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Impact of foliar spraying of nano micronutrient fertilizers on the growth, yield, physical quality, and nutritional value of two snap bean cultivars in sandy soils

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Abstract

Background: Nanotechnology introduces smart agricultural products which may be a milestone in solving many common economic and ecological issues. Nano-fertilizers show unique characters which do not exist in their conventional counterparts.This work aimed to determine the effects of three foliar spraying of nano micronutrient fertilizers iron, manganese, and zinc as well as the controlon the vegetative growth, productivity, physical quality, and pod nutritional value of two snap bean cultivars Bronco and Flantino and also their interactions.

Results: Flantino cultivar recorded the highest values of vegetative growth, fresh pod yield, pod physical quality (length, diameter, and fresh weight), dry weight, and pod nutritional value content expressed as P, K, Zn, Mn, Fe, Cu, crude protein, total soluble solids, and fiber.

Conclusion: Foliar application of zinc nano-fertilizer increased the studied characteristics significantly compared with other nano micronutrients. Also, the combined effect of Flantino cultivar with zinc nano-fertilizer treatment recorded the highest values of vegetative growth, fresh pod yield, pods physical quality and nutritional value.

Keywords: Snap bean, Nano micronutrient fertilizers, Cultivars, Growth, Yield and nutritional value

Background

Snap bean, *Phaseolus vulgaris* L., Fabaceae, is a widespread international vegetable crop. Its fresh pods or dry seeds are rich with mineral elements (Ca, P, Fe, K, Mg, and Mn), fibers, and proteins (Şehirali 1988 and Priscila et al. 2014). In Egypt, snap bean comes after potatoes in export trade (FAO 2018).Cultivars of snap beans differ from each other in apparent traits such as the length and size of pods, growth conditions, and tastes to consumers (Orzolek et al. 2000).

The increase in crop productivity depends largely on the type of fertilizer used to supplement the essential nutrients of plants. Growing snap bean plants in newly reclaimed sandy soils faces many problems such as low soil organic matter content, unreliable rainfall, and soil nutrient deficiency. To overcome this, many farmers use large amounts of mineral or organic fertilizers (Arisha and Bradisi 1999; Stewart et al. 2005). Plants need micronutrients in small quantities; these elements play a vital role in plant development (Mohsen et al. 2016). The importance of the micronutrients comes from its effect of stimulating the process of photosynthesis and thus its positive impact on the yield and quality (Hänsch and Mendel 2009).

The use of conventional fertilizers, whether chemical or organic, may result in some problems; large applied quantities cause soil and ground water pollution, deficiency of micronutrients, and soil degradation, finally leading to low product quality (Meena et al. 2017). Hence, each type of fertilizer has its positive or negative impact on crop growth and soil fertility (Chen 2008). Recently, the continuous progress of fertilization technology introduces the nano-fertilizers.

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Table 1 Physical properties and chemical analysis of the experimental soil

Physical properties							
Sand	Clay	Silt	Texture	F.C.%	W P%		
90.02	9.24	0.67	sandy	16.51	5.23		
Chemical analysis							
E.c. dS/m	pH	Meq/ L					
		Ca	Mg	Na	K	HCO3	Cl
1.6	8.1	7.01	0.526	0.982	0.31	1.3	0.565

The nano-fertilizers deal with the elements in nanometer dimensions (1–100 nm). When minimized to the nanoscale, these nutrients show some characteristics that differ from the presence of the nutrients in the macro scale, allowing unique applications (Naderi and Danesh-Shahraki 2013). In which using fertilizer in the nanoform releases the nutrients at a slower rate for a longer period, consequently limiting nutrient loss from the soil and reducing soil-groundwater pollution (Naderi and Danesh-Shahraki 2013; Liu and Lal 2015; Tulasi et al. 2015 and Meena et al. 2017).

The current study aimed to evaluate the effect of nano micronutrients fertilizer on the growth,productivity, physical quality, and pod nutritional value of two snap bean cultivars in sandy soils.

Materials and methods

The experiment was carried out in the Experimental Station of the National Research Centre in El Nobaria region, Behira Governorate, Egypt, during two successive growth seasons (2017–2018) using seeds of snap bean (*Phaseolus vulgaris* L.). Seeds of green bean cultivars 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 two seasons. Physical and chemical analyses of soil samples took place according to (Chapman and Pratt 1978) and illustrated in Table 1.

