

BIOMASS ACCUMULATION AND ARBUSCULAR MYCORRHIZAL COLONIZATION IN PEJIBAYE (*Bactris gasipaes* Kunth) AS A FUNCTION OF NPK FERTILIZATION

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Abstract

Pejobaye or peach palm (*Bactris gasipaes* Kunth) is being cultivated in many countries for heart-of-palm or palmito. The estimated area of pejobaye cultivation in Brazil is over 12,000 hectares. Large amounts of nutrients are exported during harvest, and fast and constant growth is imperative for economic large-scale cultivation; hence, replacement of nutrients, based on adequate fertilization, is essential. It is known that unbalanced fertilization can cause nutritional problems in palms, impairing growth and yield. In order to identify responses of pejobaye to NPK fertilization, a long-term trial is being carried out in Sao Paulo State, Brazil. The experimental design is an (1/2) 43 incomplete factorial, with 32 treatments, with four yearly rates of N (0-400 kg N ha⁻¹), P (0-200 kg P₂O₅ ha⁻¹) and K (0-200 kg K₂O ha⁻¹), split into five applications. Data collected from five-year old plants showed that shoot and root biomass varied with NPK fertilizer rates, as did root arbuscular mycorrhizal (AM) colonization. A significant and positive linear effect of N was detected for shoot biomass, whereas for mycorrhizal colonization a quadratic N effect was found. Quadratic effects of P for root biomass and shoot/root biomass were detected. Potassium produced significant negative effects on mycorrhizal colonization and shoot/root ratio, and positive effects on root biomass; a quadratic effect of K was detected on offshoot number. Nutrient interactions were only significant for mycorrhizal colonization (P*K) and for shoot biomass (N*K). Significant positive correlation coefficients were found for AM colonization with root biomass and soil organic matter, while negative correlations were found with soil pH and magnesium content. Root biomass was negatively correlated with soil pH, base saturation, calcium and magnesium. The importance of a balanced combination of macronutrients for the overall growth of pejobaye plants was emphasized.

1. Introduction

Pejobaye or peach palm (*Bactris gasipaes* Kunth) is cultivated in several tropical

countries for heart-of-palm production, although heart-of-palm or palmito, can be extracted from other palm genera (Tabora, P.C. *et al.*, 1993). It is basically composed of the unexpanded leaves immediately above the apical meristem. Large-scale pejibaye cultivation aiming heart-of-palm production has some especial characteristics in relation to the cultivation of this and other palms for fruit. It involves periodical and constant harvesting, with plants in a continuous juvenile vegetative stage. The speed with which above-ground biomass is renewed (due to the high suckering capacity of the species) is a good indicator of the productivity and the economic life span of this crop.

The area cultivated with pejibaye for heart-of-palm purpose in Brazil is exponentially increasing since 1990 (Bovi, M.L.A., 1997). Nowadays it is estimated as over 12,000 hectares. Different ecological regions are going into cultivation and various degrees of technology and inputs are applied to this new crop. Nevertheless, high yields at relatively low costs have been achieved in regions with high temperatures and high and well distributed rainfall, since pejibaye is a neotropical palm. However, soils in the more adapted regions are frequently allic, with low nutrient levels and high aluminum content. Large amounts of nutrients are exported or lost during harvests (Cantarella, H. and Bovi, 1996; Mora-Urpí, J. *et al.*, 1997), hence constant and high yields are based on high annual fertilizer inputs. Consequently, the magnitude of growth responses depends on the soil nutrient status, natural nutrient losses or unavailability (leaching, denitrification, and immobilization), plant uptake and its ability to interact effectively with environmental variables and with soil macro and microbiota.

Fertilizers in developing country are costly and its use must be optimized in order to increase yield economically while meeting environmental concerns. Improved root systems and their close relationship with soil microorganisms lead to efficient nutrient uptake. Pejibaye is a mycorrhizal dependent species (Sudo, A., 1996), showing enhanced growth due to increased nutrient acquisition (Janos, D.P., 1977; Ruiz, P.O., 1993; Sudo, A., 1996). Mycorrhizal colonization increases the spatial availability of soil mineral nutrients, with consequent enhancement of host plant growth, particularly on nutrient-poor soils (Marschner, H., 1996).

In order to identify responses of pejibaye to NPK fertilization, a series of long-term NPK trials are underway in Brazil. This paper presents partial results of one five-year trial, with three heart-of-palm harvests (beginning two years after planting), using data on root and shoot biomass prior to the fourth harvest. Emphasis is given also to indigenous arbuscular mycorrhizal (AM) colonization due to the intricate, always present, soil-plant-microbiota relationship.

2. Materials and methods

2.1. Plant material

The plants studied belong to the Pará landrace and were obtained from seeds collected at the pejibaye germplasm bank, maintained by Instituto Agronomico (IAC) at its Experimental Stations. At the time of this study, plants were five years old and had been harvested three times since the beginning of the experiment.

2.2. Location

The trial was located in the Experiment Station of Ubatuba (23°27'S, 45°04'W, 6 m alt.) São Paulo, Brazil, in a region originally covered by the Atlantic Forest, with mean annual temperature and rainfall of about 20.8° C and 2,841 mm, respectively. The soil is an Allic Alluvial (Udifluvents), sandy-textured, with the following chemical properties at 0-20 cm: pH (CaCl₂) 4.2; organic matter 34 g dm⁻³, P 12 mg dm⁻³, K⁺ 2.2, Ca²⁺ 6, Mg²⁺ 4, H⁺+Al³⁺ 72 mmol_c dm⁻³, and 14% base saturation of the CEC at pH 7.0, determined by methods described by Raij, B. *et al.* (1986), which involves an ion-exchange procedure for the P, Ca, Mg, and K extraction. The area was limed prior to setting up the experiment to attain 50% base saturation.

