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Yield of "Pipiana" squash (*Cucurbita argyrosperma* Huber) in Vertisol soil due to the effect of biostimulants

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ABSTRACT

Objective: To evaluate the effect of liquid (supermagro) and solid (bocashi) biostimulants on the yield of Pipiana squash (*Cucurbita argyrosperma* Huber) in a Vertisol soil.

Design/Methodology/Approach: The research was carried out at "Central Flores" farm, in May-August 2018. Treatments were: T1 = Control, T2 = 400 g of bocashi + supermagro 1:20 v/v, T3 = 400 g of bocashi + supermagro 1:30 v/v, T4 = 500 g of bocashi + supermagro 1:20 v/v, T5 = 500 g of bocashi + supermagro 1:30 v/v, with four replicates (plots) each. For the statistical analysis, 11 variables were recorded in plants, flowers and fruits, and 12 variables in seed, the experimental design used was completely randomized. An ANOVA and a means comparison test (Tukey, $\alpha \leq 0.05$) were performed with the Statistical Analysis System version 9.1 (SAS, 2003).

Results: The plants of treatment 4, showed the highest values in most of the variables evaluated, the yield of fresh fruit and dry seed was 4.48 t ha^{-1} and 1.76 t ha^{-1}, respectively, higher results than those reported in the scientific literature.

Limitations/Implications: No limitations were found in this study.

Findings/Conclusions: The application of foliar and soil bio-stimulant increases quantity and quality of fruits and seed of *Cucurbita argyrosperma* Huber.

Keywords: Supermagro, bocashi, nutrition, organic fertilizer.

INTRODUCTION

The production of (*Cucurbita* sp.) squash seed in Mexico in 2017 accounted a sown area of 68,637.90 ha and a value of $23,915.79 pesos MX per ton (SIAP, 2017). Seed represent the most important food and commercial product obtained from this species (Ireta-Paredes *et al*., 2018; Kates, 2019); since they are consumed directly, and are the main ingredient for the preparation of meals known in Mexico as "pipianes" (Lira *et al*., 2016; SR Lira, 1995; Villanueva, 2007). Seed contain the main saturated fatty acids: palmitic (21.5%), stearic (11.6%), oleic (37.0%), linoleic (28.1%) and linolenic (0.3%) (Ribeiro *et al*., 2018).

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Traditionally, squash is grown using chemical fertilizers, which cause increase of nitrate in the soil, and indirectly inhibit decomposition of organic matter (Nicholls, Altieri, & Vázquez, 2017; Zhou *et al*., 2018), since they cause the absence of edaphic microorganisms (bacteria and fungi) and leaf litter degrading enzymes (Zhang *et al*., 2018). As a consequence, the soil aggregates lose their stability (Cardona, Benavides, & Montoya, 2016); therefore, alternatives have been sought, such as sustainable agriculture, which establishes friendly relationships with natural resources (FAO, 2017; SEMARNAT, 2019). This type of agriculture is based on the use of organic fertilizers as a means for crop nutrition, also seeking to increase water retention, contribute to organic matter, and a greater microbial activity (Czekała, Jezowska, & Chełkowski, 2019; Ireta *et al*., 2018; Piya *et al*., 2018). However, the volume required to meet the needs of macroelements in crops is high and consequently expensive. Another solution is the use of organic stimulators, which promote biochemical and physiological mechanisms in plants that culminate in an increased productivity (Ertani *et al*., 2013; Garcia-Martinez *et al*., 2010). This latter can be attributed to peptide, amino acids, polysaccharides, humic acids and phytohormones contents (Parrado *et al*., 2008). Based on the above, the effects caused by the application of a liquid and a solid biostimulant were evaluated on the yield of Pipiana squash (*Cucurbita argyrosperma* Huber), grown in a Vertisol soil in Quintana Roo, Mexico.

