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FOLIAR APPLICATION OF FULVIC ACID FOR INCREASING THE PRODUCTIVITY AND FRUIT QUALITY OF SNAP BEAN (*PHASEOLUS VULGARIS* L.) IN SANDY SOIL

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Abstract

Producing snap bean in sandy soil with a good quantity and quality is a big target to meet the demand for local consumption and exportation, in this concern field experiments were established for studying the effect of foliar application of fulvic acid concentrations (0, 3 and 6 g/L) on three snap bean cultivars (Giza 3, Bronco and Flantino) during two growing seasons (2018-2019). The experiments were conducted in sandy soil at the Experimental and Production Station of National Research Centre, El-Noubaria region, Beheira Governorate, Egypt. Results clearly indicated that increasing the concentration of fulvic acid as a foliar application increased vegetative growth characteristics and fruit yield and quality of snap bean, where plants were treated by fulvic acid at rate of 6 g/L produced the highest significant values of plant height, number of leaves and branches per plant, total fresh weight and dry weight of plant as well as total chlorophyll. Results also revealed that the maximum values of pod length and diameter, fresh and dry weights of pods, total green pods yield per feddan, TSS and total protein percentage were obtained with 6 g/L treatment. Regarding snap bean cultivars, Flantino cv. out performed to the other studied cultivars and showed the highest vegetative growth and fruit yield and quality compared to other cultivars. It could be concluded that Flantino cv. is recommended for cultivation in sandy soil with using fulvic acid as foliar application at rate of 6 g/L to achieve the highest yield and quality of green bean.

Key words: Snap bean, cultivars, fulvic acid, yield, quality.

Introduction:

Snap bean (*Phaseolus vulgaris*, L.) is one of the most important export crops in Egypt and this is clearly shown by the expansion of beans cultivation area year by year. On the other hand, green bean belongs to sensitive vegetable crops for abiotic stresses (El-Zaher *et al*., 2001 and Abdel-Mawgoud, 2006). Growing snap bean in the new reclaimed soil experience many problems especially the poor contents of organic material and mineral elements (Kulikova *et al*., 2002). Using biostimulants have multiple significant impacts on the soil and plants together.

Biostimulants improve the nutrients status of the soil, increase the fertilizers uptake, enhance plant growth under the stress conditions and increase the water use efficiency (Nardi *et al*., 2002 and Van Oosten *et al*., 2017). Increasing the organic matter in the soil demonstrates its extent efficiency for the agriculture production, humic substancesre present around 65-70% of these organic complexes in the soil (Stott and Martin, 1990 and Mackowiak *et al*., 2001). Humic substances include fulvic acids, humic acids and humins (Berbara and García, 2014), which play a role in increasing the vegetative growth and uptake of some mineral elements such as N, K, P, Ca, Fe, Zn and Mg (Rose *et al*., 2014).

Biodegradation of lignin for the plant residuals increases the organic matter in soil and produces biostimulants such as a fulvic acid (Malan, 2015). The molecular weight for fulvic acid (FA) distinguishesit than humic acid, which helps in mobilizing the minerals by forming fulvic complexes (Aiken and McKnight, 1985). Furthermore, FA enhance the performance of foliar fertilizers by stimulating the absorption of mineral elements from plant leaves surface. In addition, foliar application of FA improve the metabolic process by transporting the trace minerals directly inside plant cells. In the same trend, Chen *et al*., (2004) suggested that increasing the productivity of plants could be achieved by using FA at specific stages of plant growth.

Foliar application of FA improved vegetative growth characteristics of faba bean plants, where Abdel-Baky *et al.,* (2019) studied the effect of 4 concentrations (0, 3, 6 and 9g L^{-1}) of fulvic acid as a foliar application on 4 faba bean cultivars. The results revealed that increasing the concentrations of FA increased plant height, number of leaves per plant and total fresh and dry weight per plant, leaf area and leaf area index and crop growth rate of faba bean plants. In the same trend, Mahmoud *et al*., (2019) investigated the impact of FA rates (0, 3 and 6g/ L^{-1}) as a soil application on onion plants grown in sandy soil, the results indicated that the rate of 3g/L of FA produced the highest significant values of vegetative growth characteristics and production of onions. Furthermore, many investigators found that application of FA enhanced the vegetative growth of faba bean (Ismail and Fayed, 2020) and increased plant height of radish (Khang, 2011), increased the numbers of roots for and root elongation of maize (Eyheraguibel *et al*., 2008) and tomato (Dobbss *et al*., 2007) as well as increased dry weight of shoot of maize (Anjum *et al*., 2011).

For the effect of foliar application of FA on plants production, increasing the FA concentrations increased the seed and straw yield of faba bean (Abdel-Baky *et al*., 2019), the productivity and quality of onions (Mahmoud *et al*., 2019), as well asincreased the marketable yield of tomatoes (Suh *et al*., 2014 and Aggag *et al*., 2015) and cucumber (Kamel *et al*., 2014). In addition, using FA improved the chemical compositions and fruit quality of faba bean plants, where increasing FA concentration up to 9 gL^{-1} enhanced leaf's photosynthetic pigments, nutritional value and seeds quality, as well as increased mineral content (N, P and K) of faba bean seeds (Abdel-Baky *et al*., 2019) and onions (Mahmoud *et al*., 2019). In the same trend, many previous studies demonstrated that FA application improved chlorophyll content in soybean (Chen *et al*., 2004) and maize (Anjum *et al*., 2011), as well as increased potassium concentration in the leaves of tobacco plants (Priya *et al*., 2014). Fulvic acids enhanced the uptake of P and increased N content in maize plants (Eyheraguibel *et al*., 2008), increased chlorophyll content in both soybean and ryegrass (Chen *et al*., 2004), photosynthesis rate in maize (Anjum *et al*., 2011).

