values were obtained with irrigation every 16 days in both growing seasons. Potassium% recorded its high values with irrigation every 12 days followed by irrigation every 8 days, while the lowest values were obtained with irrigation every 16 days.

In the same Table, the effect of foliar treatments showed significant differences in both seasons regarding chemical constituents. Foliar application with salicylic acid at 10 ppm recorded the highest mean values of chlorophyll followed by foliar treatment with salicylic acid at 20 ppm. Also foliar potassium sulphate at 1% or 2% gave higher significant values compared with the control. The high values of nitrogen and phosphorus content were obtained after foliar application of SA 20 ppm followed by SA at 10 ppm then potassium sulphate at 2% and potassium sulphate at 1% while control plants recoded the lowest values of chemical constituents. The highest values of potassium content in bean leaves were recorded when plants were treated with 2% of potassium sulphate followed by 1% potassium sulphate then SA at 20 ppm and SA at 10 ppm while control plants recoded the lowest values of potassium % in bean leaves.

As regard to the interaction effect between irrigation intervals and foliar application treatments, data in Table 5 showed that the combination treatments of foliar salicylic acid at 20 ppm and irrigation every 8 or 12 days gave the highest values of chlorophyll, nitrogen and phosphorus in both seasons. Combinations of irrigation every 12 days and SA at 20 ppm or potassium sulphate 2% or irrigation every 8 days and treatment with potassium sulphate 2% gave the highest values of potassium content in bean leaves. Irrigation every 16 days without applying either SA or potassium sulphate resulted in the lowest values for chlorophyll, nitrogen, phosphorus and potassium in both seasons.

Our results are in harmony with those of Fayez and Bazaid 2014 , who indicated that exogenous spraying of SA or KNO_3 successfully ameliorated leaf chlorophyll and carotenoid contents of barley plants grown in water stresses. Drought conditions resulted in limited photosynthesis due to a decline in Rubisco activity and reduced gas exchange (Bota *et al*., 2004). Similarly, Idrees *et al.* (2010) reported that SA protected photosynthesis and enhanced Rubisco activity in water stress treated wheat. In soybean, pod set was positively correlated with photosynthetic rate (Liu *et al.* 2004) and ovary abortion was caused by only 2 or 3 days of low water potential, which was enough to inhibit leaf photosynthetic rates (Westgate and Boyer 1986). Charles-Edwards *et al.* (1986) suggested that number of seeds per plant of soybean was positively and linearly correlated with leaf photosynthetic rate.

Table (5): Chlorophyll content, nitrogen, phosphorus and potassium percentages of bean in response to irrigation intervals, foliar application treatments with SA and $K_2SO_4$and their interaction during 2014 and 2014 seasons.

Treatments		Chlorophyll		N %		P %		K %	
Irrigation Intervals	Foliar Application	2014	2015	2014	2015	2014	2015	2014	2015
A: Irrigation Intervals									
Irrigation every 8 days		20.09	19.70	3.561	3.620	0.505	0.515	1.286	1.312
Irrigation every 12 days		19.33	18.89	3.372	3.438	0.531	0.541	1.356	1.382
Irrigation every 16 days		15.78	15.47	2.854	2.912	0.497	0.507	1.200	1.222
LSD 5%		0.63	0.84	0.075	0.116	0.015	0.014	0.052	0.054
B: Foliar Application									
Control		14.83	14.53	2.973	3.033	0.493	0.502	1.18	1.200
SA 10 ppm		20.71	20.29	3.458	3.523	0.517	0.527	1.243	1.267
SA 20 ppm		20.69	20.19	3.570	3.623	0.531	0.542	1.333	1.360
K_2SO_4 1%		18.28	17.92	3.090	3.153	0.505	0.515	1.300	1.327
K_2SO_4 2%		17.48	17.16	3.320	3.283	0.508	0.519	1.347	1.373
LSD 5%		0.70	0.90	0.108	0.109	0.018	0.015	0.037	0.036
C: Interaction									
Irrigation every 8 days	Control	15.21	14.82	3.150	3.210	0.482	0.491	1.180	1.200
	SA 10 ppm	21.80	21.36	3.820	3.890	0.512	0.522	1.220	1.240
	SA 20 ppm	22.14	21.70	3.970	4.000	0.532	0.543	1.350	1.380
	K_2SO_4 1%	19.11	18.73	3.340	3.410	0.495	0.505	1.300	1.330
	K_2SO_4 2%	18.12	17.83	3.520	3.590	0.505	0.515	1.380	1.410
Irrigation every 12 days	Control	16.15	15.90	3.000	3.060	0.521	0.531	1.210	1.230
	SA 10 ppm	22.80	22.34	3.740	3.810	0.535	0.546	1.330	1.360
	SA 20 ppm	23.15	22.69	3.790	3.870	0.542	0.553	1.450	1.480
	K_2SO_4 1%	19.41	19.02	3.110	3.170	0.530	0.541	1.380	1.410
	K_2SO_4 2%	18.93	18.55	3.220	3.280	0.525	0.536	1.400	1.430
Irrigation every 16 days	Control	13.14	12.88	2.770	2.830	0.475	0.485	1.150	1.170
	SA 10 ppm	17.53	17.18	2.810	2.870	0.503	0.513	1.180	1.200
	SA 20 ppm	16.52	16.19	2.950	3.000	0.520	0.530	1.200	1.220
	K_2SO_4 1%	16.32	16.00	2.820	2.880	0.490	0.500	1.220	1.240
	K_2SO_4 2%	15.40	15.10	2.920	2.980	0.495	0.506	1.250	1.280
LSD 5%		1.21	1.55	0.187	0.198	0.019	0.018	0.064	0.062

