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FOLIAR FERTILIZATION ON PINEAPPLE QUALITY AND YIELD[1]

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RESUMO

ADUBAÇÃO FOLIAR NA
QUALIDADE E PRODUTIVIDADE DE ABACAXI

Poucos são os estudos desenvolvidos com a aplicação via foliar de micronutrientes, na cultura do abacaxi. Este trabalho teve como objetivo avaliar os efeitos de B e Zn, em forma de quelato, ácido ou sal, via foliar, buscando-se obter respostas sobre os efeitos na produtividade e qualidade dos frutos. O experimento foi realizado em Guaraçaí (SP), em solo com textura média. Foram utilizadas mudas tipo filhote, da cultivar Smooth Cayenne (Havaiano). O delineamento experimental adotado foi o de blocos ao acaso, com quatro repetições, utilizando-se fontes para fornecer, em cada aplicação, 110 g ha^{-1} de B e 250 g ha^{-1} de Zn. Foram realizadas duas pulverizações foliares, aos 7 e 9 meses após o plantio. As fontes de B e Zn não exerceram efeito nos teores de sólidos solúveis totais, acidez titulável, diâmetro médio do fruto, comprimento do fruto sem coroa e índice de maturação. Apenas os teores de B, Zn e K, na folha, foram influenciados pelos tratamentos utilizados.

PALAVRAS-CHAVE: *Ananas comosus* L.; Smooth Cayenne; boro; zinco.

ABSTRACT

There are just a few studies using foliar sprays with micronutrients on pineapple crops. The objective of this study was to evaluate the B and Zn effect, as chelate, acid or salt, via foliar feeding, on fruit yield and quality. The experiment was carried out in Guaraçaí, São Paulo State, Brazil, in a loamy medium texture soil, by using Smooth Cayenne (Hawaiian) pineapple seedlings. A randomized block design with four replications was adopted, with 110 g ha^{-1} of B and 250 g ha^{-1} of Zn for each application. Two foliar sprays were applied, at 7 and 9 months after planting. The B and Zn sources did not affect the total soluble solids contents, titratable acidity, average fruit diameter, fruit length without crown, and maturity index. Only the B, Zn, and K concentrations in the leaves were influenced by the application of micronutrients.

KEY-WORDS: *Ananas comosus* L.; Smooth Cayenne; boron; zinc.

INTRODUCTION

Brazil is one of the biggest world fruit producers, with great variety and quality, and pineapple is one of its main fruits, being cultivated in almost all the Brazilian States. The national production has reached 1.78 million tons, obtained on 72,000 ha, with a 24.82 t ha^{-1} yield index (IBGE 2007). São Paulo State has a cultivated area of 3,414 ha and produces 114,000 tons, while Guaraçaí is one of its main producers, with a cropped area of 1,500 ha and 45,000 tons yield (IEA 2008).

The Smooth Cayenne cultivar is the most popular in the world. It is estimated that 70% of the world production corresponds to this cultivar. Its fruit is attractive, cylindrical in shape, with an orange-yellow skin when ripe, yellow pulp, rich in sugars (13-19 °Brix), with acidity levels higher than other cultivars, and weighs 1.5-2.5 kg. These characteristics make it suitable for industrialization and commercialization as fresh fruit (Cunha et al. 1999).

Foliar fertilization has recently become important, due to the total supply, when referring to micronutrients. There are various other factors that contribute to the use of foliar sprays containing

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micronutrients, such as plant anatomy, presence of aquifer parenchyma in the leaves, and cost reduction. Tropical soils are naturally poor in organic matter, what normally results in a micronutrient deficiency that can be efficiently corrected by leaf spraying, while the nutrient application to the soil does not always provide satisfactory results, due to the slight limit between deficiency and toxicity.

Among micronutrients, boron and zinc deserve special attention, because their deficiencies are more frequent in crops. Their presence is also fundamentally important, because they are directly related to fruit formation and quality (Malavolta et al. 1997).

