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Response of common bean (*Phaseolus vulgaris* L) to foliar application with some antioxidants under different irrigation intervals

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ABSTRACT

This study was conducted in the Private Farm at Mansoura district, Dakahlia, Governorate, Egypt during the two summer seasons of 2015 and 2016 to study response of vegetative growth and yield of common bean *cv*. Bronco to irrigation intervals treatments include short, moderate and long irrigation intervals (every 7.11 and15 days, respectively) and foliar application with some antioxidants consisted of (without, 800 ppm chitosan, 2000 ppm citric acid and 200 ppm potassium silicate) and their combinations. The results showed that decreasing irrigation intervals to 7 days or increasing up to 11days led to decreasing of vegetative growth attributes, *i.e*, Plant height (cm), plant fresh weight (g), number of branches, leaf number and leaf area per plant. Leaves chemical composition *i.e* NPK %, photosynthesis pigments. Pods yield and its component, *i.e*, Pods weight/plant, number of pods/plant, pods yield per fed, and seeds dry weight per fed) and chemical quality Vit. C, TSS, carbohydrates%, protein % and Leaf relative water content (LRWC). On contrary, long irrigation intervals gave the highest values of leaf dry matter percentage, pods fiber %, seeds dry matter percentage and electrolyte leakage %. Respecting of the influence of foliar application with some antioxidant, results show that, the mentioned characters were increased compare with control (zero antioxidant) except pods fiber % and electrolyte leakage. Chitosan at 800 ppm followed by 200 ppm potassium silicate were registered the best values of most effective previous attributes. The interactions between irrigation intervals and foliar application with some antioxidants show that the combination of moderate irrigation intervals (every 11 days) with 800 ppm chitosan gave the maximum values of great effective previous parameters.

Key words: common bean, irrigation intervals, antioxidants, Plant water relations and green pods yield.

Introduction

Common bean (*Phaseolus vulgaris* L) is considered an important edible leguminous seed crop for human nutrition. Its seeds contain carbohydrates, protein, 18-20% dry matter, vitamins, minerals. Egypt is considered as 6th ranked with 263.080 tones (FAO, 2013).

Common bean growth parameters, yield and even pods quality are affected by several stress conditions such as environmental conditions, flooding, insects and other pests, disease, low fertility and high salinity of soil, pH, chemical toxicity and water deficit which resulted in low productivity (Jin *et al*., 2014).

Among these stresses, water deficit is of the most significant stresses of agriculturally important crops, which limits the plant growth criteria, yield and its component of Common bean. Many investigators have shown that water shortage has been reported as key factor to limit vegetative growth and yield criteria (leaf area, leaf number and pods yield) of pea plant (Ashraf *et al*., 2011). In addition, the highest values of branches number, seeds number / pods and seeds yield (t/ha) of faba bean were registered by using 100% of irrigation requirement (Migdadi *et al*., 2016). On the other hand, reduction of irrigation water caused decreasing of cow pea seeds yield (Hayatu *et al*., 2014) and chlorophyll content of common bean (Marzouk *et al*., 2016). Also, nodulation and nitrogen fixation of common bean were decline under water deficit (Ndimbo, 2015). On contrast, the highest values of water use efficiency were recorded under water deficit (Nayak *et al*., 2015) on common been.

Increasing of reactive oxygen species (ROS) was the more effective mean to mitigation the worst effects of water deficit, but, they are very toxic for the cells (Chaves *et al*., 2003). Non balance

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between antioxidants protection and (ROS) led to oxidative stress; hence, high concentration of (ROS) can caused damage of lipids, chloroplasts, proteins, DNA and RNA. (Srivalli *et al*., 2003). The non-enzymatic antioxidant system includes many component such as chitosan, citric acid and potassium silicate (Farouk and Ramadan, 2012; Hussein *et al*., 2012).

Antioxidants such as chitosan and citric acid have main functions in plant as antioxidant and enzyme cofactors. They are involved in a variety of processes such as photosynthesis, growth, cell division and synthesis both of anthocyanin, ethylene, gibberellins, hydroxyl proline and abscisic acid. They have synergistic impact on improving growth parameters, flowering, yield and its quality. They also play an essential role membrane stability, metabolism, activating transporter enzymes, and translocation of carbohydrates (Javan *et al*., 2013; Zayed *et al*., 2017).