For the role of fulvic acid in improving the plant growth and fruit yield and quality, this study was established to test different concentrations of FA on three snap bean cultivars grown in sandy soil.

Materials and Methods

Three snap bean (*Phaseolus vulgaris* L.) cultivars were used to investigate the effect of fulvic acid on their vegetative growth and fruit yield and quality. The experimental field was located at latitude: 30°29'50"N and longitude: 30°19'16"E, in the Experimental Station of National Research Centre in El-Nobaria region, Behira Governorate, Egypt during two successive growth seasons (2018-2019). Sample analyses of soil is shown in table 1.

Plant materials and cultivation

Three snap bean cultivars; Giza 3, Bronco and Flantino were used as a plant material. Two field experiments were conducted in newly reclaimed sandy soil, seeds were sown on two sides of soil beds, 40 cm width at 10 cm apart within the plant rows on the 1st of March in the both years. Before planting, drip lines were placed on soil surface at 1.5 meter apart in each row at the center of the soil beds. The agricultural practices were done according to the recommendation of Egyptian Ministry of Agriculture and Land Reclamation. Plants received fertilizers as calcium superphosphate (15% P_2O_5) at a rate of 300 kg ha^{-1} was applied during soil preparation, 250 kg N ha^{-1} as ammonium nitrate (33% N) and 150 kg K ha^{-1} as potassium sulphate (48% K_2O), which applied during the growth season. Also plants received Mn, Fe and Zn at rate 50 mg L^{-1} (oxides of elements) as a spray solution.

Treatments and experimental design

Snap bean plants were treated by fulivc acid as a foliar application, falvic acid is soluble in the water under all pH conditions and remain in solution after removal of humic acid by acidification. Fulvic acids can also be described as being "humic acids" of lower molecular weight and higher oxygen content. The color of fulvic acids can vary from light yellow to brown in color. It obtained from the Canza group company in Egypt.

The three snap bean cultivars (Giza 3, Bronco and Flantino) were exposed to three rates of fulvic acid (0, 3 and 6 g/L) as a foliar application in 3 times; 21 days after seeding, 10 and 20 days after

Table 1: Chemical properties of the experimental soil.

Samples (cm)	Chemical analysis						
	pH 1:2.5	EC dSm^{-1}	$CaCO_3$ %	CEC C mole Kg^{-1}		O.M %	
0-15	7.63	0.98	3.22	4.95		0.04	
15-30	7.30	1.09	2.76	4.32		0.02	
Samples (cm)	**Macronutrients (%)**			**Micronutrients (ppm)**			
	N %	P %	K %	Fe	Zn	Mn	Cu
0-15	2.10	0.53	1.19	231	145	322	76
15-30	2.11	0.69	1.68	324	172	286	41

Table 2: Effect of foliar application of fulvic acid on vegetative growth characteristics and chlorophyll content of snap bean cultivars during 2018 and 2019 seasons.

Treatments		2018						2019					
		Plant height (cm)	Number of		Total plant fresh weight (g)	Dry matter (%)	Chlorophyll (SPAD)	Plant height (cm)	Number of		Total plant fresh weight (g)	Dry matter (%)	Chlorophyll (SPAD)
			Leaves	Branches					Leaves	Branches			
Cultivars	Giza 3	41.6 C	13.3 C	3.5 C	53.7 C	12.5 C	24.1 C	43.3 C	12.4 C	3.7 C	53.0 C	12.8 C	23.2 C
	Bronco	43.6 B	15.4 B	4.3 B	57.3 B	14.3 B	28.1 B	45.0 B	14.7 B	4.5 B	56.7 B	14.3 B	27.2 B
	Flantino	46.5 A	17.5 A	4.8 A	60.2 A	15.8 A	30.5 A	47.7 A	16.6 A	5.0 A	59.6 A	16.1 A	29.5 A
Fulvic acid	Control	44.0 C	15.3 C	4.1 C	56.7 C	14.2 C	27.5 C	45.2 C	15.3 C	4.3 C	56.3 C	14.1 C	26.6 C
	3 g/L	45.0 B	16.5 B	4.4 B	58.6 B	14.7 B	28.8 B	46.8 B	16.5 B	4.6 B	57.7 B	15.0 B	28.2 B
	6 g/L	46.2 A	17.2 A	4.8 A	59.9 A	15.3 A	30.1 A	47.6 A	17.3 A	5.0 A	59.5 A	15.6 A	29.2 A
Giza 3	Control	41.2 h	12.6 i	3.1 h	52.1 h	11.8	22.2 i	42.4 h	11.7 h	3.3 i	51.7	12.1 h	21.3 h
	3 g/L	41.3 h	13.3 h	3.4 g	53.4 g	12.5	24.5 h	43.3 g	12.4 g	3.6 h	52	12.8 g	23.6 g
	6 g/L	42.3 g	14.1 g	4.1 f	55.6 f	13.2	25.7 g	44.1 f	13.2 f	4.3 g	55.2	13.5 f	24.8 f
Bronco	Control	43.1 f	15.3 f	4.3 e	56.9 f	14.6	28.9 f	44.3 f	15.2 e	4.5 f	56.5	13.8 f	28.0 e
	3 g/L	45.3 e	16.7 e	4.6 d	59.4 e	15.2	29.6 e	46.5 e	15.8 de	4.8 e	58.4	15.5 e	28.7 de
	6 g/L	46.4 d	17.8 d	4.8 c	60.1 d	15.9	30.3 d	47.6 d	16.9 d	5.0 d	59.7	16.2 d	29.2 d
Flantino	Control	47.7 c	18.1 c	4.9 c	61.2 c	16.2	31.6 c	48.9 c	17.2 c	5.1 c	60.8	16.5 c	30.7 c
	3 g/L	48.5 b	19.5 b	5.3 b	63.2 b	16.4	32.4 b	50.7 b	17.4 b	5.5 b	62.8	16.8 b	32.4 b
	6 g/L	50.1 a	19.8 a	5.5 a	64.2 a	16.8	34.5 a	51.3 a	18.9 a	5.7 a	51.7	17.1 a	33.6 a