2.3. Design

The experimental design was an $(1/2)^4$ fractional factorial with two blocks, without replication, and a total of 32 plots, as proposed by Colwell, J.D. (1978), with treatments adjusted to allow calculation of all first order interactions. Treatments consisted of four annual rates of N (0, 100, 200, and 400 kg N ha⁻¹, as nitrochalk), P (0, 50, 100, and 200 kg P₂O₅ ha⁻¹, as triple superphosphate), and K (0, 50, 100, and 200 kg K₂O ha⁻¹, as potassium chloride), split in five applications during the rainy season. No micronutrients were applied. Fertilizers were surface-applied in 50 cm-wide bands along plant rows. Each plot consisted of 24 plants, of which the eight centrally located were the sampling units. Planting spacing was 2 x 1 m.

2.4. Measurements and estimates

Plant growth was assessed by measurements of plant diameter and height, as well as number of green leaves and offshoots. Shoot biomass was estimated, considering only the main stem biomass, by means of an allometric function developed with plant samples from the same experiment.

Root samples were collected, between and within planting rows, using a root-soil auger sampler, at a 50 cm distance from the main stem and at 0-20 cm soil depth. Root biomass was estimated from root density data, assuming radial symmetry and that more than 80% of the root system of this palm is located at 0-20 cm depth (Vandermeer, J., 1977; Ferreira, S.A.N. *et al.*, 1980; 1995; Morales, A.L. and Vargas, 1990). Root and shoot biomasses were expressed as dry weight (kg plant⁻¹). Soil samples were collected periodically and analyzed by the methods described by Raij, B. *et al.* (1986).

AM colonization was calculated following standard procedures. Rhizospheric soil and roots were stored at 4° C until processing. Roots were washed in tap water and cleared in 10% KOH, 90° C for one hour, then 0.75% H₂O₂ was added. After washing in water, the material was acidified with 1% HCl for 10 minutes and stained in trypan blue in 70% acidified glycerol (w:v) for 10 minutes (Phillips, J.M. and Hayman, 1970; Grace, C. and Stribley, 1991). Percent root length with mycorrhizal infection was determined by the grid line intersect method (Giovannetti, M. and Mosse, 1980).

2.5. Statistical analysis

Data were analyzed, following the established design, using SAS GLM and REG procedures. Response functions of the type $Y = b_0 + b_1N + b_2N^2 + b_3P + b_4P^2 + b_5K + b_6K^2 + b_7NP + b_8NK + b_9PK$ were adjusted to the measured variables, where Y is the variable response, b is the regression coefficient, and N, P, and K are rates of N, P₂O₅, and K₂O, in kg ha⁻¹ year⁻¹, respectively. Stepwise regression, with maximum R statement, was applied to identify the best fitting equations.

3. Results

3.1. Shoot biomass

Main stem biomass varied among treatments, with values ranging from 1.33 to 2.14 kg plant⁻¹ (Table 1). There was a significant interaction between nitrogen (N) and potassium (K) levels affecting shoot biomass (F 6.12*). A negative effect of increasing K supply at low levels of N was found. The intensity of this effect decreased with increasing doses of N, until no significant effect of K was detected at maximum nitrogen supply (Fig. 1). Although mean shoot biomass showed a positive linear relationship with phosphorus (P) (Table 2 and Fig. 2), no significant effect of P was detected by the analysis of variance.

3.2. Root biomass

Variation among treatment means for root biomass was higher than that for shoot biomass, ranging from 1.51 to 5.14 kg plant⁻¹. P and K showed significant effects on root

biomass (5.88* and 5.39*, respectively). Root biomass increased linearly with K supply (Fig. 3), while a negative quadratic effect was found for P, with a minimum value (2.12 kg plant⁻¹) at 100 kg ha⁻¹ (Fig. 4). Nitrogen supply did not affect root biomass (Tables 1 and 2).

3.3. Offshoot number

Mean offshoot number of pejiabaye plants also differed among treatments, with values varying from 2.41 to 3.96. The results showed a positive quadratic effect of K (Fig. 6), with a maximum value found at 150 kg ha⁻¹, and a significant NP interaction (4.85*). There was an increase in offshoot number with P supply, which was more intense at low levels of N (Fig. 5).

3.4. Shoot/root biomass ratio

Shoot/root biomass ratio varied from 0.34 to 1.39. There was a significant positive quadratic effect for P (maximum value of 0.96 at 100 kg ha⁻¹) and a negative linear effect for K, with values ranging from 0.47 to 0.74 (Figs. 7 and 8). There was no significant effect of N on shoot/root biomass ratio.

3.5. Mycorrhizal colonization

Arbuscular mycorrhizal (AM) colonization, estimated as percentage of root infection, varied among treatments, with values ranging from 7 to 70%. A positive quadratic effect of N on mycorrhizal colonization was found, with a maximum value of 54% detected at 300 kg ha⁻¹ (Table 2 and Fig. 9). A significant interaction between P and K was also found for this trait. At higher P levels there was a slight decrease in AM colonization with increasing K supply (Fig. 10).

3.6. Best fit equations to estimate maximum and minimum nutrient effects

Table 3 presents the best fit equations relating the traits measured or estimated to the rates of NPK fertilizer applied. Determination coefficients varied from 0.39 to 0.48. Simplified models, taking into account only those elements that presented significant effect on the studied variables, were used to calculate rates of nutrients necessary to achieve maximum and minimum values. In these equations, nutrients to which no response was found were considered at the minimum rate.

Maximum mycorrhizal infection of 56% was estimated by the following NPK combination: N = 275-360 kg N ha⁻¹, P = 180-200 kg P₂O₅ ha⁻¹, and K = 0 kg K₂O ha⁻¹. A minimum value for AM colonization was 24%, obtained when N = 0, P = 200, and K = 200.

