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Optimal Leaf Analysis Norms for Avocado (cv. Fuerte)

T.J. Koen and S.F. du Plessis
Citrus and Subtropical Fruit Research Institute, Private Bag X11208,Nelspruit, 1200, Republic of South Africa.

Abstract. **The objective of this investigation was to determine a suitable leaf sample for analysis and fertilizer advisory purposes and to obtain optimal analysis norms for that sample. The leaf sample proposed by Koen and du Plessis (1991. S. A. Avocado Growers' Yrbk. 14:19-21), Fig. 1, conformed to all the requirements necessary for sampling purposes. Firstly, the concentration of elements in the leaves was constant from 6 to 8 months of the leaf's age. Secondly, the nutrient concentration of the sample was highly significantly affected by changes in the fertilizer applications and thirdly, nutrient concentration was also related to changes in yield. The sample was especially suitable for N, with an optimal level of 2.0 to 2.3% N. This analysis could be used for the same or subsequent season. In the case of P the leaf P concentration must be higher than 0.17% to ensure optimal yield in the next season. The relationship between leaf K and yield was relatively poor.**

Leaf analysis as a diagnostic tool for fertilizer advisory purposes is widely used on many subtropical crops throughout the world (Du Plessis, 1977; Gustafson, 1981; Lahav *et al.,* 1990). Embleton and Jones (1966) proposed tentative leaf analysis norms for avocados based mainly on their own previous research and experience (Embleton *et al.,* 1958; Embleton *et al.,* 1959 and Embleton and Jones, 1964). They expressed their hope "...that presenting these tentative guides will encourage more critical research on leaf analysis standards for the avocado". However, very little improvement on these norms has been proposed up to the present, although several researchers have criticized the sample taken (Oppenheimer *et al.,* 1961; Bergh, 1975 and Lahav *et al..* 1976). Gustafson (1981) was still advocating the exact same sample and analysis norms for avocados in California as proposed some 1 5 years ago. Recently, Lahav *et al.* (1990) stressed the importance of sampling leaves from the spring flush only, but concluded that there was no basis to change the critical level of N in avocado leaves as proposed by Embleton and Jones (1966). This level was 1.6% N for 'Fuerte' and 1.8% N for 'Hass'.

The purpose of this investigation was to evaluate the sample and norms proposed by Embleton and Jones (1966) under South African conditions and to obtain a more suitable sample, if necessary. This investigation was carried out over several seasons at the Burgershall and Friedenheim Experimental Stations near Nelspruit, Eastern Transvaal, South Africa.

Materials and Methods

Comparing different leaf samples and establishing the time of sampling. This experiment was carried out on the Burgershall Research Station, 50 km north of Nelspruit. For this purpose 35 uniform, healthy, five year old 'Fuerte[1] trees on Edranol seedling rootstock were selected. Spring flush branches were marked in August and rootstock were selected. Spring flush branches were marked in August and 3 different leaves were sampled monthly from September throughout the season until harvest. The three samples (A, B and C) were differentiated as follows :

A - sampled according to Embleton *et al.* (1958); this is spring cycle leaves, 5 to 7 months of age from non-fruiting and non-flushing terminals

B - leaf at the position shown in Fig. 1 from a non-fruiting branch showing no new flush at the time of sampling

C - the youngest leaf at the tip of a branch with new growth. This sample will always be less than two months old.

Approximately 40 leaves were collected per sample per month and analyzed chemically.

Establishing analysis norms. Three separate N, P and K fertilizer experiments with 8 levels of each element, 3 trees per plot and 3 replicates were laid out on 4-yr-old 'Fuerte' trees on Duke seedling rootstock at Friedenheim Experimental Station. Data from 1982 to 1987 are presented. At the start of the experiment the soil had a pH (water) of 6.15 with a very low P status of 1 mg P/kg soil (resin extractable P); and 60 mg exchangeable K/kg soil. The levels of applied fertilizers are shown in Table 1. In the case of the N-experiment the levels of N were increased from 1985.

Leaf samples B, (Fig. 1) were taken at the beginning of March (6- to 8-month-old leaves). This sample was taken from the middle of the spring flush branches containing no new growth at the time of sampling (Koen and du Plessis, 1991).