Many studies reported that application of chitosan and citric acid as foliar spray led to increasing on vegetative growth, yield and its component. Farouk and Ramadan. (2012) on cowpea; Shehata *et al*. (2012) on cucumber and Abd El-Gawad and Bondok (2015) on tomato.

In addition, Potassium is an important nutrient and plays a vital role in water relation, stomata movement, osmotic adjustment and finally plant resistance to drought. It assists in osmo-regulation of plant cell, opening and closing of stomata (Yang *et al*., 2004).Potassium silicate is a source of highly soluble potassium and silicon. Silicon nutrition has several beneficial effects on plant growth as photosynthetic activity, formation of new roots, reduced grains discoloration, promotes ammonium assimilation and restrains the increase in soluble N compound, including amino acid and amide, which are effective for the propagation of hyphae (Zhu *et al*., 2004). Silicon is reported that it reduces multiple stresses including biotic and abiotic stresses in plants. Abuo- Baker *et al*. (2011) on been and Abd El-Gawad *et al*. (2017) on potato.

Therefore, this study was conducted to assess the impact of some antioxidants such as chitosan, citric acid and potassium silicate to reducing the worst effects of irrigation intervals on growth and yield of common been.

Materials and methods

In order to determine the effects of irrigation intervals and some antioxidants on growth and yield of common bean (cv. Bronco), two field experiments were carried out in the Private Farm at Mansoura district, Dakahlia, Governorate, Egypt in the two summer seasons of 2015 and 2016 using surface irrigation system. Data in Table 1 show the measured soil characters of the studied soil from the top layer (0-30 cm depth).

Table 1: The characterized of soil during the two seasons of 2015 and 2016.

Seasons	Silt %	Clay %	Sand %	Texture soil	Field Capacity %	Welting point %	Available water %
2015	40.7	36.4	22.9	Clay loamy	33.9	17.2	16.7
2016	41.2	36.2	22.6	Clay loamy	33.8	17.0	16.8

Seasons	pH	E.C (dSm-1)	Organic matter %	$CaCO_3$ %	N ppm	P ppm	K ppm
2015	7.79	1.52	1.80	2.69	55.0	5.6	276
2016	7.81	1.67	2.04	2.78	56.2	6.0	278

Seeds of common bean were sown in moderately moisture soil (approximately 60%) on 25th and 28th of February in the 1st and the 2ed seasons, respectively in hills on one side of ridges which were (3.5 m length and 0.7 m in width) at distance of 30 cm, four to five seeds were sown in hills, the hill plants were thin into two plants after three weeks (40,000 plant per fed.). Each sub plot planted with of six ridges, the plot occupying an area of 14. 7 m2.

Irrigation intervals treatments i.e short, moderate and long irrigation intervals every (7.11 and15 days), respectively, were initiated after 22 days after sowing in the 1st and 2^{ed} seasons respectively.

Some antioxidants treatments (without exogenous antioxidant. 800 ppm chitosan, 2000 ppm citric acid and 200 ppm potassium silicate) were sprayed three times at 30, 45 and 60 day after sowing.

All treatments received 20 m^3/fed. of farmyard manure and phosphorus fertilizer (45 kg as P_2O_5 /fed) were added during soil preparation. Also, 69 kg N and 48 kg K_2O kg/ fed. as urea (46 %), and potassium sulfate (48 % K_2O), respectively. urea and potassium sulphate were divided in two equal doses 1st and 2ed irrigation, respectively.

Experimental design:

The experiments were designed in in a split - plots with four replications. 3 irrigation intervals were designation in the main plots, and 4 foliar antioxidants treatments were allocated in the sub plots.

Measurements:

After 75 days from sowing four plants were randomly chosen to measure the next criteria in both seasons.

Vegetative growth characters:

Plant height (cm), plant fresh weight (g), branches number, leaf number, leaf area (cm^2) and leaves dry matter % per plant.

Leaves chemical composition:

NPK, chlorophyll a, b and carotenoids concentrations were measured according to AOAC (1990).

Green pods yield and its component:

Pods weight per plant, pods number per plant, pods yield per fed, pods fiber %, seeds dry weight per fed and seeds dry matter percentage were recorded at 85 days after sowing except seeds dry weight per fed. (120 days after sowing).

Seeds chemical quality and Plant water relations:

Vit. C, TSS were determined according to AOAC (1990) after 85 days from sowing. Carbohydrates%, protein% were determined according to AOAC (1990) after 120 days from sowing. Leaf relative water content (LRWC) and Electrolyte leakage % were determined according to (Kataria and Singh, 2013) after 85 days from sowing.

