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Effect of Some Stimulative Substances as Foliar Applications on Snap Bean (*Phaseolus vulgaris* L.) Productivity Under Milder Thermo-Stress of Local Summer Season.

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ABSTRACT

Snap bean (*Phaseolus vulgaris* L.) is one of the most important vegetable crops grown in Egypt for both local consumption and exportation. Growing snap bean under local environmental condition of summer season experience brief and problematic seasonal heat waves, resulting in leaves and blossom abscission, and consequently, reduction in yield and product quality. This study was designed in private farm at Kafr Hassan, Sammanoud district, Garbia governorate (10 Km apart of Mansoura city) to investigate the influence of foliar application of some antioxidant substances, i.e., KCL, Ca-citrate 25%, Mg-Edta/cit 10%, Zn-citrate 12%, ascorbic acid (AsA) and salicylic acid (SA) towards better and higher productivity of snap bean plants Bronco cultivar during the two summer seasons of 2011 and 2012. The obtained results showed that exogenous foliar application with aforementioned substances were greatly effective in enhancing the tolerance of adverse conditions, which were manifested by improving vegetative growth and yield and its attributes, as well as pod soluble solid substances (S.S.S) and pigments constituents of leaves and pods of snap bean plants compared with untreated control (tap water) in both seasons. The most favorite applications in diminished order were K, Ca and Mg combination and/or individual, SA, Zn and at least AsA. This enhancement of yield capacities was related to pod quality, i.e., pod length, pod weight and number of pods per plant, therefore, it can be concluded that spraying snap bean plants, growing under milder thermo-stress of local summer season, with some simulative substances can enhance growth and yield capacities of snap bean.

Keywords:

Introduction

To keep up with population growth, a 30% increase in common bean yield is needed by 2050, while increasing temperatures are predicted to gradually limit the regions and/or seasons favorable for common bean production in most countries (Palomino, 2012). Among the climate change-associated constraints, high temperature and drought stress are likely to have the greatest effect on common bean productivity. Heat sensitivity is a major limiting factor in the production of common beans, causing reducing yields, reduced product quality, and restricted geographic adaptation. Temperate common bean production areas experience brief and problematic seasonal heat waves during flowering, resulting in blossom drop, and in the case of snap bean, a split set. Also, distally located ovules fail to develop, reducing seed number in dry bean and product quality in snap bean due to misshapen pods (Myers and Baggett, 1999). The crop also faces water deficit due to excessive transpiration caused by high temperature (Omae *et al.*, 2004 and Omae *et al*., 2005).

Current climate change estimates predict global temperature increases of between 1.4 and 3 °C by 2050 and region-specific increases or decreases in precipitation (Solomon *et al*., 200 7, and Rowlands *et al.*, 2012), resulting in changes in agro-ecological zones and in the disruption in crop production systems. These dramatic climatic change scenarios over the short-term result in sobering predictions of yield reduction in crops, especially in abiotic stress-sensitive crops such as common bean. Because drought has the potential to affect about two-thirds of common bean production areas, improvements in heat tolerance and drought tolerance could increase areas suitable for common bean production by 54% and 31%, respectively (Beebe, 2012). Hence, improving tolerance of bean plants to the possible environmental stresses by using different treatments is important to enhance its growth and productivity.

Calcium is required for the normal functioning of plant membranes and has been implicate as a second messenger for various plant responses to both environmental and hormonal signals (Sanders *et al.*, 1999). Its ions (Ca^{2+}) are used in the synthesis of new cell walls, particularly the middle lamellae that separate newly divided cells. Calcium is also used in the mitotic spindle during cell division (Marschner, 1995).

It was documented that beans are sensitive to deficiency of magnesium so application with Mg should be used where magnesium deficiency is suspected (A. F. A., 2005). Magnesium ions (Mg^{2+}) have a specific role in the activation of enzymes involved in respiration photosynthesis, and the synthesis of DNA and RNA. Magnesium is also a part of the ring structure of the chlorophyll molecule. Studies indicate that 15 to 30% of the total magnesium in plants is associated with the chlorophyll molecule (Neales, 1956**;** Marschner, 1995). Changa

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et al.(1996) showed that calcium or magnesium bridges between the free carboxyl groups of adjacent pectin molecules, resulted in increases in tissue firmness of snap bean pods. McKently *et al*. (1982) worked with snap beans grown without calcium, and they observed an 80% decrease in plant growth and 90% reduction in the pod number. They suggested that this effect was due to low calcium mobility in vegetal tissues.