Verawudh (1993) assessed combinations of Fe, Cu, Zn, and B levels, applied via foliar sprays, on plants of the Smooth Cayenne variety, and verified increase in the fresh plant weight, at 12 months after planting, and a significant increase in fruit yield, from 71.5 t ha^{-1}, for the control, to 81.4 t ha^{-1}, with the application of the highest doses (49.75 mg $plant^{-1}$ for Cu, 6.1 mg $plant^{-1}$ for Fe, 9.5 mg $plant^{-1}$ for Zn, and 15 mg $plant^{-1}$ for B). The total soluble solids concentration and titratable acidity were not affected by the treatments. However, Santos et al. (2007) reported that ornamental pineapple plants cultivated without micronutrients did not flower naturally, but responded well to induction with ethefon.

Usha & Singh (2002) observed increases in grapevine fruits yield and quality, with B and K via foliar application, and Stover et al. (1999) in apple yield, with foliar application of B and Zn as solubor and Zn as zinc chelate. For Kavati (1992), micronutrient supply via foliar spraying, for the atemoya (*A. cherimolia* Mill. x *A. squamosa* L.) crop, especially of Zn and B, resulted in visual responses in the plant development.

The present study was carried out to assess the effects of B and Zn, as chelate, acid or salt, via foliar application, on fruit yield and quality.

MATERIAL AND METHODS

The experiment was carried out at the São José farm, in Guaraçaí, São Paulo State, Brazil, in a medium texture soil, in the 0.0-0.20 m layer, with the following attributes: a) macronutrients: P (resin) = 6 mg dm^{-3}; O.M. = 12 g dm^{-3}; pH ($CaCl_2$) = 3.7; S = 3 mg dm^{-3}; K = 1.4 $mmol_c$ dm^{-3}; Ca = 3 $mmol_c$ dm^{-3}; Mg = 1 $mmol_c$ dm^{-3}; H+Al = 29 $mmol_c$ dm^{-3}; CEC = 34.4 $mmol_c$ dm^{-3}; and 16% base saturation; b) micronutrients: Cu = 0.9 mg dm^{-3}; Fe = 48 mg dm^{-3}; Mn = 26.6 mg dm^{-3}; Zn = 0.5 mg dm^{-3} (DTPA); and B = 0.17 mg dm^{-3} in hot water.

Suckers of the Smooth Cayenne cultivar (Hawaiian) were used in the experiment, planted in plots on March 2004, with 1.50 m x 0.40 m x 0.30 m spacing, and 35,000 plants ha^{-1}, arranged in double rows. Fertilization with 500 kg ha^{-1} of simple superphosphate (90 kg ha^{-1} of P_2O_5) was used in the planting drill, and a total of 140 kg ha^{-1} of N and K_2O were divided in two applications (October and December 2004). The experiment was carried out following the usual recommendations for the São Paulo State, according to Spironello & Furlani (1997) and Giacomelli (1990). Flowering was induced at nine months after planting, based on the crop development stage, with Ethrel 720 (720 g etephon L^{-1}), at 4.6 L ha^{-1}.

A randomized block design with 10 treatments and four replications was adopted, with each plot containing 15 plants, with 10 useful plants. Foliar sprayings were carried out in the morning (8 a.m.), at the 7th (10/05/2004) and 9th (12/01/2004) months after planting.

The treatments used were: T1: control; T2: boric acid; T3: zinc sulfate; T4: T2 + T3; T5: boric acid + urea + citric acid + EDTA (8% B, 1% N, 1.5% citric acid, and 4.5% EDTA); T6: zinc sulfate + urea + citric acid + EDTA (9% Zn, 8.9% S, 0.5% N, 1.5% citric acid, and 4.5% EDTA); T7: T5 + T6; T8: boric acid + urea + citric acid + EDTA + sodium molybdate + sulfur + calcium chloride (1% B, 5% N, 0.05% Mo, 3% S, 12.2% Cl, 7% Ca, 3.5% citric acid, and 2.6% EDTA); T9: zinc sulfate + citric acid + EDTA + iron sulfate + manganese sulfate + magnesium sulfate (9.4% S, 5% Zn, 1% Fe, 1% Mn, 1% Mg, 1.5% citric acid, and 4.3% EDTA); T10: T8 + T9.

