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MINERAL COMPOSITION IN RELATION TO LEAF MATURITY FROM 2000, 3000 AND 4000 CLONAL SERIES: LEAF ANALYSIS AS A GUIDE IN TEA CROP NUTRITION

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In order to investigate and thereby improve the desirable ranges of leaf nutrient concentrations in particular and soil nutrient status that are being used in the interpretation of crop performances in relation to clonal teas grown under different climatic conditions in Sri Lanka, flush (i.e. bud 1st and 2nd leaves), 4 different types of leaves and soils at depths of 0-15 and 15-30 cm were sampled from clonal field trials and analysed for nutrient status. The leaf samples were analysed for a range elements such as N,P,K,Mg, S, Ca, Zn, Mn, Cu, Fe and Al whereas soil samples were analysed for pH, organic carbon, P, K, Mg, Ca, Zn, Cu, Fe and Al.

While the N,K and P concentrations in the leaves decreased the Ca, Mn, Fe and Al concentrations increased with leaf maturity. Though the magnesium concentration increased with leaf maturity, no overall consistent pattern was found. The results indicated that the first mature leaf was not an entirely reliable guide for confirmation of visual observations, particularly at a time of widespread Mg deficiency. There was no consistent pattern in the variation of leaf S with maturity. This study revealed that Al content in the mature foliage of most clonal teas varied from 0.14 to 0.74% although previous reports claimed that Al content varied from 1.6 to 2.0%.

INTRODUCTION

When the supply of an essential plant nutrient element is severely limited, or is in excess, plant growth and crop yield are affected and deficiency or toxicity symptoms may appear in different organs such as leaves, fruits, shoots, bark etc. These symptoms have been described and illustrated for many crops and they are used as a preliminary guide for the diagnosis of nutritional disorders. However, non nutritional factors such as herbicide sprays, pests and diseases may some times cause symptoms similar to those induced by nutrient deficiencies. Although many factors affect plant nutrient composition for the accurate diagnosis of plant nutritional disorders and their correct interpretation a confirmatory method is required in addition to the visual symptoms exhibited.

Mostly, the leaf is chosen as a part of the plant for this nature of analyses, and is based on the contention that the leaf is the principal site of metabolism, where changes in nutrients are reflected in its composition. Leaf analysis is concerned with the total nutrients in leaves, at specific growth stages in relation to plant performance, as the changes in nutrient are more pronounced at certain stages of development than others, which are in turn reflected in the crop performance.

For precise diagnosis, the best leaf position and stage of plant development to reflect nutritional status, the nutrient concentrations associated with optimum growth or crop yield and the nutrient levels associated with deficiency and toxicity symptoms need to be established by experimentation. Once available these data could be employed, in the absence of non-nutritional limiting factors to adjust the fertiliser programs of crops and to improve their performance based on current nutritional status of the crop in relation to optimum levels.

Although different types of leaves and/or organs of tea plants have been sampled to assess the plant nutritional status, no commonality has been followed by all tea-growing countries in this respect due to differences in cultural practices adopted.

The desirable ranges of both leaf nutrient concentrations (First Mature Leaf ; FML) and soil nutrient status (0-15 cm depth) associated with better yields, crop performances and deficiency symptoms etc, in the tea-growing areas of Sri Lanka are given in Table 1 (Zoysa and Ananthacumaraswamy, 1995).

TABLE 1 – *Desirable ranges of leaf and soil nutrient status*

Element	*Leaf (%)*	*Soil*
Nitrogen	3 - 4	0.2 - 0.3%
Phosphorus	0.2 - 0.3	10 - 20 ppm
Potassium	1.5 - 2.0	80 - 200 ppm
Magnesium	0.2	60 ppm
Calcium	0.5 - 1.0	20 - 40 ppm

Tea plants accumulate Al in the foliage (egs. Haliara, 1922; Chenery, 1955). Further, Al content in the mature foliage is varied from about 16,000 to 20,000 ppm. (i.e. 1.6 & 2.0% respectively) both in seed and vegetatively propagated tea (Chenery, 1955; Sivasubramanium and Talibudeen, 1971). However, the Al content in the flush (bud, 1st and 2nd leaves), the component of tea plant that is harvested in order to manufacture made tea, varies from about 300 to 500 ppm (Chenery, 1955; Ananthacumaraswamy and Sivapalan, 1990). However, it is notewothy that even though reports claim that when Al or Al contaminated foods are consumed such inhabitants are likely to suffer from *Alzheimer* disease that causes mental disorders (Peiris, 1987). Ananthacumaraswamy and Sivapalan (1990) found that inspite of made tea containing high levels of Al, the brew did not contain even 5-10% Al.