Potassium, present within plants as the cation K^+, plays an important role in regulation of the osmotic potential of plant cells. It also activates many enzymes involved in respiration and photosynthesis (Marschner, 1995).

It was stated that zinc plays a defensive protective role against adverse effects of higher temperature via its antioxidants and gene regulatory functions (Cakmak and Marschner, 1988 and Chesters, 1992). Moreover, it was reported that calcium (Ferguson, 1988) and zinc (Cakmac and Marschner, 1988) enhance translocation of bio assimilates and nutrients within tissues as they activate the membrane transporter enzymes.

SA has direct involvement in plant growth, thermo genesis, flower induction and uptake of ions. It affects ethylene biosynthesis, stomata movement and also reverses the effects of ABA on leaf abscission. Enhancement of the level of chlorophyll and carotenoid pigments, photosynthetic rate and modifying the activity of some important enzymes are other roles assigned to SA (Abdel-Ati *et al*., 2000 and Galal *et al*., 2000).

Concerning, utilization of vitamins as antioxidants, many investigations had been carried out to protect plants against adverse effects of environmental stresses. In this regard, Gabriela *et al*. (2003) recorded that vitamin C (L- ascorbic acid) is a multifunctional compound in both plants and animals. It plays an important role in photosynthesis as an enzymes co-factor including synthesis of abscisic acid, ethylene, gibberellins and anthocyanin and control of cell growth (Smirnoff and Wheeler, 2000). Also, it's a good scavenger of activated oxygen as O_2, OH, $^1O_2$ and reducing hydrogen peroxide (H_2O_2) to water via ascorbate peroxidase reaction (Bodannes and Chan, 1979 and Noctor and Foyer, 1998), as well as, enhancing the accumulation of chlorophyll and delay senescence (Mattagajasingh and Kar, 1989 and Novabour *et al*., 2003).

Material and Methods

Two field experiments were carried out in vegetable private farm at Kafr Hssan, Gharbia Governorate (10 Km apart of Mansoura) during the two summer seasons of 2011 and 2012 to study the effect of foliar application of some nutrients and antioxidants on snap bean (*Phaseolus vulgaris* L.) plants cv. Bronco towards improving quality and productivity during summer condition Table (1). Seeds of Bronco cv. were sown, in the moderately moist soil at 1st April in the two seasons of 2011& 2012, in hills on one side of ridges at 15 cm apart and 65 cm width, the plot area was 16.25 m^2(5 lines × 5 m long × 0.65 m width). The experimental design was complete block with three replicates. Plants were sprayed three times, 20 days after sowing and repeated every 15 days, with solution of the following treatments:

- Potassium (K) at concentration of 40 mMl\l in the form of potassium chloride.
- Calcium (Ca) at concentration of 2.5 ml\l in form of Ca-citrate 25% calcium.
- Magnesium (Mg) at concentration of 5 ml\l in the form of Mg-EDTA\Cit 10% Mg.
- Combination among K, Ca and Mg used half concentration of each.
- Zinc (Zn) at concentration of 100 mg\l in the form of Zn-citrate 12%.
- Salicylic acid (SA) at 150 mg\l.
- Ascorbic acid (AsA) at 250 mg\l.
- Control (tap water) treatment.

The monthly mean temperature and relative humidity during crop period in 2011 and 2012 seasons (table 1).

Month	Temperature C						Relative humidity %					
	2011			2012			2011			2012		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Apr.	24	13	19	22	12	17	85	45	65	86	47	67
May.	29	22	26	28	20	24	84	42	63	85	44	65
Jun.	33	22	28	31	19	25	83	42	63	85	43	64

Data from ministry of Agriculture (Agriculture Extension Services).

At random representative samples of 5 plants from each plot were randomly chosen at 55 days after sowing in both seasons to determine the vegetative growth characters, i.e., plant height, number of branches and leaves\plant and fresh and dry weight\plant, as well as leaf area/plant.

Green pods of two rows from each plot were harvested at the proper maturity stage to determine the following parameters:

- Average pod diameter (means diameter of 20 pods).
- Average pod length (means length of 20 pods).
- Average pod weight (means weight of 20 pods).
- Number of pods\plant (random mean of 10 plants from each plot).

