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# USE OF FERTILIZER EUCALYPTS PLANTATIONS: RESPONSE TO APPLICATIONS AND CONSUMPTION EVOLUTION

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**ABSTRACT** – This work presents results N, P, K, and S applications during the first rotation of eucalypts on experimental areas of the Copener/Norcell in Northern Bahia, Brazil. Phosphorus has been show as the only element significantly increasing productivity. Small doses of water sluble $P_2O_5$ applied with natural rock phosphate resulted in similar responses to high doses of water soluble $P_2O_5$ alone. Phosphorus can be applied as a single application at planting or in three annual applications. The results from these trials have been implemented in the general fertilization program of the company's plantations. Consumption and costs on commercial plantations are presented.

**RESUMO** – O trabalho apresenta resultados de aplicação de N, P, K e S em experimentos de primeira rotação de eucaliptos pertencentes à COPENER/NORCELL, ao noroeste da Bahia, Brasil. O fósforo demonstrou ser o único elemento significatio no aumetno da produtividade. Doses pequenas de água solúvel em $P_2O_5$ aplicadas com fosfato de rocha natural resultou em respostas semelhantes às aplicações de altas doses de água solúvel em $P_2O_5$. O fósforo pode ser usado numa única aplicação no plantio ou em três aplicações anuais. Os resultados desses ensaios foram incrementados com o programa geral de adubação nos povoamentos da COPENER/NORCELL. São apresentados também o consumo e custo nos plantios comerciais.

## INTRODUCTION

According to several studies, phosphorus (P) applications to eucalypts crops have been shown to have significant effects on the performance of stands (MELLO et alii, 1970; ROY, 1976; BARROS et alii, 1981; VALERI et alii, 1985; DANTAS, 1988).

Natural rock phosphate applications to eucalypt crops as a source of P have been an important alternative to water soluble inorganic P sources for "cerrado" soils, since these soils are characterized as having low pH, low levels of P and Calcium (Ca) and a high P fixation capacity. One of the advantages of natural rock phosphate applications is its relatively low solubility when compared to soluble inorganic phosphate sources, which means an adequate P supply for the plants as they grow (DANTAS, 1988).

According to NOVAIS et alii (1983), the influence of phosphorus fertilization on eucalypts seedlings or cuttings at planting is shortlived, and further applications are therefore required at regular intervals throughout the rotation.

On the other hand, it is possible that is some cases a single rock phosphate application may results in higher soluble phosphorus fixation than separate smaller applications. This strategy may have advantages in phosphate supply to the plants and in application costs.

In Brazil, the fertilization with nitrogen (N) and potassium (K) in eucalypts has been done generally at planting time, with NPK mixtures, although expected results have not always been obtained. This lack of adequate responses to N application have been associated with the lixiviation of elements or their salt effects (BARROS et alii, 1990). The same effects are observed with K. Positive increases in timber yield have been observed by BARROS et alii (1990) to applications of N and K. Potassium levels have been shown to limit productivity in certain cases (DANTAS, 1988; and LEAL et alii, 1988), whereas the response to N application has been found to be more pronounced in seedlings than in more mature trees (BARROS & PRITCHETT, 1979; LOCATELI et alii, 1984).

The response of sulphur application in eucalypts have been observed mainly in the nursery. FERREIRA (1986) noted that when $SO_4^{-2}$ was absent from the nutrient solution, a lower growth and production was observed in ***Eucalyptus granids*** biomass. FURTINI et alii (1988) applied a single application of sulphur to different eucalypt species thereby alleviating any deficiencies. Under field conditions, significant responses have been observed using gypsum as a sulphur source on 18 month old trees.

Because of the great expansion of ecualypt plantation areas in Brazil, the differences between the genetic material used, the soil and climate variation of each area, it is possible that distinct fertilizer recommendations will have to be devised. This paper discusses results obtained from fertilizer trials conducted on eucalypts as 1$^{st}$ rotation.

## EXPERIMENTAL METHODS

The experiments were established in three experimental areas belonging to Copener/Norcell. These areas are located in the Northern Forestry District of Bahia State, more specifically in Entre Rios, Inhambupe and Aramari. Entre Rios is situated at an altitude of 153m above sea level at 11$^o$57'S, 38$^o$10'W, with a mean annual rainfall of 1300mm. Inhambupe is at an altitude of 260m above sea level at 11$^o$50'S, 38$^o$28'W, with mean annual rainfall of 900mm. Aramari is at an altitude of 320m above seal level, at 11$^o$58'S, 38$^o$34'W, with mean annual rainfall of 900mm.