Maximum root biomass was estimated as 3.55 kg plant⁻¹, which corresponds to 17.75 ton ha⁻¹ in the 2 x 1 m planting density adopted. This value was obtained at the following NPK combination: N = 300-400, P = 0, and K = 180-200. Minimum root biomass of 1.55 kg plant⁻¹ (7.75 ton ha⁻¹) was obtained at N = 0, P = 100, and K = 0.

Maximum shoot biomass was estimated as 1.95 kg plant⁻¹, corresponding to 9.25 ton ha⁻¹, reached at N = 100-250, P = 180-200 and K = 0. Minimum value for shoot biomass was estimated as 1.41 kg plant⁻¹ (7.05 ton ha⁻¹) using N = 0, P = 0, and K = 200.

Maximum and minimum values for shoot/root biomass ratio were independent of the amount of N supplied. The ratio between shoot and root biomasses reached its maximum of 1.06 at the following combination: N = 0-400, P = 100, and K = 0. Minimum shoot/root biomass ratio estimate was 0.48, obtained with N = 0-400, P = 0; and K = 200.

Maximum offshoot number was estimated as 3.55, obtained with N = 180-200, P = 200 and K = 100-200. The minimum value for this trait was 2.75, reached when no nutrients were applied to the plants (N = 0, P = 0, and K = 0).

3.7. Correlation coefficients

Several significant correlations were found between the evaluated traits and soil nutrient status (Table 4). Root biomass was positively correlated with AM infection (0.3492*) and negatively correlated with shoot/root biomass ratio (-0.8850***). A significant coefficient for shoot biomass was found only with shoot/root ratio (0.3962*). No significant estimates were found with offshoot number. Soil pH showed negative correlation coefficients with AM colonization and root biomass, and positive with shoot/root biomass. Organic matter was positively correlated with AM infection and negatively with shoot/root ratio. Root biomass was negatively correlated with soil calcium and magnesium, as well as with soil base saturation. Correlations between offshoot number and soil P and Zn were positive. The ratio between shoot and root biomasses showed positive correlation coefficients not only with soil pH, but also with soil Ca and Mg, and with soil base saturation, as well.

Few significant relationships were found between the evaluated traits and leaf nutrient status. AM colonization was positively correlated with leaf Na and negatively with leaf Mg. A positive relationship between leaf B and shoot biomass was found. Leaf P, S and Zn presented positive correlation coefficient with offshoot number, whereas shoot/root biomass was only correlated with leaf P.

4. Discussion

Among the studied traits, the most striking response to N supply was found for mycorrhizal colonization. An increment of over 112% was reported at 200 kg N ha⁻¹ when compared with the no N treatment. A corresponding increment of 31% on root biomass and 9% on shoot biomass at the same N rate was also detected. Considering N and K (nutrients that showed better responses with pejibaye plants), the percent of root infection with mycorrhizal fungi was always correlated with shoot biomass (Table 2). Nitrogen is essential for the vegetative growth of palms, since it is used in protein synthesis and is part of the chlorophyll molecule (Secretaria, M.I. and Maravilla, 1997). Direct measurements and indirect estimates of shoot biomass are highly correlated with heart-of-palm weight and dimensions (Bovi, M.L.A. *et al.*, 1993; Clement, C.R. 1995; Mora-Urpí, J. 1997). Although the increment between 0 and 400 kg N ha⁻¹ on shoot biomass seems to be low (13%), it corresponds to an increase of over 146 kg of heart-of-palm per hectare, when harvested as we did. Also, this estimate is for the main stem only, and does not take into account the offshoots (mean of 2.9 to 3.4 per plant).

Pejibaye showed little response to applied phosphorus. Although not statistically significant, a slight increase in shoot biomass (6%) was detected by increasing P doses. Bonneau, X. *et al.* (1993) stated that the better the nitrogen nutrition, the lower the amount of phosphate to be applied to coconuts (*Cocos nucifera* L.). This is in accordance with our findings, in which a good response to P was found at low N levels. Positive response to N and absence of it to P, were detected earlier in the same experiment at the first harvest (Bovi, M.L.A. *et al.*, 1998) and also by Zamora, C. and Flores (1985), working with pejibaye in Costa Rica. For oil palm (*Elaeis guineensis* Jack.), as a rule, adequate N nutrition automatically improves leaf P contents and consequently growth and yield (Hartley, C.W.S., 1977; Ollagnier, M. and Ochs, 1971; Tampubolon, F.H. *et al.*, 1990). Nevertheless, as stated by Bonneau, X. *et al.* (1993), this does not remove the need for P fertilizer in the long run.

Maximum response to potassium with increasing supply of this element was detected for root biomass, which increased 40% from 0 to 200 kg K₂O ha⁻¹. Except for the enhancement in root biomass and in offshoot number, K supply showed an overall negative effect, decreasing mycorrhizal colonization (13%), shoot biomass (12%), and, most importantly, shoot/root biomass ratio (63%). This negative effect on shoot biomass and shoot/root ratio corresponds to a decrease of over 130 kg of heart-of-palm per hectare, if harvest is done as we did. These results are conflictant with those by Fremond,

Y. (1965) and Secretaria, M.I. and Maravilla (1997), for coconut, and by Kanapathy, K. (1976), for oil palm, who found marked response to K fertilizer. Nevertheless, in those papers emphasis was given in fruit yield and not vegetative growth. Potassium soil content in the plots of our experiment under K levels variation, ranged from 0.9 to 1.2 mmol dm⁻³, while K leaf content of plants in the same plots varied from 8.3 to 11.5 g kg⁻¹. These values are within the range of critical levels of this nutrient for the crop (Cantarella, H. and Bovi, 1996), suggesting that potassium was not a limiting nutrient in our soil in this growth stage, and this may explain the apparent contradiction between the behavior of pejibaye plants in response to this nutrient and that of other palms.