Results and Discussion

Comparing three different leaf samples. The effect of leaf age on the N, P and K concentrations of the different samples are shown in Figs. 2, 3 and 4. As far as N is concerned (Fig. 2), it is obvious that sample B shows a very stable concentration range for 6- to 8-month-old leaves whereas both sample A and C vary considerably during this period. For phosphorus (Fig. 3), sample B is also constant for the 6 to 8 month period, whereas the other two are either increasing or decreasing in P concentration. In the case of potassium (Fig. 4), sample B is constant for the period 5 to 8 months, whereas A and C decrease from 6 to 8 months of age.

From these results, it is obvious that the Embleton *et al.* (1958) sample (A) shows too much variation during the 6-to 8-month-old period, to be suitable for analysis purposes. Sample B as proposed by Koen and Du Plessis (1991) is the most constant for N, P and K during that period. The youngest leaf (sample C) is definitely not suitable for this purpose.

In order to verify the suitability of a particular leaf for analysis purposes the concentration of nutrients in that leaf should respond to changes in fertilization and should also be related to yield (Langenegger and Du Plessis, 1977). The usefulness of sample B was thus further investigated in three different fertilizer experiments.

<u>Sensitivity of the leaf sample to changes in fertilizer applications.</u> The effect of increasing the application rates of N, P or K on the concentration of these elements in the leaves over four seasons is shown in Table 2.

N-experiment: The leaf N concentrations were highly significantly increased in all 4 seasons shown by increased rates of nitrogen.

P-experiment: Except for 1986, the leaf P concentrations were also highly significantly increased by the increased P application rates.

K-experiment: As was the case in the N and P experiment, the increased application of K caused a highly significant increase in the K concentration of the leaves.

These findings clearly demonstrated that by increasing fertilizer rates, the concentration of the corresponding element in the leaves was significantly increased. This was one of the prerequisites set by Langenegger and Du Plessis (1977) for a leaf sample to be suitable for analysis purposes.

<u>Relationship between leaf analysis and yield.</u> Probably the most important characteristic of the ideal sample for the purpose of leaf analysis is that a change in the concentration of elements in the leaf should be reflected by a change in yield (Langenegger and Du Plessis, 1977). In Table 3, the effect of increasing levels of application of either N or P or K on yield is shown in the 3 different experiments.

N-effect: N had the most marked effect on yield of the three elements tested in these experiments. In 1983, the increased levels of N applied had a linear effect on yield, whereas in 1985 and 1986, the effect was curvilinear reaching a maximum and declining again with higher N rates (this decline was not significant). In the 1987 season, a maximum yield of 73 kg fruit/tree was obtained at the *N$* level, thereafter showing a slow but significant decline with higher N rates to a very low yield of 15.2 kg fruit/tree.

P-effect: Only in the 1985 season did increased rates of *P* increase the yield significantly. Trends were noticeable in the other seasons but were not significant.

K-effect: A significant effect of K application on yield was only obtained in the 1983 season, thereafter no clear cut trends emerged.

In order to establish possible relationships between the leaf analysis of a particular season and yield of that or the following season, regression analyses were done using 24 data samples per season (8 treatments with 3 replicates). These data are shown in Figs. 5 to 8.

Leaf N and yield: A very highly significant relationship existed in all 4 seasons between leaf N concentration for that season and yield for the same season. In 3 of the 4 seasons, this relationship was improved upon by using leaf N data of the current season to predict the yield in the following season. These relationships were curvilinear in most cases.

Leaf P and yield: From these data it is obvious that leaf P concentration in the current season only effects the next season's yield significantly.

Leaf K and yield: A very poor relationship was shown between leaf K concentration and yield. Only for one season (1984) could the yield of the following season be predicted to a limited extent.

<u>Leaf analysis norms.</u> From the graphs shown in Figs. 5 to 8, optimal concentration ranges were determined and tabulated in Table 4. In the case of nitrogen the average optimal concentration of 2.03 to 2.27 % can be used for either the yield of the sampling season or the yield of the following season. In the case of P, only the yield of the next season can be predicted. The adequate leaf P value seems to be higher than 0.17 % for two of the three seasons. In the case of potassium, only one season (1984/85) showed an acceptable relationship between leaf K and yield, with an optimal leaf K value of 0.93 to 1.41 % K.

