Growth and Flowering of 'Imperial' Pineapple Plants under Macronutrient and Boron Deficiency

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Keywords: *Ananas comosus* var. *comosus,* nutrient solution, number of leaves, concentration of nutrients

Abstract

This work was carried out under greenhouse conditions to evaluate the influence of macronutrient and boron deficiencies on growth and flowering of 'Imperial' pineapple plants. The treatments Complete, - N, - P, - K, - Ca, - Mg, - S and - B were applied as nutrient solutions in plastic pots with 14 kg of purified beach sand and one pineapple plant as the experimental unit. The trial was set up in a randomized complete blocks design with six replications. Evaluations were done on fresh and dry weight, length and width of 'D' leaves, 'D' leaf area and number of leaves at forcing date and percentage of flowering in response to forcing. In addition, foliar concentrations of macronutrients and boron were determined. The deficiencies of N and K reduced fresh and dry weight, length, width and area of 'D' leaves at nine and 12 months after planting; that of Ca reduced fresh weight and 'D' leaf area at 12 months and the deficiencies of P, Mg, S and B did not significantly affect the leaf variables studied. At seven months after planting only N deficiency reduced leaf number and 'D' leaf area. The deficiencies of K, P, Ca and S accelerated flowering, while those of N and Mg delayed it. The appropriate and deficient concentrations in leaf dry matter at time of floral induction were, respectively: N = 14.8 and 6.6; P = 1.37 and 0.70; K = 23.0 and 11.6; Ca = 4.40 and 1.30; Mg = 2.30 and 0.90, S = 1.54 and 0.56 (all expressed as g kg^{-1}), and B = 20.0 and 5.6 mg kg^{-1}.

INTRODUCTION

The time of pineapple flowering and fruit harvest can be advanced and homogenized by application of growth regulators both into the central leaf rosette and over the whole plant (Reinhardt and Cunha, 2000).

Under favorable growing conditions after planting, roots will start to develop and thereafter new leaves will begin to emerge. From planting to the initiation of flower differentiation, which is the vegetative stage of pineapple plant development, roots, stem and leaves will be growing (Malézieux et. al., 2003), but leaves will represent about 90% of total shoot fresh weight. Leaf number may reach up to 80 per plant (Cunha and Cabral, 1999) and the largest ones may be more than 1,6 m long and 7 cm wide, depending on the cultivar and the environmental conditions (d´Eeckenbrugge and Loyal, 2003).

The effect of a moderate water stress on pineapple plants seems to be similar to that of a moderate nitrogen deficiency (Evans, 1959), but no study under controlled conditions was found in the literature. Sampaio (1997) did not observe significant effects of nitrogen supply as urea, in addition to regular mineral fertilization, and different planting dates on vegetative growth and natural flower differentiation of 'Smooth Cayenne' pineapple plants under the environmental conditions of the interior of São Paulo State.

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According to Das et al. (2000), the application of under doses of N and K delayed flowering of 'Giant Kew' pineapples in all planting densities studied. The importance of phosphorus for the metabolism of pineapple plants has been pointed out, especially at floral differentiation stage, when severe deficiency does not allow fruit formation (Gonçalves and Carvalho, 2000).

Some cultivars seem to be more susceptible to natural flowering than 'Smooth Cayenne' pineapples. Reinhardt et al. (2002) reported that the main Brazilian pineapple cultivar, 'Pérola', is more sensitive to floral differentiation than ' Smooth Cayenne', both under forced and natural conditions.

'Imperial' is a new Brazilian pineapple cultivar, produced by Embrapa Cassava & Tropical Fruits as a 'Smooth Cayenne' × 'Perolera' hybrid. It is resistant to fusariosis, the main constraint to the pineapple crop in Brazil. Its management recommendations have to be adjusted from those applied to 'Smooth Cayenne' and 'Pérola' crops. No specific information has been available on its response to nutrient deficiencies.

This work aimed at evaluating the influence of macronutrient and boron deficiencies on growth variables and flowering of 'Imperial' pineapple plants.

MATERIALS AND METHODS

The experiment was set up in a greenhouse in Campos dos Goytacazes, RJ, on December 19, 2003, using plantlets of 'Imperial' pineapple obtained by tissue culture at Campo Biotecnologia Vegetal Ltd., Cruz das Almas, Bahia, Brazil.