No attempts were made to classify the indigenous mycorrhizal fungi present in our experiment. Nevertheless, Silva (E.M.R. da Silva, unpublished data, 1994) had previously found two different species at this site - *Acaulospora* sp. and *Glomus macrocarpum* – with spore densities varying from 5.4 to 21.2 spores cc⁻¹ of rhizosphere soil. There was a significant negative relationship between mycorrhizal infection and soil pH. According to Siqueira, J.O. and Moreira (1997), diversity and occurrence of arbuscular mycorrhizal fungal species are influenced by soil acidity and soil aluminum saturation. Both genera were reported to be more tolerant to soil acidity (Fernandes, A.B. and Siqueira, 1989; Habte, M., 1995).

Our findings emphasize the importance of a balanced combination of macronutrients for the overall growth of pejibaye plants. A complex relationship among shoot biomass, root biomass and arbuscular mycorrhizal root infection was found, suggesting that nutrient efficiency can be improved in this crop by enhancing this relationship. This also means that researchers must decide what is an appropriate partition between shoot and root biomass in their growing conditions. Although shoot biomass is directly correlated with heart-of-palm yield, a well developed root system is necessary, not only to improve nutrient uptake, but also to buffer the plants from periodic water constraints, common in the tropics.

5. Conclusions

1. Data collected from five-year old plants showed that shoot and root biomass varied with NPK fertilizer rates. Variation was found also for root arbuscular mycorrhizal (AM) colonization.
2. Significant and positive linear effect of N was found for shoot biomass, whereas for mycorrhizal colonization a quadratic N effect was found.
3. Quadratic effects of P for root biomass and shoot/root biomass were detected.
4. K showed significant negative effects for mycorrhizal colonization, and for the relation shoot/root biomass. Positive effects on K application was found for root biomass. Quadratic effect on K doses was also detected for offshoot number.
5. Nutrient interactions were only significant for mycorrhizal colonization (P*K) and for shoot biomass (N*K).
6. Significant positive correlation coefficients were constated for AM colonization when paired with root biomass and soil organic matter. Negative correlations were found for this variable when paired with soil pH and magnesium content.
7. Root biomass showed negative correlations with soil pH, base saturation, calcium and magnesium.

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Tables

1. Magnitudes of F values, their significance and coefficients of variation for mycorrhizal colonization (AM - %), root and shoot biomass (kg plant⁻¹ - dry weight), offshoot number and shoot/root biomass ratio of pejíbaye plants, as a function of four doses of N P K, at Ubatuba, São Paulo, Brazil, 1998.

Sources	mycorrhizal colonization	root biomass	shoot biomass	offshoot number	shoot/root biomass
N	8.36**	3.96	5.23*	0.01	1.68
N*N	8.77**	0.23	0.80	0.57	0.33
P	0.64	0.23	2.98	2.63	0.33
P*P	0.16	5.88*	0.01	0.00	5.12*
K	0.51	5.39*	6.84*	4.78*	8.73**
K*K	0.03	0.00	0.16	4.15*	0.15
N*P	1.18	0.02	0.01	4.85*	0.01
N*K	0.02	0.22	6.12*	0.50	1.68
P*K	4.49*	1.01	0.03	0.62	0.98
CV(%)	34.19	28.99	9.69	9.89	30.75

***, **, * significant at 0,1; 1; 5% probability, respectively.

2. Mean values of mycorrhizal colonization (AM - %), root and shoot biomass (kg plant⁻¹ - dry weight), offshoot number and shoot/root biomass ratio of pejobaye plants, as a function of four doses of N P K, at Ubatuba, São Paulo, Brazil, 1998.

Sources	mycorrhizal colonization	root biomass	shoot biomass	offshoot number	shoot/root biomass
N					
0	21.41	2.39	1.67	3.31	0.76
100	32.41	2.31	1.85	3.24	0.86
200	45.50	3.02	1.82	3.20	0.71
400	38.20	3.01	1.90	3.28	0.66
P					
0	32.75	3.08	1.77	3.19	0.65
50	34.63	2.66	1.72	3.22	0.70
100	32.36	2.12	1.87	3.36	0.94
200	37.79	2.87	1.88	3.38	0.70
K					
0	35.88	2.28	1.88	2.98	0.93
50	34.95	2.61	1.88	3.30	0.75
100	34.95	2.66	1.79	3.40	0.74
200	31.75	3.19	1.68	3.35	0.57

3. Best fit equations (intercept, coefficients and determination coefficient) for mycorrhizal colonization (AM - %), root and shoot biomass (kg plant⁻¹ - dry weight), offshoot number and shoot/root biomass ratio of pejobaye plants, as a function of four doses of NPK, at Ubatuba, São Paulo, Brazil, 1998.