Magnesium deficiency (Yellowing of mature leaves due to interventional chlorosis) in tea was observed in middle 1950's. Since then dolomitic limestone has been applied at various levels purely as a prophylactic measure. However, when acute Mg deficiency symptoms are observed, foliar applications of 4% commercial Epsom salt is recommended until deficiency symptoms disappear 3-4%. Further, Mg fortified NPK fertiliser mixtures are also recommended to fields that contain soil Mg below 40 ppm. (Anon., 1993). In order to assess plant nutrient status, the FML of a shoot (as shown in Plate 1 & Fig. 1) is recommended to be sampled in the leaf analyses procedure (Anon., 1984b). Although the FML is accepted as the leaf to be sampled it is observed that in the case of Mg, deficiency symptoms appear mostly in the lower maintenance foliage. In view if this, a range of leaves (flush, 3rd leaf, 1st mature leaf, 2nd mature leaf and maintenance foliage) were sampled and analysed for Mg which will also provide an opportunity to test the appropriateness of the FML for this purpose. In this study an attempt has been made to investigate the variation in mineral composition of the foliage of 3 clonal series (one older series and two newer).

MATERIALS AND METHODS

Leaves

The leaf samples were collected from clonal field trials established by the Plant Breeding Division of TRI, from three tea-growing regions such as Up Country -St. Coombs and Pundaluoya (about 1400 m amsl), Mid country - Passara (about 1120 m amsl), Low Country - St. Joachim, Noragolla and Watapotha (Ratnapura - about 600 m amsl). Some of the details from the above clonal field trials are also given in Tables 2 and 3.

TABLE 2 – *Some of details from the clonal field trials*

Region	*Clone*	*Year of planting*
Up-Country, St. Coombs	2023, 2024, 2025, 2026 and 2027	1970
	3015, 3017, 3018, 3025 and 3055	1991
Up-County, Pundaluoya	4052, 4053, 4067, 4071, and 4079	1992
Mid-Country, Passara	2023, 2024, 2025, 2026 and 2027	1972
	3030, 3035, 3051, 3057, and 3060	1976
	4051, 4052, 4054, 4067 and 4082	1984
Low-Country,	St. Joachim2022	1990
(Ratnapura)	Watapotha 2023	1988
St. Joachim	2025	1990
Watapotha	2026	1988
St. Joachim	2027	1990
Noragolla	3014	1988
Watapotha	3020	1988
Noragolla	3032, 3051, 3069 and 4047	1988
Watapotha	4053, 4054, 4055 and 4059	1988

TABLE 3 – *Some of details from leaf sampling and fertiliser practices*

Location	*Month of sampling*	*Fertiliser used*	*Month of last application*		
			Fertiliser	*Foliar sprays (Zn/Cu)*	*Dolomite*
St. Coombs	Aug. 95	U235	July 95	July 95	Jan. 91
Pundaluoya	Aug. 95	U709	Dec. 94	Dec. 95	N.K
Passara	Aug. 95	U235	May 95	May 95	Oct. 92
St. Joachim	Oct. 95	U709	July 95	July 95	N.K

U 709 - Consists of NPK at the ratio 6:1:3
U 235 - Consists of NPKMgS at the ratio 11:2:6:1:1
Rate of both mixtures varied from 60 to 80 kg N.
N.K. - Not known

Field trials

In clonal field trials, the performance of the clones are evaluated mainly by recording the yield and by making visual observations their susceptibility/tolerance to pest diseases and drought etc. Generally, their performance are evaluated under different agro-climatic regions, to test their suitability to those locations.

The above evaluation process is divided into three phases such as I, II and III, based on the availability of the planting material after hybridisation/pollination program, and they are as follows.

Phase I - Clonal rows; Each row consists of 07 plants in duplicate.

Phase II - Clonal blocks; Each block consists of 24 plants and in replicates.

Phase III - Clonal blocks in estate fields; large blocks of 150 to 500 bushes in duplicate.

Leaf samples

The different types of leaves as shown in Figures 1 and 2 were sampled from the above field trials, at the phase II and III stage. The details of these leaf samples and their respective abbreviations in this paper are given in Table 4. In each plot about 100 leaves were collected from all the bushes in the morning hours (i.e. between 0800 to 1200 hours) (Anon., 1984b).

Leaf sample preparation

Leaf samples were brought to the laboratory and dried in an oven at 80°C. The dried samples were ground in a Willy mill, through a 2 mm sieve. These samples were used for leaf analysis.

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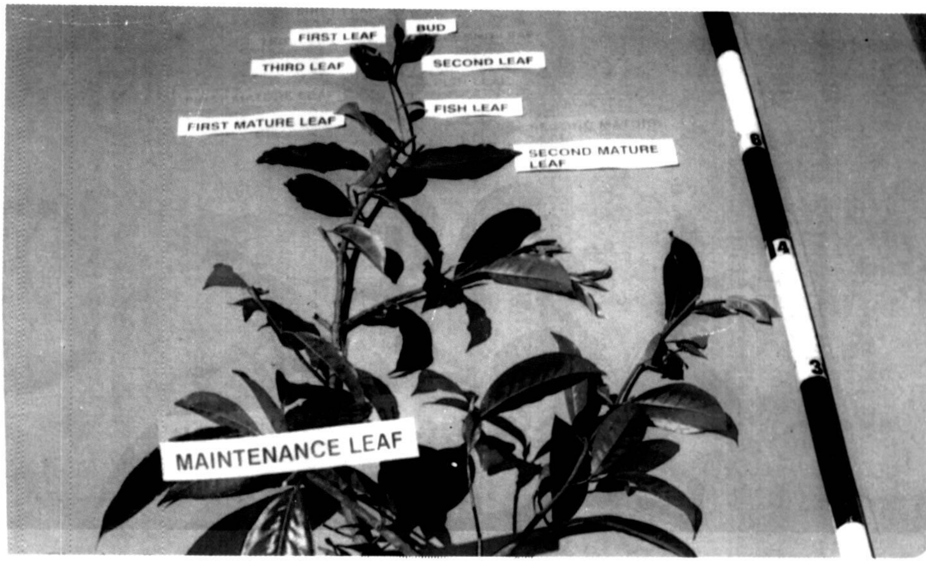