The flow included 300 L ha^{-1} diluting the products for application, at 110 g ha^{-1} B and 250 g ha^{-1} Zn doses, for each application. The citric acid was added to the product, in order to increase the element absorption by the leaves. The EDTA plays the role of chelating the zinc element, facilitating the element mobility in the leaf.

To determine the plants nutrient contents, on the ninth day after planting (15/12/2004), eight "D" leaves were collected (the newest completely developed leaf) per plot, and the central 20 cm of the leaf (Souza 1999) were placed to dry in a forced air circulation chamber, at 65°C, for about 96 hours. After drying, the material was ground in a Willey mill equipped with 1 mm mesh sieves, and placed in plastic bags to analyze the total N, P, K, Ca, Mg, S, B, Cu, Mn, Fe, and Zn contents, following the methods proposed by Malavolta et al. (1997).

At 140 days after inducing flowering, the fruits from each plot were collected at the maturation point (CEAGESP 2000), counted, and weighed (whole fruit). The quantitative analysis was carried out by using five fruits from each plot and determining the fruit length without crown (cm), average fruit diameter (cm), and yield (t ha^{-1}).

Two fruits per plot were used for the physical and chemical analyses, with pure juice extracted from one quarter of the fruit used to determine the titratable acidity (TA) and total soluble solids contents (TSS), according to the Adolfo Lutz Institute (1985), and the maturation index (SST/AT).

The data were submitted to the variance analysis (F test) and the means compared by using the Tukey test (5%). The statistical analyses were carried out with the aid of the SANEST software (Zonta & Machado 1984).

RESULTS AND DISCUSSION

The N, P, K, Ca, Mg, and S contents in the Smooth Cayenne pineapple leaves are detailed in Table 1. The K means ranged 18.37-26.81 g kg^{-1} (Table 1) in the leaf, and, in some treatments, they were below the range levels considered adequate for the crop: 21-30 g kg^{-1} (Quaggio et al. 1997). Significant effect was observed for the treatments with K content in the leaf, because the soil was known for lacking that element. The treatment with zinc sulfate presented the highest K concentration in the leaf (26.81 g kg^{-1}), differing from the treatments with B, Zn, N, Ca, Mg, S, Cl, Fe, Mn, Mo, citric acid, and EDTA (Treatment 10), with a lower K concentration in the leaf (18.37 g kg^{-1}).

The N, Mg, and Ca contents in the leaves were above the ones considered adequate for the crop: 15-17 g kg^{-1}, 3-4 g kg^{-1}, and 8-12 g kg^{-1}, respectively (Quaggio et al. 1997). However, the supply of nutrients such as N, Ca, Mg, S, and others, in the Treatments 8 and 9, did not result in a significant response of the plant to the absorption of those nutrients, probably due to the small number of leaf sprayings, or because the sampling was carried out shortly after the second application. The P level on the leaf varied from 0.83 g kg^{-1} to 0.70 g kg^{-1} (Table 1) and was below the contents range considered suitable for the crop: 0.8-1.2 g kg^{-1} (Quaggio et al. 1997).

The B, Cu, Mn, Fe, and Zn leaf concentrations are present in Table 2. Significant effects were observed only for the B and Zn leaf contents. These results were already expected, because the soil was known for lacking those micronutrients (Raij et al. 1997).

Table 1. Effects of fertilizer treatments on the nutrient composition of pineapple leaves. Mean values of N, P, K, Ca, Mg, and S leaf concentrations on pineapple plants submitted to foliar fertilization on 05/10/2004 and 01/12/2004 (Guaraçaí, São Paulo State, Brazil, 2004/2005).