the first time. The experiment consisted of 9 treatments, with three replicates. The experiment was laid out in a split plot design where snap bean cultivars were arranged in the main plots and fulvic acid treatments were randomly distributed in the sub-plots. The area of the experimental plot was 12.8 m^2.

Measured characteristics

- **Plant Growth Measurements:**

A representative sample of 6 plants was taken by random 45 days after sowing (flowering stage), from each experimental plot for measuring the plant growth characters, as follows: Plant height from soil surface to the highest point of the plant, number of leaves and branches per plant, total fresh weight and dry weight of plant (determined at 65ºC for 72 hours using the standard methods as illustrated by (A.O.A.C., 1990). Total Chlorophyll: Total chlorophyll content of the sixth mature leaves was measured as SPAD units using monitor chlorophyll meter (SPAD-501).

Table 3: Effect of foliar application of fulvic acid on fruit yield characteristics of snap bean cultivars during 2018 and 2019 seasons.

Treatments		2018						2019					
		No. of pods	Pod length (cm)	Pod diameter (cm)	Fresh weight pods (g)	Dry weight pods (g)	Total yield (ton/ fed.)	No. of pods	Pod length (cm)	Pod diameter (cm)	Fresh weight pods (g)	Dry weight pods (g)	Total yield (ton/ fed.)
Cultivars	Giza 3	16.9 C	9.1 C	0.55 C	4.4 C	1.6 C	3.4 C	16.4 C	8.9 C	0.56 C	4.1 C	1.1 C	3.3 C
	Bronco	19.0 B	9.6 B	0.62 B	5.2 B	2.2 B	4.1 B	18.2 B	9.5 B	0.63 B	4.6 B	1.6 B	4.0 B
	Flantino	22.7 A	10.4 A	0.68 A	5.9 A	2.7 A	4.8 A	22.1 A	10.2 A	0.70 A	5.0 A	2.1 A	4.5 A
Fulvic acid	Control	19.9 C	9.8 C	0.61 C	5.2 C	2.0 C	4.1 C	19.0 C	9.5 C	0.62 C	4.6 B	1.6 C	3.9 C
	3 g/L	20.8 B	10.1 B	0.64 B	5.5 B	2.4 B	4.4 B	20.3 B	9.9 B	0.66 B	4.8 B	1.9 B	4.2 B
	6 g/L	22.5 A	10.5 A	0.68 C	5.8 A	2.7 A	4.6 A	22.0 A	10.2 A	0.69 A	5.0 A	2.1 A	4.5 A
Giza 3	Control	16.2 g	8.9 h	0.51 h	4.1 i	1.1 h	3.1 h	15.7 g	8.6h	0.52 i	3.9 h	0.9 i	3.1 i
	3 g/L	16.7 g	9.1 g	0.56 g	4.5 h	1.7 g	3.4 g	16.2 f	8.9 h	0.57 h	4.1 g	1.1 h	3.3 h
	6 g/L	17.8 f	9.3 f	0.59 g	4.7 g	1.9 g	3.6 g	17.3 ef	9.3 g	0.59 g	4.3 g	1.3 g	3.6 g
Bronco	Control	19.0 ef	9.6 e	0.62 f	5.3 f	2.1 f	4.1 f	17.5 e	9.4 g	0.62 f	4.6 f	1.6 f	4.0 f
	3 g/L	20.2 e	10.0 d	0.64 e	5.6 e	2.5 e	4.5 e	19.7 d	9.8 e	0.67 e	4.8 e	1.9 e	4.3 e
	6 g/L	23.4 d	10.5 c	0.69 d	5.9 d	2.7 d	4.7 d	22.9 c	10.2 d	0.69 d	5.1 d	2.1 d	4.6 d
Flantino	Control	24.6 c	10.8 b	0.71 c	6.1 c	2.9 c	5.1 c	23.8 b	10.5 c	0.73 c	5.2 c	2.3 c	4.7 c
	3 g/L	25.6 b	11.3 ab	0.73 b	6.5 b	3.1 b	5.3 b	25.1 ab	10.9 b	0.74 b	5.4 b	2.6 b	5.1 b
	6 g/L	26.3 a	11.6 a	0.76 a	6.8 a	3.4 a	5.6 a	25.8 a	11.2 a	0.79 a	5.6 a	2.8 a	5.4 a

• Green Pod Yield and its Attributes:

At harvest stage (60 days from seeds sowing), green pods were collected along the harvesting season (40 days) and the following data were recorded: fresh and dry weights of pods (g) total green pods yield per feddan (ton).

