PEACH PALM GROWTH AND HEART-OF-PALM YIELD RESPONSES TO LIMING[1]

M. L. A. BOVI[2], S. H. SPIERING[2] & L. A. SAES[3]

SUMMARY

The effects of liming rates on growth and heart-of-palm yield of peach palm plants (*Bactris gasipaes* Kunth) were studied in a two-year field experiment conducted in Pariquera-Açu, State of Sao Paulo, Brazil. Soils in this region are allic (sub group Ultic Haplorthox), with base saturation ranging from 15 to 26 % of the cation exchange capacity (CEC). A randomized complete block design, with five rates of dolomitic limestone (0, 0.7, 4.7, 8.7, and 14.6 Mg ha^{-1}) and five replications was utilized. Individual plots were composed of 80 plants but only the inner rows (24 plants) were used for data recording. Planting spacing was 2 x 1 m. There was a cubic effect of liming rates on growth and yield. Maximum heart-of-palm yield was estimated to be achieved at 4.3 Mg ha^{-1} of limestone application, corresponding to 51.4 % soil base saturation. A significant decrease in growth and yield was observed when large amounts of limestone were applied (8.7 and 14.6 Mg ha^{-1}), probably due to a decreased micronutrient availability.

Index terms: *Bactris gasipaes*, biomass, limestone, pejibaye.

RESUMO: *RESPOSTAS DE CRESCIMENTO E PRODUÇÃO DE PALMITO DA PUPUNHEIRA À CALAGEM*

*Os efeitos de doses de calcário sobre o crescimento e a produção de palmito de pupunheiras (*Bactris gasipaes *Kunth) foram estudados em experimento realizado em campo em Pariquera-Açu, estado de São Paulo, Brasil. Solos dessa região são álicos (subgrupo Ultic Haplorthox), com saturação por bases variando de 15 a 26% da capacidade de troca catiônica. Foi utilizado um delineamento em blocos completos dispostos ao acaso, com cinco*

[1] Recebido para publicação em janeiro de 2004 e aprovado em setembro de 2004.
[2] Pesquisador do Centro de Horticultura, Instituto Agronômico de Campinas – IAC. Caixa Postal 28, CEP 13001-970 Campinas (SP). E-mail: mlabovi@iac.sp.gov.br
[3] Pesquisador do PRDSA do Vale do Ribeira. Caixa Postal 9, CEP 32097-000 Registro (SP). E-mail: polovaledoribeira@apta.sp.gov.br

doses de calcário dolomítico (0, 0,7, 4,7, 8,7 e 14,6 Mg ha^{-1}) e cinco repetições. Parcelas individuais eram compostas por 80 plantas, das quais apenas as linhas mais internas (24 plantas) foram utilizadas para análise dos dados. O espaçamento entre plantas foi 2 x 1 m. Foram observados efeitos cúbicos para doses de calcário tanto para o crescimento quanto para a produção. Estimativas indicam que máxima produção de palmito pode ser obtida com a aplicação de 4,3 Mg ha^{-1} de calcário, correspondendo a 51,4% de saturação por bases. Ocorreram efeitos negativos no crescimento e na produção quando altas doses de calcário foram aplicadas (8,7 e 14,6 Mg ha^{-1}), provavelmente em virtude do decréscimo na disponibilidade de micronutrientes.

Termos de indexação: Bactris gasipaes, *biomassa, calcário, pupunha.*

INTRODUCTION

In the last decades, peach palm (*Bactris gasipaes* Kunth) has been increasingly cultivated for palm heart production (Bovi, 1998a; Ares et al., 2002a). Owing to its precocity, suckering capacity, and overall product quality cultivated peach palm it could replace the exploitation of native palm stands.

High yields with low costs have been achieved in regions with well-distributed and high rainfall, coupled with high temperature. *Bactris gasipaes* is a tropical palm and its fast and constant growth is highly correlated with heart-of-palm yield, as well as with early and frequent harvests (Bovi et al., 1993; Clement & Bovi, 2000; Ares et al., 2002b).

The Vale do Ribeira region in Sao Paulo State has favorable climatic conditions for peach palm growth (Bovi, 1998b). Nevertheless, soils in this region are frequently allic, with low nutrients and high aluminum contents (Lepsch et al., 1990).

In this fast growing crop a large amount of nutrients is extracted during harvest (Cantarella & Bovi, 1996; Ares et al., 2002a; 2003). Sustained high yields, as well as the economic lifespan of each stand require high annual fertilizer applications (Cantarella & Bovi, 1996; Bovi et al., 2002; Schroth et al., 2002; Ares et al., 2003).