The rain falls mainly from April to July but is highly variable. There is little variation in temperature in these areas, and the mean annual temperature is 24$^o$C. Most eucalypt plantations belonging to Copener are situated in these areas. Table 1 shows the results of soil analyses of the experimental areas.

Hybrid genetic material (***E. grandis*** **x** *E. urophylla*) propagated from seeds was used. The seeds were produced by Aracruz (Brazil). The spacing was 3 x 2m, and basic fertilization placed directly on the planting lines and incorporated in the bedding. The seedlings were planted immediately after a rainfall event. All experimental plots consisted of 14 lines, each with 20 plants (total area 1680m$^2$ and 280 plants). There were 36 measured plants (6 x6).

**TABLE 1** Properties of soils at Entre Rios, Inhambupe and Aramari (0-20 cm).

| Characteristics | Entre Rios | Inhambupe | Aramari |
|---|---|---|---|
| pH | 5.4 | 4.8 | 4.6 |
| P (ppm) | 1 | 1 | 1 |
| K (ppm) | 31 | 8 | 4 |
| $Ca^2$ + (eq. mg/100g) | 2.9 | 0.4 | 0.4 |
| $Mg^2$ + (eq.mg/100g) | 1.0 | 0.2 | 0.0 |
| $Al^3$ + (eg.mg/100g) | 0.0 | 0.9 | 0.2 |
| O.M. (%) | 2.5 | 1.0 | 0.3 |
| Sand (%)* | 67/43 | 82/80 | 96 |
| Clay (%)* | 27/54 | 17/19 | 3 |
| Silt (%) | 6/3 | 1/1 | 1/1 |
| Soil Classification | UTISOL | OXISOL | AQUARTMENT |

* 0-20CM/20-60CM (Depth) pH = Relation soil: water 1 : 2,5 P = Mehich-1 Ca, Mg, Al = 1N KCI O.M. = Walkley - Black

The trials were split into five groups of treatments, described as follows:

**Phosphorus applications**

There were ten treatments. In addition to the inorganic phosphate treatments, 4 of these were superimposed with rock phosphate, i.e., levels of water soluble $P_2O_5$ (0; 15; 30 and 60 kg/ha) as a concentrated superphosphate and rock phosphate – araxá (300kg/ha). The other six treatments had no rock phosphate application and the water soluble $P_2O_5$ levels were 0; 15; 30; 60; 90 and 120kg/ha.

Strip applications with 4 replications were used and all treatments received basal applications of 60kg/ha of N and 60kg/ha of $K_2O$ applied in the planting line.

**Phosphate sources and time of application**

There were eight treatments. Concentrated superphosphate (41% of $P_2O_5$ total) was used in four of the treatments (275 kg/ha) and rock phosphate araxá (300 kg/ha). As a result, each treatment received 105 kg/ha of $P_2O_5$.

The two phosphate soruces were tested at the same time and the treatments to each phosphate source were:

a) Total at planting time.
b) Total 12 months after planting.
c)Half 12 months and half 24 months after planting.
d) 33% 12, 24 and 36 months after the planting.

The basic fertilization was 60kg/ha of N, 32 kg/ha of P2O5 (concentrated superphosphate) for all treatments. the phosphate applied at planting was included in the basic fertilization. The four other phosphate treatments were broadcast between the planting lines and incorporated. The experimental design was in strips with four replications.

### Nitrogen and Potassium levels

There were 16 treatments in a full factorial design. There were four levels of N (0, 26, 50, 75kg/ha as urea) and four levels of $K_2O$ (0, 20, 40, 60kg/ha) as KCI.

The treatments were applied soon after the basal fertilization was undertaken with 60kg/ha of $P_2O_5$ as concentrated superphosphate. A total of 300 kg/ha of rock phosphate-araxá was applied between the line 90 days after planting in Entre Rios and Inhambupe. The rock phosphate application was not done in Aramari. The experimental design was a randomized block with four replications.

### Sulphur levels

There were eight treatments. Sulphur levels were o, 20, 40, 60kg/ha with or whithout 300 kg/ha of rock phosphate-araxá. Sulphur sources were $CaSO_4$ (gypsum) or $MgSO_4$. For all treatments up to 50,6kg/ha of Ca and 10.0 kg/ha of Mg with carbonate or oxide were applied. All fertilizers were applied into the planting line in addition to a basal fertilizer application of 60kg/ha of N, 60kg/ha of $P_2O_5$ and 60kg/ha of $K_2O$. The experimental design was a randomized block with four replications.

### Cost and consumption of fertilizers evolution

COPENER files were the source for the studies of the evolution of quantities and costs involved in the fertilization process. The amount and cost were weighted according to fertilizers prices, which were based in American dollar. Current prices per hectare were considered when fertilizer prices were calculated.