Treatments	N	P	K	Ca	Mg	S
	g kg^{-1}					
T. 1. Control	22.75 a[(1)]	0.80 a	21.02 ab	12.93 a	4.84 a	1.05 a
T. 2. B (H_3BO_3)	22.38 a	0.75 a	19.76 ab	12.31 a	4.26 a	1.00 a
T. 3. Zn ($ZnSO_4$)	22.40 a	0.83 a	26.81 a	12.86 a	4.58 a	1.07 a
T. 4. B + Zn	22.73 a	0.79 a	24.25 ab	12.93 a	4.56 a	1.01 a
T. 5. BM[(2)]	22.43 a	0.82 a	20.17 ab	13.72 a	4.74 a	0.97 a
T. 6. ZnM[(3)]	23.31 a	0.78 a	23.05 ab	12.68 a	4.55 a	0.99 a
T. 7. BM + ZnM	23.17 a	0.74 a	21.86 ab	12.67 a	4.39 a	0.97 a
T. 8. NB[(4)]	23.27 a	0.77 a	22.22 ab	13.05 a	4.54 a	1.07 a
T. 9. NZn[(5)]	23.08 a	0.74 a	22.76 ab	12.92 a	4.45 a	1.03 a
T. 10. NB + NZn	23.32 a	0.70 a	18.37 b	13.09 a	4.14 a	0.94 a
CV (%)	7.21	8.09	14.11	6.20	10.84	8.65
IRFA (%)[(6)]	> 1.2	> 0.08	> 2.8	> 0.10	> 0.18	-
Dalldorf & Langenegger (%)[(7)]	1.5-1.7	0.10	2.2-3.0	0.8-1.2	0.30	-
Quaggio et al. (1997) (%)[(8)]	1.5-1.7	0.08-0.12	2.2-3.0	0.8-1.2	0.3-0.4	-

(1) Means followed by the same letter in the column do not differ by the Tukey test (5%). (2) BM = urea + boric acid + citric acid + EDTA. (3) ZnM = urea + zinc sulfate + citric acid + EDTA. (4) NB = B, N, Ca, Mo, S, Cl, citric acid, and EDTA. (5) NZn = Zn, N, Mg, S, Fe, Mn, Cl, citric acid, and EDTA. (6) Ideal concentrations at flowering induction. (7) Ideal concentrations at the inflorescence emergence (Souza 1999). (8) Raij et al. (1997).

Table 2. Effects of fertilizer treatments on the nutrient composition of pineapple leaves. Mean values of B, Zn, Cu, Mn, and Fe leaf concentrations on pineapple plants submitted to foliar fertilization on 05/10/2004 and 01/12/2004 (Guaraçaí, São Paulo State, Brazil, 2004/2005).

Treatments	B	Zn	Cu	Mn	Fe
	mg kg^{-1}				
T. 1. Control	39.25 b[(1)]	15.25 bc	6.00 a	1026.25 a	137.00 a
T. 2. B (H_3BO_3)	41.00 ab	14.50 bc	11.00 a	1017.00 a	224.75 a
T. 3. Zn ($ZnSO_4$)	41.25 ab	20.25 bc	13.00 a	1014.50 a	197.00 a
T. 4. B + Zn	53.50 a	17.50 bc	5.25 a	1032.50 a	243.25 a
T. 5. BM[(2)]	43.00 ab	14.25 bc	8.50 a	1028.25 a	256.75 a
T. 6. ZnM[(3)]	38.25 b	24.75 ab	5.75 a	1013.25 a	111.75 a
T. 7. BM + ZnM	41.25 ab	19.00 bc	5.75 a	1017.75 a	142.25 a
T. 8. NB[(4)]	42.25 ab	13.50 c	7.75 a	1016.50 a	175.75 a
T. 9. NZn[(5)]	40.50 b	32.00 a	6.75 a	1014.50 a	194.00 a
T. 10. NB + NZn	41.00 ab	21.75 abc	6.25 a	1026.25 a	119.00 a
CV (%)	12.36	23.22	58.01	2.15	45.98
Dalldorf & Langenegger (mg kg^{-1})[(6)]	30.0	10.0	8.0	50-200	100-200
Quaggio et al. (1997) (mg kg^{-1})	20-40	5-15	5-10	50-200	100-200