As a relatively new crop, there is a lack of overall scientific knowledge, especially on mineral nutrition. High nitrogen applications are routinely recommended for this crop (Cantarella & Bovi, 1996; Ares et al., 2002a; Bovi et al., 2002). Nonetheless, it is recognized that in acid soils and when large amounts of nitrogen fertilizer are frequently applied, liming is essential to promote adequate plant development (Tisdale & Nelson, 1975). However, no research data in this respect is available for peach palm. Yield responses to lime have been reported for other palms such as coconut and oil palm (Manciot et al., 1980; Chew et al., 1984; Romney, 1987; Resende et al., 1991).

The objective of this study was to evaluate liming effects on peach palm growth and heart-of-palm yield and to determine the ideal soil base saturation for this crop.

MATERIAL AND METHODS

The experiment was conducted in Pariquera-Açu county, Sao Paulo State (24 ° 35 ' S, 47 ° 50 ' W, altitude 25 m), where peach palm plantations have increased in the last ten years (Bovi et al., 1998a). The climate of the region is mesothermic, tropical, hot and humid, with average annual temperature of 21.8 °C, annual rainfall of 1587 mm, and evapotranspiration of 1140 mm (Lepsch et al., 1990). The soil of the experimental area is classified as allic Yellow Latosol (Ultic Haplorthox), with a moderate, clayey A horizon (Sakai & Lepsch, 1984) in a gently undulating topography.

Liming rates were established after the soil chemical analysis according to the soil base saturation method, as reported by Raij (1991). Treatments aimed at elevating the initial soil base saturation from 26 % at 0–20 cm depth (control) to 30, 50, 70 and 100 %, which required application of 0, 0.7, 4.7, 8.7 and 14.6 Mg ha^{-1} of dolomitic limestone (35.4 % of CaO and 16 % of MgO with 97 % of CaO_3 equivalent). A randomized complete block design, with five replications and 80 plants (8 x 10 rows) per plot was utilized. Limestone was broadcasted and incorporated by plowing.

One month after liming, 10 month-old peach palm seedlings (Yurimaguas spineless population) with mean plant diameter and height of 1.69 and 37.4 cm, respectively, were planted in the plots in a 2 x 1 m spacing. Single superphosphate (20 g P_2O_5/plant) was applied in the planting hole. A sidedressing of 50 g per plant of a 20-5-15 NPK formula, beginning six months after planting, four times a year, was also applied.

Plant growth was evaluated every six months, taking measurements of the following variables: diameter (at soil level during the first year and at 50 cm height after that period) and height of the main stem, number of suckers per plant and percentage of suckered plants, as recommended by Clement & Bovi (2000). The heart-of-palm yield was evaluated two years after planting, by harvesting all plants with the main stem at least 160 cm high, measured from the soil to the intersection of the first leaf (spear). The weight of the edible parts (heart-of-palm itself plus apical and basal edible residues) was assessed. Only the inner 24 plants of each plot were considered for the statistical analysis in order to avoid border effects. Growth and yield data used in the analysis represent plant means. Results reported here for number of suckers and percentage of suckered plants were taken 12 months after planting (time of best expression of both traits), while plant diameter, height, as well as the percentage of harvestable plants were recorded 18 months after planting (also time of best expression of those traits).

Soil samples were taken before applying treatments and then two and 24 months after the beginning of the experiment. Six soil samples per plot were taken at two depths (0–20 and 20–40 cm). The samples were carefully mixed and a composed sample was obtained for each depth. Samples were dried at 45 ºC and passed through a 2 mm mesh sieve. Soil analysis was performed following standard procedures, with the cation exchange capacity (CEC) determined at pH 7.0 (Raij 1991; Abreu et al., 2001).

Leaf samples were taken at harvest and consisted of leaflets of six plants from the inner rows. From each plant, 12 leaflets were collected in the middle portion of the second fully expanded leaf (leaf +2). Twe samples after conventional preparation procedures, were analyzed according to methods described by Bataglia et al. (1983) and Abreu et al. (2001), and expressed as total contents. N quantification was carried out by Kjeldahl distillation. After dry ashing the tissue and HCl dissolution, other nutrients were determined by spectrophotometry (P, B), flame photometry (K), and inductively coupled plasma spectrometry (Ca, Mg, Cu, Fe, Mn, and Zn).

Data analysis was performed by polynomial regression and curve fitting (Steel & Torrie, 1980; Hyams, 1997). The dose of lime that led to maximum plant response was calculated by equaling the derivative of the best-fitted equation to zero.