## RESULTS

### Phosphorus levels

On all three locations, increasing applications of P resulted in a concomitant increase in volume (Table 2). In absolute rerms, the best productivities were obtained in Entre Rios, which is associated with the best soil fertility and the greatest precipitation. On the other hand, the influence of precipitation could not have contributed to the higher productivity in Aramari, compared to Inhambupe. The quality of the Entre Rios site was thus superior to Aramari, which in turn is superior to Inhambupe. The best productivities are related to the improvmenet of the site as recognized by MORA (1986) and MENEGOL & LOUZADA (1990).

Increasing volumes were observed at the three locations, with increasing applications of P, even in the absence of rock phosphate. These increases were quadratic at Entre Rios, and maximum production was obtained when applying 60kg/ha of $P_2O_5$ in Inhambupe and Aramari. The results have shown that on sandy textured soil (Aramari), the increase obtained with higher levels of water soluble P was not significantly greater than those obtained with 15kg/ha $P_2O_5$, as opposed to the other two locations which had clayey soils.

**TABLE 2**. Volume measurements of (***E. granids x E. urophylla)*** hybrid using different levels of water soluble $P_2O_5$, in the presence (+ RP) or absence (-RP) or 300kg/ha of rock phosphate.

| Levels $P_2O_5$ | Locality/Age | | | | | |
|---|---|---|---|---|---|---|
| | Entre Rios 48 months | | Inhambupe 46 months | | Aramari 47 months | |
| | +RP | -RP | +RP | -RP | +RP | -RP |
| Kg/ha | $m^3$/ha | | $m^3$/ha | | $m^3$/ha | |
| 0 | 187.9 | 101.7 | 129.2 | 56.4 | 134.7 | 106.3 |
| 15 | 211.7 | 147.8 | 120.0 | 76.9 | 161.4 | 144.6 |
| 30 | 213.6 | 184.5 | 128.0 | 97.0 | 160.2 | 130.4 |
| 60 | 201.8 | 201.1 | 122.8 | 114.1 | 161.8 | 152.7 |
| 90 | - | 218.7 | - | 112.1 | - | 148.5 |
| 120 | - | 225.7 | - | 106.2 | - | 155.9 |

In the presence of rock phosphate, the major volume increases were obtained with the application of water soluble P (concentrated superphosphate) when compared to the application of pure rock phosphate, in Aramari (increases of 20%). In Entre rios the increase was 13.7% and there was no increase at Inhambupe. However, when applications higher than 15kg/ha of $P_2O_5$ were used, there was no volume gain which justified the increased application of water soluble P. For this treatment, the production in Entre Rios was comparable to those obtained between 60kg/ha to 90kg/ha of $P_2O_5$.

In Aramari, the presence of rock phosphate with the lower levels of water soluble P exceeded the maximum production obtained with the application of $P_2O_5$ alone. In Inhambupe, the maximum production occurred in the presence of phosphate rock. These data indicate the advantages of applying water soluble P in the presence rock phosphate (NOVAIS et alii, 1983). However, under Inhambupe conditions, the effect of the water soluble P application is limited when compared to the effect of the rock phosphate. Nevertheless, under conditions such as at Entre Rios and Aramari, where the volume increase related to water soluble P levels greater than 15kg/ha $P_2O_5$ were less dramatic, it is suggested that the use of phosphate rock with an initial application of water soluble P will be sufficient. Phosphate fertilizers with these characteristics are available on the Brazilian market and have already been used by COPENER in 1990.

### Phosphate sources and time of application

The volume productions (Table 3) obtained from the application of the concentrated superphosphate and the rock phosphate did not vary between treatments at the three locations or the different application times. According to DANTAS (1988), the differences between the two phosphate sources are related to phosphorus retention by the exchange capacity of soil.

In the present work, the results indicate that the phosphorus retention by the soil is similar at the three sites/localities.

There were no significant differences in volume between the application times for both phosphate sources at the three locations. It is therefore possible to split the phosphate applications over three years. This strategy would reduce the effect of phosphate fixation by the soil, thereby maintaining an adequate supply of phosphate to the plant.

**Nitrogen and Potassium levels**

No significant differences were found between individual applications of N and K, or the combination of these elements (Table 4). The absence of significant responses can be attributed to possible leaching of the elements, since the fertilization was undertaken during the rainy season. The soils had a low cation exchange capacity which could have assisted the lixiviation of K. Other plausible reasons are the absorption of K in the lower soil horizons or a contribution from the K accumulated during the forest rotation in spite of the increased fixation of K by the soil (RICCI, 1987; LEAL et alii, 1988). KREJCI et alii (1986) and MORA (1986) observed root systems of eucalypts at a depth of 3.6m in the same region where these trials were conducted.