Statistical analysis:

All data collected were subjected to analysis of variance according to Snedecor and Cochran (1980). Least significant difference (LSD) at the probability of 5 % was used as reported by Gomez and Gomez (1984).

Results and Discussion

Vegetative growth characters:

Presented results in Table 2 reveal that irrigation intervals, i.e short, moderate and long (7, 11 and 15 days, respectively) caused significant effects on vegetative growth attributes as plant height (cm), plant fresh weight (g), branches number per plant, leaves number /plant and leaf area per plant .

Moderate irrigation intervals was recorded the highest values followed by application leaves of the short irrigation intervals in the two seasons. On contrary, the long irrigation intervals was registered the lowest values. In addition, the leaf dry matter % was significantly affected with irrigation intervals, on, contrast, the long irrigation intervals gave the maximum values followed by moderate while the short irrigation intervals was recorded the lowest values.

Table 2: Impact of irrigation intervals and foliar application with some antioxidants on vegetative growth characters of common bean at 75 days after sowing during the two seasons of 2015 and 2016.

Treatments		Plant height (cm).		Plant fresh weight g / plant		Branches No / plant		Leaf No / plant		Leaf area (cm^2) / plant		Leaf DM%	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation intervals													
7 days (short)		38.7	39.4	65.6	66.7	5.23	5.31	10.5	10.7	946	962	13.01	13.33
11 days (moderate)		43.8	44.6	74.3	75.6	5.93	6.02	11.9	12.1	1071	1089	14.68	14.93
15 days (long)		34.3	34.9	58.1	59.2	4.62	4.70	9.3	9.5	838	853	16.62	16.91
LSD 5%		0.4	0.6	0.7	1.1	0.07	0.35	0.1	0.3	10	27	0.16	0.76
Foliar application with some antioxidants (ppm)													
Without		37.0	37.3	62.7	63.3	4.98	5.04	10.0	10.1	903	913	14.02	14.16
Chitosan (800)		41.1	42.1	69.6	71.3	5.54	5.66	11.2	11.4	1003	1029	15.57	16.08
Citric acid (2000)		38.4	39.0	65.1	66.1	5.20	5.27	10.4	10.6	939	953	14.57	14.79
Potassium silicate (200)		39.4	40.1	66.7	67.9	5.32	5.41	10.7	10.9	961	979	14.91	15.19
LSD 5%		1.8	2.0	3.1	3.4	0.25	0.43	0.5	0.7	45	55	0.70	0.98
Interaction													
7 days	Without	37.7	38.1	63.9	64.5	5.10	5.13	10.2	10.3	922	931	11.81	11.93
	Chitosan	40.1	41.0	67.9	69.6	5.40	5.53	10.9	11.2	979	1004	13.98	14.69
	Citric acid	38.1	38.7	64.6	65.6	5.16	5.23	10.4	10.5	932	946	12.92	13.12
	Potassium silicate	39.0	39.7	66.0	67.2	5.26	5.36	10.6	10.8	952	969	13.33	13.57
11 days	Without	42.1	42.5	71.3	72.0	5.66	5.73	11.4	11.6	1028	1038	14.30	14.44
	Chitosan	46.3	47.4	78.4	80.4	6.26	6.36	12.6	12.9	1130	1159	15.20	15.58
	Citric acid	43.1	43.7	73.0	74.1	5.83	5.93	11.7	11.9	1052	1068	14.46	14.67
	Potassium silicate	44.0	44.8	74.4	75.8	5.96	6.06	11.9	12.2	1073	1093	14.76	15.03
15 days	Without	31.2	31.5	52.8	53.3	4.2	4.26	8.5	8.5	761	769	15.96	16.12
	Chitosan	36.9	37.8	62.5	64.0	4.96	5.10	10.0	10.3	901	923	17.54	17.98
	Citric acid	34.1	34.6	57.8	58.6	4.6	4.66	9.3	9.4	833	845	16.33	16.57
	Potassium silicate	35.2	35.8	59.6	60.7	4.73	4.80	9.5	9.7	859	875	16.65	16.96
LSD 5%		3.2	3.4	5.4	5.9	0.44	0.75	0.8	1.1	78	96	1.21	1.71

The increases parameter values for moderate irrigation intervals can be due to that the moderate irrigation intervals gave the best or most appropriate amount of irrigation which had more oxygen which led to better respiration of root, absorption of the elements and less loss of nutrients by leaching, on contrast, the short irrigation intervals resulted in decreasing in oxygen in root zone and more leaching which led to loss more of essential nutrients, Also, the decreasing in previous characters by application of the long irrigation intervals may be due to the reduction of cells division, cell elongation and development in organs of plant especial in stem and leaves. So that, water shortage stress led to reduction in plant height, leaf area and photosynthesis which reflected negatively on plant growth. Our results were in agreement with the results reported by Hussein *et al*., (2012) on cowpea and Hegab *et al*., (2014) on faba been.