RESULTS AND DISCUSSION

Selected soil chemical characteristics at different liming rates sixty days after liming application, are presented in table 1. Two months after liming, soil base saturation was 26, 37, 46, 56, and 74 % at 0–20 cm soil depth. Soil base saturation increased markedly with liming, but even 60 days after lime application the observed base saturation values were lower than those predicted at the beginning of the experiment. The relationship between the two values (theoretically estimated and analytically determined) can be expressed by the following equation: V % determined = 23.834 + 0.479 V % estimated ($R^2 = 0.9880$; $P < 0.01$). Factors such as lime granulometry, soil-buffering capacity, chemical balance of lime reactions, and possible losses of Ca and Mg are responsible for this behavior (Raij 1991; Quaggio, 2000).

The increments in pH, Ca and Mg, and the decrease in Al in the 20–40 cm layer indicate a positive sub-superficial effect of lime. As pointed out by Quaggio (2000), liming effects (increased soil pH, Ca and Mg contents, and reduced exchangeable Al, decreasing P adsorption) are doses related and normally restricted to the application layer (0–20 cm) or immediately above that (20–40 cm). Nevertheless, we should bear in mind that the root system of peach palm is very superficial, with around

Table 1. Selected soil chemical characteristics of the plots, sixty days after liming. Pariquera-Açu, São Paulo, Brazil

Soil depth	Limestone applied	Organic matter	pH in $CaCl_2$	P Resin	K	Ca	Mg	H + Al	CEC(1)	Soil base saturation
cm	Mg ha^{-1}	%		Mg dm^{-3}		cmol$_c$ dm^{-3}				%
0–20	0	2.2	4.1	1	0.09	1.5	0.9	7.2	9.7	26
	0.7	2.3	4.2	1	0.06	2.2	1.2	5.8	9.3	37
	4.7	2.2	4.5	1	0.03	2.8	1.2	4.7	8.7	46
	8.7	2.2	4.8	1	0.11	3.5	1.3	3.8	8.7	56
	14.6	2.1	5.3	24	0.04	6.3	1.7	2.8	10.8	74
20–40	0	1.6	3.9	1	0.01	1.1	0.3	8.0	9.4	15
	0.7	1.9	4.1	1	0.05	1.6	0.8	6.5	8.9	27
	4.7	1.6	4.6	1	0.03	2.6	1.2	4.3	8.1	47
	8.7	1.6	4.6	2	0.07	3.8	1.5	3.8	9.2	59
	14.6	1.3	5.7	16	0.01	7.4	1.8	2.0	11.2	82

(1) CEC - Cation Exchange Capacity.

70-80 % of it in the first 0–20 cm soil layer (Bassoi et al., 1999; Bovi et al., 1999; Lopez-Zamora et al., 2002; Ramos, 2002; Vega, 2003). Therefore, some benefic effects of liming, such as decreased subsoil acidity and promotion of a deeper root development, are not potentially useful for this palm.

Twenty-two months after liming application, the soil base saturation at 0–20 cm depth was 29, 39, 50, 62, and 79 % for 0, 0.7, 4.7, 8.7, and 14.6 Mg ha^{-1} of magnesium limestone, respectively. These values are higher than those reported two months after liming (Table 1), and suggested that lime reactions had not ended by the time of first soil sampling. Lime reaction in soils, even 24 months after its application, was observed by Camargo et al. (1982), Quaggio et al. (1982) and Oliveira et al. (1997).

Plant response to liming, leading to maximum efficiency in growth and yield as an interaction of factors related to the studied crop, to the soil itself, as well as to the rate, purity, and particle size of the lime utilized (Quaggio, 2000). The regression analysis of growth data showed significant differences ($P < 0.05$) among liming rates for plant diameter and height, as well as for percentage of plants with suckers and number of suckers per plant.

Peach palm plant diameter (Figure 1a) and height (Figure 1b), as well as number of suckers (Figure 1c) and percentage of plants with suckers (Figure 1d) responses to liming followed significant ($P < 0.01$) cubic trends (Figure 1). There was a good fit up to 8.7 Mg ha^{-1} for all growth traits. For higher doses the fitted third order (cubic) curve has no biological meaning, and responses are better represented by a linear equation fitted at that interval. Growth response, as indicated by these four measured variables, increased up to a 46 % soil base saturation (corresponding to 4.7 Mg ha^{-1}). It worth noting that especially for plant height (a trait highly correlated to the harvest time and heart-of-palm yield), the highest tested liming rate (14.6 Mg ha^{-1}) resulted in smaller values than the control (Figure 1b), suggesting overliming effects. As suggested by Sanchez (1976) and Quaggio (2000), the major consequences of overliming are yield reduction, soil structure deterioration, and reduced availability of phosphorus, boron, zinc, and manganese.