Fig. 1 – *Branch of a tea–plant, showing different types of leaves sampled in this study*

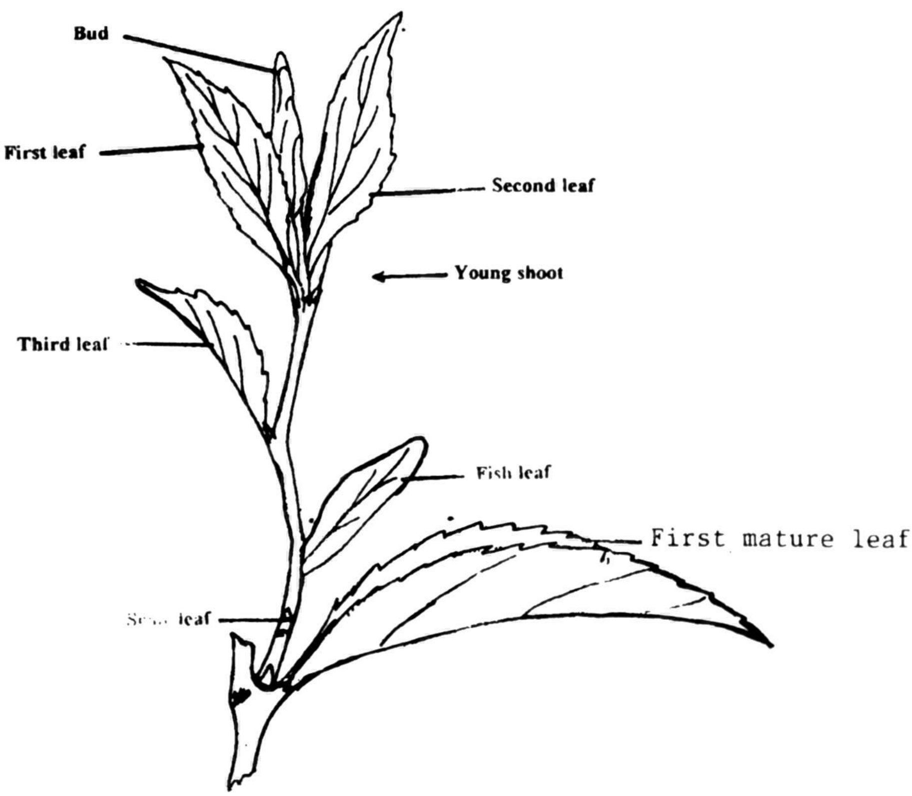

Fig. 2 – *A tea shoot showing the 1st mature leaf sampled for nutrient analysis*

L.S.K. Hettiarachchi, A. Balasingham, S. Ananthacumaraswamy, G.P. Gunaratna and A.A.P. Warnasiri

TABLE 4 – *The details of leaf samples and their abbreviations*

Details of leaf samples	*Abbreviation*
The flush (bud 1st and 2nd leaves; the component of the tea bush plucked at each harvest)	F
Third leaf on plucked shoot or the leaf above the fish leaf	TL
First mature leaf or mother leaf; leaf from the axil of which the present pluckable shoot has emerged	FML
Second mature leaf or the leaf below mother leaf; leaf from the axil of which the previous pluckable shoot has emerged	SML
Maintenance leaf, as low down in the bush as possible, but still green (generally between 5 to 10 leaves below plucking table)	MTL

Laboratory methods in leaf analysis

The mineral composition (N, P, K, Mg, Ca, Fe, Al, Mn, Zn, Cu, and S) of the different types of leaf samples were determined in duplicate. The Al content of leaves was determined to see whether these leaves are consistent with the results obtained in previous studies.

Soil

Soil samples were collected from all the above clonal field trials from which leaf samples were taken.

Soil samples

Soil samples from each location were obtained from 0-15 and 15-30 cm depths (Anon., 1984 a). Samples from each location were mixed and a sub sample of 1000 g was taken from each composite sample for the analyses.

Soil sample preparation

The sub sample was air dried and sieved through a 2mm sieve. The 2 mm soil samples were further ground in a motor and pestle to a fine powder and used for determination of percentage C.