As for antioxidants treatments spraying with 800 ppm chitosan, 2000 ppm citric acid and 200 ppm potassium silicate significantly increased previous attributes of common been plant compared to control in both seasons (Table 2). Also, the maximum growth parameters values were registered by 800 ppm of chitosan which followed by 200 ppm potassium silicate. On contrast, the control treatment gave the minimum values in two season of study.

This enhancement in vegetative growth criteria could be due to the long irrigation intervals (every 15 days) led to producing more of (ROS) (Cruz de Carvalho, 2008). Antioxidants more active against stresses by decreasing oxygen free radicals or prevent ROS activity, improving cell division, increasing ion transports, polyamines content and membrane stability under stress or non-stress

conditions. In addition, Potassium is an important nutrient and plays an essential role in water relation, osmotic adjustment, stomata movement and finally plant resistance to drought, activation of enzymes, protein synthesis and photosynthesis. Silicon nutrition has several beneficial impacts on plant growth largely due to its unique physiological role. These findings are in accordance with Abou-Baker et al., (2011) on broad bean and Farouk and Ramadan, (2012) on cowpea.

Concerning the interaction between irrigation intervals and spraying antioxidants results in Table 2 showed that common bean plants which irrigated moderate intervals (every 11 days) and foliar sprayed by 800 ppm chitosan were registered the greatest values of all previous attributes. On contrast, the minimum values were achieved with application of long irrigation intervals (every 15 days) and without antioxidants in both seasons. Our results were in coincidence with those obtained by Ibrahim *et al*., (2011) on cabbage and Abd El-Gawad *et al*., (2017) on potato.

2- Leaves chemical composition parameters:

Results in Table 3 reveale that decreasing irrigation intervals to 7 days or increasing up to 11days led to significant decreasing in concentration of chlorophyll a, chlorophyll b, carotenoids and NPK (%) in common bean leaf tissue. The moderate irrigation intervals (every 11 days) registered the biggest values of the mentioned attributes followed by short irrigation intervals (every 7 days) in both season. On contrary, the application of long irrigation intervals (every 15 days) gave the worst values. These findings may be due to that long irrigation intervals resulted in decreasing of nutrients elements uptake. Also, long irrigation intervals caused reducing in mineral content of leaf, especially N and Mg which are essential for synthesis of chlorophyll pigments. On contrast, short irrigation intervals resulted in decreasing of oxygen in root zone and more leaching which led to loss more of essential nutrients. Similar results were obtained by Ndimbo (2015) on common bean; Hegab *et al*. (2014) on faba bean and Marzouk *et al*., (2016) on snap bean.

Table 3: Impact of irrigation intervals and foliar application with some antioxidants on N, P, K percentage and photosynthesis pigments in leaves of common bean after 75 days after sowing during the two seasons of 2015 and 2016.