Conclusions

The results of this investigation show that the 6- to 8-month-old leaf sample proposed by Koen and du Plessis (1991, Fig. 1) can be successfully used for fertilizer recommendations for 'Fuerte' avocados. This sample is especially suitable for nitrogen, but to a lesser extent also for phosphorus and potassium. In the case of phosphorus, the present season's analysis figures are only relevant to the next season's crop, whereas nitrogen is related to both the present and subsequent season's crop. For nitrogen the optimal (adequate) level ranges from 2.0 to 2.3 % N; for phosphorus, it should be higher than 0.17 % P; and for potassium between 0.9 and 1.4 % K.

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Table 1. Fertilizer levels applied[z] in the N, P and K fertilizer experiments (g/tree/annum).

Nutrient Level	Experiment [y]			
	N	N	P	K
	1982-1984	1985-1987	1982-1987	1982-1987
0	0	0	0.0	0
1	112	126	31.5	144
2	224	252	63.0	288
3	334	378	94.5	432
4	448	504	126.0	576
5	560	630	157.5	720
6	672	756	189.0	864
7	784	882	220.5	1008

[z] Time of application July: 1/3 N + 1/3 K; December: 1/3 N + 1/3 K + 1 P ; April: 1/3 N + 1/3 K.
[y] N experiment received the P_3 and K_3 level; P-experiment received the N_3 and K_3 level; K experiment received the N_3 and P_3 level.

Table 2. Effect of increasing the level of application of N, P or K on the concentration of these elements (%) in the B leaf over 4 seasons.

Nutrient Level	N-experiment (%N)				P-experiment (%P)				K-experiment (%K)			
	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
0	1.76	1.71	1.65	1.69	0.125	0.114	0.102	0.116	0.76	0.87	0.98	1.07
1	1.81	1.64	1.47	1.66	0.144	0.121	0.097	0.132	0.99	1.09	1.18	1.19
2	1.92	1.89	1.85	1.94	0.144	0.134	0.124	0.139	1.39	1.27	1.15	1.33
3	2.15	1.99	1.81	2.03	0.133	0.128	0.121	0.143	1.59	1.48	1.38	1.50
4	2.08	1.98	1.87	2.27	0.146	0.138	0.130	0.159	1.67	1.52	1.36	1.57
5	2.19	2.10	2.01	2.31	0.150	0.134	0.118	0.153	1.82	1.58	1.33	1.60
6	2.23	2.30	2.36	2.32	0.150	0.152	0.154	0.157	1.88	1.70	1.51	1.59
7	2.36	2.32	2.27	2.54	0.157	0.152	0.148	0.160	1.76	1.66	1.55	1.62
LSD												
$P \leq 0.05$	0.25	0.23	0.38	0.28	0.013	0.019	0.034	0.016	0.35	0.21	0.25	0.17
$P \leq 0.01$	0.35	0.32	0.53	0.39	0.018	0.026	-	0.022	0.48	0.29	0.35	0.24

Table 3 - Effect of increasing the level of application of N, P or K on yield (kg/tree) over 4 seasons.

Nutrient Level	N-experiment (%N)				P-experiment (%P)				K-experiment (%K)			
	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
0	0.5	2.6	0.4	9.8	4.2	28.2	13.5	51.9	2.1	39.3	21.9	42.0
1	1.0	7.5	2.7	33.9	3.9	40.9	25.3	45.3	2.2	22.1	16.3	32.1
2	3.6	21.4	14.2	51.2	4.8	40.8	28.6	50.9	4.0	37.9	31.9	56.9
3	4.9	42.7	25.9	73.0	2.9	39.8	30.9	58.9	8.1	34.1	19.4	45.5
4	8.7	32.5	20.2	52.6	2.7	39.3	26.3	62.2	2.1	24.0	18.9	31.3
5	10.5	39.5	27.9	47.0	5.3	45.6	27.6	60.3	6.7	40.9	33.2	55.2
6	18.6	40.5	17.2	39.2	7.5	50.5	30.2	63.4	2.2	36.2	31.1	43.7
7	22.3	35.8	19.0	15.2	9.4	60.7	29.9	67.6	2.4	33.7	28.2	38.1
LSD												
$P \leq 0.05$	8.5	16.6	14.2	23.9	-	17.9	-	-	3.5	-	-	-
$P \leq 0.01$	11.8	23.1	19.7	33.2	-	-	-	-	4.8	-	-	-

Fig. 1. Position B indicates the leaf to be sampled from non-fruiting branches which are not showing signs of new flush.