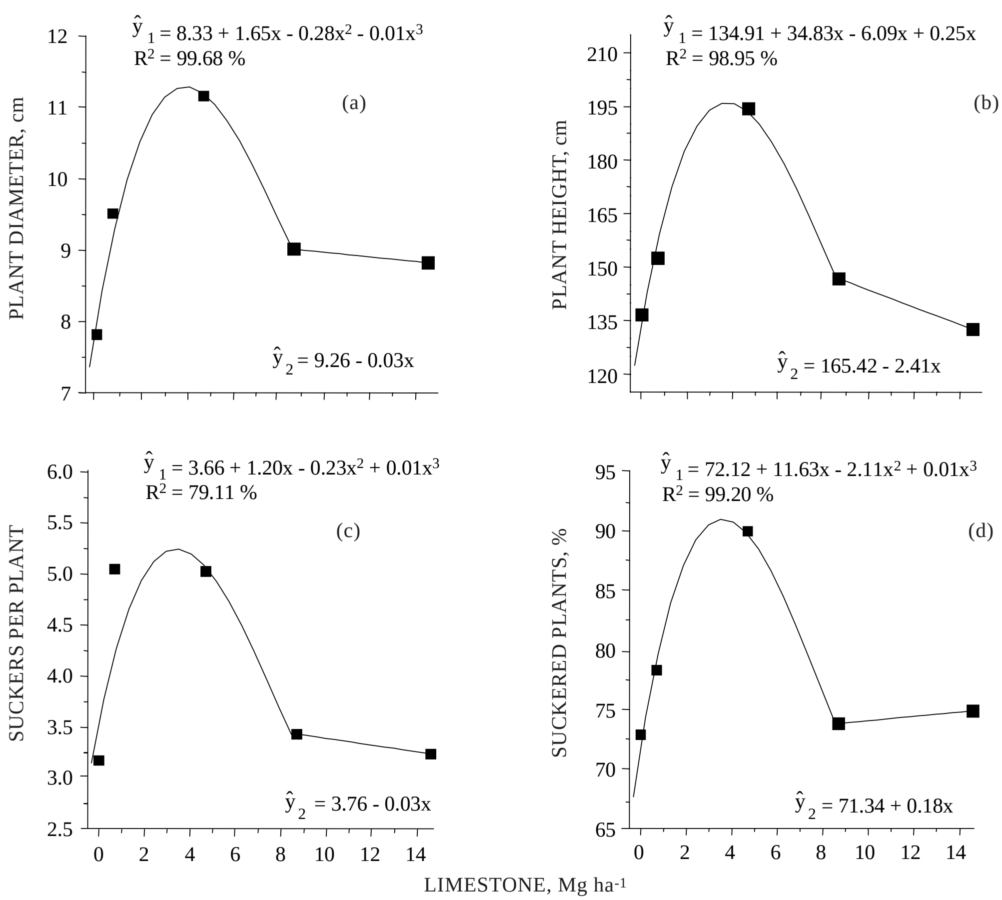

Figure 1. Mean growth of peach palm plants submitted to five liming rates, evaluated for plant diameter (a), plant height (b), number of suckers (c), and percentage of plants with suckers (d). Bars represent the standard deviation. Pariquera-Açu, São Paulo, Brazil.

Yield response to lime, as evaluated by percentage of harvestable plants (Figure 2a), heart-of-palm (Figure 2b), and residue (basal and apical) yield at the first harvest (Figure 2c), was significant ($P < 0.01$) and similar to plant diameter and height (Figures 1a and 1b). This was expected, as the total yield (Figure 2d) is a function of the number of plants harvested per plot and the individual yield of each harvested palm. Heart-of-palm yield also showed a significant ($P < 0.01$) cubic trend for the data. There was a marked yield response to liming up to a 46 % soil base saturation (obtained by the application of 4.7 Mg ha^{-1} of limestone), with a sharper decrease after words.

When 4.7 Mg ha^{-1} of limestone per hectare was applied to the plots, there was an increase of 30 % in harvestable plants compared to the control (Figure 2a), indicating that harvest could be started earlier than 18 months in the best treatments. Also, heart-of-palm and residue yield (Figures 2b and 2c) was significantly higher in that treatment when compared to all the others. At this lime rate the relative yield response was 77 % higher than that of the control treatment.