Treatments		N %		P %		K %		Chl. a mg/100 FW		Chl.b mg/100 FW		Carotenoids mg/100g FW	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation intervals													
7 days (short)		2.80	2.85	0.397	0.404	1.17	1.19	38.4	39.1	16.9	17.2	9.7	9.9
11 days (moderate)		3.17	3.23	0.449	0.457	1.33	1.35	43.5	44.3	19.2	19.5	11.0	11.2
15 days (long)		2.48	2.53	0.352	0.358	1.04	1.05	34.1	34.7	15.0	15.3	8.6	8.8
LSD 5%		0.03	0.11	0.004	0.009	0.01	0.07	0.4	1.4	0.2	0.7	0.1	0.6
Foliar application with some antioxidants (ppm)													
Without		2.67	2.70	0.379	0.383	1.12	1.13	36.7	37.1	16.2	16.3	9.3	9.4
Chitosan (800)		2.97	3.05	0.421	0.431	1.24	1.27	40.8	41.8	17.9	18.4	10.3	10.6
Citric acid (2000)		2.78	2.82	0.394	0.400	1.16	1.18	38.1	38.7	16.8	17.0	9.6	9.8
Potassium silicate (200)		2.85	2.90	0.403	0.411	1.19	1.21	39.0	39.8	17.2	17.5	9.9	10.1
LSD 5%		0.13	0.18	0.019	0.021	0.05	0.09	1.8	2.4	0.8	1.14	0.4	0.8
Interaction													
7 days	Without	2.73	2.76	0.387	0.390	1.14	1.15	37.4	37.8	16.5	16.6	9.5	9.6
	Chitosan	2.90	2.98	0.411	0.421	1.21	1.24	39.8	40.8	17.5	18.0	10.1	10.3
	Citric acid	2.76	2.80	0.391	0.397	1.16	1.17	37.8	38.4	16.7	16.9	9.6	9.7
	Potassium silicate	2.82	2.87	0.399	0.407	1.18	1.20	38.6	39.4	17.0	17.3	9.8	10.0
11 days	Without	3.05	3.08	0.432	0.436	1.28	1.29	41.8	42.2	18.4	18.6	10.6	10.7
	Chitosan	3.35	3.43	0.474	0.486	1.40	1.44	45.9	47.1	20.2	20.7	11.6	11.9
	Citric acid	3.12	3.17	0.442	0.448	1.31	1.32	42.8	43.4	18.8	19.1	10.8	11.0
	Potassium silicate	3.18	3.24	0.451	0.459	1.33	1.35	43.6	44.4	19.2	19.6	11.0	11.2
15 days	Without	2.25	2.28	0.319	0.323	0.94	0.95	30.9	31.2	13.6	13.7	7.8	7.9
	Chitosan	2.67	2.74	0.378	0.387	1.12	1.14	36.6	37.5	16.1	16.5	9.3	9.5
	Citric acid	2.47	2.50	0.349	0.355	1.03	1.05	33.8	34.3	14.9	15.1	8.6	8.7
	Potassium silicate	2.54	2.59	0.360	0.367	1.06	1.08	34.9	35.5	15.4	15.6	8.8	9.0
LSD 5%		0.23	0.31	0.032	0.037	0.09	0.15	3.1	4.3	1.4	1.9	0.8	1.4

Respecting the effect of antioxidants, results in Table 3 indicates that previous characters were significantly increased in the first and the second seasons with spraying antioxidants application comparing the control. Chitosan at 800 ppm followed by potassium silicate at 200 ppm were recorded the maximum values of these criteria. On contrast, the control treatment gave the minimum amounts of previous parameters in both seasons. This may be due to shortage of water resulted in increasing of ROS which has devastating influence for photosynthesis pigments under long irrigation intervals. Chitosan, potassium silicate are beneficial for mitigation the deleterious influences of ROS on chlorophyll pigment by stimulating cell division, ion transport and improving plant growth. Also, Chitosan, potassium silicate probably prevent oxidase enzymes of chlorophyll. These data are in harmony with that reported by Zhu *et al*. (2004) on cucumber; Abd El-Gawad *et al*. (2017) on potato and Abu-Muriefah, (2013) and Zayed *et al*. (2017) on common bean.

Data presented in Table 3 illustrate that the interaction between irrigation intervals and antioxidants treatments significantly affected on the previous characters, the best values were achieved with application of moderate irrigation intervals (every 11 days) and 800 ppm chitosan, On contrary, the worst values were recorded with long irrigation intervals (every 15 days) and without antioxidants in the two season of study. Similar results have been detected by Kataria and Sing (2013) on chickpea; Hira *et al*. (2016) on cucumber and Yaya *et al*. (2017) on soybean.

3- Green pods yield and its component:

Data listed in Table 4 indicate that pods weight per plant, pods number per plant, pods yield per fed, pods fiber %, seeds dry weight per fed. and seeds dry matter percentage were recorded were affected significantly, by irrigation intervals. The moderate irrigation intervals (every 11 days) gave the maximum values of green pods weight per plant, pods number per plant, pods yield per fed., and seeds dry weight per fed followed by short irrigation intervals (every 7 days), On contrast, the lowest values of mentioned parameters were obtained by using long irrigation intervals (every 15 days) in both seasons. As for, pods fiber % and seeds dry matter percentage date presented in Table 4 show that the maximum value were achieved by application of long irrigation intervals(every 15 days). On contrast, the minimum values were acieved with short irrigation intervals (every 7 days) in both seasons.