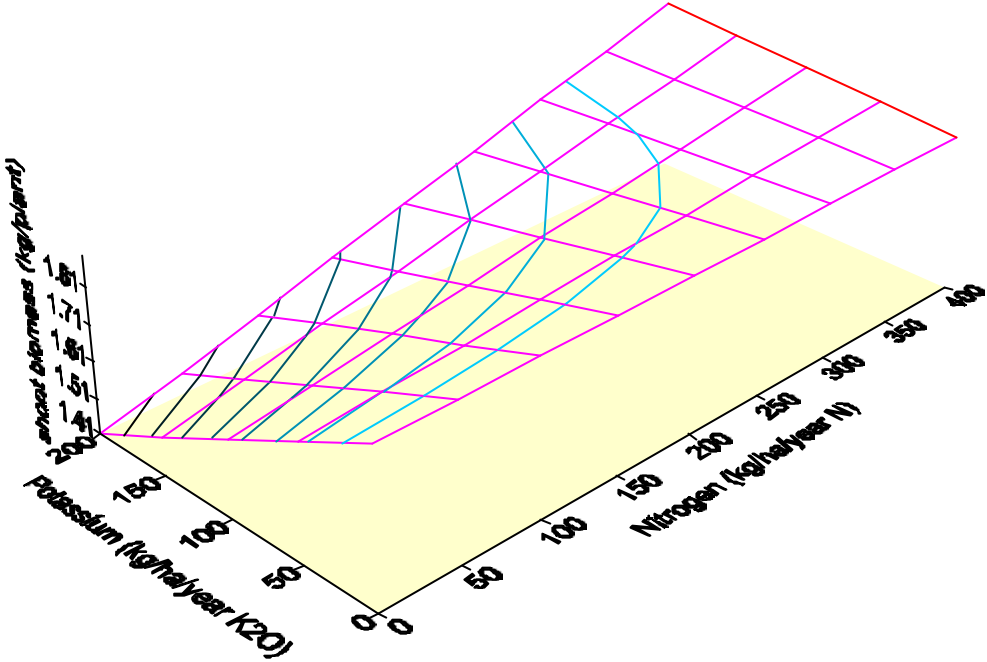
Sources	mycorrhizal colonization	root biomass	Shoot biomass	offshoot number	shoot/root biomass
intercept	23.5454458	2.43650227	1.84292138	2.76566130	0.80544098
N	0.1583137	0.00185079			
N*N	-0.0003437			0.00000226	-0.0000009
P		-0.01648852	0.00071950	0.00315746	0.00461742
P*P		0.00007532			-0.00002076
K		0.00431957	-0.00216660	0.00671975	-0.00162459
K*K				-0.00002455	
N*P	0.0002829			-0.00001114	
N*K			0.00000611		
P*K	-0.0004126				
R ²	0.4832365	0.3969284	0.4745188	0.4236702	0.3939999

4. Correlation coefficients between mycorrhizal colonization (AM %), root and shoot biomass (kg plant^{-1} - dry weight), offshoot number and shoot/root biomass ratio of pejiabaye plants, and soil and leaf analysis, in an experiment examining the effects of four doses of NPK, at Ubatuba, São Paulo, Brazil, 1998.

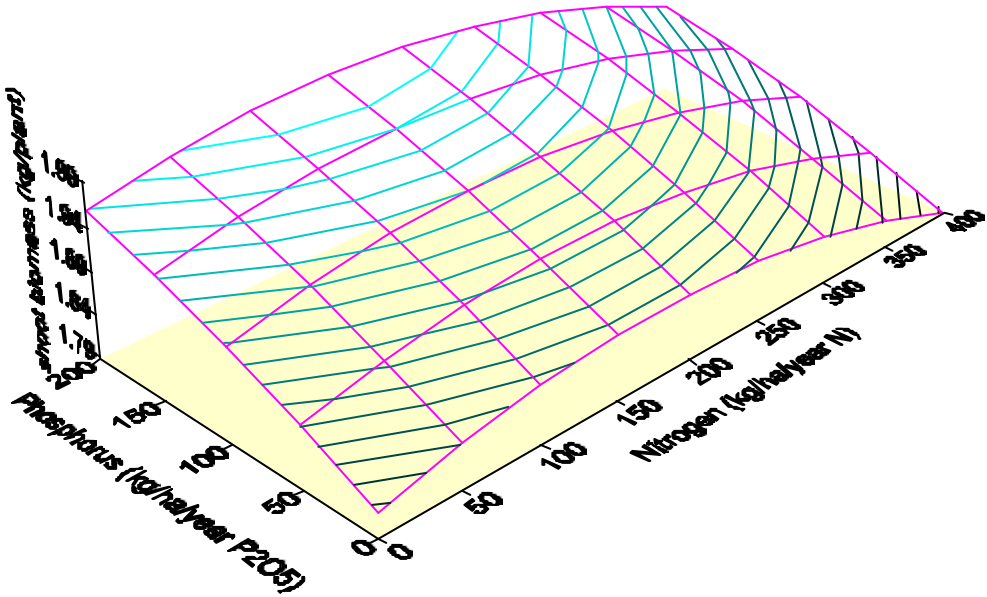
Sources	Mycorrhizal colonization	root biomass	shoot biomass	offshoot number	shoot/root biomass
root biomass	0.3492*	-	-0.1626	0.1448	-0.8850***
shoot biomass	0.1015	-0.1626	-	-0.2535	0.3962*
offshoot n.	0.0338	0.1448	-0.2535	-	0.0421
shoot/root ratio	-0.2541	-0.8850**	0.3962*	0.0421	-
Soil					
PH	-0.3243*	-0.4981**	0.1880	-0.2093	0.3659*
organic matter	0.3874*	0.1669	-0.1527	-0.2617	-0.3668*
P resin	0.1311	-0.0949	0.1663	0.3090	0.2419
Potassium	0.0908	-0.1253	-0.1949	0.1191	0.0270
Calcium	-0.3078	-0.4665**	0.1757	-0.2338	0.3719*
Magnesium	-0.3522*	-0.4795**	0.0989	-0.2426	0.3506*
Aluminum	0.3280	0.4419**	-0.2305	0.2430	-0.2901
CTC	-0.2976	-0.3396	-0.1129	-0.2554	0.1906
Hydrogen	0.1537	0.3511*	-0.3616*	0.0377	-0.3769*
Base saturation	-0.2855	-0.4546**	0.2521	-0.1462	0.3985*
Sodium	-0.1961	0.1329	-0.3248	0.2475	0.0954
Zinc	-0.0700	0.0486	-0.3876*	0.4570**	-0.0447
Boro	0.3034	0.0666	-0.1188	-0.2761	-0.2733
Leaf					
N	0.2489	0.0025	-0.1653	-0.0425	0.0052
P	0.2397	-0.1129	0.1474	0.3609*	0.3465*
K	0.2174	-0.0310	0.0371	0.1225	0.1768
Ca	-0.2980	0.0678	-0.0220	0.0625	-0.0513
S	-0.0909	-0.0721	0.0061	0.4531**	0.2639
B	0.0899	-0.0119	0.3360	0.0706	-0.0086
Na	0.4427**	0.0985	0.1141	-0.3050	-0.1518
Zn	-0.1005	-0.0102	-0.0028	0.4354**	0.0848
Mg	-0.4128*	0.0326	-0.1495	-0.0038	-0.0804