Fig. 2 The effect of leaf age on the N concentration of avocado leaves.

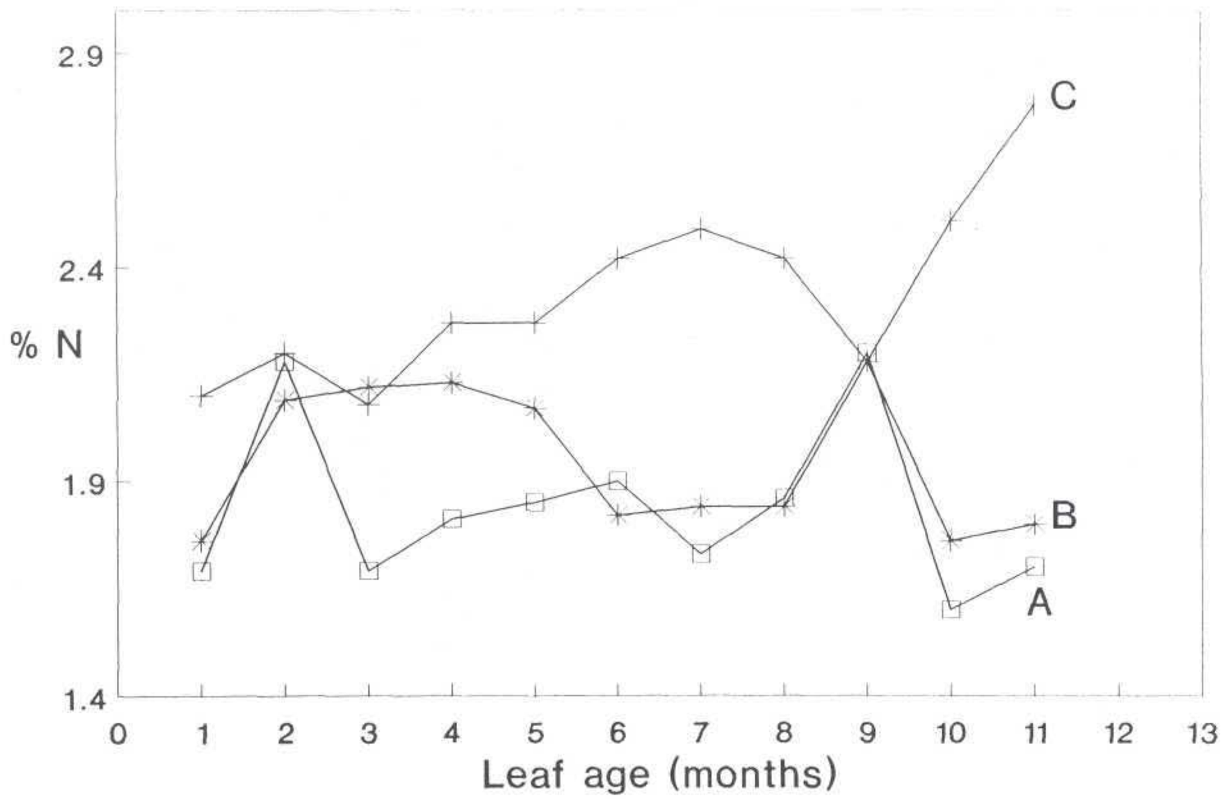

Fig. 3 The effect of leaf age on the P concentration of avocado leaves.