• Green Pod Quality:

A random sample of 100 green pods at 2-picking were taken, average pod length (cm) and diameter (cm) were recorded.

• Nutritional Value:

A random sample of 50 green pods at 2-picking were taken and the following data were recorded: The total soluble solids (TSS%): was measured by using the hand refractometer, according to method described by (A.O.A.C., 1990). Fiber percentage in pods: was determined according to Rai and Mudgal, (1988). Total protein percentage in pods: a factor of 6.25 was used for converting the total nitrogen to protein percentage (A.O.A.C., 1988).

• Statistical analysis:

All data were subjected to statistical analysis using MSTAT Computer Program (MSTAT Development Team, 1989). The Duncan's New Multiple Range test at 5% level of probability was used to test the significance of differences among mean values of treatments (Steel and Torrie, 1980).

Results and Discussion

Vegetative growth characteristics

Data in table 2 present the effect of fulvic acid treatments on vegetative growth characteristics and total

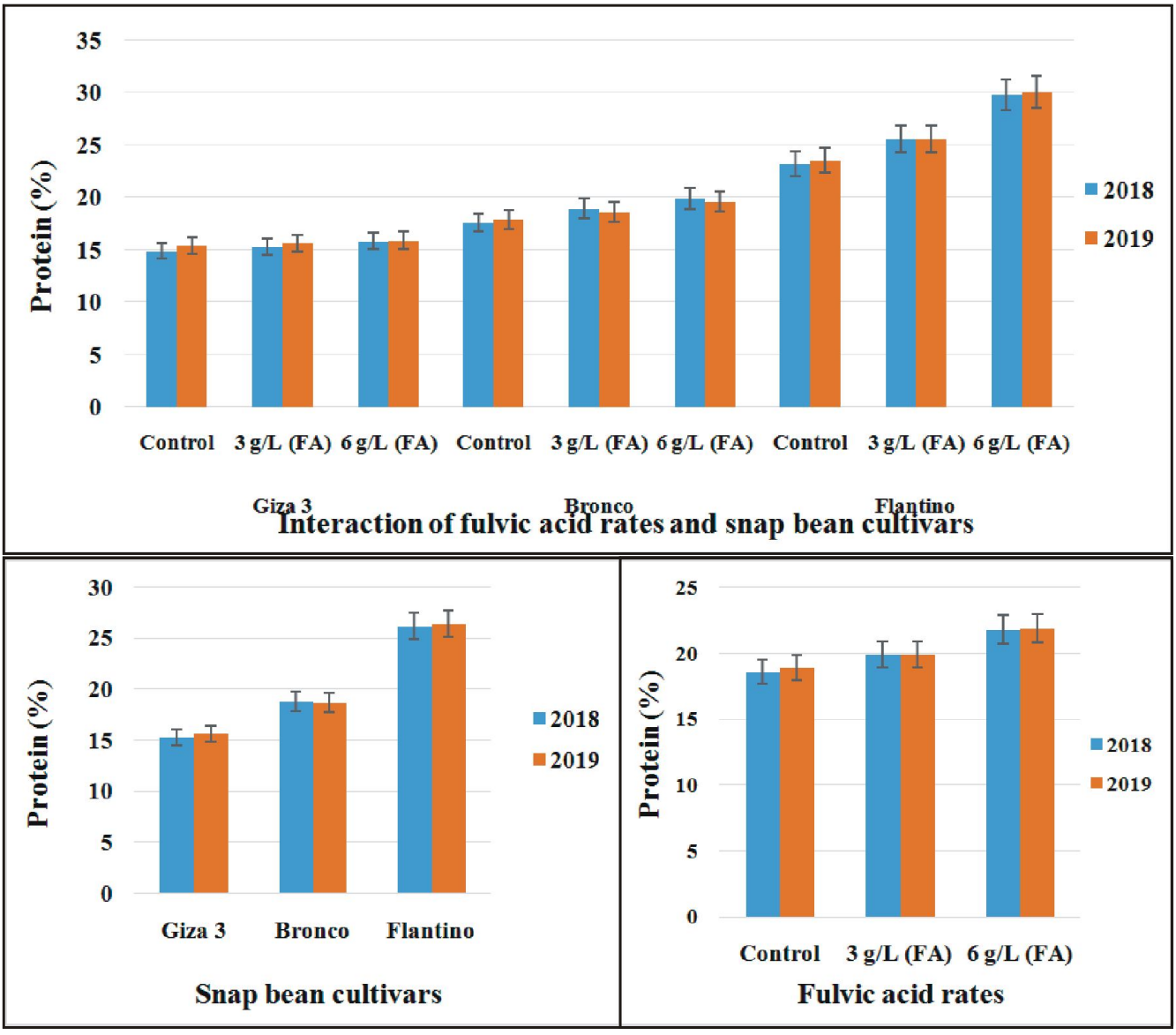

Fig. 1: Effect of foliar application of fulvic acid on pod's protein % of snap bean cultivars during 2018 and 2019 seasons.

chlorophyll of snap bean cultivars.