Before planting, drip lines were placed on the soil surface at 1.5 m apart in each row at the center of the soil beds.These experiments included eight treatments which were the combinations of two snap bean cultivars and three nano micronutrient fertilizers as foliar spray and control. The design of the experiments was split plot with three replications. The cultivars were in the main plots and nano micronutrient fertilizers treatments were in the subplots. The treatments were replicated three times in 12.8-m^2 plots.

The treatments comprised of two snap bean cultivars (Bronco and Flantino), nano micronutrient fertilizers as foliar spray (Mn, Fe, and Zn), and control. Fertilization with calcium super phosphate (15% P_2O_5) at a rate of 300 kg ha^{-1} was applied during soil preparation. Nitrogen at rate of 250 kg N ha^{-1} as ammonium nitrate (33% N) and potassium a rate of 150 kg K ha^{-1} as potassium sulphate (48% K_2O) were applied during the growth season. Spray solution was Mn, Fe, and Zn at a rate of 50 mg L^{-1}(oxides of elements). Plants received three sprays: 21 days after seeding and 10 and 20 days after the first.

Data recorded

Plant growth measurements

A representative sample of six plants was taken at random 45 days after sowing (flowering stage), from each experimental plot for measuring the plant growth characters, as follows: lant height from soil surface to the highest point of the plant, the number of leaves and branches per plant, total fresh weight and dry weight of the plant (determined at 65 °C for 72 h using the standard methods as illustrated by (AOAC 1990).

SPAD readings

Leaf greenness of the sixth mature leaf was measured as SPAD units using SPAD-501.

Green pod yield and its attributes

At the 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) and total green pod yields per feddan.

Table 2 Effect of cultivars on vegetative growth of snap bean plants during 2017 and 2018 seasons

Cultivars	Plant length (cm)		Number of						Total plant fresh weight (g)		Dry matter (%)		SPAD readings	
			Leaf		Branches		Pod							
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	1st season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Bronco	44.8^B	45.5^B	13.9^B	14.0^B	3.9 ^{B}	4.0^B	16.9^B	16.9^B	53.8^B	53.7^B	14.5^B	14.0^B	27.9B	29.6A
Flantino	52.1^A	51.8^A	20.5^A	20.6^A	5.8^A	5.9^A	19.1^A	19.1^A	65.4^A	65.2^A	17.4^A	17.2^A	29.5A	28.7B

Values followed by the same letter(s) are not significantly different toDuncan's multiple range test

Table 3 Effect ofnano micronutrient fertilizerson vegetative growth of snap bean plants during 2017 and 2018 seasons

Nano micronutrient fertilizers	Plant length (cm)		Number of						Total plant fresh weight(g)		Dry matter (%)		SPAD readings	
			Leaf		Branches		Pod							
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	42.5^{D}	43.2^{D}	11.9^{D}	12.55^{D}	3.5^{C}	3.5^{C}	19.45^{D}	18.4^{D}	50.95^{D}	47.7^{D}	13.8^{D}	12.8^{D}	22.8^{D}	21.0^{D}
Mn	46.5^{C}	47.2^{C}	15.6^{C}	15.7^{C}	4.5^{B}	4.5^{B}	22.9^{C}	22.8^{C}	35.8^{A}	35.2^{A}	15.4 ^{B}	15.0 ^{B}	25.3^{C}	27.8^{C}
Fe	48.9^{B}	48.2^{B}	16.9^{B}	17.0^{B}	5.0^{A}	5.2^{A}	24.2^{B}	24.4^{B}	59.6^{B}	59.4^{B}	15.7 ^{B}	15.6 ^{B}	31.1^{B}	32.6^{B}
Zn	50.1^{A}	50.7^{A}	19.2^{A}	19.3^{A}	5.1^{A}	5.2^{A}	25.6^{A}	25.8^{A}	61.5^{A}	61.3^{A}	16.8^{A}	16.3^{A}	35.8^{A}	35.2^{A}

Values followed by the same letter(s) are not significantly different toDuncan's multiple range test

Green pod quality

A random sample of 100 green pods at the second picking were taken; the average pod length and diameter were recorded.