- Fresh pod yield (green pods harvested three times from each plot collected and weighted then converted to ton\fed).
- Pigments determination for chlorophyll a,b and carotenoids of leaves and pods were determined according (Yadava, 1986).
- Soluble solid substances (S.S.S) determined by using Zeiss Laboratory Refractometer.

Data were subjected to the statistical analysis of variance according to the procedure outlined by (Gomez and Gomez, 1984). The treatment means were compared using Duncan's Multiple Range Test as published by Duncan (1955).

Results and Discussion

1-Vegetative growth:

Data in Table (2) indicate that all the applied sprays of used substances, as antioxidants, significantly increased plant height, number of branches and leaves/plant and fresh and dry weight/plant, as well as leaf area/plant of snap bean plants Bronco cv. compared with control (tap water), they differed considerably among them, during 2011 and 2012 seasons. The tallest plants with more branches and leaves and heaviest fresh and dry weight of plant, as well as, largest leaf area/plant were obtained by foliar treatments with K, Ca and Mg combination and/or individual. Also, Zn, ascorbic acid and salicylic acid has significant promotive effects on mentioned characters. These results were inconformity with those obtained by Amer, 2004; Elballa *et al.*, 2004; El-Tohamy and El-Greadly, 2007; Shokr and Fathy, 2009; Abdel-Hakim *et al*., 2012 and Nour *et al*., 2012 on snap bean plants, Ahmed, 2005; El-Dosuki and El-Greadly, 2006 and Shokr and Abdelhamid, 2009, on pea plants.

The stimulative responses of such treatments above control, may be due to the role of such substances in, achieving growth, and alleviating the seasonal heat waves during growing stages of plant (table, 1), hence, K, Ca, Mg and Zn as plant nutrients and/ or antioxidants play a greater role in improving the temperature stress tolerance (Waraich *et al*., 2012). Furthermore, ascorbic acid plays multiple roles in plant growth, functioning in cell division, cell wall expansion and other developmental processes (Asada, 1999; Conklin, 2001 and Pignocchi and Foyer, 2003), also salicylic acid has direct involvement in plant growth, thermogensis, flower induction and uptake of ions. It affects ethylene biosynthesis, stomata movement and reverse effects of ABA on leaf abscission (Abdel-Ati *et al.*, 2000).

2-Fresh pod yield and its components:

It was clearly noticed that all the studied characters were significantly responded to using antioxidants substances as foliar application compared with untreated one through the two growing seasons, (table 3). The combination among K, Ca and Mg had the superiority parameters of yield and its components, followed by K as for pod diameter, pod weight, number of pods/plant and fresh pod yield, and meanwhile, Mg and SA gathered the tallest pods, that's true in both seasons. The most effective characters associated to yield capacity were pod weight and number of pods/plant. In contrast, plants exposure to environmental potential during reproductive stage (May and June, table, 1) without treatment (control) exhibited decline in pod parameters, and consequently, reduction of fresh pod yield. These results were coincided with those reported by, Abd-Allah *et al.*, (2007) on common bean; Kamal *et al*., (2006); El-Tohamy and El-Greadly (2007) and Shokr and Fathy, (2009) on snap bean.

Generally, the applied treatments increased fresh pod yield by 24.47% (K+Ca+Mg), 23.32% (K), 19.61% (Ca), 14.83% (Mg), 13.48% (SA), 10.39% (Zn) and 6.5% (AsA), mean of both seasons, respectively over the control. Such increments may be explained on the basis that all used substances had favorable stimulatory effects on vegetative growth habits and enhanced photosynthetic apparatus, and consequently reproductive growth triggers a switch in partitioning from vegetative sinks to reproductive sinks Tables (2, 3 and 4). However, potassium (K) plays a crucial role for many physiological processes, such as photosynthesis, translocation of photosynthetic into sink organs, maintenance of turgidity and activation of enzymes under stress conditions (Marschner, 1995 and Mengel and Kirkby, 2001). It was stated that zinc plays a defensive protective role against adverse effects of higher temperature via its antioxidants and gene regulatory functions (Cakmak and Marschner, 1988 and Chesters, 1992). Moreover, it was reported that calcium (Ferguson, 1988) and zinc (Cakmac and Marschner, 1988) enhance translocation of bioassimilates and nutrients within tissues as they activate the membrane transporter enzymes. Moreover, Magnesium ions (Mg^{2+}) have a specific role in the activation of enzymes involved in respiration photosynthesis, and the synthesis of DNA and RNA (Marschner, 1995). Furthermore, the role of ascorbic acid (AsA) plays multiple roles in plant growth, functioning in cell division, cell wall expansion, and other developmental processes (Asada, 1999; Conklin, 2001 and Pignocchi and Foyer, 2003).