Results clearly indicated that foliar application of fulvic acid significantly increased vegetative growth characteristics; plant height, number of leaves and branches per plant, total fresh weight and dry weight of plant as well as total chlorophyll of snap bean plants compared to control treatment (0 g/L FA). Increasing the concentration of FA increased the vegetative growth characteristics where the highest significant values were obtained with (6 g/L) of FA in both tested seasons. These results are in harmony with those obtained by Mahmoud *et al*., (2019) on onion plants, Abdel-Baky *et al.,* (2019) and Ismail and Fayed, (2020) on faba bean plants, Dobbss *et al*., (2007) on tomato plants and Khang, (2011) on radish plants. These results may be due to the role of fulvic acid as natural chelators which increase the mobilization and transportation of micronutrients (Bocanegra *et al*., 2006) and enhance the photosynthesis rate and increase chlorophyll content, which reflect on the plant growth and fruits development (Chen *et al*., 2004 and Anjum *et al*., 2011).

Regarding the snap bean cultivars; Giza 3, Bronco and Flantino, data in table 2 revealed that Flantino cv. had the highest significant values for the previous characteristics compared to other cultivars and followed by Bronco cv., while Giza 3 cv. showed the lowest values of vegetative growth characteristics and total chlorophyll in the two studied seasons.

Concerning the interactions of snap bean cultivars and fulvic acid treatments, the obtained data revealed that Flantino cv. plants which received the highest concentration of FA (6 g/L) produced the maximum significant values for vegetative growth characteristics and total chlorophyll.

Green pod yield and quality characteristics

Fulvic acid treatments enhanced the productivity and fruit quality of green bean plants. In table 3 the effect of foliar application of fulvic acid is clear regarding; average pod length and diameter, fresh and dry weights of pods and total green pods yield per feddan.

Data in table 3 shows that, the fruit yield and quality

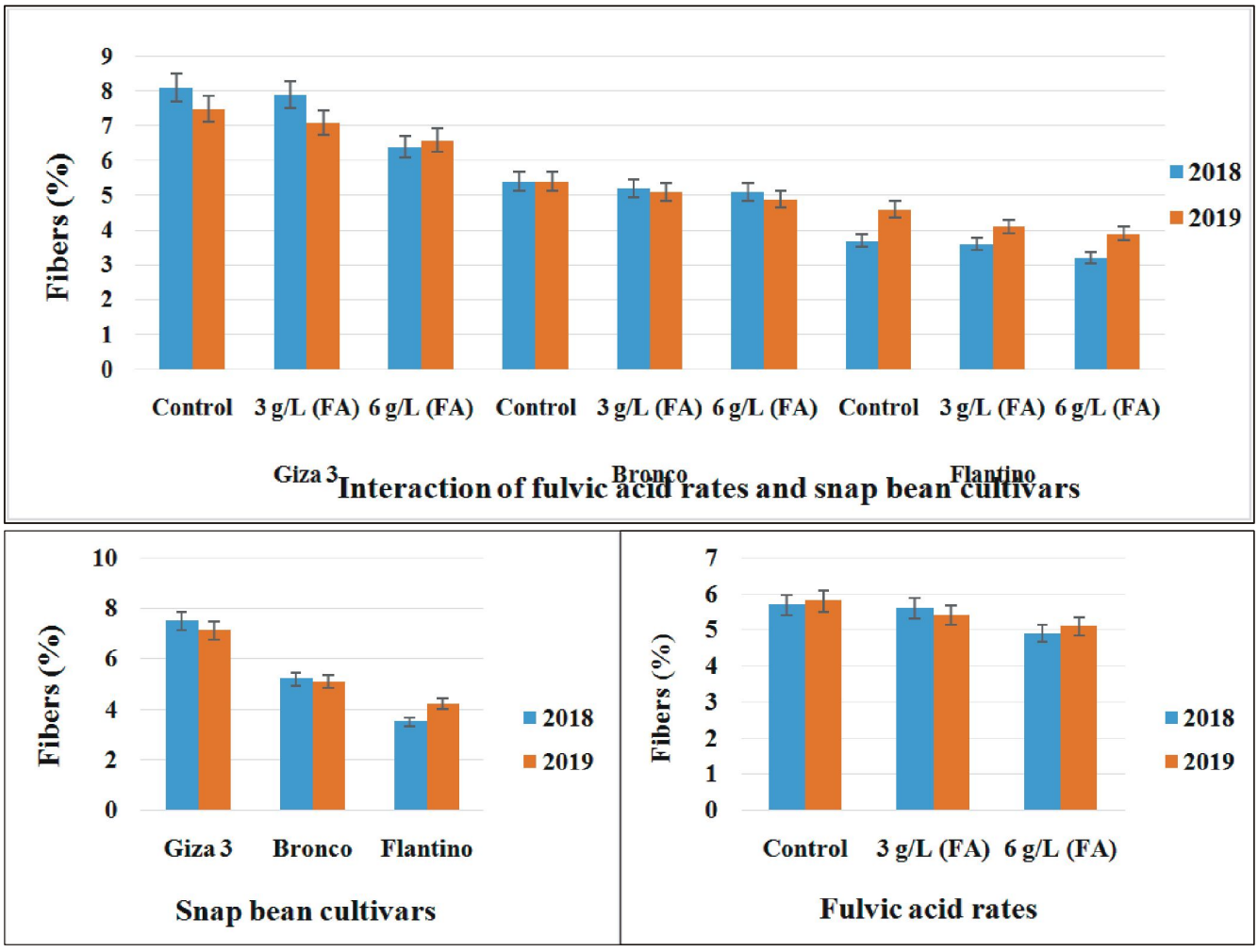

Fig. 2: Effect of foliar application of fulvic acid on pod's fibers % of snap bean cultivars during 2018 and 2019 seasons.