Laboratory methods in soil analysis

From these soil samples pH in water suspension, oxidisable organic carbon, borax extractable P, exchangeable K, Mg, Ca, Al, Zn, Cu and Fe were determined in duplicate.

Computing

The statistical analysis of data were carried with the aid of the Statistical Analysis System (SAS) computer package. Least Significant Differences (LSD) were calculated at 0.05 probability level. All graphs were drawn using Harward Graphics 3.0 (HG3) version.

Data analysis

The data were subjected to the analysis of variance procedure (ANOVA) for a randomised block design. The types of clones, the types of leaves and replicates (i.e 2) were taken as the sources of variations. However, location was not taken as a source of variation because the differences in climatic conditions and types of soil in each location and the differences in the fertiliser mixtures (i.e. NPK or NPK and Mg) as well as the doses etc, that perhaps influence the overall growth of plants, are different for each location. The clonal series was also not taken as a source of variation as well because in each series, higher and lower yields of clonal teas that perhaps relates or varies with overall nutrient composition are found.

RESULTS

Macronutrients

The variations of macronutrient concentrations such as N, K, P, Mg, S, and Ca in different clones in relation to leaf maturity are shown in Figs. 3 to 8 respectively.

Nitrogen, Potassium and Phosphorus

In all clonal teas, the N, K, and P concentrations decreased with leaf maturity (Figs. 3 to 5). The highest concentrations of these macro nutrients were found in flush (bud, 1st and 2nd leaves), that is harvested in order to manufacture made-tea. Generally, greater variation in N, K and P concentrations were found between F and FML than that between FML and MTL (see Figs. 3 to 5).

The ranges of N, K and P percentages in F, TL, FML, SML and MTL varied from 2.94 - 4.62, 2.45 - 4.20, 2.45 - 3.85, 2.38 - 3.46 & 2.07 - 3.22; 1.23 - 2.25, 1.04 - 2.15, 0.75 - 1.25, 0.64- 1.22, & 0.54 - 1.20 and 0.18 - 0.4, 0.12 - 0.3, 0.07- 0.28, 0.06 - 0.24 and 0.05 - 0.21 respectively.

Magnesium

Although, the variation of Mg concentration appeared to increase with leaf maturity, no overall consistent pattern was observed. The lowest concentration of Mg was found either in the flush or in the 3rd leaf (Fig. 6). The ranges of Mg precentage in F, TL, FML, SML and MTL varied from 0.15 - 0.28, 0.11 - 0.28, 0.12 - 0.31, 0.13 - 0.40 respectively.

Sulphur

There was no consistent pattern in the variation of leaf S with leaf maturity (Fig. 7). The ranges of S percentage in F, TL, FML, SML and MTL varied from 0.21 - 0.46, 0.21 - 0.49, 0.21 - 0.46, 0.26 - 0.49 and 0.21 - 0.49 respectively.

Calcium

In all, clonal teas, the Ca concentration increased with leaf maturity (Fig. 8). Greater variation in Ca concentration was found between F and FML than that between FML and MTL. The ranges of Ca percentage in F, TL, FML, SML and MTL varied from 0.10 - 0.45, 0.19 - 0.72, 0.39 - 1.64, 0.65 - 1.73 and 0.6 - 1.52 respectively.

Micronutrients

The variations of micronutrient concentrations such as Mn and Fe in different clones in relation to leaf maturity are shown in Fig. 9 and 10 respectively.

Manganese and Iron

In all clonal teas, the Mn and Fe concentrations increased with leaf maturity (Figs. 9 and 10). The lowest concentrations of Mn was found in flush (bud, 1st and 2nd leaves). However, the lowest concentration of Fe was found either in F or in TL. The ranges of Mn (%) and Fe (ppm) concentrations in F, TL, FML, SML and MTL varied from 0.01 - 0.10, 0.01 - 0.01, 0.01 - 0.19, 0.03 - 0.23 & 0.03 - 0.22 and 49 - 139, 49 - 105, 60 - 188, 78 - 215 and 96 - 316 respectively.

Zinc and Copper

The ranges of Zn and Cu concentrations (ppm) in F, TL, FML, SML, and MTL varied from 20 - 60, 8 - 39, 2 - 131, 3 - 162 and 3 - 136 and 9 - 45, 4 - 32, 5 - 129, 7 - 120 and 6 - 129 respectively.

Non-nutrient elements

The variation of Al concentration in different clones in relation to leaf maturity is shown in Fig. 11.

Aluminium

In all clonal teas, the Al concentration increased with leaf maturity (Fig. 11). Greater variation in Al concentration was found between F and FML than that between FML and MTL. The ranges of Al percentage in F, TL, FML, SML and MTL varied from 0.03 - 0.15, 0.05 - 0.29, 0.14 - 0.57, 0.17 - 0.64 and 0.25 - 0.74 respectively.

Soil nutrient status

Some of the physico-chemical parameters in relation to soil nutrient status are given in the Table 5, in order to support the interpretation of plant nutrient status if required.