MATERIALS AND METHODS

The study was conducted from May to August 2018 at the Central Flores property in Quintana Roo, Mexico (18° 40' 16.3128" N and 88° 44' 44.4456" W). The climate according to the Köppen system and adapted by García (2004) is AW_1 (sub-humid warm, with a cumulative rainfall regime of 1306.1 mm in summer and winter), average annual temperature of 27.5 °C and maximum of up to 32.5 °C (CONAGUA, 2018). As part of the sowing, the land was prepared with a heavy harrow pass, 20 experimental plots (12 × 6 m) were established, with five treatments: T1 = Control, T2 = 400 g of bocashi + supermagro 1:20 v/v, T3 = 400 g of bocashi + supermagro 1:30 v/v, T4 = 500 g of bocashi + supermagro 1:20 v/v, T5 = 500 g of bocashi + supermagro 1:30 v/v, with four replicates (plots) per treatment. Seed were obtained from own farm's harvest in August 2017 and two seeds were deposited per strain no deeper than 5 cm in a plantation squared frame arrangement 2 × 2 m. Weed removal was carried out manually. To control pests and diseases, an insecticide-fungicide based on sulfur and lime (CaS) called calcium sulfide broth, was applied weekly at a dose of 2.5% v/v. Bioindicators were recorded in plants, flowers, fruits and seed, and a completely randomized experimental design was used. For the statistical analysis, 11 variables were registered in plant, flowers and fruits, and 12 in seed, of 10 plants per plot, chosen at random and ANOVA and comparison test of means by Tukey's method ($\alpha \leq 0.05$) were carried out with the Statistical Analysis System program version 9.1 (SAS, 2003).

RESULTS AND DISCUSSION

Among treatments were recorded highly significant differences ($P \leq 0.01$) according to ANOVA results from variables: number of male and female flowers, number of vines, fresh weight and dry fruit, polar and equatorial fruit diameter, pulp thickness, and number of fruits per plant; and treatment four (500 g of bocashi plus 1:20 v/v of supermagro) was the one that registered those highest values for all the aforementioned variables (Table 1). The positive effect to use of supermagro in squash pipiana has been reported by Gonzáles, Mosquera & Trujillo (2015) in watermelon cultivation of and by Favor *et al*. (2019) in corn (*Zea mays* L.); because supermagro can be a foliar biostimulant. In this regard, Yakhin *et al*. (2017) indicate that fermented fertilizers contain a mixture of substances (peptides, amino acids, polysaccharides, humic acids and phytohormones) in addition to microorganisms (bacteria and fungi) that stimulate biochemical and physiological processes in plants; As suggested by Huang *et al*. (2010) these processes unleashed mechanisms that help protect bodies photosynthesis, conferring tolerance to abiotic stress and increment an efficiency of the N.

At the cellular level, it has been shown that fermented fertilizers due to their content of humic substances, inhibit the activity of IAA-oxidase, thereby contributing a higher concentration of IAA in the tissues (Mato, Olmedo & Méndez, 1972), in similar way with the synthesis of auxin transporters in the plant (Du Jardin, 2015), as electron donors-receptors, intervening in the cellular respiration chain and increasing the energy supply to the cells (Csicsor, Gerse & Titkos, 1994; Nadporozhzkaya, 1996) and increasing chlorophyll levels due to the greater availability of (Fe) iron chelates, and the uncoupling of oxidative phosphorylation (Albuzio *et al*., 1994). In this regard, Jindo *et al*. (2012) observed in corn than humic acid applied to root resulted in higher elongation due to activation of ATP-ases mediating proton pumping in the plasma membrane, thus increasing the permeability of the cell wall. Other authors such as Gonzáles *et al*.

(2015) indicated that foliar application of supermagro, stimulates the vigorous growth of the plant due to the presence of micro and macro nutrients; composition described by Peñafiel & Ticona (2015): nitrogen (0.209 kg m^{-3}), soluble phosphorus (0.168 kg m^{-3}), total phosphorus (0.437 kg m^{-3}), soluble potassium (1.807 kg m^{-3}), sodium soluble (1.019 kg m^{-3}), soluble calcium (0.465 kg m^{-3}), soluble magnesium (0.388 kg m^{-3}), sulfides (2.778 kg m^{-3}) and sulfates (1.173 kg m^{-3}), all elements necessary for the physiological activity of the cultures.

Table 1. Differences of mean values for the seed variables in Pipiana squash cultivation.