characteristics significantly responded to increasing the concentration of fulvic acid, where plants received FA with (6 g/L) produced the highest pod length and diameter and fresh and dry weights of pods, as well as the maximum total yield were achieved with (6 g/L) treatment in both tested seasons. These results are in conformity with those obtained by Mahmoud *et al*., (2019) on onion plants, Abdel-Baky *et al.,* (2019) and Ismail and Fayed, (2020) on faba bean plants and Suh *et al*., (2014) and Aggag *et al*., (2015) on tomato plants. In addition, Aminifard *et al*., (2012) found that FA improved fruit yield and quality of peppers. This improvement of yield and quality may be due to the effect of fulvic acid application on snap bean plants, where FA enhances the uptake of mineral elements by affecting the cell membranes, leading to improvement of protein synthesis and the activation of plant hormone as well as promoting photosynthesis and carbohydrate accumulation (Malan, 2015).

Respecting the behavior for three snap bean cultivars, there were significant differences among studied cultivars. The maximum total yield and the pods yield quality characteristics were observed with Flantino cv. plants in both studied seasons compared to the other cultivars.

The interaction between studied treatments shows, foliar application of fulvic acid by 6 g/L on Flantino cv. plants achieved the highest significant values of average pod length and diameter, fresh and dry weights of pods and total green pods yield per feddan in both studied seasons.

Nutritional value of Green pods

Data in figs. 1, 2 and 3, illustrated the effect of fulvic acid treatments on total protein percentage, fiber percentage and total soluble solids (TSS) in snap bean pods with different cultivars.