Nutritive value

A random sample of 50 green pods at the second picking were taken and the following data were recorded: the total soluble solids (TSS %): it was obtained by using the hand refractometer, according to method described by (AOAC 1990); fiber percentage in pods: it was determined according to Rai and Mudgal (1988); total protein percentage in pods: a factor of 6.25 was used for conversion of total nitrogen to protein percentage.

P and K in pods were determined according to Pregl (1945), John (1970) and Brown and Lillel (1946); Zn, Mn, Fe, andCu was determined as described by Chapman and Pratt (1978).

Statistical analyses

All data were subjected to statistical analysis using Mstatic software. The comparison among means of the different treatments was determined, as illustrated by Snedecor and Cochran (1982). In all tables,the means were compared with Duncan's multiple range test, not LSD as written.

Results

Vegetative growth

Effect of cultivars

Data in Table 2 shows that vegetative growth was significantly affected by cultivars in both seasons. Flantino cultivar had higher values of plant length; number of leaves, branches, and pod; SPAD reading instead of chlorophyll content; total plant fresh weight; and dry matter percentage than Bronco cultivar.

Effect of nano micronutrient fertilizers and its interaction with cultivars

Table 3 illustrates that using nano micronutrients enhanced the vegetative growth of snap bean plants, especially foliar application of zinc nano-fertilizer. Moreover, Flantino cultivar with foliar application of

Table 4 Effect of interaction between cultivars andnano micronutrient fertilizerson vegetative growth of snap bean plants during 2017 and 2018 seasons

Treatments		Plant length (cm)		Number of						Total plant fresh weight (g)		Dry matter (%)		SPAD readings	
				Leaf		Branches		Pod							
Cultivars	Nano micronutrient fertilizers	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Bronco	Control	39.5^{g}	38.7^{g}	9.8^{f}	10.1^{f}	2.8^{g}	2.9^{g}	17.5^{g}	16.8^{f}	46.5^{g}	43.2^{g}	12.3^{f}	11.4^{f}	22.4^{f}	20.9^{f}
	Mn	43.4^{f}	44.3^{f}	11.0^{e}	11.0^{e}	3.5^{f}	3.4^{f}	19.3^{f}	19.5^{e}	52.2^{f}	52.1^{f}	13.6^{f}	13.3^{e}	23.6^{e}	29.0^{d}
	Fe	45.3^{e}	46.0^{e}	13.3^{d}	13.5d	4.0^{e}	4.1^{e}	20.7^{e}	21.0^{d}	53.8^{e}	53.3^{e}	14.0^{e}	13.5^{e}	30.0^{c}	33.5^{b}
	Zn	45.6^{d}	46.2^{d}	17.3^{c}	17.5^{c}	4.2^{d}	4.5^{d}	21.4^{d}	21.3^{d}	55.4^{d}	55.6^{d}	15.9^{d}	15.1^{d}	35.9^{a}	35.1^{a}
Flantino	Control	45.4^{d}	47.6^{d}	14.0^{d}	15.0^{c}	4.2^{d}	4.1^{e}	21.4^{d}	20.0^{d}	55.4^{d}	52.2^{f}	15.3^{d}	14.2^{e}	23.2^{e}	21.2^{f}
	Mn	49.5^{c}	50.0^{c}	20.1^{b}	20.3^{b}	5.4^{c}	5.5^{c}	26.4^{c}	26.2^{c}	63.4^{c}	63.1^{c}	17.1^{c}	16.6^{c}	27.1^{d}	26.6^{e}
	Fe	52.4^{b}	50.3^{b}	20.4^{b}	20.5^{b}	5.9^{b}	6.3^{a}	27.6^{b}	27.7^{b}	65.3^{b}	65.5^{b}	17.3^{b}	17.7^{b}	32.3^{b}	31.7^{c}
	Zn	54.5^{a}	55.1^{a}	21.0^{a}	21.1^{a}	6.0 ^{a}	5.9^{b}	29.8^{a}	30.2^{a}	67.5^{a}	67.0^{a}	17.7^{a}	17.4^{a}	35.7^{a}	35.4^{a}