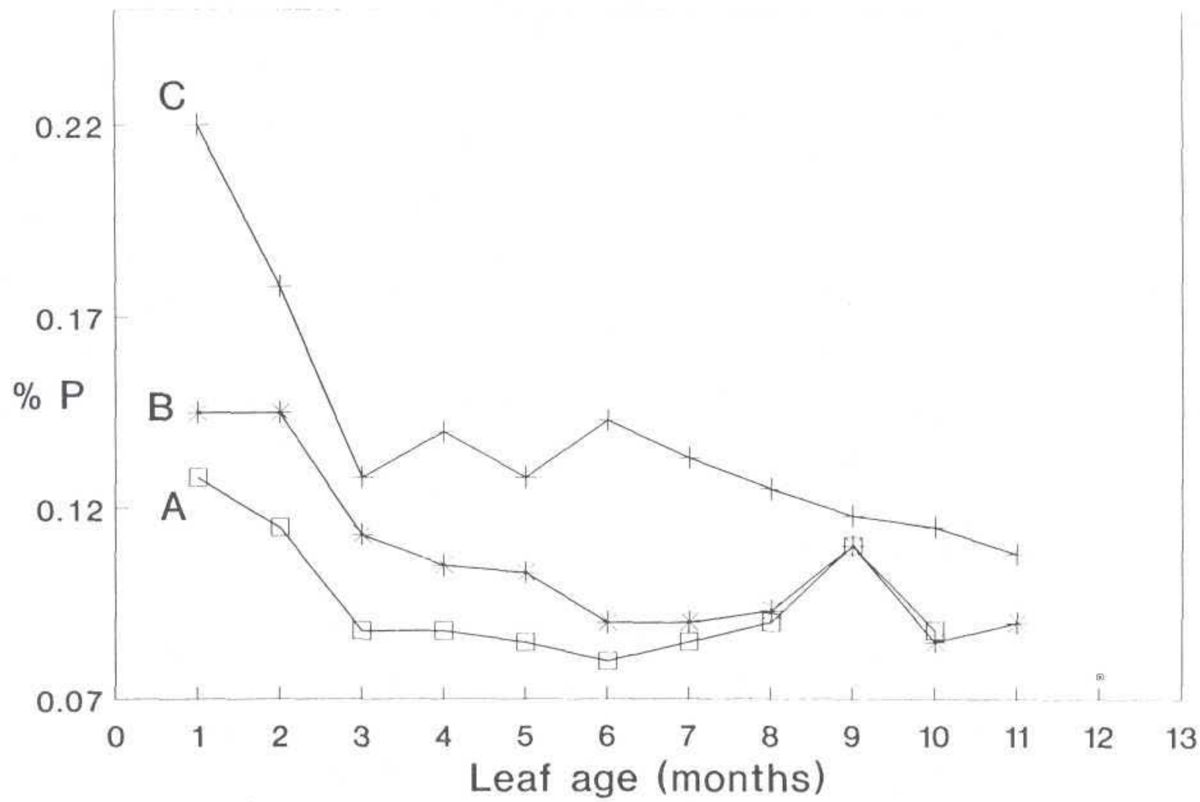

Fig. 4 The effect of leaf age on the K concentration of avocado leaves.