The experiment consisted of eight treatments: Complete, -N, -P, -K, -Ca, -Mg, -S and -B, distributed in a randomized complete block design with six replications. The experimental unit was represented by one plant placed into a plastic pot containing 14 kg of beach sand previously purified by soaking it with hydrochloric acid diluted in water (1:4) during four hours and subsequently washing it with pure water until stable pH of 5, followed by a final wash with deionized water.

Plantlets had an average size of 6 cm. From planting each pot received 500 ml of deionized water every other day for 15 days, when new roots began to be emitted. From then each pot was supplied three times per week with 500 ml of the complete nutrient solution that presented the following composition, in mg L^{-1}: $N(NO_3^-)$ =112; $N(NH_4^+)$ =3.5; P =7.74; K =156.4; Ca =80; Mg =24.3; S =32;0; Cl =1.77; Mn =0.55; Zn =0.13; Cu =0.03; Mo =0.06; B =0.27; Fe =2.23, set to pH =5.5. From 50 days after beginning of the application of the complete solution or 65 days after planting, the –B treatment was started to be applied. The other treatments continued to get the complete solution up to 105 days after planting. Thereafter the concentration of macronutrients was reduced to 10% of the complete solution and from 150 days after planting the treatments -N, -P, -K, -Ca, -Mg and -S started to be fully applied. At 240 days after planting, the plants of the - N treatment presented very severe symptoms of deficiency. Therefore they received a nutrient solution with 10% of N of the complete solution for a period of four weeks in order to reduce the risk of absence of fruit formation by these plants. The volumes of nutrient solution applied varied with plant age, from 500 ml up to 150 days after planting, to 700 ml from 150 days to 330 days after planting and finally 1 L until fruit harvest, applied three times a week.

At eight months (19/08/2004) after planting flowering forcing was done by applying a 50 mL solution of Ethrel 0.1%, urea 2% and calcium hydroxide 0.035% into the central rosette of each plant. At that stage 'D' leaves of plants in the complete treatment reached on average 63.4 cm of length and 39.2 g of fresh weight and a total of 55 leaves. The climatic conditions at forcing time are shown in Table 1. A second application of the forcing solution was done on November 8, 2004, in plants that had not bloomed until then.

Plant growth was assessed based upon 'D' leaves variables taken at 5, 7, 9 and 12 months after planting: fresh and dry weight, length, width and leaf area (measured by using a leaf area meter model Licor 3100, Lincoln, Nebrasca). The specific leaf area was calculated by means of the relationship leaf area/leaf dry weight. The concentrations of N, P, K, Ca, Mg, S, and B in the whole 'D' leaf were determined according to the methodology of Malavolta et al. (1997) modified by Monnerat (w/d). The percentage of flowering plants was calculated from number of inflorescences visible in the central rosette determined at daily intervals starting on September 20, 2004.

Data obtained were submitted to the variance analysis and averages of the treatments under nutrient deficiency were compared with those of the complete treatment by the test of Dunnet at 5%.

RESULTS AND DISCUSSION

Vegetative Growth

At five months after planting, there were no significant effects of the mineral nutrient deficiencies studied on plant vegetative growth (Tables 2, 3, 4), in spite of the significant reduction of leaf nutrient concentrations already shown by the plants in relation to the complete treatment (Table 6).

At 7 months after planting, leaf number and area were significantly reduced by N deficiency (Tables 2 and 4) and 'D' leaf width by K deficiency (Table 3). At 9 months after planting only the deficiencies of N and K determined statistically significant reductions of fresh and dry weight, length, width and area of 'D' leaf (Tables 2, 3, 4). And at 12 months after planting 'D' leaf length was decreased by N deficiency only, whereas 'D' leaf fresh weight and area were reduced by N, K and Ca deficiencies; in addition, N and K deficiencies reduced 'D' leaf dry weight and width (Tables 2, 3, 4). These results show that N deficiency has the most negative effects on 'Imperial' pineapple plant growth.