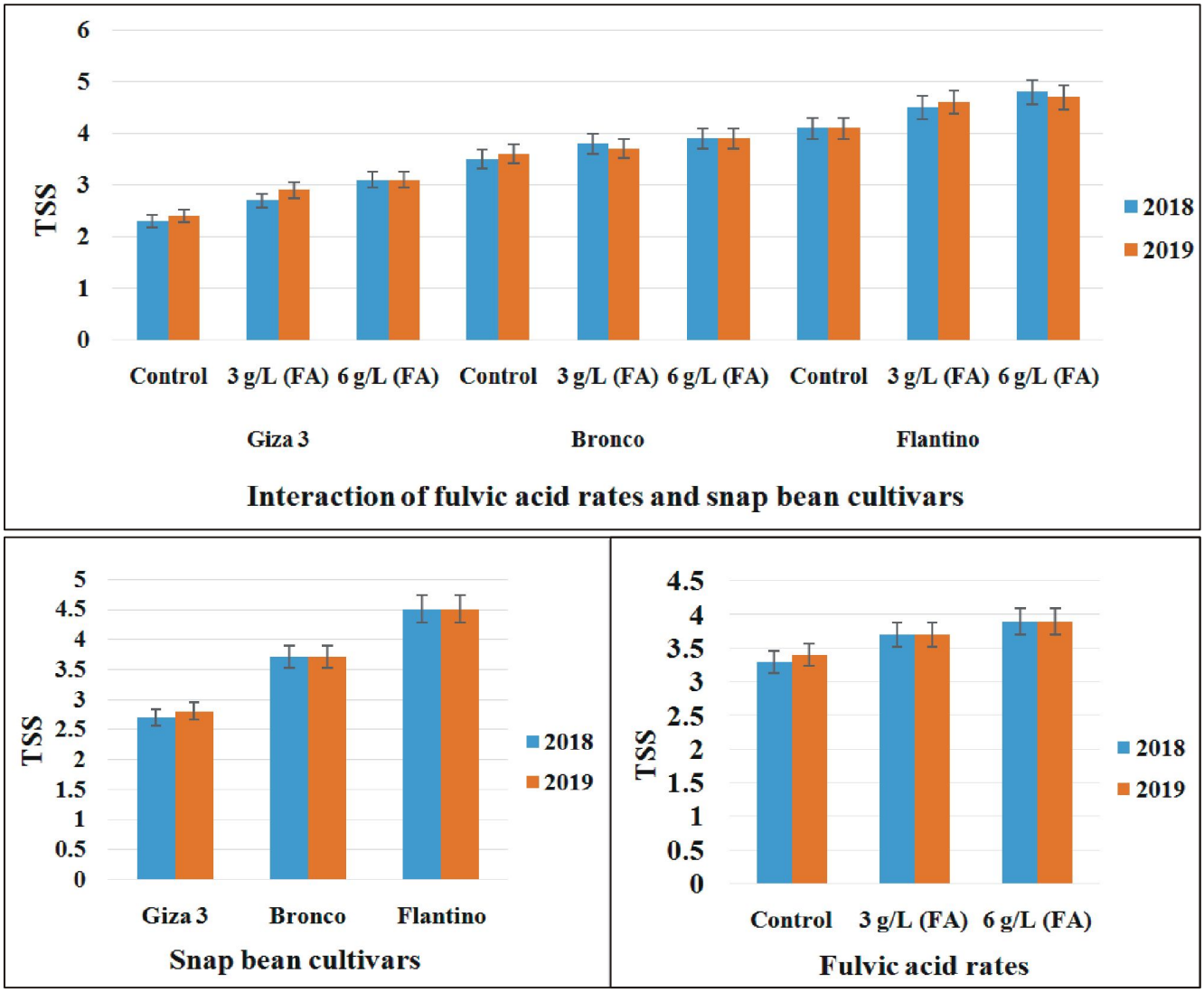

Fig. 3: Effect of foliar application of fulvic acid on pod's total soluble solids (TSS) of snap bean cultivars during 2018 and 2019 seasons.

Results clearly indicated that, while the total soluble solids (TSS) and total protein percentage in snap bean pods increased with increasing the fulvic acid concentration, fiber percentage decreased in the pods. Where the highest significant values of TSS and total protein percentagewere observed with plants received 6 g/L of fulvic acid, while the maximum significant values for fiber percentage were obtained with 6 g/L of fulvic acid treatment in the both tested seasons. In this concern, Mahmoud *et al*., (2019) found that FA treatments improve the fruit quality of onions, the same results were found on faba bean (Abdel-Baky *et al.,* 2019 and Ismail and Fayed, 2020) and tomatoes (Suh *et al*., 2014 and Aggag *et al*., 2015).

Concerning the snap bean cultivars; Giza 3, Bronco and Flantino, data in fig. 1, 2 and 3 showed that snap bean pods for Flantino cv. had the highest significant values of TSS and total protein percentage and the lowest values were observed with pods of Giza 3 cv. plants. In contrast, pods of Giza 3 cv. had the highest significant values of fiber percentage and the lowest values were observed with pods of Flantino cv. in both studied seasons.

Regarding the interactions of snap bean cultivars and fulvic acid treatments, data in fig. 1, 2 and 3 revealed that Flantino cv. plants which received the highest concentration of FA (6 g/L) had the maximum significant values of TSS and total protein percentage. While the highest significant values of fiber percentage were achieved with treatment of Giza 3 cv. and 6 g/L of FA and the lowest values were noticed with treatment of Flantino cv. and 6 g/L of FA.

Conclusions

According the results of this study, it could be concluded that the recommended foliar application of fulvic acid on snap bean plants should be at 6 g/L in 3 times (21 days after seeding, 10 and 20 days after the first time) during the season with Flantino cv., for achieving the maximum vegetative growth and fruit yield and quality under sandy soil conditions.

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References

A.O.A.C (1988). Official methods of analysis, 21st edn. Association of Official Analytical Chemists, Washington, D.C.

A.O.A.C. (1990). Official Methods of Analysis (15th Edn). Association of official analytical chemists, Washington, D.C. USA.

Abdel-Baky, Y.R., H.F. Abouziena, A.A. Amin, M. Rashad El-Sh and A.M. Abd El-Sttar (2019). Improve quality and productivity of some faba bean cultivars with foliar application of fulvic acid. *Bulletin of the National Research Centre*, **43(2):** 1-11.

Abdel-Mawgoud, A.M.R. (2006). Growth, Yield and Quality of Green Bean (*Phaseolus Vulgaris*) in Response to Irrigation and Compost Applications. *Journal of Applied Sciences Research,* **2(7):** 443-450.

Aggag, A.M., A.M. Alzoheiry and A.E. Abdallah (2015). Effect of kaolin and fulvic acid antitranspirants on tomato plants grown under different water regimes. *Alexandria Science Exchange Journal*, **36(2):** 169-179. DOI: 10.21608/ASEJAIQJSAE.2015.2875.

Aiken, G.R. and D.M. McKnight (1985). Humic Substances in Soil, Sediment and Water. Geochemistry, Isolation and Characterization. New York, John Wiley & Sons.

Aminifard, M.H., H. Aroiee, H. Nemati, M. Azizi and H.Z.E. Jaafar (2012). Fulvic acid affects pepper antioxidant activity and fruit quality. *African Journal of Biotechnology*, **11(68):** 13179-13185. DOI: 10.5897/AJB12.1507.

Anjum, S.A., L. Wang, M. Farooq, L. Xue1 and S. Ali (2011). Fulvic Acid Application Improves the Maize Performance under Well-watered and Drought Conditions. *J. Agronomy & Crop Science*, **197:** 409-417.

Berbara, R.L.L. and A.C. García (2014). Humic substances and plant defense metabolism. In: Ahmad P, Wani MR (eds) Physiological mechanisms and adaptation strategies in plants under changing enviornoment: volume 1. Springer Science+Business Media, New York, 297-319

Bocanegra, M.P., J.C. Lobartini and G.A. Orioli (2006). Plant uptake of iron chelated by humic acids of different molecular weights. *Communications in Soil Science and Plant Analysis*, **37:** 1- 2.

Chen, Y., M. De Nobili and T. Avid (2004). Stimulatory effects of humic substances on plant growth. *In: F. MAGDOFF, R. R. WEIL (Eds.): Soil Organic Matter in Sustainable Agriculture,* 103-129 CRC Press, New York, USA.