Values followed by the same letter(s) are not significantly different to Duncan's multiple range test

Table 5 Effect of cultivars on pod physical quality and yield of snap bean plants during 2017 and 2018 seasons

Cultivars	Pod length (cm)		Pod diameter (cm)		Pod fresh weight (g)		Poddry weight(g)		Total yield (ton/feddan)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd Season	1st season	2nd season
Bronco	9.5^{B}	9.6^{B}	0.50^{B}	0.51^{B}	5.2^{B}	4.5^{B}	1.9^{A}	1.6 ^{B}	4.1^{B}	4.0^{B}
Flantino	11.5^{A}	11.6^{A}	0.82^{A}	0.82^{A}	5.0^{A}	5.4^{A}	1.5^{B}	1.7^{A}	5.3^{A}	5.2^{A}

values followed by the same letter(s) are not significantly different toDuncan's multiple range test

zinc nano-fertilizer produced the highest values of all vegetative growth characteristics of snap bean plants compared with the other interactions.On the other hand, the lowest values were recorded by Bronco without nano-fertilizer addition in both seasons (Table 4).

Pod physical quality and fresh pod yield

Effect of cultivars

It is clear from Table 5 that plants of Flantino cultivar significantly gave the highest values of pod physical quality(length, diameter, fresh and dry weights) and fresh pod yield as compared with Bronco cultivar in the two seasons.

Effect of nano micronutrient fertilizers

The pod physical quality and fresh pod yield of snap bean plants were statistically influenced by nano micronutrient fertilizers. The three treatments of nano micronutrient caused a significant increase in pod physical quality and fresh pod yield. However, this increase was significant among the nano micronutrient fertilizer treatments (Table 6).

Interaction between cultivars and nano micronutrient fertilizers

Interaction between cultivars and nano micronutrient fertilizer treatments recorded a significant increase in pod physical quality and yield in both seasons (Table 7). The highest values of pod physical quality and yield were recorded by Flantino cultivarwhen treated by zinc nano-fertilizer. On the other hand, the lowest values were recorded by Bronco cultivar without nano micronutrient fertilizer addition in both seasons.

Nutritional value of snap bean pod

Effect of cultivars

It is clear from Table 8 that the nutritional value of snap bean pods, i.e., crude protein, fiber, total soluble solid content, P, K, Mg, Fe, and Cu percentages were significantly affected by cultivars in both seasons, where the highest values of these parameters were obtained from Flantino cultivar. Other than that, the highest fiber percentage in snap bean pod was recorded in Bronco cultivar.

Effect of nano micronutrient fertilizers and its interaction with cultivars

Data in (Table 9) showed that crude protein, fiber, and total soluble solids content, P, K, Mn, Fe, and Cu percentages were affected significantly using nano micronutrient fertilizers in both seasons of the experiment. The highest values of crude protein, total soluble solid content, P, K, Mn, Fe, and Cu percentages were recorded by the foliar spraying of zinc nano-fertilizer compared with the other treatments. On the other hand, the lowest values were obtained by control.The highest value of fiber was recorded by control. Morever, the highest significant increase of crude protein, total solube solids, P, K,Mn, Fe, and Cu percentages were recorded by Flantino cultivar treated with foliar spray of zinc nano-fertilizer treatment compared with the other treatments (Table 10). However, the highest value of fiber was recorded by Bronco cultivar with control.

Table 6 Effect of nano micronutrient fertilizers on pod physical quality and yield of snap bean plants during 2017 and 2018 seasons

Nano micronutrient fertilizers	Pod length(cm)		Pod diameter (cm)		Pod fresh weight (g)		Dry weight pod (g)		Total yield (ton/feddan)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	9.15^{D}	9.2^{D}	0.5^{D}	0.50^{D}	4.2^{D}	3.5^{D}	1.2^{D}	1.0 ^{D}	3.2^{D}	3.3^{D}
Mn	10.0^{C}	10.1^{C}	0.60^{C}	0.58^{C}	5.1^{C}	4.9^{C}	1.6^{C}	1.5^{C}	4.4^{C}	4.3^{C}
Fe	10.5^{B}	10.6^{B}	0.67^{B}	0.66^{B}	5.3^{B}	5.6^{B}	1.8^{B}	1.9^{B}	4.8^{B}	4.7^{B}
Zn	11.1^{A}	11.2^{A}	0.72^{A}	0.77^{A}	5.9^{A}	5.8^{A}	2.3^{A}	2.3^{A}	5.0^{A}	4.9^{A}