According to Malézieux et al. (2003), reduced leaf size is a common consequence of N deficiency. They also observed that low potassium levels are associated with reduced growth and narrower leaves in relation to its length. The effect of K on vegetative growth may be linked to its effect on the synthesis of proteins in meristematic tissues and on cellular elongation.

The effect of N deficiency on pineapple plant growth was also shown by Razzaque et al. (1999), who observed reduction of leaf number and of 'D' leaf dry weight and area in 'Gandul' pineapple. The effect of N deficiency on the reduction of leaf number was also mentioned by Manica (1999) and Malézieux et al. (2003).

The deficiencies of P, Mg, S and B did not present statistically significant effects on leaf variables at all four plant development stages studied, although their leaf concentrations were much lower than those determined for the complete treatment (Tables 2, 3 and 4). In addition, none deficiency had significant influence on the specific 'D' leaf area (Table 4), suggesting that those deficiencies reduced proportionally leaf dimensions and weight.

Flowering

The period from forcing treatment to inflorescence appearance in plants of the complete treatment fell inside the time range mentioned by Cunha (1999), from 40 to 50 days.

Plants with P, Ca and S deficiencies showed their inflorescence earlier. At 40 days after forcing, all plants of these treatments presented inflorescences, while in the complete treatment this was the case only for 67% of the plants. Some acceleration of inflorescence appearance was also observed for K deficient plants (Table 5). These results suggest that the deficiencies of those nutrients altered the hormonal balance of the plant, favoring the action of the IAA auxin in the apical meristem towards flowering (Cunha, 1999).

The deficiency of Mg also delayed the appearance of the inflorescence (Table 5) and this effect can be a consequence of reduction of photoassimilate production due to decrease of chlorophyll synthesis (Marschner, 1995).

In the -N treatment only 50% of the plants showed their inflorescence until 45 days after forcing, while this was true for 83% of the plants from the complete solution treatment. A similar result was found by Das et. al. (2000), who observed a decrease in the flowering percentage of 'Giant Kew' pineapple plants in response to application of under doses of nitrogen.

The small increase in leaf N concentration observed at nine months after planting in the –N treatment was determined by 12 applications of a solution containing N during the preceding four weeks carried out in order to avoid absence of fruit formation due to the severity of the deficiency. In apple and in citrus, one pre-flowering application of ammonium nitrogen has a greater effect on plant development than the continuous supply of nitric nitrogen, increasing the floral initiation, probably by the synthesis of nitrogen compounds, as the polyamines, that activate the floral initiation (Pimentel, 1998).

In response to the second flowering forcing treatment all plants that remained in the vegetative stage until then formed their inflorescence, except for those from the -N treatment, confirming the strong negative effect of this deficiency on floral initiation.

CONCLUSIONS

Under the conditions of this work the following conclusions can be pointed out for the effects of macronutrient and boron deficiencies on ‘Imperial’ pineapple plant development:

N deficiency had very strong negative effects, affecting both growth and response to flowering forcing.

K and, to a lower degree, Ca deficiencies showed negative effects on plant growth, but did not affect response to flowering forcing treatment.

P, Mg, S and B did not significantly affect plant growth and had no major effects on flowering.

The appropriate and deficient concentrations observed in the leaf dry matter at time of floral induction were respectively: N = 14.8 and 6.6; P = 1.37 and 0.70; K = 23.0 and 11.6; Ca = 4.40 and 1.30; Mg = 2.30 and 0.90, S = 1.54 and 0.56 (all expressed as g kg^{-1}), and B = 20.0 and 5.6 mg kg^{-1}.

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Tables

Table 1. Climatic conditions at flowering forcing of 'Imperial' pineapple plants. Campos dos Goytacazes, RJ, Brazil, 2004.

Days before and after flowering forcing	Climatic variables				
	Temperature (°C)			Hours of light [2]	Solar radiation [1] (Wm^{-2})
	Média[1]	Máxima[1]	Mínima[1]		
19/8/2004	20.2	27.7	14.7	11.00	234
* 20/08/2004	20.7	28.0	14.8	7.65	227
21/08/2004	21.8	30.0	16.6	11.05	240
22/08/2004	22.4	31.8	17.1	11.00	235
23/08/2004	22.5	31.6	18.5	8.60	218
24/08/2004	21.2	25.7	18.7	5.80	151

1 - EEC - Pesagro Rio, Campos dos Goytacazes; 2 - UENF Evapotranspirometric Station, * - Date of flowering forcing

Table 2. Effect of macronutrient and boron deficiencies on 'D' leaf fresh and dry weights at five, seven, nine and 12 months after planting and leaf number of 'Imperial' pineapple plants, at five and seven months after planting. UENF, Campos dos Goytacazes, RJ, 2004.