These results may be attributed to long irrigation intervals increasing reactive oxygen species (ROS) which destructive to proteins, vital membranes, DNA and RNA. Also,, it's increasing production of ethylene and abscisic acid, on the other hand, decreasing nutritious elements uptake, photosynthesis pigments and cytokinins which will resulted in reduction of chlorophyll pigments in plants which could be a great effect on vegetative growth parameters and yield. On the other hand, less of oxygen in root zone and more of leaching which led to loss more of essential nutrients occur under short irrigation intervals condition. The same results trend obtained by Hussein *et al*. (2012); Hayatu *et al*. (2014) on cowpea and Ndimbo (2015) on common bean.

Regarding the effect of spraying of antioxidants on common bean plants, the results in Tables 4 indicate that, the mentioned criteria were increased compared to the control expect the pods fiber % character. The best values of these attributes were observed by using 800 ppm Chitosan followed by 200ppm potassium silicate, respectively, in both seasons. On other hand, the lowest values of previous parameters were recorded with the control treatment in the two seasons. This ameliorate in the yield and its quality of common bean may be chitosan and potassium silicate have a role as adjuncts to certain enzymes (peroxidases, catalases and dismutases) which led to breakdown of the toxic free radicals. In additions, antioxidants increasing ion uptake, cell division and protein which caused ameliorate of plant growth parameters (Li *et al*., 1992). Similar results were reported by Hussain *et al*. (2011) on mungbean; Abou- Baker *et al*. (2011) on bean and Zayed *et al*. (2017) on common bean.

Data represented in Table 4 revealed that, the interactions treatments were have significant impacts in the 1st and the 2ed seasons, the biggest values of pods weight per plant, pods number per plant, pods yield per fed, and seeds dry weight/ fed were noticed with moderate irrigation intervals (every 11 days) and 800 ppm chitosan treatment. On contrary, the lowest values were noticed with long irrigation intervals (every 15 days) and without antioxidants in both seasons. On the other hand, the highest pods fiber % and seeds dry matter percentage was recorded by application of long

irrigation intervals (every 15 days) application and without antioxidant in the two seasons. But, the minimum values were achieved short irrigation intervals (every 7 days) and 800 ppm chitosan. Similar findings were recorded by Farouk and Ramadan (2012) on cowpea; Kataria and Singh (2013) on chickpea and Yaya *et al*. (2017) on soybean.

Table 4: Impact of irrigation intervals and foliar application with some antioxidants on seeds, pods yield and its quality of common bean during the two seasons of 2015 and 2016.

Treatments		Pods weight (g) per plant		Pods number per plant		Green pods yield (ton) per fed		Pods fiber content%		Seeds dry weight kg/fed.		Seeds dry matter percentage	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation intervals													
7 days (short)		75.5	76.9	13.7	14.3	3.02	3.07	6.12	6.22	1305	1327	19.30	19.64
11 days (moderate)		96.9	98.6	15.6	16.2	3.87	3.94	6.90	7.02	1674	1703	21.78	22.15
15 days (long)		59.6	60.7	12.2	12.7	2.38	2.42	7.82	7.95	1029	1048	24.66	25.09
LSD 5%		0.9	3.3	0.3	0.4	0.03	0.13	0.07	0.31	14	44	0.24	0.50
Foliar application with some antioxidants (ppm)													
Without		69.9	70.6	13.2	13.5	2.79	2.82	7.32	7.51	1210	1223	20.80	21.01
Chitosan (800)		85.7	87.8	14.6	15.4	3.42	3.51	6.59	6.66	1508	1546	23.11	23.68
Citric acid (2000)		75.1	76.3	13.7	14.1	3.00	3.05	7.01	7.14	1310	1330	21.62	21.94
Potassium silicate (200)		78.7	80.1	13.8	14.6	3.14	3.20	6.85	6.95	1316	1340	22.13	22.54
LSD 5%		7.2	7.5	0.7	0.8	0.29	0.31	0.33	0.48	125	128	1.04	1.25
Interaction													
7 days	Without	71.7	72.4	13.3	13.8	2.86	2.89	6.57	6.74	1240	1253	17.52	17.70
	Chitosan	80.9	82.9	14.3	15.0	3.23	3.31	5.55	5.61	1423	1459	20.74	21.26
	Citric acid	73.4	74.5	13.6	14.0	2.93	2.98	6.27	6.38	1279	1298	19.18	19.46
	Potassium silicate	76.3	77.8	13.6	14.4	3.05	3.11	6.08	6.17	1277	1300	19.78	20.14
11 days	Without	89.3	90.2	15.0	15.3	3.57	3.60	7.15	7.32	1546	1562	21.21	21.43
	Chitosan	107.7	110.4	16.6	17.4	4.31	4.41	6.72	6.79	1897	1944	22.55	23.11
	Citric acid	93.4	94.9	15.3	15.8	3.74	3.79	6.94	7.07	1629	1653	21.45	21.77
	Potassium silicate	97.1	99.0	15.6	16.3	3.88	3.95	6.80	6.90	1625	1655	21.91	22.31
15 days	Without	48.8	49.3	11.3	11.3	1.95	1.97	8.25	8.46	845	854	23.68	23.91
	Chitosan	68.4	70.1	13.0	13.7	2.73	2.80	7.50	7.58	1204	1234	26.03	26.68
	Citric acid	58.6	59.5	12.3	12.6	2.34	2.38	7.83	7.98	1022	1038	24.23	24.59
	Potassium silicate	62.5	63.7	12.3	13.0	2.50	2.54	7.68	7.80	1046	1066	24.71	25.17
LSD 5%		12.6	13.1	1.3	1.4	0.50	0.52	0.57	0.83	216	222	1.80	2.18