Values followed by the same letter (s) are not significantly different toDuncan's multiple range test

Table 7 Effect of interaction between cultivars andnano micronutrient fertilizerson pod physical quality and yield of snap bean plants during 2017 and 2018 seasons

Treatments		Pod length (cm)		Pod diameter (cm)		Fresh weight pod (g)		Dry weight pod (g)		Total yield (ton/feddan.)	
Cultivars	Nano micronutrient fertilizers	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Bronco	Control	8.5[g]	8.2[g]	0.35[g]	0.39[g]	4.3[g]	3.2[f]	1.3[e]	1.1[f]	2.2[f]	2.6 [f]
	Mn	9.0 [f]	9.1[f]	0.40 [f]	0.37[f]	5.1[e]	4.5[e]	1.7[c]	1.3[e]	3.8[e]	3.7[e]
	Fe	9.5[e]	9.6[e]	0.51[e]	0.48[e]	5.4[b]	5.2[d]	1.9[b]	1.9[c]	4.1[d]	4.0[d]
	Zn	10.1[d]	10.2[d]	0.60[d]	0.68[d]	6.2[a]	5.4[c]	2.8[a]	2.4[a]	4.5[c]	4.4[c]
Flantino	Control	9.8[e]	10.2[d]	0.65[d]	0.62[d]	4.1[f]	3.9[f]	1.2[e]	0.9 [g]	4.3 [c]	4.1 c
	Mn	11.0[c]	11.1[c]	0.79[c]	0.79 c	5.1[d]	5.4[c]	1.5[d]	1.7[d]	5.0 [b]	4.9[b]
	Fe	11.4[b]	11.5[b]	0.82[b]	0.83[b]	5.3[c]	6.1[b]	1.7[c]	1.9[c]	5.4[a]	5.3[a]
	Zn	12.1[a]	12.2[a]	0.84[a]	0.85[a]	5.7[b]	6.3[a]	1.9[b]	2.3[b]	5.4[a]	5.3[a]

Values followed by the same letter(s) are not significantly different toDuncan's multiple range test

Discussion

Increased vegetative growth among cultivars can be attributed to the role of their genetic differentiation which may allow higher plant capacity to absorb more nutrients of the soil, more photosynthetic surfaces, and, therefore, better photosynthetic capacity (Abdel-Mawgoud et al. 2005; Marlene et al. 2008 and Salwa et al. 2013; Said et al. 2018).

Vegetative growth enhancement may be due to the role of nano micronutrient stimulatory effects on the production of chlorophyll, photosynthesis, mitochondrial respiration, and hormone biosynthesis, e.g. ethylene, gibberellic acid, and jasmonic acid (Hänsch and Mendel 2009).The positive effects of foliar spraying of zinc nano-fertilizer on vegetative growth parameters come along with results reported by Tarafdar et al. (2014) on pearl millet and Nahla et al. (2017) on snap bean plants.Similarly, the combined effects of Flantino cultivar with the foliar application of zinc nano-fertilizer may be basically due to the increase in the chlorophyll content (Table 3). Many investigators have obtained similar results (Moazam et al. 2017) on rice.

Since Flantino cultivar had higher leaf number, had higher photosynthetic chlorophyll content, and recorded higher values of total plant fresh and dry weights (Table 2), it recorded the highest yield and quality. This result was in harmony with previous findings of Abdel-Mawgoud et al. (2005).

This could be explained by the fact that the foliar application of micronutrients has led to an increase in vegetative growth, consequently higher production capacity which reflected on the quality. These results come in accordance with Mohsen et al. (2016) on barley and (Gomaa et al.(2016) on faba bean.