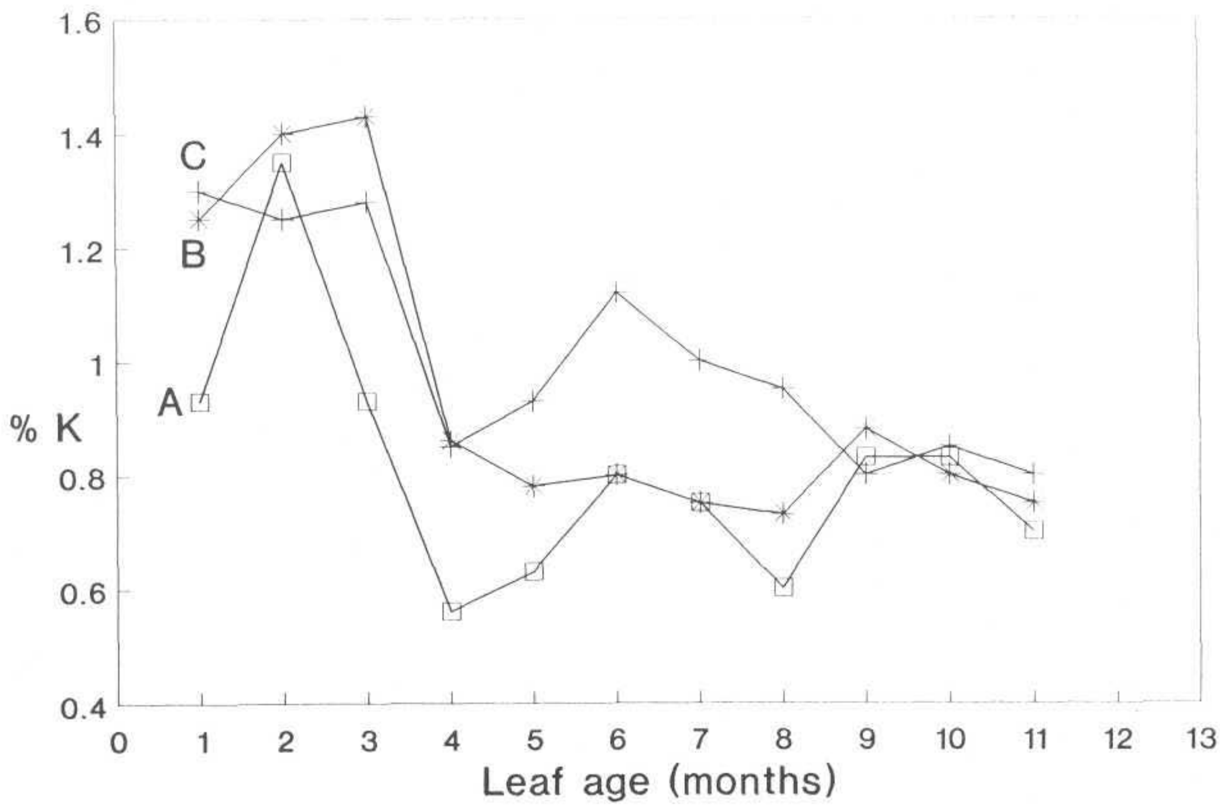

Fig. 5 Relationship between leaf N (x) of a particular season and yield (kg/tree) (y) of the same season. (1983, R^2 =0.69, y = -58.15 + 34.03x; 1985, R^2 =0.73, y = 1894.77 - 31 17.1 8x + 1676.51 x^2 - 291.85x^3; 1986, R^2=0.51, y = -399.31 + 393.89x -91.64x^2; 1987, R^2 = 0.71, y = -530.18 + 564.24x - 135.78x^2).