The N and K withdrawal from the fertilizer mixture on medium and clayey-textured soils did not cause any trouble, but on sandy-textured soils this process may not be completely effective due to the low exchange capacity of the soils.

**TABLE 3**. Volume and relative yield of a hybrid (***E. gradis x E. urophylla***) when concentrated superphosphate or rock phosphate at different time is applied.

| Phosphate | Times | Locality/Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | Entre Rios 48 months | | Inhambupe 46 months | | Aramari 47 months | |
| | | $m^3$/ha | % | $m^3$/ha | % | $m^3$/ha | % |
| Concentrated | Planting | 221.0 | 101 | 130.4 | 105 | 104.4 | 78 |
| | 12 month | 210.2 | 96 | 120.4 | 97 | 134.2 | 101 |
| | 12 & 24 month | 229.0 | 105 | 117.6 | 94 | 133.2 | 100 |
| | 12, 24 & 36 month | 215.3 | 98 | 120.9 | 97 | 123.1 | 92 |
| Block Phosphate Araxá | Planting | 219.1 | 100 | 124.6 | 100 | 133.4 | 100 |
| | 12 month | 228.9 | 104 | 132.2 | 106 | 116.0 | 87 |
| | 12 & 24 month | 222.9 | 102 | 115.8 | 93 | 117.6 | 88 |
| | 12, 24 & 36 month | 205.1 | 94 | 123.7 | 99 | 129.3 | 97 |
| Average superphosphate | | 218.9 | - | 122.3 | - | 123.7 | - |
| Average rock phosphate | | 219.0 | - | 124.1 | - | 124.1 | - |

**Sulphur levels**

The sulphur (S) application, in the presence or absence of rock phosphate, did not provides significant increases in volume (Table 5), but these results are contrary to those obtained by BARROS et alii (1990). This can be attributed to the organic matter decomposition, and to greater rooting depth, which could promote the supply of S to the plants. However, in the treatments which included gypsum, the responses which were attributed to S could, in fact, have been responses to Ca, since the forest soils, as noted by BARROS et alii (1990), are deficient in Ca.

**TABLE 4.** Volume and relative yield of a hybrid (***E. grnaids x E. urophylla***) when different levels of N and K are applied.

| Levels Kg/ha | | Locality/Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | E. Rios 48 months | | Inhambupe 48 months | | Aramari 38 months | |
| N | $K_2O$ | $m^3/ha$ | % | $m^3/ha$ | % | $m^3/ha$ | % |
| 00 | 00 | 209.6 | 100 | 120.3 | 100 | 143.4 | 100 |
| 00 | 20 | 215.7 | 103 | 137.2 | 114 | 11.0 | 77 |
| 00 | 40 | 227.5 | 109 | 118.5 | 99 | 114.0 | 80 |
| 00 | 60 | 239.0 | 114 | 129.4 | 108 | 121.2 | 85 |
| 25 | 00 | 202.3 | 97 | 130.3 | 108 | 111.6 | 78 |
| 25 | 20 | 225.9 | 108 | 136.8 | 114 | 126.7 | 88 |
| 25 | 40 | 226.6 | 108 | 120.6 | 100 | 126.6 | 88 |
| 25 | 60 | 207.7 | 99 | 123.8 | 103 | 129.6 | 90 |
| 50 | 00 | 224.4 | 107 | 141.7 | 118 | 107.7 | 75 |
| 50 | 20 | 225.8 | 108 | 127.1 | 106 | 142.1 | 99 |
| 50 | 40 | 232.8 | 111 | 127.1 | 106 | 145.4 | 101 |
| 50 | 60 | 224.1 | 107 | 117.2 | 97 | 113.5 | 79 |
| 75 | 00 | 237.4 | 113 | 143.9 | 120 | 135.1 | 94 |
| 75 | 20 | 209.8 | 100 | 127.4 | 106 | 135.0 | 94 |
| 75 | 40 | 235.5 | 112 | 133.1 | 111 | 127.9 | 89 |
| 75 | 60 | 216.3 | 103 | 128.1 | 115 | 151.7 | 106 |

**TABLE 5**. Volume a hybrid (***E. grandis x E. urophylla)*** when different amounts of sulphur are applied using (+RP) or not using (-RP) 300kg/ha of rock phosphate.