Enhancement of nutritional values by nano micronutrient may be explained by increasing nutrient availability for plants through leaves (Hebaet al. 2016).This explanation agrees also with other findings (Rozhin et al. 2016 and Kandil and Marie 2017).Our results revealed that the effect of nano micronutrient fertilizer had the same pattern with two snap bean cultivars; meanwhile, the genotype was the controlling factor that affects the final performance of each cultivar.

Concerning yield and quality of any crop, it varies frequently according to nutrition management and genotype(Mohsen et al. 2016).The obtained results showed that the effect of foliar spraying of micronutrient fertilizers had the same pattern of effect with both cultivars.This means the genotype was the control factor that affects the final performance of each cultivars. These results are consistent with those of Bouis (2003) and Arora and Singh (2004).

The genotype nutritional value among cultivars can be attributed to the role of their genetic differentiation as a determining factor to vegetative growth which results in better nutritional values (Abdel-Mawgoud et al. 2005; Marlene et al. 2008 and Salwa et al. 2013; Said et al. 2018). Marlene et al. (2008) and Priscila et al. (2014) showed that pod quality (fiber and soluble solid contents) differed significantly among snap bean cultivars. Priscila et al. (2014) added that protein, fiber, phosphorus, potassium, copper, iron and zinc contents differed significantly between snap bean cultivars.

Conclusion

It could be concluded that foliar application with zinc nano-fertilizer increased the studied characteristics significantly compared with other nano micronutrients. Also, the combined effect of Flantino cultivar with zinc nano-fertilizer treatment recorded the highest values of vegetative growth, fresh pod yield, pod physical quality and nutritional value.

Table 8 Effect of cultivars on nutritional value of snap bean pod during 2017 and 2018 seasons

Cultivars	Protein (%)		Fibers (%)		TSS content		P (%)		K (%)		Zn (ppm)		Mn (ppm)		Fe (ppm)		Cu ppm	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd Season	1st season	2nd season
Bronco	22.9^{B}	21.8^{B}	6.4^{A}	6.5^{A}	3.1^{B}	3.4^{B}	0.34^{B}	0.30^{B}	2.1^{B}	1.5^{B}	24.6^{B}	27.0^{B}	13.5^{B}	13.4^{B}	68.5^{B}	70.5^{B}	7.8^{B}	8.1^{B}
Flantino	27.6^{A}	27.9^{A}	4.7^{B}	5.1^{B}	4.0^{A}	4.3^{A}	0.36^{A}	0.32^{A}	2.2^{A}	1.9^{A}	27.4^{A}	29.8^{A}	14.3^{A}	14.2^{A}	69.5^{A}	70.4^{A}	8.3^{A}	8.7^{A}

Values followed by the same letter(s) are not significantly different toDuncan's multiple range test

Table 9 Effect of nano micronutrient fertilizers on nutritional value of snap bean pods during 2017 and 2018 seasons

Nano micronutrient fertilizers	Protein (%)		Fibers (%)		TSS content		P (%)		K (%)		Zn ppm		Mn ppm		Fe ppm		Cu ppm	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st Season	2nd Season
Control	20.5^{C}	21.5^{C}	6.2^{A}	6.6^{A}	3.1^{D}	3.3^{D}	0.32^{D}	0.30^{C}	1.60^{D}	1.50^{C}	20.2^{D}	21.3^{D}	12.2^{D}	11.0^{D}	63.2^{D}	64.9^{D}	5.9^{D}	6.1^{D}
Mn	25.6^{B}	24.6^{B}	5.6^{B}	5.9^{B}	3.6^{C}	4.0^{C}	0.38^{C}	0.33^{B}	2.28^{C}	1.95^{B}	26.5^{C}	29.1^{C}	13.6^{C}	12.7^{C}	68.3^{C}	68.5^{C}	7.1^{C}	7.3^{C}
Fe	27.2^{A}	26.6^{A}	5.4^{C}	5.6^{C}	3.8^{B}	4.1^{B}	0.40^{B}	0.34^{B}	2.22^{B}	1.90^{B}	30.4^{B}	32.5^{B}	14.8^{B}	15.4^{B}	73.8^{B}	76.3^{B}	9.9^{B}	10.5^{B}
Zn	27.8^{A}	26.9^{A}	5.1^{D}	5.3^{D}	3.9^{A}	4.2^{A}	0.44^{A}	0.36^{A}	2.67^{A}	2.40^{A}	32.5^{A}	34.8^{A}	16.1^{A}	16.6^{A}	75.9^{A}	77.8^{A}	10.4^{A}	10.9^{A}