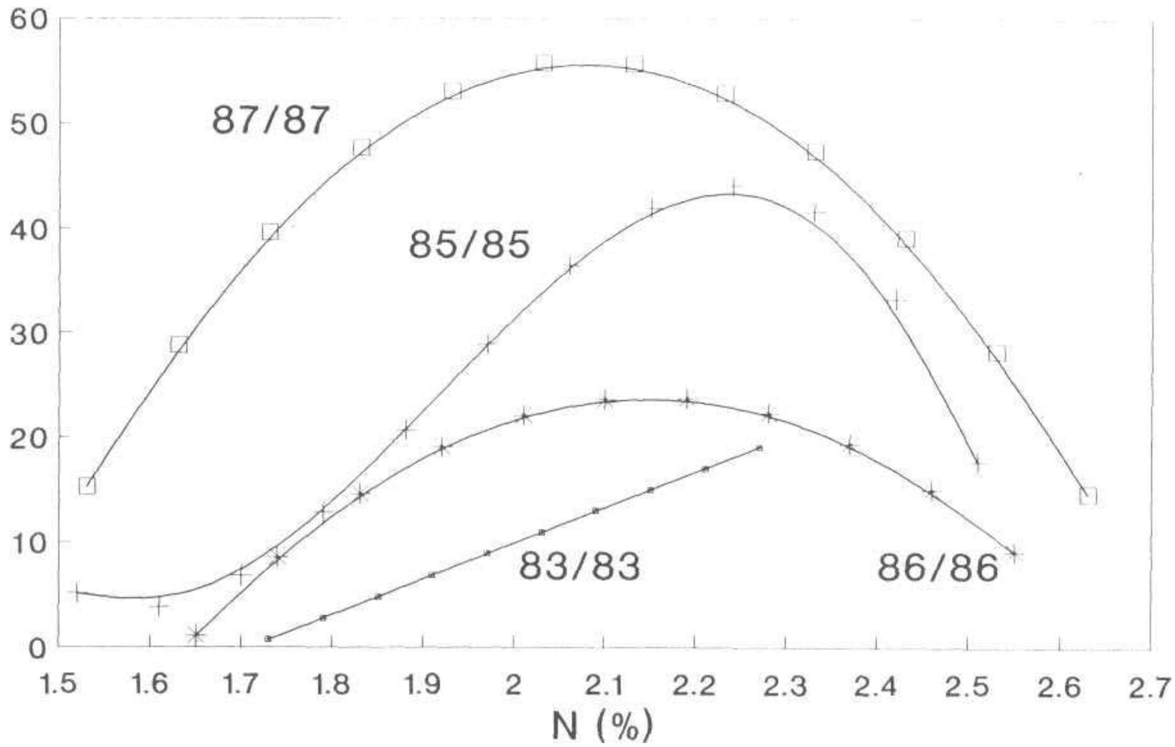

Fig. 6 Relationship between leaf N (x) of a particular season and yield (kg/tree) (y) of the next season. (1984/1985, R^2 =0.83, y = 4360.97 - 6914.69x + 3602.46x^2 - 613.98x3; 1985/1986, R^2=0.70, y = 945.91 - 1607.1 3x + 890.32x2 . 159.29$_X$3; 1986/1987, R^2=0.58, y = -472.51 + 510.56x - 124.49x^2).