CONCLUSIONS

The results of this study emphasize the role of SA and K_2SO_4 in regulating water stress response of bean, and suggest that salicylic acid or potassium sulphate acts as a potential growth enhancer to improve plant growth and seed yield as well as its quality. SA and K_2SO_4 can help to reduce the adverse effects of drought and will increase the bean growth and yield.

REFERENCES

Abdul–Baki, A.A. and J.D. Anderson (1973). Vigor determination in soybean by multiple criteria. Crop Sci., 13: 630-633.

Akram, M.S., M. Ashraf and N.A. Akram (2009). Effectiveness of potassium sulfate in mitigating salt-induced adverse effects on different physio-biochemical attributes in sunflower (*Helianthus annuus* L.). Flora 204: 471–483

Al-Ghzawi, A.A., S. Zaitoun, H.Z. Gosheh and A.M. Alqudah (2009). The impacts of drought stress on bee attractively and flower pollination of *Trigonella moabitica* (fabaceae). Arch Agron Soil Sci 55(6):683–692

Barnabas, B., K. Jager and A. Feher (2008). The effect of drought and heat stress on reproductive processes in cereals. Plant Cell Environ 31:11–38

Bota, J., J. Flexas and H. Medrano (2004). Is photosynthesis limited by decreased Rubisco activity and RuBP content under progressive water stress? New Phytol. 162: 671–681.

Charles-Edwards, D.A., D. Doley and G.M. Rimmington (1986). Modeling plant growth and development, North Ryde, NSW. Academic, Australia

Cottenie, A., M. Verloo, L. Kiekens, G. Velghe and R. Camerlynck (1982). Chemical Analysis of Plant and Soil Laboratory of Analytical and Agrochemistry, State Univ., Ghent, Belgium.

Dawa, K.K., H.M.I. Ahmed and M.H. Fekry (2015). Vegetative growth, yield and some chemical constituents in leaves and pods of common bean as affected by salicylic acid and potassium foliar application under different irrigation intervals. J. Plant Production, Mansoura Univ., Vol. 6 (1): 57 -72 .

Dornbos, D.L. and R.E. Mullen (1985). Soybean seed quality and drought stress intensity during development. Iowa Seed Sci 7:9–11

Drummond, E.A., J.L. Rabb and D.R. Melville (1983). Effect of irrigation on soybean seed quality. LaAgric 26:9–16

Emam Y. (1985). Effects of N levels and moisture regimes on agronomic characteristics of four cultivars of dry beans (*Phaseolus vulgaris* L.) M.Sc. thesis, Shiraz University, Iran.

Emam, Y., A. Shekoofa, F. Salehi, A.H. Jalali and M. Pessarakli (2012). Drought stress effects on two common bean cultivars with contrasting growth habits. Archives of Agronomy and Soil Science .58, (5):527-534.

Ertek, A., S. Ensoy, M. Yıldız and T. Kabay (2002). Estimation of the most suitable irrigation frequencies and quantities in eggplant grown in greenhouse condition by using free pan evaporation coefficient. K.S. Univ. Life Sci. Eng. J. 5 (2), 57–67.

Fayez, K.A. and S. A. Bazaid (2014). Improving drought and salinity tolerance in barley by application of salicylic acid and potassium nitrate. Journal of the Saudi Society of Agricultural Sciences, 13: 45–55.

Ghanbari, A.K., S.H. Mousavi, A.M. Gorji and R.A. Idupulapati (2013). Effects of water stress on leaves and seeds of bean (*Phaseolus Vulgaris* L.) Turkish Journal of Field Crops., 18(1): 73-77.

Gomez, K.A. and A.A. Gomez (1984). Statistical Proceedings for Agricultural Research. Second Edition. John Wiley, New York.