Growth and yield responses to liming have been reported for coconut and oil palm (Manciot et al., 1980; Chew et al., 1984; Romney, 1987; Resende et al., 1991). Although significant responses to lime application have been frequently observed on acid peat soils, especially for those two palm species, it is not clear whether this response was due to a direct effect of Ca and Mg supply and reduction in toxic Al, or to an indirect effect of making N, P and micronutrients more readily available. Acid soil infertility is frequently due to three major factors: aluminum toxicity, calcium or magnesium deficiency, and manganese toxicity (Sanchez, 1976). Nevertheless, palms are known to tolerate high concentration of exchangeable Al and they usually do not respond to P supply (Ollagnier et al., 1970, Romney, 1987; Tampubolon et al., 1990), due to their high mycorrhizal colonization (Sieverding, 1991; Marschner, 1996; Sudo et al., 1996). They are, however, very responsive to N and Mg (Davis & Pillai, 1966; Manciot et al., 1980; Secretaria & Maravilla, 1997; Ramos, 2002).

Limestone rates of 8.7 and 14.6 Mg ha^{-1} promoted a significant reduction in growth and, especially yield, compared to the best treatment (4.7 Mg ha^{-1}).

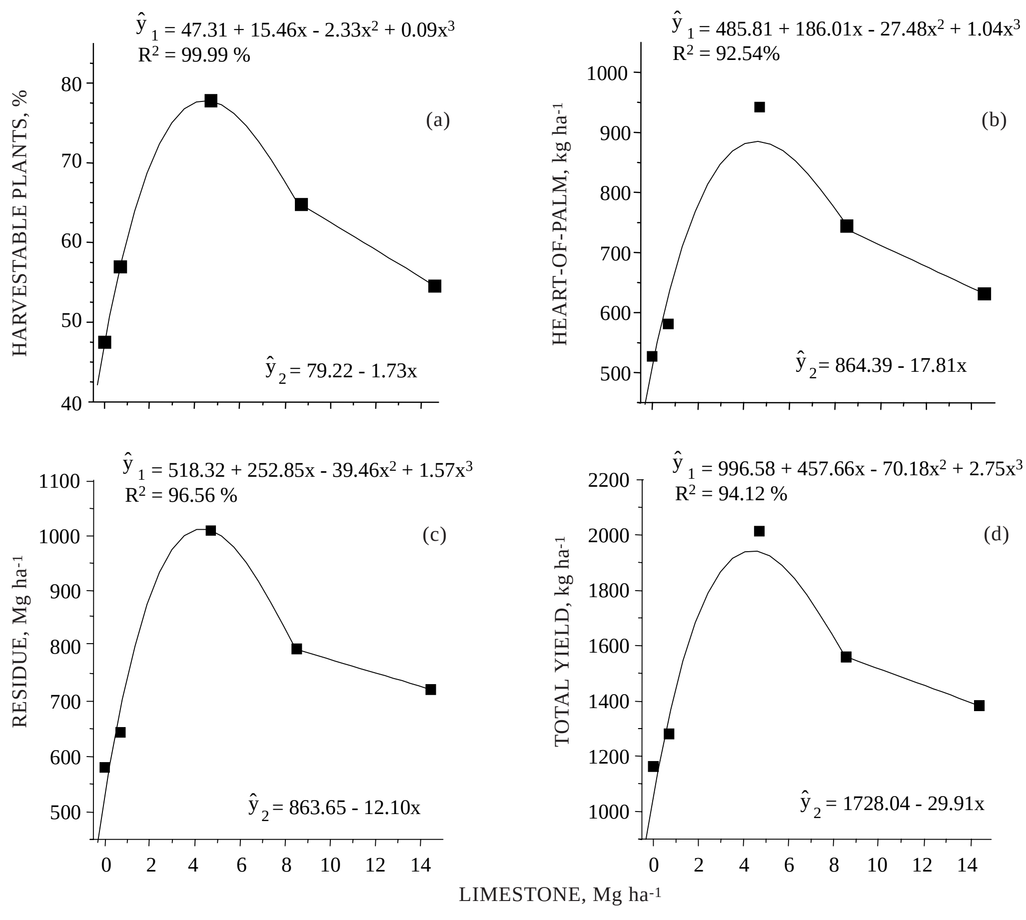

Figure 2. Mean yield of peach palm plants submitted to five liming rates, evaluated for percentage of harvestable plants (a), palm heart weight (b), residue weight (c), and total yield (d). Bars represent the standard deviation. Pariquera-Açu, São Paulo, Brazil.