3- Chemical constituents:

Data in Table (4) show the influence of foliar treatments of K, Ca, Mg, Zn, AsA and SA on leaf and pod contents of chlorophyll a, b and carotenoids, as well as soluble solid substances (SSS) of snap bean pods in 2011 and 2012 growing seasons. It was clearly noticed that all obtained results were greatly affected by aforementioned treatments compared with untreated one (control), and they differed among of them, through the two studied seasons. Since, the combination among K, Ca and Mg achieved the highest concentrations, of leafe and pod chlorophylls, and pod SSS, followed by AsA, Mg and SA for leaf and pod chl.a, Mg, AsA and K for leaf and pod chl.b, SA, Zn and Mg for leaf car., Mg and AsA as for pod car., and K, Mg and Zn for pod SSS, that's true in both seasons. In this respect, El-Tohamy and El-Greadly (2007) mentioned that the higher levels of Zn treatment significantly improved the total chlorophyll content of snap bean leaves. Also, Shokr and Fathy (2009) went to such results, on snap bean leaves and pods, with using Ca, Mg, SA and AsA.

Table 2: Plant height, no. branches and leaves/plant, fresh weight, dry weight and leaf area as affected by some foliar substances in 2011 and 2012 seasons.

characters / Treatments	Plant height cm		No. branches/plant		No. leaves/plant		Fresh weight g		Dry weight g		Leaf area cm^2	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
K	48.20 d	46.47 c	4.77 bcd	4.40 cd	19.42 d	18.57 c	87.20 d	83.52 e	17.44 b	15.86 b	197.29 c	170.23 d
Ca	46.53 e	45.45 d	4.53 bcd	4.33 de	20.43 c	18.17 d	88.27 cd	84.23 d	16.64 c	15.16 e	188.32 d	172.62 c
Mg	52.08 b	46.60 c	4.83 bc	4.70 b	21.87 b	19.32 b	98.30 a	85.07 b	16.82 c	15.31 c	199.76 b	174.72 b
K + Ca + Mg	52.70 a	47.57 a	5.67 a	5.03 a	23.43 a	19.75 a	98.93 a	85.92 a	17.81 a	16.00 a	203.29 a	176.06 a
Zn	49.07 c	47.10 b	4.43 cd	4.23 de	19.67 d	18.13 de	89.07 c	84.85 c	16.00 d	15.27 cd	185.71 e	167.25 e
AsA	47.90 d	45.30 d	4.90 b	4.67 bc	17.67 e	17.40 f	84.90 e	82.20 f	16.15 d	15.12 e	181.69 f	164.34 g
SA	46.47 e	47.23 ab	4.87 bc	4.77 ab	20.40 c	17.90 e	90.60 b	84.72 c	16.31 d	15.25 d	186.33 e	165.62 f
Control	45.87 f	44.00 e	4.33 d	4.10 e	17.27 e	17.13 g	77.33 f	80.87 g	13.89 e	14.54 f	179.14 g	161.04 h

Means followed by the same letters within each column do not differ significantly according to Duncan's Multiple Range Test at the 5% level.

Table 3: Pod diameter, pod lenght, pod weight, no. pods/plant and fresh pod yield as affected by some foliar substances in 2011 and 2012 seasons.