TABLE 5 - *Some of the physico - chemical parameters in relation to soil nutrient status*

				ppm							
Location	*Depth (cm)*	*pH*	*C%*	*P*	*K*	*Mg*	*Ca*	*Al*	*Zn*	*Cu*	*Fe*
St. Coombs	0-15	5.0	3.1	108	240	163	349	1008	5	2.6	7
	15-30	5.0	2.9	73	200	149	338	1170	3	0.9	1
Passara	0-15	4.5	2.2	66	115	54	15	742	1	1.1	22
	15-30	4.5	1.4	26	90	37	114	836	2	2.1	10
St. Joachim	0-15	4.1	0.6	50	95	14	35	452	14	N.D	28
	15-30	4.1	0.5	35	75	8	30	429	29	N.D	42

N.D. - not detectable

DISCUSSION

Desirable ranges of plant nutrient status and the choice of leaf in the diagnosis

Nitrogen

The N deficiency symptoms, i.e. general yellowing are initially shown in the flush and/or younger leaves, except some specific clones where they are seen as pinkish - yellow flush. In Sri Lanka, generally, ground application of fertiliser N varies from 240 to 360 kg N ha $^{-1}$ yr $^{-1}$. However, measurement of soil N is not being carried out except under special circumstances where both soil NH_4^+ - N and/or NO_3^- - N are measured.

Leaf N concentration decreased with leaf maturity as in the case of all other investigations (Barua and Deb, 1960; Hasselo, 1965). In Sri Lanka, the FML is recommended to be sampled in order to confirm the visual observations and to assess the nutritional status (Anon, 1984b). However deficiency or toxicity symptoms have not been pointed out although most of symptoms are known elsewhere. The desirable/optimum range of N% in the FML is considered as 3 to 4% based on the earlier leaf analysis. The results of this study also showed that the N% in the FML of most clonal teas varied from 3 to 4% except Pundaluoya location where no fertiliser was applied during the previous year (Table 3, Fig. 3). Even in Kenya, where upper-most mature leaf is sampled, the adequate N concentration is considered as above 3.5% (Otheino, 1988).

Potassium

The K deficiency symptoms, i.e. marginal scorching at tips, are first shown in the mature leaves which extends towards leaf blade later. Generally, ground application of fertiliser K varies from 120 to 180 kg k_2O ha $^{-1}$ yr $^{-1}$. Measurement of soil K is usually being carried out in 1.0 N NH_4CL solution. The soils and leaf (i.e. seed tea) data from the Eden long-term fertiliser trial revealed that the optimum K concentration in the FML (1.7%) was found when soil solution K level was about 12 ppm. This level was related to 107 ppm K extracted by 1.0 N NH_4CL solution (Sivasubramanium and Jayman, 1976). From a recent nutrient survey from South India Verma (1992), reported that the K concentration in the mother leaf that is likely to be of FML varied from 0.81 to 1.54%. This survey was carried out from 02 fields of 02 estates in Anamallais that produced higher and lower yields. In Kenya, where upper most mature leaf is sampled, the adequate K concentration is considered to be above 1.5% (Otheino, 1988).

Although, the desirable/optimum range of K% in the FML is considered as 1.5 to 2% based on the earlier established figures, the results of this study revealed that the K% in the FML varied from 0.75 to 1.25%. The extractable K levels of some these soils also varied from 75 to 240 ppm as well. Therefore the present desirable/optimum range of K% in the FML, particularly in relation to clonal teas need to be carefully evaluated. Here again, if K deficiency symptoms are described in the Advisory Circular then it is easier to sample the FML based on the observation which would undoubtedly lead to a better diagnosis.

Phosphorus

The P deficiency symptoms, i.e. bluish green colouration, are first noticed in the mature leaves. Nevertheless, symptoms of P deficiency have hardly been observed in tea in Sri Lanka (Wickremasinghe and Krishnapillai, 1986). Leaf P concentration decreased with leaf maturity as in the case of all other studies (Hasselo, 1965; Jayman and Sivasubramanium, 1980). Generally, ground application of fertilizer P varies from 30 to 60 kg P_2O_5 ha^{-1} yr^{-1}. Extractable soil P content is measured from borax solution (pH 1.5). The soils and leaf (i.e. seed tea) data from the Eden long-term fertiliser trial revealed that the optimum P concentration in the FML (0.25%) was found when borax extractable P level was about 25 ppm (Jayman and Sivasubramanium, 1980). In South India, from a recent nutrient survey, the P concentration in the mother leaf that is likely to be the equivalent of the FML varied from 0.11 to 0.20% (Verma, 1992). In Kenya, where upper most mature leaf is sampled, adequate P concentration is considered to be above 0.17% (Otheino, 1988).

The desirable/optimum range of P% in the FML is considered as 0.2 to 0.3% based on the earlier established figures. However, the results of this study revealed that the P% in the FML of most clonal teas except few varied from 0.11 to 0.28%. The range of P% averaged over each clone varied from 0.13 to 0.21%.