Table 2. Macro and micronutrients in the leaves of peach palm plants two years after planting. Pariquera-Açu, São Paulo, Brazil

Limestone rates	N	P	K	Ca	Mg	B	Cu	Fe	Mn	Zn
Mg ha^{-1}			g kg^{-1}					mg kg^{-1}		
0	32.25	4.30	13.45	2.89	2.12	14.00	4.95	126.75	33.25	24.10
0.7	32.52	3.52	17.87	3.88	2.75	14.75	6.32	167.00	37.00	32.00
4.7	30.90	3.33	13.80	2.85	2.25	14.25	4.57	183.25	26.25	24.32
8.7	35.42	3.08	14.45	3.35	2.22	12.75	4.32	136.25	18.75	24.20
14.6	36.25	2.90	13.45	4.37	2.54	12.25	4.27	151.00	17.75	25.20

The often observed yield decrease in some plants submitted to liming has normally been associated to a decrease in Zn, Cu, Fe, and Mn (Kamprath, 1970; Quaggio, 2000). Although there was no clear relationship between leaf zinc contents (Table 2) and the soil of base saturation or the pH of the soil (Table 1), there was a significant negative correlation between leaf Mn, B and P concentration with soil base saturation, pH, or other related parameters. The relationship between leaf Mn and soil pH or soil base saturation was especially strong ($r = -0.9138$, $P < 0.01$), suggesting that peach palm could be very sensitive to the decreased availability of Mn as a result of soil pH elevation. Micronutrients were not applied to the plants and soil initial levels of those elements were usually low (B 0.20, Cu 0.10, Fe 159, Mn 1.57 and Zn 0.53 mg dm^{-3}).

Although there are no reports of micronutrient requirements for peach palm, responses to Mn, B, Fe and Zn have been reported for other related crops such as coconut and oil palm (Ollagnier et al., 1970; Manciot et al., 1980; Romney, 1987). Davis & Pillai (1966) found a clear relationship between the leaf micronutrient status, especially Mn and Mo, and root diseases in coconut. The application of those elements contributes to restore plant growth and yield. Low foliar manganese levels had also been associated with diseases caused by *Fusarium* in oil palm (Ollagnier et al., 1970). In Africa, there was a decrease in the progression of this disease in plots where manganese sulphate had been applied. Occurrence of *Fusarium* in peach palm has been reported in Vale do Ribeira in the last ten years (Bovi, 1998b; Pizzinatto et al., 2001). A severe incidence of this disease was observed in 1997 by the authors in an area previously cultivated with banana and limed with 6 to 8 Mg ha^{-1} of limestone. These reports, together with the significant growth and yield decrease when soil base saturation increased above 46 %, and the corresponding decrease in leaf Mn and B concentration, seem to indicate that micronutrients play an important role in peach palm nutrition. Nevertheless, further research on this subject is necessary to confirm such hypothesis.

Estimated maximum growth and yield responses suggest that for soils with chemical characteristics similar to the one studied here and using the same type of limestone, lime should be applied in peach palm culture up to 4.3 Mg ha^{-1} of dolomitic limestone. This rate results in an initial determined soil base saturation of 51.4 %, which, considering the relationship expressed in the formula previously shown, resulted in an estimated value of 57.3 %, very close to 60 %, which is the soil base saturation empirically recommended earlier for this crop (Cantarella & Bovi, 1996).

It should be pointed out that plant responses to liming are not long-lasting, especially in crops where nitrogen applications are high and frequent, as in peach palm (Bovi, 1998b, Bovi et al., 2002; Ares et al., 2002a; Schroth et al., 2002). Therefore, soil acidity and liming needs should be monitored by periodical soil testing. Practical experience has shown that liming in peach palm cultivation should be reapplied every four years, in order to maximize plant response to liming. Nonetheless, due to the large and superficial root system of this palm (Bassoi et al., 1999; Bovi et al., 1999; Lopez-Zamora et al., 2002; Ramos, 2002; Vega, 2003), topsoil lime dressing without incorporation is recommended, thus decreasing the liming efficiency. Therefore, liming rates should be tested for these conditions.

CONCLUSIONS

1. Peach palm is responsive to liming in the first two years after planting, attaining maximum growth and heart-of-palm yield at 51.4 % soil base saturation.

2. Overliming results in decreased growth and yield in comparison to the best treatment (4.3 Mg ha^{-1} of magnesium limestone).

3. Adequate liming enhances the suckering capacity of peach palm plants, contributing to the sustainability of the crop.

ACKNOWLEDGMENT

To Heitor Cantarella, scientific researcher at the Instituto Agronomico (IAC), for his suggestions for analyses and critical review of the manuscript.

LITERATURE CITED

ABREU, M.F.; ABREU, C.A. & ANDRADE, J.C. Determinação de fósforo, potássio, cálcio, magnésio, enxofre, cobre, ferro, manganês, zinco, níquel, cádmio, cromo e chumbo em ácido nítrico usando métodos de US-EPA. In: RAIJ, B. van; ANDRADE, J.C.; CANTARELLA, H. & QUAGGIO, J.A., eds. Análise química para avaliação da fertilidade de solos tropicais. Campinas, Instituto Agronômico de Campinas, 2001. p.151-161.