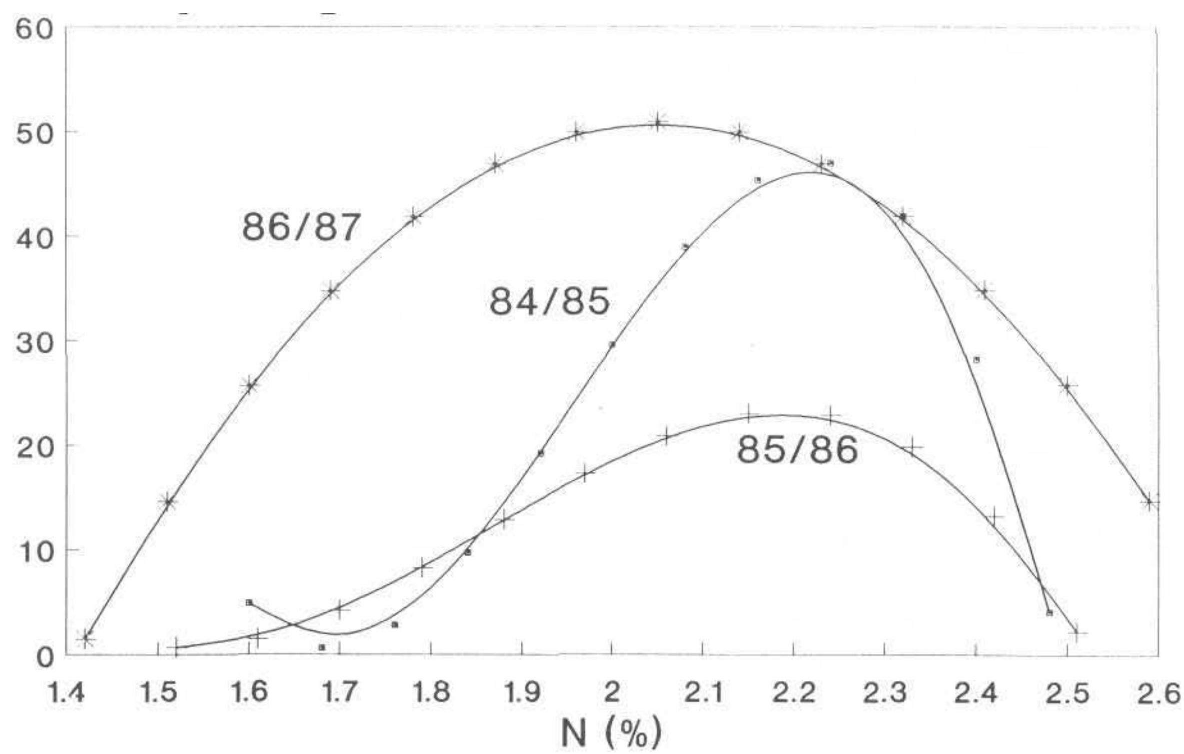

Fig. 7 Relationship between leaf P (x) of a particular season and yield (kg/tree) (y) obtained the following season. (1984/1985, R^2 =0.62, y = 271.72 - 3869.3x + 15863.41x^2; 1985/1986, R^2=0.26, y = -157.34 + 2468.67x - 8107.85x^2; 1986/1987, R^2=0.43, y = 13.66 + 362.68x).

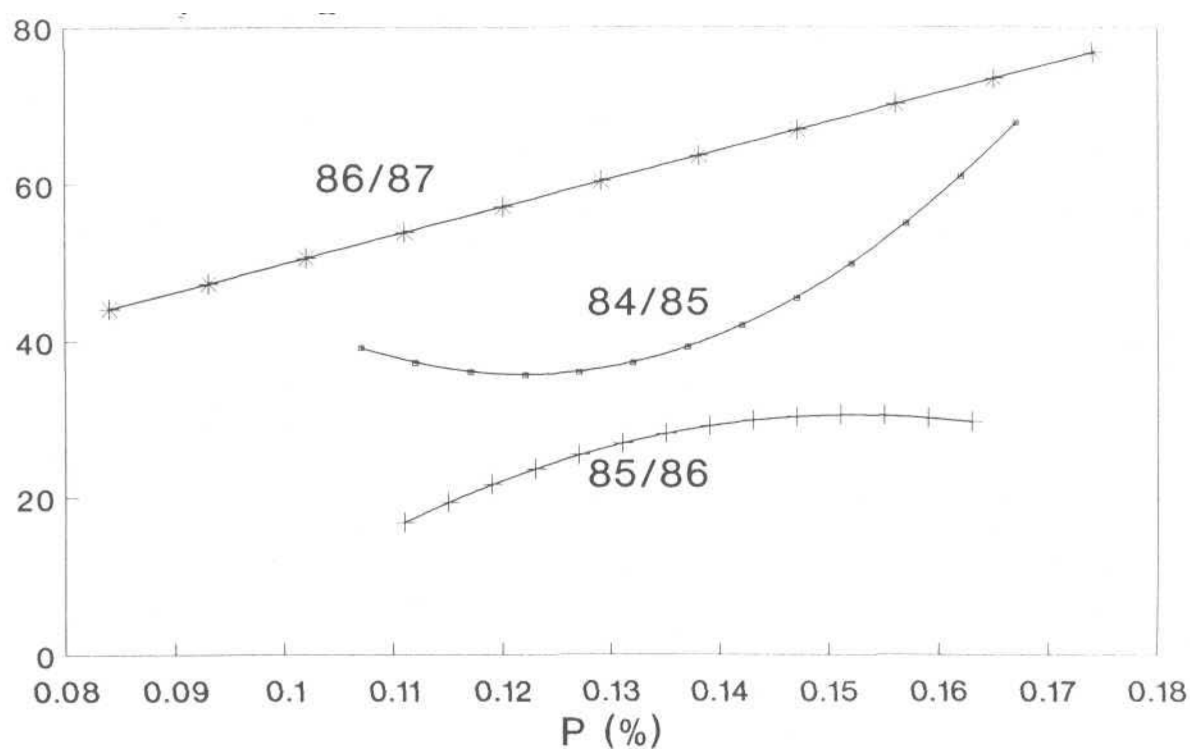

Fig. 8 Relationship between leaf K (x) in the 1984 season and yield (kg/tree) (y) obtained in the 1985 season. (R^2 =0.25, $y = -86.211 + 271.82x - 185.15x^2 + 39.46x^3$).