Treatments	Fresh Weight(g)				Dry Weight(g)				Number of leaves	
	Months after planting				Months after planting				Months after planting	
	5	7	9	12	5	7	9	12	5	7
Complete	36.2	39.2	40.7	47.9	4.30	5.03	5.55	7.22	40.5	55.2
-N	34.,0ns	31.5ns	26.2-	27.1-	4.00ns	3.93ns	3.36-	4.10-	36.2ns	48.0-
-P	34.7ns	34.1ns	35.4ns	42.3ns	4.30ns	4.44ns	5.06ns	7.40ns	38.5ns	52.7ns
-K	30.9ns	31.8ns	27.8-	36.4-	3.90ns	4.34ns	4.09-	5.86-	40.0ns	54.3ns
-Ca	32.0ns	33.0ns	33.8ns	38.7-	4.00ns	4.17ns	4.80ns	6.30ns	40.7ns	56.0ns
-Mg	32.3ns	36.4ns	36.5ns	40.6ns	3.90ns	4.59ns	4.87ns	6.24ns	40.0ns	55.2ns
-S	36.7ns	42.8ns	39.6ns	51.0ns	4.50ns	5.31ns	5.20ns	7.44ns	39.0ns	53.5ns
-B	33.3ns	37.4ns	38.1ns	45.5ns	4.08ns	4.70ns	5.25ns	6.94ns	38.3ns	53.8ns
Mean values	33.8	35.8	34.8	41.2	4.12	4.56	4.77	6.44	39.2	53.6
CV (%)	14.5				16.5				5.9	

In each column, means followed by + , - or ns either are larger, smaller or don't differ from the complete treatment, respectively, according to Dunnett's test at 5% level.

Table 3. Effect of macronutrient and boron deficiencies on 'D' leaf length and width of 'Imperial' pineapple plants at five, seven, nine and 12 months after planting. UENF, Campos dos Goytacazes, RJ, Brazil, 2004.

Treatments	Leaf lenght (cm)				Leaf width (cm)			
	Months after planting				Months after planting			
	5	7	9	12	5	7	9	12
Complete	60.1	65.7	64.8	68.0	5.80	4.90	5.17	5.27
-N	58.5ns	58.1ns	54.6-	56.5-	5.60ns	4.50ns	3.93-	4.02-
-P	61.2ns	65.2ns	66.1ns	71.3ns	5.50ns	4.83ns	4.73ns	5.00ns
-K	58.9ns	61.2ns	55.5-	63.5ns	5.30ns	4.40-	4.22-	4.68-
-Ca	57.4ns	59.4ns	59.0ns	64.4ns	5.50ns	4.82ns	4.82ns	4.85ns
-Mg	58.3ns	63.9ns	63.2ns	66.2ns	5.50ns	4.85ns	4.78ns	4.85ns
-S	61.6ns	67.7ns	65.1ns	71.9ns	5.80ns	5.23ns	5.13ns	5.27ns
-B	57.6ns	60.0ns	59.7ns	66.3ns	5.80ns	5.15ns	4.92ns	5.22ns
Mean values	59.2	62.7	61.0	66.0	5.60	4.84	4.71	4.90
CV (%)	8.46				6.49			

In each column, means followed by +, - or ns either are larger, smaller or don't differ from the complete treatment, respectively, according to Dunnett's test at 5% level.

Table 4. Effect of macronutrient and boron deficiencies on 'D' leaf area and specific leaf area of 'Imperial' pineapple plants at five, seven, nine and 12 months after planting. UENF, Campos dos Goytacazes, RJ, Brazil, 2004.