[(1)] Means followed by the same letter in the column do not differ by the Tukey test (5%). [(2)] BM = urea + boric acid + citric acid + EDTA. [(3)] ZnM = urea + zinc sulfate + citric acid + EDTA. [(4)] NB = B, N, Ca, Mo, S, Cl, citric acid, and EDTA. [(5)] NZn = Zn, N, Mg, S, Fe, Mn, Cl, citric acid, and EDTA. [(6)] Ideal concentrations at the inflorescence emergence (Souza 1999).

The B means in the leaf ranged 39.25-53.50 mg kg^{-1} (Table 2) and were within the concentrations range considered adequate for the crop: 20-40 mg kg^{-1} (Quaggio et al. 1997). The treatments with boric acid (T2), zinc sulfate (T3), boron + urea + citric acid (T5), T5 + chelated zinc (T7), T8, and T9 presented similar results for B contents in the leaf. The treatments without leaf nutrient application, chelated zinc, and T9 did not differ and were similar to the treatments previously reported. The treatment with boric acid + zinc sulfate resulted in the highest B mean in the leaf (53.50 mg kg^{-1}).

Thus, the B absorption, via leaf application, can be influenced by different factors: species (Goor & Lune 1980), concentration of the application solution, leaf cuticle permeability, relative air humidity, leaf age (Shu et al. 1994), and also amount of applications. Basso & Suzuki (2001) reported that there are usually no problems of B deficiency in soils well provided with organic matter and pH less than 7, differing from the results observed in the present study.

The Zn means in the leaf ranged from 13.50 mg kg^{-1} to 32 mg kg^{-1} (Table 2), and were within the range of contents considered adequate for the crop: 5-15 mg kg^{-1} (Quaggio et al. 1997). The treatment without nutrients via leaf (T1), boric acid (T2), zinc sulfate (T3), boric acid + zinc sulfate (T4), boron + urea + citric acid (T5), and T5 + chelated zinc (T7) performed similarly, regarding Zn contents in the leaf. The treatment T9 showed the highest leaf zinc mean (32 mg kg^{-1}). Santos et al. (1999) compared the efficiency of chelated leaf fertilizer formulations for the absorption of B, Mn, and Zn micronutrients with the conventional application of salts to orange trees (*Citrus sinensis* L.) and observed an increase in the Mn and Zn leaf content, but not of B, due to its low mobility in the plant.

Canesin & Buzetti (2007) studied B and Zn leaf fertilization, for Japanese pear and pine tree crops, and did not observe increase in fruit yield, as it happened in the present study. Swietlik (2002) worked with apple trees, citrus trees, and grapevines, and concluded that an essential prerequisite for plant responses to Zn leaf fertilization seemed to be the presence of Zn deficiency symptoms.

The Cu, Mn, and Fe concentrations in the leaf were considered adequate for the crop (5-10 mg kg^{-1}, 50-200 mg kg^{-1}, and 100-200 mg kg^{-1}, respectively) (Quaggio et al. 1997). The Mn content in the leaf was especially high, much above the range considered adequate for the pineapple crop (Table 2), what can be explained by the low soil pH.

Data for the average fruit diameter (FD), fruit length without crown (CF), total soluble solids contents (TSS), titratable acidity (TA), maturation index, and fruit yield can be observed in Table 3. There was no difference among the treatments tested for mean diameter and fruit length without crown. The total soluble solids contents and titratable acidity were also not affected by the treatments, and ranged 13.74-15.50 °Brix and 0.82-0.94 g citric acid 100 mL^{-1}, respectively (Table 3).

Table 3. Effects of fertilizer treatments on the yield characteristics. Mean values for the average fruit diameter (FD), fruit length without crown (CF), total soluble solids contents (TSS), titratable acidity (TA), maturation indexes (MI), and fruit yield (FY) for pineapple fruits collected at 140 days after the flowering induction (Guaraçaí, São Paulo State, Brazil, 2004/2005).