4- Seeds chemical quality and plant water relations

Tabulated data in Table 5 indicated that Vit. C, TSS, carbohydrates%, protein %, LRWC and Electrolyte leakage were significantly influenced by the irrigation intervals. The observed data demonstrate that increasing of irrigation intervals up to every 11 days led significantly to decreasing all mentioned parameters except Electrolyte leakage during both seasons of study. The maximum values of Vit. C, TSS, carbohydrates%, protein % and LRWC were registered with moderate intervals treatment (every 11 days) followed by the short irrigation intervals (every 7 days). On contrary, the long irrigation intervals treatment (every 15 days) gave the lowest value. As for, electrolyte leakage characters data present in Table 4 clear that either long irrigation intervals or short irrigation intervals was recorded the highest values compared the moderate irrigation intervals. These finding may be due to long irrigation intervals caused increasing of ethylene production and decreasing of elements uptake and cytokinins production which resulted in poor roots production, closing of the stomata to avoid further loss of water, the same negative effects occur with short irrigation intervals. On the other hand, moderate irrigation intervals give the suitable amounts of water and oxygen in root zoon for plants to maintain high water content in plant tissues. Similar results have been indicated by Faisal and suliman (2010) on cowpea; Dogan *et al*. (2015) on pea and Marzouk *et al*. (2016) on snap bean.

As for effect of antioxidants, the results in Table 5 show that Vit. C, TSS, carbohydrates%, protein %, Leaf LRWC and Electrolyte leakage were significantly affected by foliar application with some antioxidants. The previous parameters were increased compared to the control except electrolyte leakage. The best values of the mentioned criteria were observed by application of chitosan at 800

ppm followed by 200 ppm potassium silicate in the two seasons. On contrast, the lowest values were noticed with the control treatment. On other hand, electrolyte leakage % was decreased compared to untreated plants. The highest values were registered by using of without antioxidants. The lowest values of electrolyte leakage % were observed with the application of chitosan at 800 ppm in the both seasons. These results could be antioxidants caused increasing protein, soluble carbohydrates and water content which stimulate plant growth and declined electrolyte leakage. Also, increasing in leaf relative water content may be chitosan and potassium silicate have a great role in accumulation of compatible osmolytes in plants tissues. Similar finding has been recorded by Zhu *et al*. (2004) on cucumber; Hussain *et al*. (2011) on mungbean; Abu-Muriefah, (2013) on common bean and Abd El-Gawad and Bondok (2015) on tomato.

Table 5: Impact of irrigation intervals and foliar application with some antioxidants on chemical quality of seeds and some plant water relations parameters of common bean during the two seasons of 2015 and 2016.