Values followed by the same letter(s) are not significantly different toDuncan's multiple range test

Table 10 Effect of interaction between cultivars and nano micronutrient fertilizers on nutritional value of snap bean pods during 2017 and 2018 seasons

Treatments		Protein (%)		Fibers (%)		TSS content		P (%)		K (%)		Zn (ppm)		Mn (ppm)		Fe (ppm)		Cu (ppm)	
Cultivars	Nano micronutrient fertilizers	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Bronco	Control	19.8^{f}	18.7^{g}	7.2^{a}	7.3^{a}	2.5^{g}	2.7^{g}	0.31^{e}	0.29^{e}	1.7^{f}	1.1^{f}	19.2^{f}	20.5^{f}	11.2^{e}	10.9^{f}	62.3^{g}	64.1^{e}	5.2^{f}	5.4^{e}
	Mn	22.5^{e}	21.3^{f}	6.4^{b}	6.5^{b}	3.1^{f}	3.5^{f}	0.34^{d}	0.30^{d}	2.0^{e}	1.6^{e}	22.1^{e}	24.3^{e}	13.0^{d}	11.2^{e}	67.3^{e}	69.6^{c}	6.8^{e}	6.9^{d}
	Fe	24.4^{d}	23.8^{e}	6.1^{b}	6.3^{c}	3.3^{f}	3.7^{e}	0.35^{d}	0.31^{d}	2.1^{d}	1.7^{e}	27.6^{d}	30.0^{d}	14.2^{c}	15.3^{c}	71.2^{d}	73.2^{b}	9.4^{c}	10.0^{b}
	Zn	25.0^{d}	23.8^{e}	5.9^{c}	6.0^{d}	3.5^{e}	3.7^{e}	0.37^{d}	0.32^{c}	2.9^{a}	1.9^{d}	29.7^{c}	33.4^{c}	15.7^{b}	16.3^{b}	73.2^{c}	75.4^{b}	9.9^{c}	10.4^{b}
Flantino	Control	21.2^{e}	24.3^{d}	5.2^{d}	5.9^{d}	3.7^{d}	3.9^{d}	0.32^{e}	0.31^{d}	1.5^{g}	1.9^{d}	21.3^{e}	22.1^{f}	13.2^{d}	11.1^{e}	64.2^{f}	65.7^{e}	6.7^{e}	6.9^{d}
	Mn	28.8^{c}	28.1^{c}	4.9^{e}	5.3^{e}	4.1^{c}	4.5^{c}	0.42^{c}	0.36^{c}	2.6^{b}	2.3^{b}	31.0^{c}	34.0^{b}	14.3^{c}	14.3^{d}	69.4^{d}	67.4^{d}	7.4^{d}	7.8^{c}
	Fe	30.0^{b}	29.4^{b}	4.6^{f}	4.9^{f}	4.2^{b}	4.4^{b}	0.45^{b}	0.37^{b}	2.4^{c}	2.1^{c}	33.2^{b}	35.0^{b}	15.4^{b}	15.6^{c}	76.5^{b}	79.5^{a}	10.5^{b}	11.0^{a}
	Zn	30.6^{a}	30.0^{a}	4.2^{g}	4.6^{g}	4.3^{a}	4.7^{a}	0.50^{a}	0.39^{a}	2.4^{c}	2.9^{a}	35.4^{a}	36.2^{a}	16.5^{a}	17.0^{a}	78.6^{a}	80.2^{a}	11.0^{a}	11.4^{a}

Values followed by the same letter(s) are not significantly different toDuncan's multiple range test

Abbreviations
1st season: First season; 2nd season: Second season; F.C.%: Field capacity; TSS content: Total soluble solids; WP%: Wilting point

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Authors' contributions
NMM, HAA, AMME and SHM preformed the field experiments. NMM;HAAwrote the paper, and AMME and SHM performed the chemical analysis of the samples and coordinated the data collection and analysis. All authors read and approved the final manuscript.

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