| Sulphur Kg/ha | Locality/Age | | | | | |
|---|---|---|---|---|---|---|
| | E. Rios 48 months | | Inhambupe 48 months | | Aramari 47 months | |
| | +RP | -RP | +RP | -RP | +RP | -RP |
| | $m^3/ha$ | | $m^3/ha$ | | $m^3/ha$ | |
| 00 | 223.9 | 211.5 | 111.0 | 112.6 | 147.6 | 161.1 |
| 20 | 224.9 | 225.1 | 118.2 | 115.6 | 155.1 | 140.0 |
| 40 | 230.5 | 196.9 | 112.4 | 112.4 | 170.3 | 149.5 |
| 60 | 230.9 | 196.7 | 120.5 | 116.1 | 154.4 | 158.6 |

### Evolution of the cost and consumption of fertilizers

The results of the eucalypts fertilization studies were important for the improvement of the amount of fertilizer used and the method of application which had been adopted by COPENER. Since the results from the first years of the experiments were acceptable, and showed lower fertilization costs, the recommendations were implemented almost immediately. The results obtained in 1982 were thus used in 1983, and since then the annual evaluation has permited ongoing changes in the composition and levels of the mixtures, as well as the methods of application, for example, in 1990, NK absorption was suppressed in some soils, and so in 1991 a basic fertilizer operation will be undertaken in all areas.

Nutrient sources, nutrient costs, fertilizer application and efficiency in each area are considered to be important now. Figure 1 shows the evolution of the fertilizers used at COPENER eucalypts plantations, the costs of application (base fertilization, fertilization after planting, and phosphate use), and the cost of fertilizers over the years. The most notable changes in fertilizer costs are associated with the changes in mixtures, levels and the methods of application. Despite the increased costs per kg for fertilizer in Brazil, due to transportation and production, the cost per kg of the mixtures at COPENER/NORCELL has been decreasing.

## CONCLUSION

The results of the inorganic fertilizer experiments at COPENER eucalypt plantations suggests that, for the studied region, the fertilizer programme should be based on phosphorus. The combination of water soluble P with rock phosphate on clay and sandy soils is advisable. Fertilization with N, K and S is not necessary for the establishment of eucalypt plantations in this region, but on very sandy soils N and K deficiencies should be carefully monitored.

The immediate adoption of the results of these experiments has shown improvement in inorganic fertilizer cost and has allowed the opportunity to verify the results under field conditions.

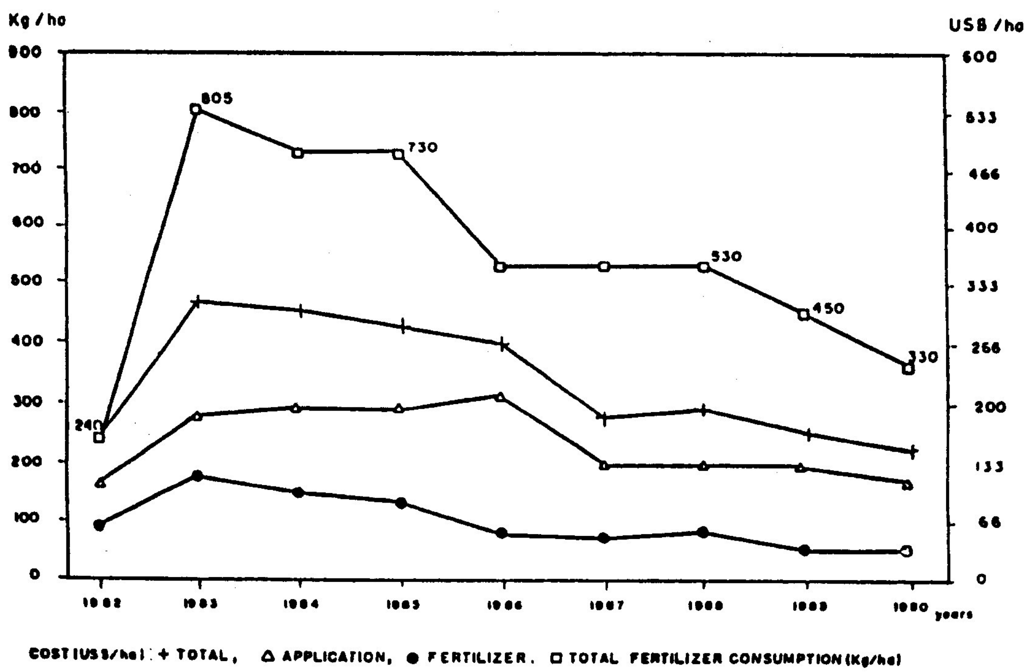


FIGURE 1. Fertilizer consumption and cost evolution at COPENER.

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