T	NMF	NFF	NG	LG	FWF	DWF
T1	47.78 b	9.87 b	9.30 c	4.08 cb	1.25 d	0.07 d
T2	52.29 b	11.03 b	12.45 b	4.00 c	1.56 c	0.08 d
T3	51.87 b	10.92 b	12.55 b	4.39 cb	2.06 b	0.12 c
T4	71.09 a	19.01 a	18.78 a	5.37 a	2.70 a	0.20 a
T5	54.08 b	9.35 b	14.73 b	4.56 b	2.22 b	0.16 b
MHSD	10.615	3.839	2.648	0.532	0.253	0.026
T	PDF	EDF	PTF	FPT	NFPP	
T1	14.70 d	15.46 c	2.10 a	15.23 dc	3.33 c	
T2	15.88 c	16.28 c	2.06 a	17.34 d	3.85 cb	
T3	17.26 b	18.07 b	2.17 a	20.72 ba	4.18 cb	
T4	19.33 a	20.35 a	2.30 a	23.48 a	6.63 a	
T5	18.10 b	18.97 b	2.09 a	20.12 bc	5.03 b	
DMHS	0.961	0.921	0.330	3.312	1.201	

T = Treatment; NMF = Number of male flowers; NFF = Number of female flowers; NG = Number of guides; LG = Length of guides, m; FWF = Fresh weight of fruit, kg; DWF = Dry weight of the fruit, kg; PDF = Polar diameter of the fruit, cm; EDF = Equatorial diameter of the fruit, cm; PTF = Peel thickness of the fruit, cm; FPT = Fruit pulp thickness, cm; NFPP = Number of fruits per plant. MHSD = Minimal Honest Significant Difference. Values with equal letters between columns are not statistically different (Tukey, P≤0.05).

For seed variables, the analysis of variance showed highly significant differences (P≤0.01) among treatments on total fresh weight, total ambient dry weight, full and empty seed dry weight, number of full and empty seeds, polar and equatorial seed diameter, seed thickness, weight of seed coat, weight of cuticle and weight of cotyledons. Treatment four (500 g of bocashi plus 1:20 v/v of supermagro) was the one that showed the highest values for all the studied variables except empty seed weight and number (Table 2).

Table 2. Differences in average values for the seed variables in Pipiana squash cultivation with organic fertilizers.

T	TFWS	TDWSE	DWFS	DWVS	NFS	NVS
T1	100.70 c	46.54 c	42.12 c	4.42 a	179.25 c	16.63 ba
T2	123.65 c	60.18 c	56.05 c	4.13 a	228.18 bc	22.63 a
T3	158.78 b	76.19 b	71.75 b	4.44 a	274.30 ba	18.95 ba
T4	201.10 a	106.33 a	105.6 a	0.73 b	300.75 a	5.33 c
T5	171.08 b	82.92 b	81.83 b	1.09 b	204.45 c	9.08 bc
MHSD	24.848	14.524	13.946	2.935	51.642	10.208
T	PSD	ESD	ST	WSSC	CUW	COW
T1	25.83 d	12.86 c	2.75 dc	0.04 c	0.04 a	0.17 b
T2	26.33 cd	13.08 c	2.54 d	0.04 c	0.04 a	0.17 b
T3	27.60 cb	14.23 b	2.91 bc	0.05 b	0.06 a	0.19 b
T4	29.01 b	14.94 ba	3.22 a	0.05 b	0.08 a	0.24 a
T5	30.71 a	15.39 a	3.01 ba	0.06 a	0.08 a	0.25 a
MHSD	1.425	0.773	0.236	0.006	0.046	0.024

T = Treatment; TFWS = Total fresh weight of seed, g; TDWSE = Total dry weight of seed to environment, g; DWFS = Dry weight of filled seed, g; DWVS = Dry weight of vain seed, g; NFS = Number of full seeds; NVS = Number of vain seeds; PSD = Polar seed diameter, mm; ESD = Equatorial seed diameter, mm; ST = Seed thickness, mm; WSSC = Weight of the seed seminal cover, g; CUW = Cuticle weight, g; WCO = Cotyledons weight, g; MHSD = Minimal honest significant difference. Values with equal letters between columns are not statistically different (Tukey, P≤0.05).