Treatments	Foliar area (cm^2)				Specific foliar area (cm^2g^{-1})			
	Months after planting				Months after planting			
	5	7	9	12	5	7	9	12
Complete	237.6	201.6	184.03	233.3	55.9	40.1ns	33.5ns	32.2ns
-N	214.8ns	160.8-	124.6-	143.2-	53.6ns	41.1ns	37.8ns	33.5ns
-P	226.4ns	196.5ns	181.4ns	220.6ns	53.5ns	44.4ns	36.3ns	29.9ns
-K	204.3ns	165.1ns	129.8-	183.1-	53.1ns	38.0ns	31.9ns	31.2ns
-Ca	212.5ns	184.6ns	157.0ns	191.1-	54.2ns	46.1ns	33.2ns	30.9ns
-Mg	217.6ns	194.9ns	173.2ns	204.7ns	56.0ns	42.8ns	35.7ns	33.3ns
-S	246.8ns	225.6ns	188.5ns	249.1ns	55.1ns	42.9ns	36.4ns	33.5ns
-B	214.9ns	194.2ns	166.5ns	222.9ns	52.8ns	41.0ns	31.6ns	32.1ns
Mean values	221.9	190.4	163.1	206.0	54.3	42.1	34.6	32.1
CV (%)	12.5				10.6			

In each column, means followed by +, - or ns either are larger, smaller or don't differ from the complete treatment, respectively, according to Dunnett's test at 5% level.

Table 5. Flowering dates (day/month) and percentage of flowering plants of 'Imperial' pineapple at 30, 32, 35, 40, 45 and 50 days after forcing. UENF, Campos dos Goytacazes, RJ, Brazil, 2004.

Treatments	Date of Flowering (Red bud stage) Blocks						Flowering plants (%) Days after induction					
	1	2	3	4	5	6	30	32	35	40	45	50
Complete	*	26/9	28/9	26/9	5/10	26/9	0	0	0	67	83	83
-N	*	1/10	29/9	*	*	26/9	0	0	0	33	50	50
-P	26/9	30/9	28/9	28/9	29/9	29/9	0	0	0	100	100	100
-K	26/9	29/9	27/9	3/10	26/9	29/9	0	0	0	83	100	100
-Ca	29/9	23/9	27/9	30/9	23/9	23/9	0	0	50	100	100	100
-Mg	9/10	26/9	*	*	1/10	1/10	0	0	0	16.7	50	50
-S	26/9	29/9	26/9	26/9	26/9	26/9	0	0	0	100	100	100
-B	26/9	30/9	2/10	*	23/9	1/10	0	0	17	50	83	83

* Plants that didn't bloom in response to the first forcing treatment (19/08/2004). Second forcing treatment done on 08/11/2004.

Table 6. 'Imperial' pineapple leaf nutrient concentrations in the complete and in the deficient treatments at four sampling times. UENF, Campos dos Goytacazes, RJ, Brazil, 2004.

Nutrient	Treatment	Sampling time Months after planting				CV (%)
		5	7	9	12	
Nitrogen						8.13
(g kg^{-1})	Complete	13.3	14.8	14.8	13.4	
	-N	8.7-	6.6-	9.7-	6.8-	
Phosphorus						11.3
(g kg^{-1})	Complete	1.30	1.37	1.23	1.04	
	-P	0.97-	0.70-	0.67-	0.32-	
Potassium						9.05
(g kg^{-1})	Complete	21.6	23.0	20.0	23.8	
	-K	13.8-	11.6-	11.6-	3.2-	
Calcium						15.6
(g kg^{-1})	Complete	4.30	4.40	4.37	7.59	
	-Ca	2.30-	1.30-	0.91-	1.72-	
Magnesium						12.0
(g kg^{-1})	Complete	2.10	2.30	2.26	3.57	
	-Mg	1.30-	0.90-	0.73-	0.54-	
Sulfur						16.2
(g kg^{-1})	Complete	1.80	1.54	1.45	1.63	
	-S	1.20-	0.56-	0.45-	0.54-	
Boron						11.5
(mg kg^{-1})	Complete	21.2	20.0	18.4	30.5	
	-B	8.5-	5.6-	5.8-	5.5-	

In each column and for each nutrient, means followed by - are smaller than the one of the complete treatment, according to Dunnett's test at 5% level.