Magnesium

The Mg deficiency symptoms, i.e. yellowing due to interveinal chlorosis, are first noticed in the mature foliage. Generally, the supply of Mg nutrient for mature tea plant is met by the application of crushed dolomitic limestone preferably at pruning or as a mid-cycle application (Anon., 1989). Application of Mg fortified NPK fertiliser mixtures to mature tea plants is specifically recommended if soil Mg extracted by 1.0 N NH_4 CL solution adjusted to pH. 7.0 is lower than 40 to 60 mg kg^{-1}, even after dolomitic limestone application (Anon., 1993). The ground application of fertiliser Mg varies from 15 to 20 kg MgO ha^{-1} yr^{-1}.

Magnesium deficiency symptoms are widespread in most of the tea plantations in Sri Lanka, and symptoms are observed particularly in lower maintenance foliage than in FML. From a series of field trials where different forms of Mg fertilisers such as kieserite ($MgSO_4.H_2O$) and sul-po-mag ($MgSO_4.K_2SO_4$) are being tested with NPK fertiliser components, the Mg concentration in the FML varied from 0.13 to 0.16% without yellowing due to interveinal chlorosis, whereas Mg concentration in the maintenance foliage (i.e. yellowed mature leaves sampled between SML and MTL; Fig. 1) varied from 0.05 to 0.09% (Unpublished data). This indicated that it is not essential that the first mature leaves (FML) should always be sampled if visual observations are to be confirmed, particularly at a time, that Mg deficiency symptoms are widespread in Sri Lanka. Thus, these results suggested the necessity to include another leaf preferably from the maintenance foliage despite first mature leaf (FML) if Mg deficiency symptoms are observed.

In South India, a recent nutrient survey, indicated that the Mg concentration in the mother leaf that is likely to be the equivalent of the FML was found to be varied from 0.06 to 0.24% (Verma, 1992). In Kenya, where upper most mature leaf is sampled, the deficit Mg concentration is considered to be below 0.1% (Otheino, 1988).

Sulphur

The S deficiency symptoms, i.e. bright yellowing leading to net veining, are initially exhibited in younger leaves, and later both in younger and mature leaves. Soil and plant S reserves were assessed from a long-term urea and ammonium sulphate fertiliser trial, laid down in St. Coombs Estate in 1980. Soil and leaf analysis carried out after 6 year period showed despite significant increase in total soil S and ammonium acetate extractable SO_4^{2-}-S in the soil (0-30 cm depth) that received ammonium sulphate compared with urea, the S status in the bud 1st and 2nd leaves and the mature leaves (i.e. 0.31 - 0.41%) remained unaffected (Wickremasinghe *et. al.*, 1986). The ammonium acetate extractable SO_4^{2-}-S levels of soil that received ammonium sulphate varied from 570 to 720 mg kg^{-1} whereas in soils that received urea the levels varied from 225 to 450 mg kg^{-1}. Further the soil survey carried out at this time revealed that tea soils contained higher S levels (500 to 600 mg kg^{-1} SO_4^{2-}-S) when compared with jungle soil. However similar analysis carried out after 12 year period showed that the S status in bud, 1st and 2nd leaves and mature leaves remained unaffected but the S status in the soil markedly decreased when compared with the S status after 6 years period. Subramanya Bhat and Ranganathan (1980) reported that S concentration in flush and mature leaves varied from 0.22 - 0.28 and 0.33 - 0.34 respectively. from South India.

The S% in the FML varied from 0.21 to 0.46% under better tea-crop performance, if deficiency symptoms of S are described in the TRI Advisory Circular, then it is easier to sample the FML based on the observations which would undoubtedly lead to a better diagnsis.

Calcium

Calcium deficiency symptoms have hardly been observed in tea in Sri Lanka. Ca deficiency symptoms are induced under controlled conditions by Pethiyagoda and Krishnapillai (1970). The development of large numbers of small translucent spots on the above leaf of the newly formed leaves have been observed. Bonheure and Willson (1992) reported when there is a gross excess of Ca, as often occurs on soil of high pH, the young shoots and leaves are affected first showing symptoms such as shortened stems, lack of leaf growth, yellowed and curled leaves etc.

Based on the earlier established figures the range of Ca concentration in the FML is considered to vary from 0.5 to 1.0%. However, the results of this study revealed that the Ca% in the FML of most clonal teas varied from 0.39 to 1.64%. Leaf Ca concentration increased with leaf maturity as in the case of all other studies (Hasselo, 1965; Jayman and Sivasubramanium, 1980).

Zinc

Zinc deficiency symptoms, i.e. the sickle shaped leaves, are initially exhibited in younger leaves. The Zn is supplied to mature tea plants by foliar sprays of zinc sulphate at the rate of 6 or 11 kg ha^{-1} yr^{-1}. In a recent nutrient survey carried out in South India, the Zn content in the mother leaf that is likely to be equivalent of the FML varied from 15 to 126 ppm (Verma, 1992). In Kenya, where upper most mature leaf is sampled, the deficiency leaves of Zn is considered below 10 ppm (Otheino, 1988). The results of this study also revealed that the Zn content in the flush varied widely (i.e. 20 to 60 ppm) whereas in the mature foliage varied from 2 to 162 ppm.