Dobbss, L.B., L.O. Medici, L.E.P. Peres, L.E. Pino-Nunes, V.M. Rumjanek, A.R. Façanha and L.P. Canellas (2007). Changes in root development of Arabidopsis promoted by organic matter from oxisosls. *Ann. Appl. Biol.,* **151:** 199-211.

El-Zaher, H., A.M. Awad and M.A. Salem (2001). Combined effect of farmyard manure and N-fertilizer on wheat production, NPK uptake and N-use efficiencies under highly calcareous soil conditions. *J. Agric. Sci. Mansoura Univ*., **26(12):** 8227-8245.

Eyheraguibel, B., J. Silvestre and P. Morard (2008). Effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of maize. *Bioresour Technol,* **99:** 4206-4212.

Ismail, A.Y. and A.A.M. Fayed (2020). Response of dry seed yield of faba bean "*Vicia Faba,* L." to spraying with amino acids, organic acids, (NAA) growth regulator and micro nutrients. *Alex. J. Agric. Sci*., **65(1):** 7-16.

Kamel, S.M., M.M.I. Afifi, F. El-shoraky and M.M. El-Sawy (2014). Fulvic acid: a tool for controlling powdery and downy mildews in cucumber plants. *International Journal of Phytopathology*, **3(2):** 101-108. https://www.researchgate.net/publication/310604804.

Khang, V.T. (2011). Fulvic foliar fertilizer impact on growth of rice and radish at first stage. *Omonrice*, **18:** 144-148. http://www.clrri.org/ver2/uploads/noidung/18-18.pdf.

Kulikova, N.A., E.V. Stepanova and O.V. Koroleva (2002). Mitigating activity of humic substances: Direct Influence on Biota. In: Use of Humic Substances to Remediate Polluted Environments: From Theory to Practice, NATO Science Series IV: Earth and Environment Series, Perminova, Kluwer, I. V. (Eds.). Acad. Pupl., U.S.A., ISBN: 978-140232509, 285-309.

Mackowiak, C., P. Grossl and B. Bugbee (2001). Beneficial effects of humic acid on micronutrient availability to wheat. *Soil Science Society America Journal*, **65:** 1744-1750.

Mahmoud, S.H., A.M.M. EL-Tanahy, Neama M. Marzouk and S.D. Abou-Hussein (2019). Effect of fulvic acid and effective microorganisms (EM) on the vegetative growth and productivity of onion plants. *Current Science International*, **8(2):** 368-377.

Malan, C. (2015). Review: humic and fulvic acids. A Practical Approach. In Sustainable soil management symposium. Stellenbosch, 5-6 November, Agrilibrium Publisher.

MSTAT Development Team (1989). MSTAT user's guide: A microcomputer program for the design, management and analysis of agronomic research experiments. Michigan State University East Lansing, U.S.A.

Nardi, S., D. Pizzeghello, A. Muscolo and A. Vianello (2002). Physiological effects of humic substances on higher plants. *Soil Biol. Biochem*. **34:** 1527-1536.

Priya, B.N.V., Mahavishnan, K. Gurumurthy, D.S. Bindumadhavh, A. Ambika and P.U. Navin (2014). Fulvic acid for enhanced nutrient uptake and growth: insights from biochemical and genomic studies. *Journal of Crop Improvement*, **28:** 740-757. DOI: 10. 1080/ 15427528. 2014.923084.

Rai, S.N. and V.D. Mudgal (1988). Synergistic effect of sodium hydroxide and steam pressure treatment on composition changes and fibre utilization of wheat straw. *Biol. Wastes*, **24:** 105-113.

Rose, M.T., A.F. Patti, K.R. Little, A.L. Brown, W.R. Jackson and T.R. Cavagnaro (2014). A metaanalysis and review of plant-growth response to humic substances: practical implications for agriculture D.S. Sparks (Ed.). *Ad. Agro.,* **124:** 37-89.

Steel, R.G.D. and J.H. Torrie (1980). Principles and Procedures of Statistics. McGraw Hill, New York.

Sulpice, R., Y. Gibon, A. Boucherean and F. Larher (1998). Exogenously supplied glycine betaine in spinach and rapeseed leaf discs: compatibility or noncompatibility? *Plant, Cell & Environment*, **1980, 21:** 1285-1292.

Stott, D.E. and J.P. Martin (1990). Synthesis and degredation of natural and synthetic humic material in soils. In 'Humic substances in soil and crop sciences: Selected readings'. (Eds P MacCarthy, CE Clapp, RL Malcolm, PR Bloom) 37-64. (Americal Society of Agronomy, Inc. Soil Science Society of America, Inc.: Madison).

Suh, H.Y., K.S. Yoo and S.G. Suh (2014). Effect of foliar application of fulvic acid on plant growth and fruit quality of tomato (*Lycopersicon esculentum* L.). *Horticulture, Environment and Biotechnology*, **55(6):** 455-461. DOI: 10.1007/s13580-016-1004-x.

Van Oosten, M.J., O. Pepe, S. De Pascale, S. Silletti and A. Maggio (2017). Review: the role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. *Chemical and Biological Technologies in Agriculture* **4:** 5. https://doi.org/10. 1186/s40538-017-0089-5.