***, **, * significant at 0,1; 1; 5% probability, respectively.

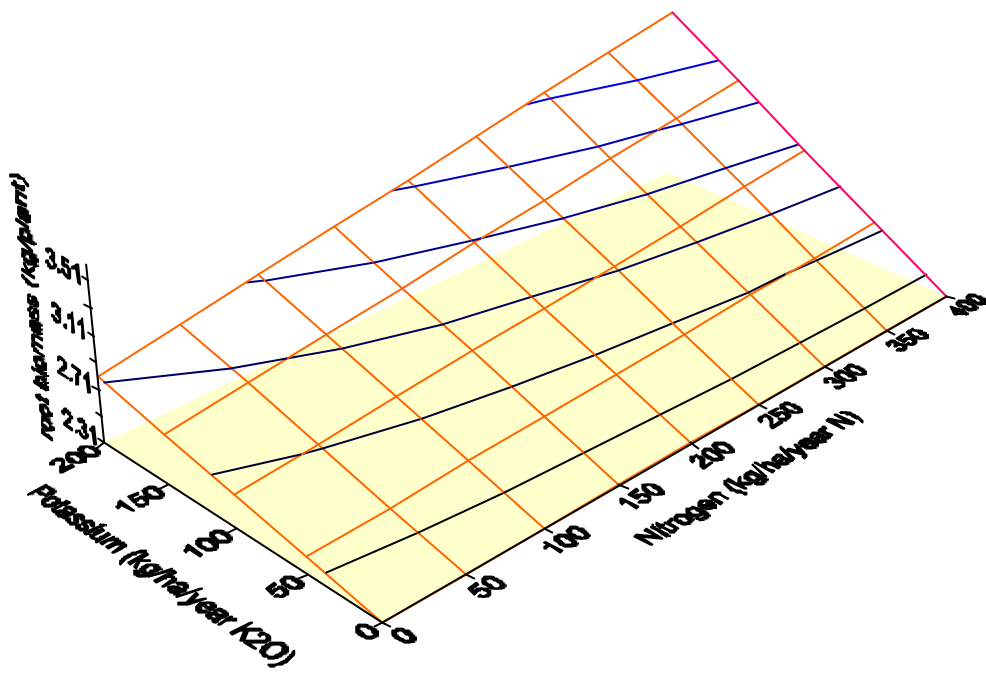
Figures



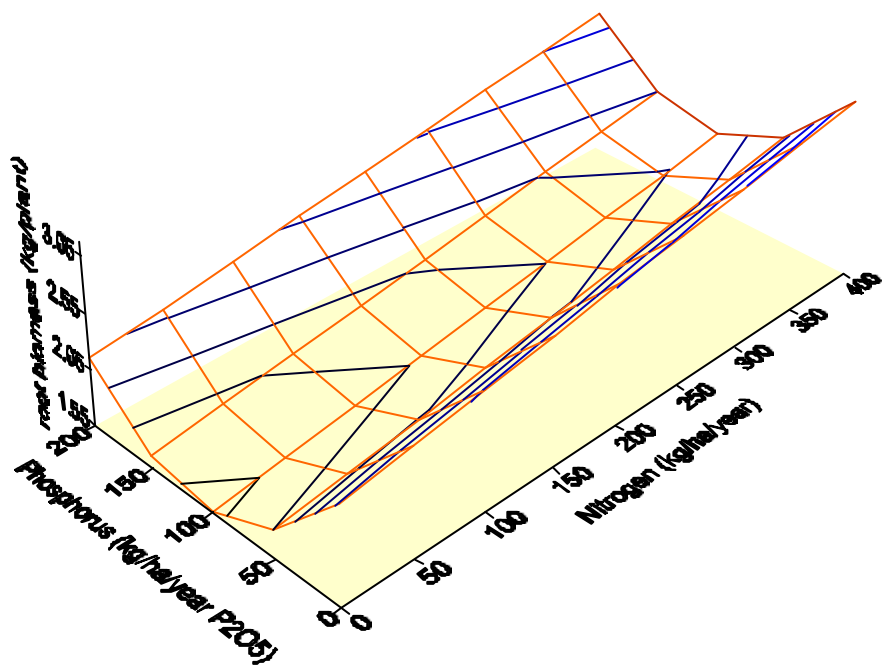
1. Shoot biomass of pejbaye as a function of NK fertilization.