Manganese and iron

Both Mn and Fe deficiency symptoms are very rare in tea, Mn deficiency symptoms are occasionally observed from soils of very high pH. Leaves turn pale yellow on the edges and develop mottled red brown spots.

However Mn toxicity is probably the second most important growth limiting factors in acid soils next to Al. The potential toxicity of Mn to a given crop depends on the total Mn content, pH, Organic matter level, aeration and microbial activity of soil (Foy, 1973). Concentration of Mn found in the tea plants were higher than are normally found in most other crops (Eden, 1976). Foliar application of 2% solution of $MnSO_4$ is effective in correcting chlorosis. Whenever Mn deficiency is suspected the soil pH should be corrected and adequate measures should be taken to bring the soil pH below 5.5.

Copper

Copper deficiency is very rare. Plant deficient in Cu have slightly darker leaves, however the difference is difficult to judge in the field.

Aluminium

Aluminium toxicity is probably the most important growth limiting factor for plants in strongly acid soils. Plant species differ widely in their tolerance to excess soluble or exchangeable Al in acid soils. In general, plants classified as calcifuges are more tolerant to Al toxicity than those classified as calcicoles.

Although Al is not regarded as an essential nutrient, Foy, Chaney and White. (1978) reported that low concentrations sometimes increase plant growth or produce desirable effects. Tea (*Camellia sinensis* L.) is one of the plants that have shown positive growth responses to Al.

Although, Chenery (1955) and Sivasubramanium and Talibudeen (1971) reported that the Al content in the mature foliage varied from 1.6 to 2.0%, the results from this study revealed that the Al content in the mature foliage of most clonal teas varied from 0.14 to 0.74%. The Al contents of the flush that is harvested in order to manufacture made-tea varied from 300 to 1500 ppm.

CONCLUSIONS

While the concentrations of N, K and P decreased those of Ca, Mn, Fe and Al concentrations increased with leaf maturity.

There was no consistent patterns in the variation of leaf S with maturity.

Further, the results of this study revealed that Al content in the mature foliage of most clonal teas varied from 0.14 to 0.74% although the previous reports claimed that Al content in the mature foliage varied from 1.6 to 2.0%.

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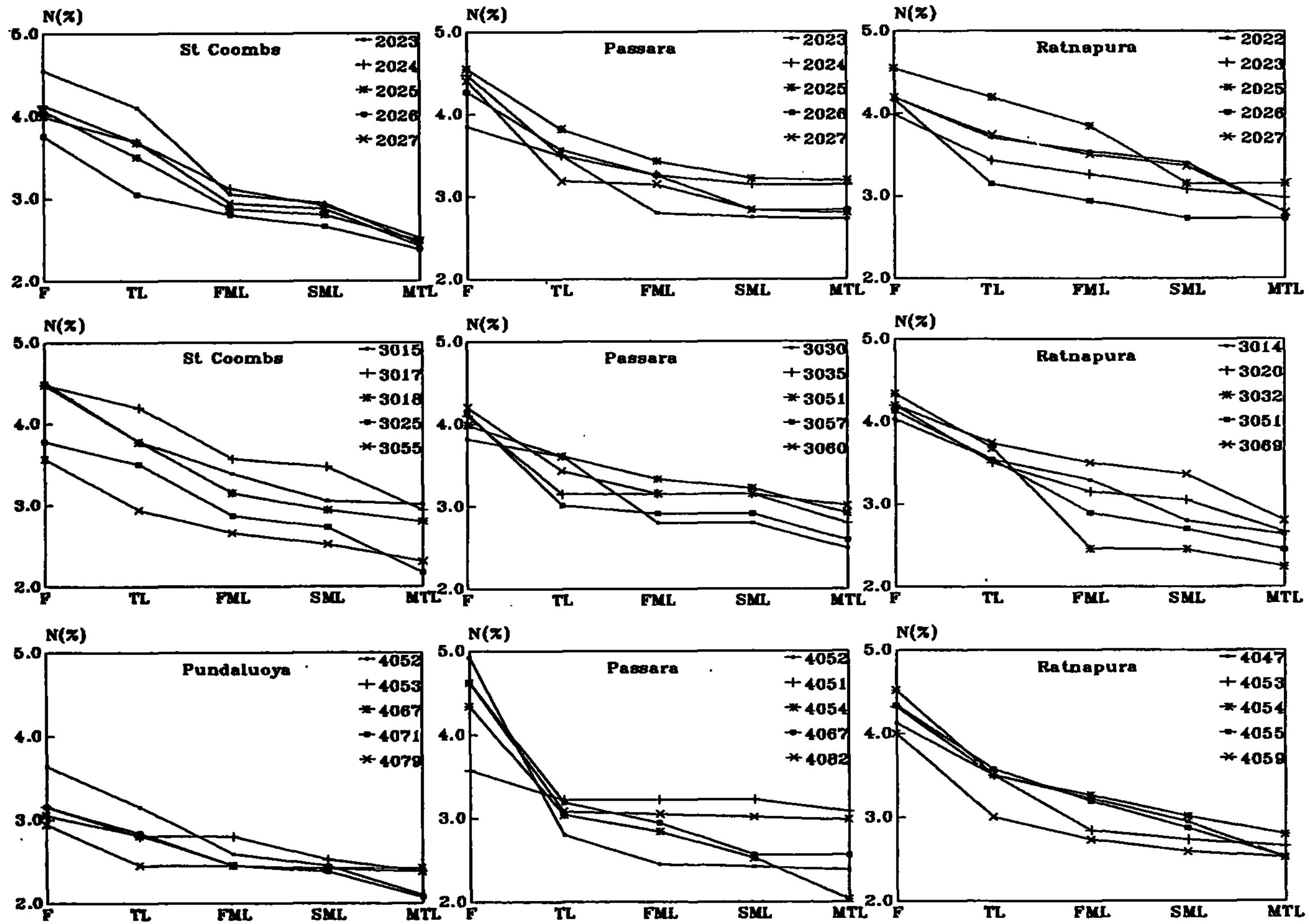