ARES, A.; BONICHES, J.; MOLINA, E. & YOST, R.S. *Bactris gasipaes* agroecosystems for heart-of-palm production in Costa Rica: change in biomass, nutrient and carbon pools with stand age and plant density. Field Crops, 74:13-22, 2002a.

ARES, A.; QUESADA, J.P.; BONICHE, J.; YOST, R.S.; MOLINA, E. & SMYTH, J. Allometric relationships in *Bactris gasipaes* for heart-of-palm production agroecosystems in Costa Rica. J. Agric. Sci., 138:285-292, 2002b.

ARES, A.; FALCÃO, N.; YUYAMA, K.; YOST, R.S. & CLEMENT, C.R. Response to fertilization and nutrient deficiency diagnostics in peach palm in Central Amazonia. Nut. Cycl. Agroec., 66:221-232, 2003.

BATAGLIA, O.C.; FURLANI, A.M.C.; TEIXEIRA, J.P. & GALLO, J.R. Métodos de análise química de plantas. Campinas, Instituto Agronômico de Campinas, 1983. 48p. (Boletim Técnico, 78)

BASSOI, L.H.; FLORI, J.E.; SILVA, J.A.M.; ALENCAR, C.M. & RAMOS, C.M.C. Distribuição espacial do sistema radicular da pupunheira em solos irrigados no Vale do São Francisco. Eng. Agrí., 19:163-176, 1999.

BOVI, M.L.A. Expansão do cultivo da pupunheira para palmito no Brasil. Hortic. Bras., 15:183-185, 1998a.

BOVI, M.L.A. Palmito pupunha informações básicas para cultivo. Campinas, Instituto Agronômico de Campinas, 1998b. 50p. (Boletim Técnico, 173)

BOVI, M.L.A.; GODOY JR., G.; CAMARGO, S.B. & SPIERING, S.H. Caracteres indiretos na seleção de pupunheiras inermes (*Bactris gasipaes* H.B.K.) para palmito. In: CONGRESO INTERNACIONAL SOBRE BIOLOGIA, AGRONOMIA E INDUSTRIALIZACION DEL PIJUAYO, 4., Iquitos, 1993. Anais. San José, Universidade Federal da Costa Rica, 1993. p.163-176.

BOVI, M.L.A.; SPIERING, S.H. & BARBOSA, A.M.M. Densidade radicular de progênies de pupunheira em função de adubação NPK. Hortic. Bras., 17:186-193, 1999.

BOVI, M.L.A.; GODOY Jr., G. & SPIERING, S.H. Respostas de crescimento da pupunheira à adubação NPK. Sci. Agric., 59:161-166, 2002.

CAMARGO, A.P.; RAIJ, B. van; CANTARELLA, H.; ROCHA, T.R.; NAGAI, V. & MASCARENHAS, H.A.A. Efeito da calagem nas produções de cinco cultivares de milho, seguidos de algodão e soja. Pesq. Agropec. Bras., 17:1007-1012, 1982.

CANTARELLA, H. & BOVI, M.L.A. Pupunha para extração de palmito. In: RAIJ, B. van; CANTARELLA, H.; QUAGGIO, J.A. & FURLANI, A.M.C., eds. Recomendações de adubação para algumas culturas do Estado de São Paulo. Campinas, Instituto Agronômico de Campinas, 1996. p.240-242. (Boletim Técnico, 100).

CHEW, P.S.; KEE, K.K. & OOI, L.H. Management of coconuts and cocoa on acid sulphate soils. Planter, 60:483-500, 1984.

CLEMENT, C.R. & BOVI, M.L.A. Padronização de medidas de crescimento e produção em experimentos com pupunha para palmito. Act. Amaz., 30:349-362, 2000.

DAVIS, T. A. & PILLAI, N.G. Effect of magnesium and certain micro-nutrients on root (wilt) affected and healthy coconut palms in India. Oleagineux, 11:669-674, 1966.

HYAMS, D. CurveExpert 1.3: A comprehensive curve fitting system for Windows. http://wwwebicom.net/~dhyams. Starkville, 1997. [software].

KAMPRATH, E.J. Exchangeable aluminum as a criterion for liming leached mineral soils. Soil Sci. Soc. Am. Proc., 34:252-254, 1970.

LEPSCH, I.F.; SARAIVA, I.R.; DONZELI, P.L.; MARINHO, M.A.; SAKAI, E.; GUILLAUMON, J.R.; PFEIFER, R.M.; MATTOS, I.F.A.; ANDRADE, W.J. & SILVA, C.E.F. Macrozoneamento das terras da região do rio Ribeira de Iguape, SP. Campinas, Instituto Agronômico de Campinas, 1990. 181p. (Boletim Científico, 19)

LOPEZ-ZAMORA, I.; FALCÃO, N.; COMERFORD, N.B. & BARROS, N.F. Root isotropy and evaluation of a method for measuring root distribution in soil trenches. For. Ecol. Manag., 166:303-310, 2002.