Treatments	DF	CF	TSS	TA	MI	Yield
	cm		ºBrix	g asc. ac. 100mL^{-1}	SS/AT	t ha^{-1}
T. 1. Control	14.08 a[1]	19.87 a	14.08 a	0.88 a	16.43 a	80.52 a
T. 2. B (H_3BO_3)	13.95 a	20.06 a	15.50 a	0.90 a	17.37 a	77.54 a
T. 3. Zn ($ZnSO_4$)	13.87 a	19.42 a	14.82 a	0.94 a	16.06 a	80.17 a
T. 4. B + Zn	13.65 a	19.39 a	14.10 a	0.92 a	15.35 a	78.07 a
T. 5. BM[2]	13.87 a	20.15 a	15.03 a	0.87 a	17.20 a	84.65 a
T. 6. ZnM[3]	13.66 a	19.13 a	14.74 a	0.82 a	18.01 a	79.91 a
T. 7. BM + ZnM	13.41 a	19.71 a	15.00 a	0.90 a	16.66 a	79.03 a
T. 8. NB[4]	14.56 a	20.55 a	13.74 a	0.83 a	16.73 a	86.04 a
T. 9. NZn[5]	13.94 a	19.63 a	14.76 a	0.93 a	15.75 a	77.36 a
T. 10. NB + NZn	13.94 a	20.07 a	13.74 a	0.86 a	17.35 a	85.61 a
CV (%)	3.95	7.19	7.89	11.51	14.88	9.41

[1] Means followed by the same letter in the column do not differ by the Tukey test (5%). [2] BM = urea + boric acid + citric acid + EDTA. [3] ZnM = urea + zinc sulfate + citric acid + EDTA. [4] NB = B, N, Ca, Mo, S, Cl, citric acid, and EDTA. [5] NZn = Zn, N, Mg, S, Fe, Mn, Cl, citric acid, and EDTA.

The values for TSS were below the average (16.84 ºBrix), while the ones for AT were above the average (0.75 g citric acid 100mL^{-1}), for the Smooth Cayenne cultivar, at 148 days after induction, according to Carvalho (1999). According to Smith (1988), pineapple for consumption *in natura* should have total soluble solids contents equal or superior to 40%. However, the pineapple classification norms (CEAGESP 2003) set 12% Brix as the minimum value for the fruit be considered ripe. The TSS values, regardless of treatment, were within the commercialization standards.

Siebeneichler et al. (2002) observed that the B contents were not sufficient to alter the fruit mass and its physical and chemical characteristics, except for the TSS content, which increased slightly.

The values detected for the maturation index (TSS/TA ratio) ranged 15.35-18.01, being above the indexes reported by Carvalho (1999), for winter fruits of the Smooth Cayenne cultivar, in the São Paulo State.

Fruit yield was not influenced by the treatments and ranged 77.36-86.04 t ha^{-1}. Even though the B and Zn contents in the soil were considered low, a response was not detected for yield, for the treatments used, showing that the soil fertility, although low, was sufficient to supply the needs of the crop to reach a high yield. So, the fact that the crop is considered vigorous, by presenting morphological, anatomic, and physiological characteristics that allow it to survive in adverse environmental conditions (Cunha et al. 1999), should be taken into account.

The use of different B and Zn sources in the experiment did not affect important parameters such as total soluble solids contents and fruit yield, thus, it would not be necessary to use foliar fertilization, in this case.

CONCLUSIONS

1. The B and Zn sources did not affect the total soluble solids contents, total titratable acidity, mean fruit diameter, fruit length without crown, and maturity index. Only the B, Zn, and K contents in the leaf were influenced by the treatments.
2. The fruit yield of the pineapple plant is not significantly affected by the different B and Zn sources, but high yield is obtained even with below adequate contents in the soil.
3. Leaf fertilization would not be recommended with the different B and Zn sources tested.

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