Treatments		Vit. C mg/100g F.W		TSS %		Total carbohydrates %		Protein %		Leaf relative water content %		Electrolyte leakage %	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation intervals													
7 days (short)		10.4	10.5	5.63	5.73	17.7	18.0	22.4	22.8	79.2	80.5	50.6	51.6
11 days (moderate)		11.7	11.9	6.38	6.49	20.0	20.4	25.3	25.8	89.7	91.2	37.4	38.0
15 days (long)		9.2	9.4	4.99	5.08	15.7	15.9	19.8	20.2	70.2	71.4	66.9	68.1
LSD 5%		0.1	0.3	0.06	0.34	0.2	0.4	0.2	0.7	0.9	1.5	0.2	0.8
Foliar application with some antioxidants (ppm)													
Without		9.9	10.0	5.38	5.43	16.9	17.0	21.4	21.6	75.6	76.4	54.4	55.8
Chitosan (800)		11.0	11.3	5.98	6.12	18.7	19.2	23.7	24.3	84.0	86.1	49.2	49.7
Citric acid (2000)		10.3	10.4	5.59	5.68	17.5	17.8	22.2	22.5	78.6	79.8	52.1	53.1
Potassium silicate (200)		10.5	10.7	5.72	5.83	17.9	18.3	22.7	23.1	80.4	81.9	50.9	51.7
LSD 5%		0.5	0.7	0.27	0.45	0.8	1.0	1.0	1.3	3.7	4.4	2.4	2.7
Interaction													
7 days	Without	10.1	10.2	5.49	5.54	17.2	17.4	21.8	22.0	77.1	77.9	52.4	53.7
	Chitosan	10.8	11.0	5.83	5.98	18.3	18.7	23.2	23.8	82.0	84.0	49.3	50.0
	Citric acid	10.2	10.4	5.55	5.63	17.4	17.7	22.0	22.4	78.0	79.2	50.9	51.9
	Potassium silicate	10.4	10.6	5.67	5.77	17.8	18.1	22.5	22.9	79.6	81.1	49.9	50.6
11 days	Without	11.3	11.4	6.12	6.18	19.2	19.4	24.3	24.6	86.1	86.9	40.2	41.2
	Chitosan	12.4	12.7	6.73	6.90	21.1	21.7	26.7	27.4	94.7	97.0	33.9	34.3
	Citric acid	11.5	11.7	6.27	6.36	19.7	20.0	24.9	25.3	88.1	89.4	38.3	39.0
	Potassium silicate	11.8	12.0	6.39	6.51	20.0	20.4	25.4	25.9	89.9	91.5	37.1	37.7
15 days	Without	8.3	8.4	4.53	4.58	14.2	14.3	18.0	18.2	63.7	64.3	70.6	72.4
	Chitosan	9.9	10.2	5.37	5.50	16.8	17.2	21.3	21.8	75.4	77.3	64.2	64.9
	Citric acid	9.1	9.3	4.96	5.04	15.5	15.8	19.7	20.0	69.7	70.8	67.0	68.3
	Potassium silicate	9.4	9.6	5.11	5.21	16.0	16.3	20.3	20.7	71.9	73.2	65.7	66.7
LSD 5%		0.8	1.1	0.46	0.79	1.4	1.7	1.8	2.4	6.5	7.6	4.2	4.6

Concerning the interaction between irrigation intervals and antioxidants, the data represented in Table 5 illustrate that the combination of moderate irrigation intervals (every 11 days) and 800 ppm chitosan was recorded the highest values Vit. C, TSS, carbohydrates %, protein %, Leaf and LRWC. On contrast, the minimum values were achieved with long irrigation intervals treatment (every 15 days) and without antioxidants in the two study seasons. As for, electrolyte leakage % the maximum values was noticed with long irrigation intervals application (every 15 days) and without antioxidants. On contrary, the combination of moderate irrigation intervals and 800 ppm chitosan gave the lowest values in the two seasons. These results are in agreement with those reported Farouk and Ramadan (2012) on cowpea; Kataria and Singh (2013) on chickpea and Abd El-Gawad *et al*., (2017) on potato

Conclusion

The results presented in this investigation show that it is possible to mitigation the negative impact of long irrigation intervals on the growth parameters and productivity of common by

application of foliar antioxidant (chitosan, citric acid and potassium silicate). The interactions treatments between irrigation intervals antioxidants showed that the combination which consist of moderate irrigation intervals and either 800 chitosan or 200 ppm potassium silicate, respectively, gave the best values for most parameters. Therefore, it is recommended for common bean grown under the same condition of the study in order to get the biggest green pods yield (ton/fed) and its physical and chemical quality using moderate treatments (every 11 days intervals) with 800 ppm chitosan.

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