MANCIOT, E.; OLLAGNIER, M. & OCHS, R. Mineral nutrition and fertilization of the coconut around the world. Oleagineux, 35:23-27, 1980.

MARSCHNER, H. Mineral nutrient acquisition in nonmycorrhizal and mycorrhizal plants. Phyton-Annales Rei Botanicae, 36:61-68, 1996.

OLIVEIRA, E.L.; PARRA, M.S. & COSTA, A. Resposta da cultura do milho, em um Latossolo Vermelho-Escuro álico, à calagem. R. Bras. Ci. Solo, 21:65-70, 1997.

OLLAGNIER, M.; OCHS, R. & MARTIN, G. Adubação do dendezeiro no mundo. Fertilité, 36:1-67, 1970.

PIZZINATTO, M.A.; BOVI, M.L.A.; SPIERING, S.H. & BINOTTI, C.S. Pathogenicity of five species of *Fusarium* to pejibaye plants (*Bactris gasipaes*). Summa Phytopatol., 27:263-266, 2001.

QUAGGIO, J.A. Acidez e calagem em solos tropicais. Campinas, Instituto Agronômico de Campinas, 2000. 111p.

QUAGGIO, J.A.; MASCARENHAS, H.A. & BATAGLIA, O.C. Resposta da soja à aplicação de doses crescentes de calcário em Latossolo Roxo distrófico do cerrado. II. Efeito residual. R. Bras. Ci. Solo, 6:113-118, 1982.

RAIJ, B. van. Fertilidade do solo e adubação. Piracicaba, Potafos, 1991. 343p.

RAMOS, A. Análise do desenvolvimento vegetativo e produtividade da palmeira pupunha (*Bactris gasipaes* Kunth) sob níveis de irrigação e adubação nitrogenada. Piracicaba, Escola Superior de Agricultura Luis de Queiroz. 2002. 113p. (Tese de Doutorado)

RESENDE, M.L.V.; BEZZERA, J.L.; SANTANA, C.J.L. & SOBRAL, L.F. The effect of fertilizers and benomyl on control of coconut verrucosis. Agrotropica, 3:45-51, 1991.

ROMNEY, D.H. Response to phosphate by coconut (*Cocos nucifera* L.) in coastal Tanzania. Oleagineux, 42:317-324, 1987.

SAKAI, E. & LEPSCH, I.F. Levantamento pedológico detalhado da Estação Experimental de Pariquera-Açu. Campinas, Instituto Agronômico de Campinas, 1984. 56p (Boletim Técnico, 83)

SANCHEZ, P.A. Properties and management of soils in the tropics. New York, John Wiley & Sons, 1976. 618p.

SCHROTH, G.; ELIAS, M.E.A.; MACEDO, J.L.V.; MOTA, M.S.S. & LIEBEREI, R. Mineral nutrition of peach palm (*Bactris gasipaes*) in amazonian agroforest and recommendation for foliar analysis. Europ. J. Agron., 17:81-92, 2002.

SECRETARIA, M.I. & MARAVILLA, J.N. Response of hybrid coconut palms to application of manures and fertilizers from field-planting to full-bearing stage. Plant., Rech., Dével., 4:126-138, 1997.

SIEVERDING, E. Vesicular-arbuscular mycorrhiza management in tropical agrosystems. Eschborn, Technical Cooperation, 1991. 371p.

STEEL, R.G. & TORRIE, J.H. Principles and procedures of statistics. New York, MacGraw-Hill, 1980. 632p.

SUDO, A.; SILVA, E.M.R.; BOVI, M.L.A; ALMEIDA,D.L. & COZZOLINO, K. Produção de mudas de pupunheira colonizadas por fungos micorrízicos arbusculares. R. Bras. Ci. Solo, 20:529-532, 1996.

TAMPUBOLON, F.H.; DANIEL, C.; OCHS, R. Réponses du palmier à huile aux fumures azotées et phosphorées à Sumatra. Oléagineux, 45:475-484, 1990.

TISDALE, S.L. & NELSON, W.L. Soil fertility and fertilizers. New York, Macmillan Publishing Co, 1975. 694p.

VEGA, F.V.A. Uso de lodo de esgoto na implantação da cultura da pupunheira (*Bactris gasipaes* Kunth). Campinas, Instituto Agronômico de Campinas, 2003. 129p. (Tese de Mestrado)