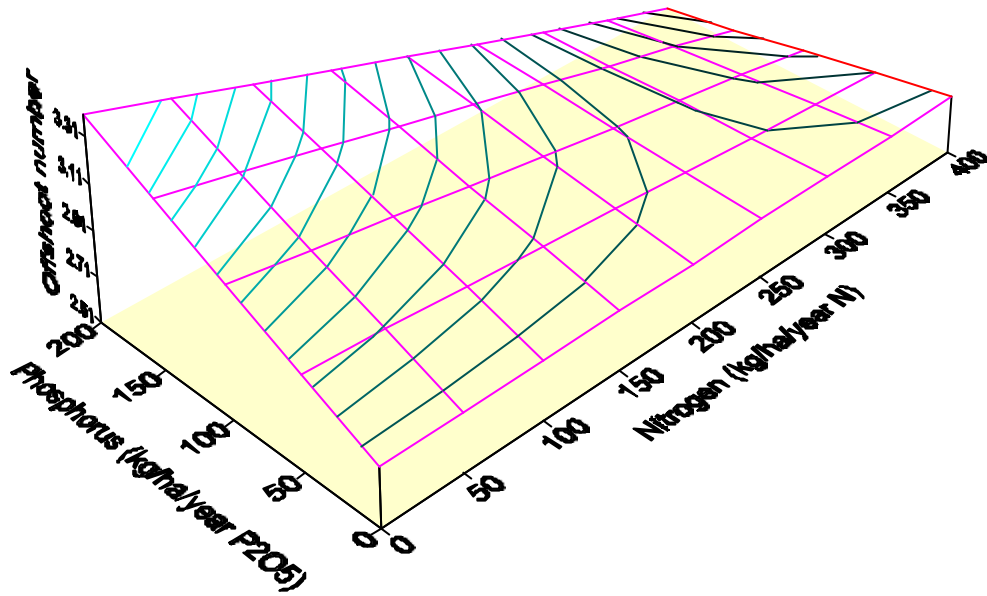
2. Shoot biomass of pejbaye as a function of NP fertilization.



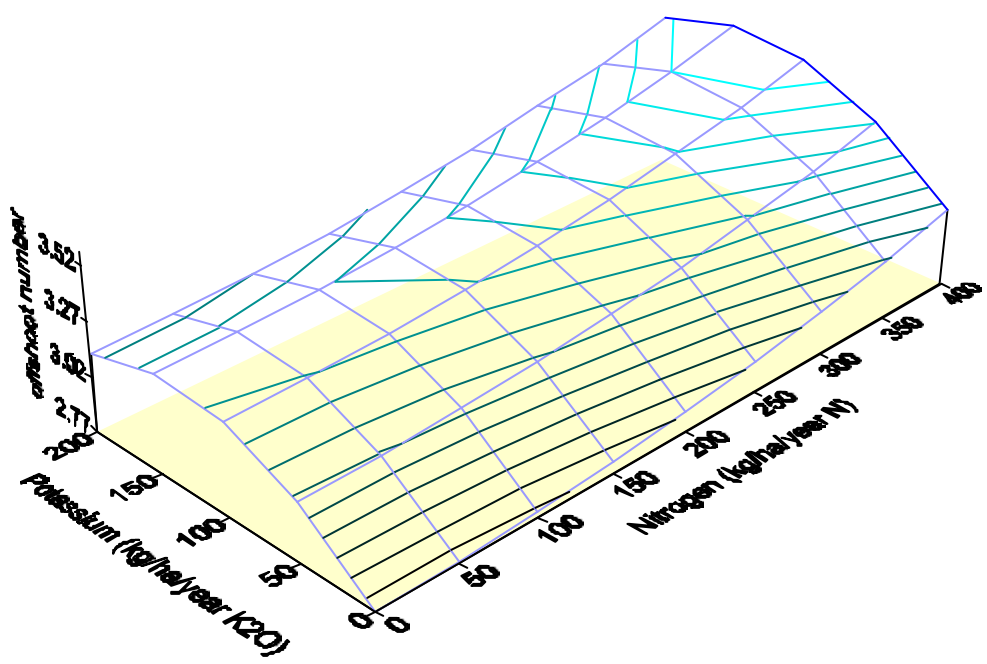
3. Root biomass of pejibaye as a function of NK fertilization.



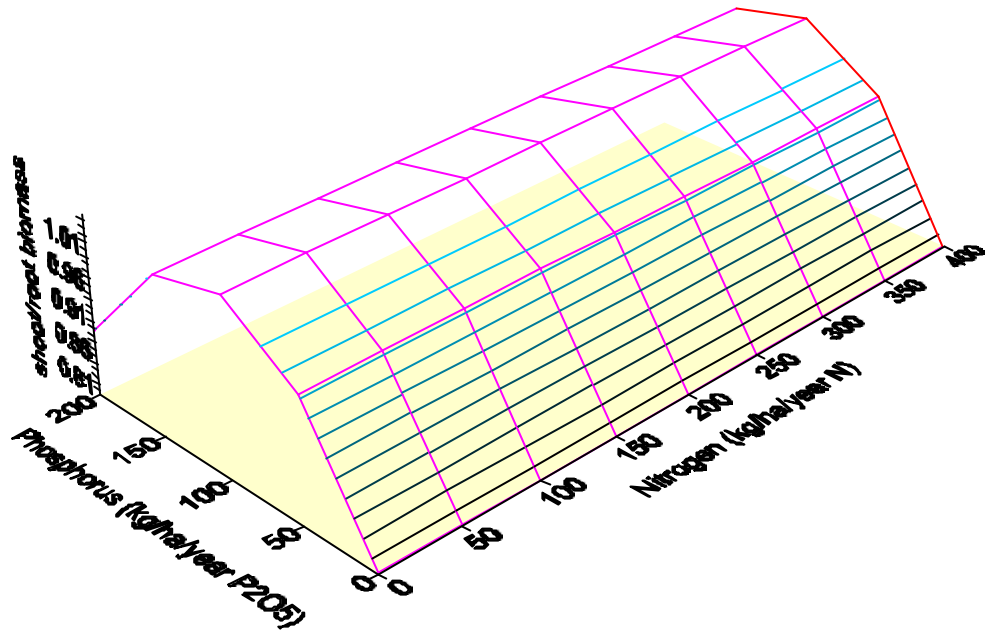
4. Root biomass of pejibaye as a function of NP fertilization.