Characters / Treatments	Pod diameter(mm)		Pod length(cm)		Pod weight (g)		No. pods/plant		Fresh pod yield ton/fed.	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
K	8.75 a	8.77 a	13.20 c	13.05 c	4.34 b	4.09 a	21.27 a	20.31 b	7.231 a	6.629 b
Ca	8.45 b	8.50 cd	12.47 e	13.09 c	4.25 d	4.07 b	20.57 b	19.89 c	6.963 b	6.484 c
Mg	8.24 cd	8.48 cd	13.83 a	13.45 b	4.28 c	4.01 c	19.72 d	18.93 e	6.825 c	6.101 d
K + Ca + Mg	8.47 b	8.79 a	13.90 a	13.75 a	4.35 a	4.09 a	21.37 a	20.54 a	7.270 a	6.726 a
Zn	8.13 e	8.49 cd	13.07 d	12.78 d	4.07 f	3.96 e	19.15 e	18.73 e	4.460 e	5.955 e
AsA	8.17 de	8.57 b	13.17 c	12.83 d	4.05 g	3.94 f	19.27 e	18.03 f	6.314 f	5.672 f
SA	8.26 d	8.51 c	13.63 b	13.40 b	4.09 e	3.98 d	20.13 c	19.32 d	6.604 d	6.122 d
Control	8.09 e	8.48 d	11.83 f	12.38 e	4.00 h	3.85 g	18.17 f	17.09 g	5.964 g	5.295 g

Means followed by the same letters within each column do not differ significantly according to Duncan's Multiple Range Test at the 5% level.

Table 4: Leaf chlorophyll a, b, and carotenoids, pod chlorophyll a, b, and carotenoids and pod SSS as affected by some foliar substances in 2011 and 2012 seasons.

Characters / Treatments	Leaf chlorophyll a (mg/g fw)		Leaf chlorophyll b (mg/g fw)		Leaf carotenoids (mg/g fw)		Pod chlorophyll a (mg/g fw)		Pod chlorophyll b (mg/g fw)		Pod carotenoids (mg/g fw)		Pod SSS (%)	
K	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
	5.53 d	5.85 d	4.280 c	4.526 d	2.365d	2.516 d	2.628 e	2.678 e	2.801 d	2.724 d	1.364 d	1.396 e	6.84 a	6.84 a
Ca	5.30 f	5.68 e	4.245 d	4.504 e	2.201 f	2.486 e	2.580 f	2.592 g	2.617 f	2.558 e	1.295 e	1.361 f	5.87 e	5.93 f
Mg	5.98 b	6.10 a	4.581 b	4.926 b	2.325 e	2.776 a	2.860 b	2.945 b	2.904 b	2.870 b	1.522 b	1.625 b	6.57 b	6.73 b
K + Ca + Mg	6.01 a	6.11 a	4.904 a	4.976 a	2.612 a	2.788 a	3.348 a	3.372 a	2.995 a	2.923 a	1.584 a	1.675 a	6.93 a	6.93 a
Zn	5.32 e	5.59 f	4.162 f	4.396 g	2.407 c	2.584 c	2.571 g	2.606 f	2.447 g	2.334 g	1.173 g	1.260 g	6.34 c	6.60 c
AsA	5.99 b	5.99 b	4.573 b	4.797 c	2.194 f	2.390 f	2.696 c	2.887 c	2.857 c	2.818 c	1.395 c	1.540 c	6.19 d	6.46 d
SA	5.83 c	5.89 c	4.231 e	4.445 f	2.468 b	2.633 b	2.662 d	2.775 d	2.735 e	2.541 f	1.224 f	1.470 d	5.83 e	6.12 e
Control	5.24 g	5.35 g	4.111 g	4.179 h	2.150 g	2.211 g	2.309 h	2.371 h	2.123 h	2.095 h	1.090 h	1.132 h	5.49 e	5.53 g

Means followed by the same letters within each column do not differ significantly according to Duncan's Multiple Range Test at the 5% level.

The increments in the obtained results over control may be due to the protective and recovered specific transporter enzymes and/or the whole machinery under stress conditions (Palta, 1990) (table, 1), in addition, increasing chlorophyll contents activate antioxidant enzymes via the simulative effects of Ca, SA and AsA under such conditions (Dat *et al.*, 1998 and Larkindale and Knight, 2002), as well as, enhancing the accumulation of chlorophyll and delay senescence (Mattagajasingh and Kar, 1989 and Novabour *et al.*, 2003). Furthermore, the role of Mg in maintenance of chloroplast structure, and consequently, enhances the photosynthetic rate under temperature stress which in turn improves the productivity (Waraich *et al.*, 2011). There is some evidence that salicylic acid may be involved in heat stress responses in plants. Exogenous application of salicylic acid and calcium improved plant tolerance to heat stress and increased the accumulation of chlorophylls (Dat *et al.*, 1998 and Larkindale and Knight 2002).

It can be concluded that spraying snap bean plants, growing under milder thermo-stress of local summer season, with some stimulative substances can enhance growth and yield capacities.

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