The dry squash seed yield in Mexico for the year 2017 was 0.56 t ha^{-1} and 0.58 t ha^{-1} in the state of Quintana Roo (SIAP, 2017), Días-Nájera *et al*. (2019) reported 0.380 t ha^{-1} by applying Bayfolan® as foliar fertilization, lower yields than those obtained in our research, where it was recorded over 1.7 t ha^{-1}. This positive response both of fruit and seed yield, is justified due to the immediate foliar incorporation of some essential nutrients for growth and development, as it was argued by Trejo-Tellez *et al*. (2003), in cultivation of jalapeño pepper (*Capsicum annuum*), cucumber (*Cucumis sativus*) and pepper (*C. annuum*); in addition to the supply of humic substances that stimulate those metabolic functions described paragraphs above.

Other authors such as Devi *et al*. (2018), when studying physical characteristics in Pipiana squash seeds collected in local markets, found the following average values: polar (16.81 mm) and equatorial (8.87 mm) seed diameter, seed thickness (2.75 mm) and dry weight of seed coat (0.054 g), all values lower than those obtained in our study. Differences are attributed to intra population variation and the production mode (without application of soil or foliar fertilizer).

CONCLUSIONS

Best treatment for estimated yield of fresh and dried fruit- and seed of Pipiana squash per hectare was treatment T4: 500 g of bocashi + supermagro 1:20 v/v in three application periods (at planting, growth and flowering start), with weekly application frequency during crop cycle, obtaining an estimated yield of 4.48 t ha^{-1} of fresh fruit, and 1.76 t ha^{-1} of dry seed, exceeding the state and national average by more than 50%.

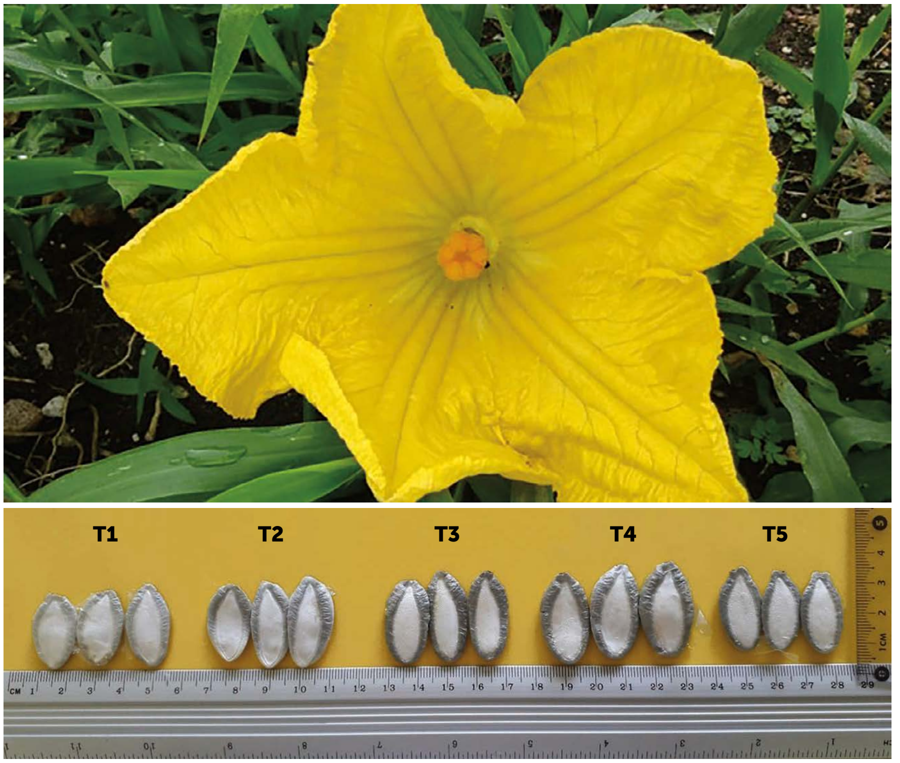

Figure 1. Flower and seed of Pipiana squash (*Cucurbita argyrosperma* Huber).

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