Graham, P.H. and P. Ranalli (1997). Common bean (*Phaseolus vulgaris* L.). Field Crops Res. 53:131–146.

Heatherly, L. (1993). Drought stress and irrigation effects on germination of harvested soybean seed. Crop Sci 33:777–781

Hussain, M., M.A. Malik, M. Farooq, M.Y. Ashraf and M.A. Cheema (2008). Improving drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower. Journal of Agronomy and Crop Sci., 194 (3): 193-199.

Idrees, M., M.M.A. Khan, T. Aftab, M. Naeem and N. Hashmi (2010). Salicylic acid-induced physiological and biochemical changes in lemongrass varieties under water stress. J. Plant Int. 5: 293–303.

Israelson, O.W. and V. E. Hansen (1962). Irrigation Principles and Practices. 3 rd Ed. John Willey and Sons, lnc, New York.

ISTA (2011). International Rules for Seed Testing. Seed Science and Technology, 39:1-333.

Jaleel, C.A., P. Manivannan, A. Wahid, M. Farooq, H.J. Al-Juburi, R. Somasundaram and R. Panneerselvam (2009). Drought stress in plants: A review on morphological characteristics and pigments composition. Int. J. Agric. Biol., 11 (1): 100-105.

Kassab, O.M. and H.A. El-Zeiny (2004). Effect of water stress and potassium foliar application on the productivity of faba bean plants. Annals of Agric. Sc., Moshtohor, 42(4):1517-1523.

Lee, T.D. (1988). Patterns of fruit and seed production. In: Lovett DJ, Lovett DL (eds) Plant reproductive ecology, patterns and strategies. Oxford University Press, New York, USA, pp 179–202

Liu, F., M.N. Andersen and C.R. Jensen (2003). Loss of pod set caused by drought stress is associated with water status and ABA content of reproductive structures in soybean. Funct Plant Biol 30:271–280

Liu, F., C.R. Jensen and M.N. Andersen (2004). Pod Set Related to Photosynthetic Rate and Endogenous ABA in Soybeans Subjected to Different Water Regimes and Exogenous ABA and BA at Early Reproductive Stages. Ann Bot 94:405–411

Loss, S.P. and K.H.M. Siddique (1997). Adaptation of faba bean (*Vicia faba*, L.) to dry land Mediterranean type environment. I. Seed yield components. Field Crops Res 54:17–28

Mathoboa, R., D. Maraisa and J. M. Steyn (2017). The effect of drought stress on yield, leaf gaseous exchange and chlorophyll fluorescence of dry beans (*Phaseolus vulgaris* L.). Agricultural Water Management 180: 118–125.

Molina, J.C., V. Moda-Cirino, N.S. da Fonseca Junior, R.T. de Faria and D. Destro (2001). Response of common bean cultivars and lines to drought stress. Crop Breed Appl Biotechnol. 1:363–372.

MSTAT-C Version4 (1987). Software program for the design and analysis of Agronomic research experiments. Michigan University, East Lansing, Michigan, USA

Nielsen, D.C. and N.O. Nelson (1998). Black bean sensitivity to drought stress at various growth stages. Crop Sci. 38:422–427.

Nishiyama, I. (1984). Climatic influence on pollen formation and fertilization. In: Takahashi ST (ed) Biology of Rice. Japan Scientific Societies Press/Elsevier, Tokyo, pp 153–171

Nonami, H. (1998). Plant water relations and control of cell elongation at low water potentials. J. Plant Res. 111: 373-382.

Page, A. L. (1982). Methods of Soil Analysis. 2nd Ed., Part 1, Soil Sci. Soc. Amer., Madison, Wisc., USA

Rezene, Y., S. Gebeyehu and H. Zelleke (2013). Morpho-physiological response to post-flowering drought stress in small red seeded common bean (*Phaseolus* *vulgaris* L.) genotypes. Journal of Plant Studies. 2 (1): 42–53.

Rosales, M.A., E. Ocampo, R. Rodriguez-Valentin, Y. Olvera-Carrillo, J. Acosta-Gallegos and A.A. Covarrubias (2012). Physiological analysis of common bean (*Phaseolus vulgaris*) cultivars uncovers characteristics related to terminal drought. Plant physiol. and Biochem. 56: 24–34.

Rosales-Serna, R., J. Kohashi-Shibata, J.A. Acosta-Gallegos, C.T.J. Lopez, J. Ortiz-Cereceres and J.D. Kelly (2004). Biomass distribution, maturity acceleration and yield in drought-stressed common bean cultivars. Field Crops Res. 85:203–211.

Sadeghipour, O. and P. Aghaei (2012). Response of common bean (*Phaseolus vulgaris* L.) to exogenous application of salicylic acid (SA) under water stress conditions, Advances in Environmental Biology, 6(3): 1160-1168.