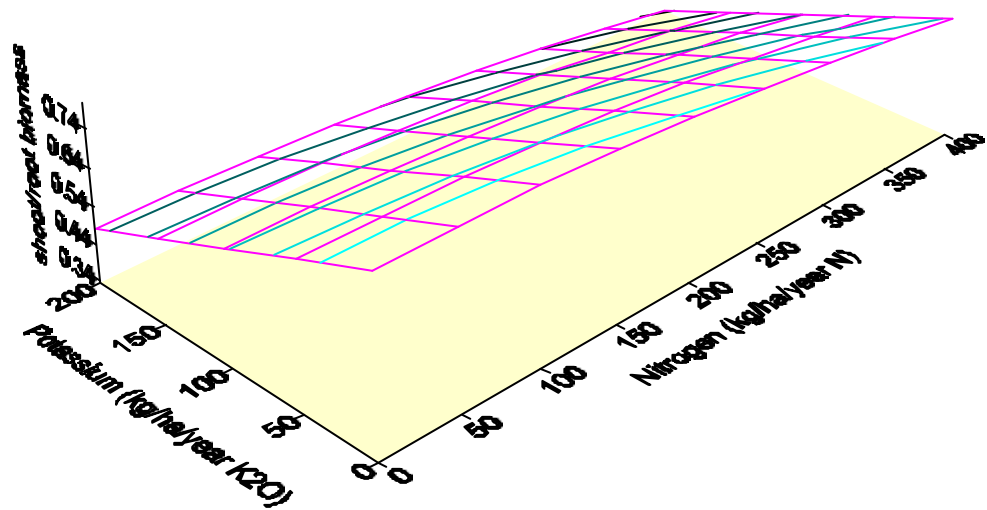
5. Offshoot number of pejobaye as a function of NP fertilization.



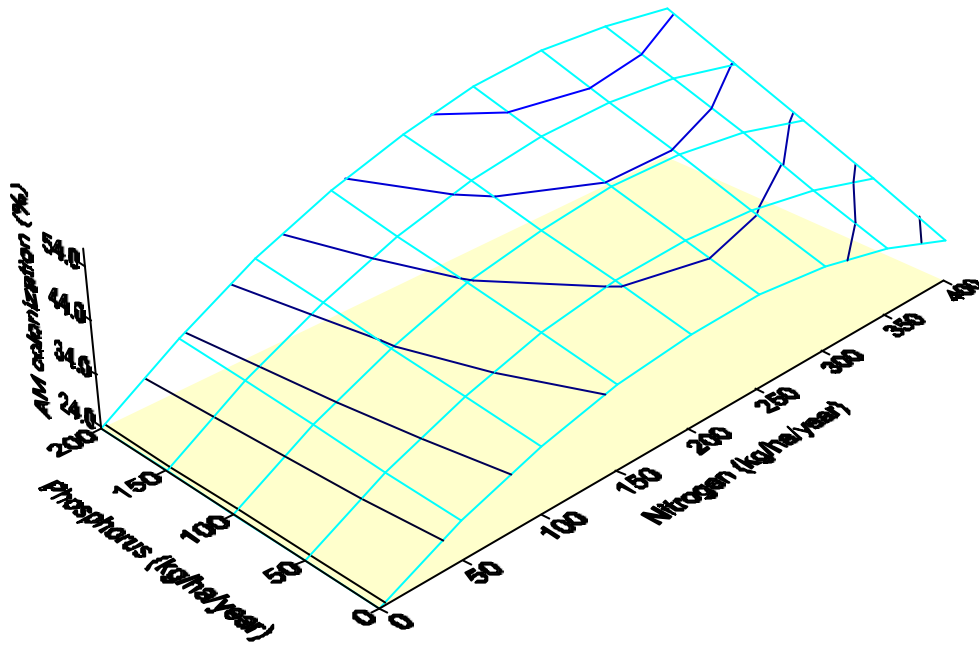
6. Offshoot number of pejobaye as a function of NK fertilization.



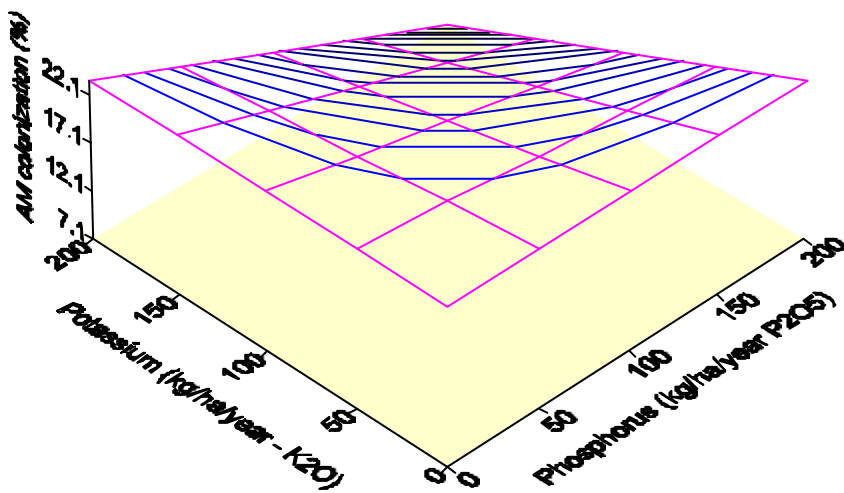
7. Shoot/root biomass ratio of pejbaye as a function of NP fertilization.



8. Shoot/root biomass ratio of pejbaye as a function of NK fertilization.



9. Arbuscular mycorrhizal colonization of roots of pejobaye as a function of NP fertilization.



10. Arbuscular mycorrhizal colonization of roots of pejobaye as a function of PK fertilization.