Samarah, N.H., N. Haddad and A. Alqudah (2009a). Yield potential evaluation in chickpea genotypes under late terminal drought in relation to the length of reproductive stage. Italian J Agron 3:111–117

Samrah, N.H., R.E. Mullen and I. Anderson (2009b). Soluble sugar contents, germination and vigor of soybean seeds in response to drought stress. J New Seeds 10:63–73

Satake, T. (1991). Male sterility caused by cooling treatment at the young microspore stage in rice plants. Relation between fertilization and the number of engorged pollen grains among spikelets cooled at different pollen developmental stages. J Crop Sci 60:523–528.

Sawada, S. (1987). Study of sterile-type cool injury in rice plants with special reference to the mechanism and inheritance of sterility. Res Bull Obihiro Univ 10:837–883

Tambussi, E.A. and J. Bort (2007). Water use efficiency in C3 cereals under Mediterranean conditions: a review of physiological aspects. Ann. Appl. Biol. 150,307–321.

Thalooth, A.T., M.M. Tawfik and H. M. Mohamed (2006). A comparative study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mung bean plants grown under water stress conditions, World Journal of Agricultural Sciences 2 (1): 37-46.

Trueman, S.J. and H.M. Wallace (1999). Pollination and resource constraints on fruit set and fruit size of *Persoonia rigida* (Proteaceae). Ann Bot 83:145–155.

Westgate, M.E. and J.S. Boyer (1986). Reproduction at low silk and pollen water potentials in maize. Crop Sci 26:951–956

Westgate, M.E. and C.M. Peterson (1993). Flower and pod development in water deficient soybean (*Glycine max* L. Merr.). J Exp Bot 44:109–117

Yaklich, R.W. (1984). Moisture stress and soybean seed quality. J Seed Technol 9:60–67

Young, L.W., R.W. Wilen and P.C. Bonham-Smit (2004). High temperature stress of *Brassica napus* during flowering reduces micro and megagametophyte fertility, induces fruit abortion and disrupts seed production. J Exp Bot 55:458–495

Zlatev, Z.S. and I.T. Yordanov (2004). Effects of soil drought on photosynthesis and chlorophyll fluorescence in bean plants. Bulg. J. of Plant Physiol. 30: 3–18.

تأثير فترات الري وبعض معاملات الرش على النمو الخضري والمحصول البذرى وجودته في الفاصوليا

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الملخص العربى

إستراتجية إستخدام حامض السالسيلك و البوتاسيوم رشا تعطى إمكانية لتوفير مياه الرى و مساعدة النبات على البقاء تحت ظروف الجفاف و فى هذا الصدد تم إجراء تجربتين حقليتين فى الموسم الصيفى لعامى 2014 و 2015 لدراسة إستجابة نبات الفاصوليا للرش بحامض السالسيلك بتركيز 10 و 20 جزء فى المليون و كذلك سلفات البوتاسيوم بتركيز 1 و 2 % تحت 3 فترات رى 8 و 12 و 16 يوم.

ولقد أظهرت النتائج أن الرى كل 8 أيام أدى إلى تحسن صفات النمو الخضرى متمثلة فى إرتفاع النبات و عدد أوراقه و وزنه الطازج و الجاف وصفات محصول البذور و جودته متمثلة فى نسبة الإنبات ووزن 1000 بذرة (دليل البذور) و كذلك طول جذر البادرة و دليل قوة البادرة . و لقد حسنت جميع المواد المستخدمة رشا سواء حامض السالسيلك بتركيز 10 و 20 جزء فى المليون أو سلفات البوتاسيوم بتركيز 1 و 2 % النمو الخضرى و محصول البذور و جودته و كان الرش بحامض السالسيلك بتركيز 20 جزء فى المليون أكفأ المعاملات فى هذا الصدد. و سجلت معاملة التفاعل بين الرى كل 8 أيام و الرش بحامض السالسيلك بتركيز 20 جزء فى المليون أعلى القيم فى الصفات المدروسة.

وعلي ذلك فإنه ينصح للحصول على أعلى محصول من بذور الفاصوليا أن يتم الرى كل 8 أيام مع الرش 3 مرات بحامض السالسيلك بتركيز 20 جزء فى المليون بعد 3 و 5 و 7 أسابيع من الزراعة و لكنه فى حالة نقص المياه فإنه يمكن إطالة فترة الرى إلى 16 يوم مع الرش 3 مرات بحامض السالسيلك بتركيز 20 جزء فى المليون و ذلك لتخفيف التأثير الضار للجفاف بدون أى نقص فى المحصول.

الكلمات الرئيسية : الفاصوليا ، الجفاف ، الرى ، المحصول البذرى ، جودة البذور ، الإنبات .