Fig. 3 - The relation between N% and leaf position from three different tea-growing regions

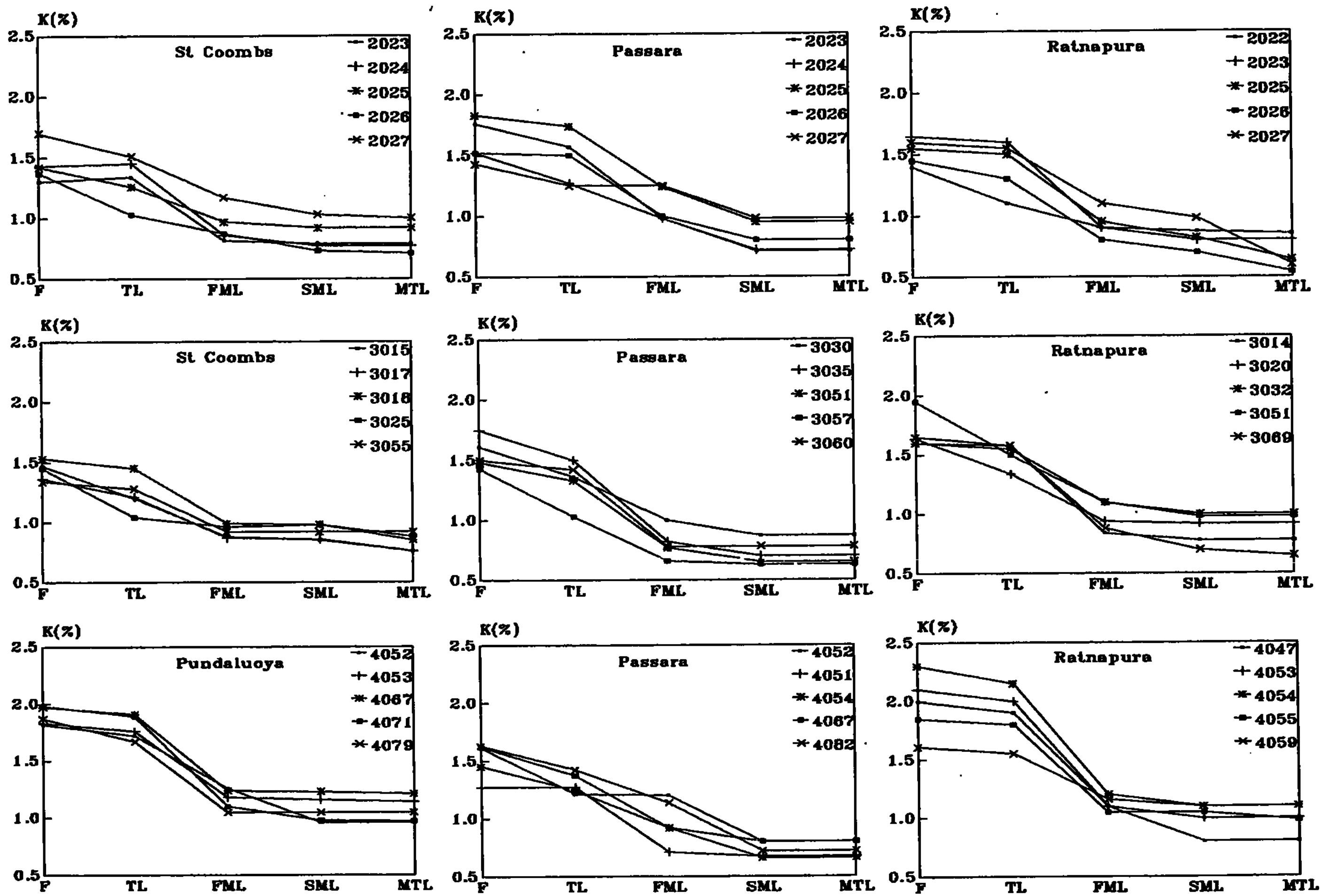

Fig. 4 – The relation between K% and leaf position from three different tea-growing regions

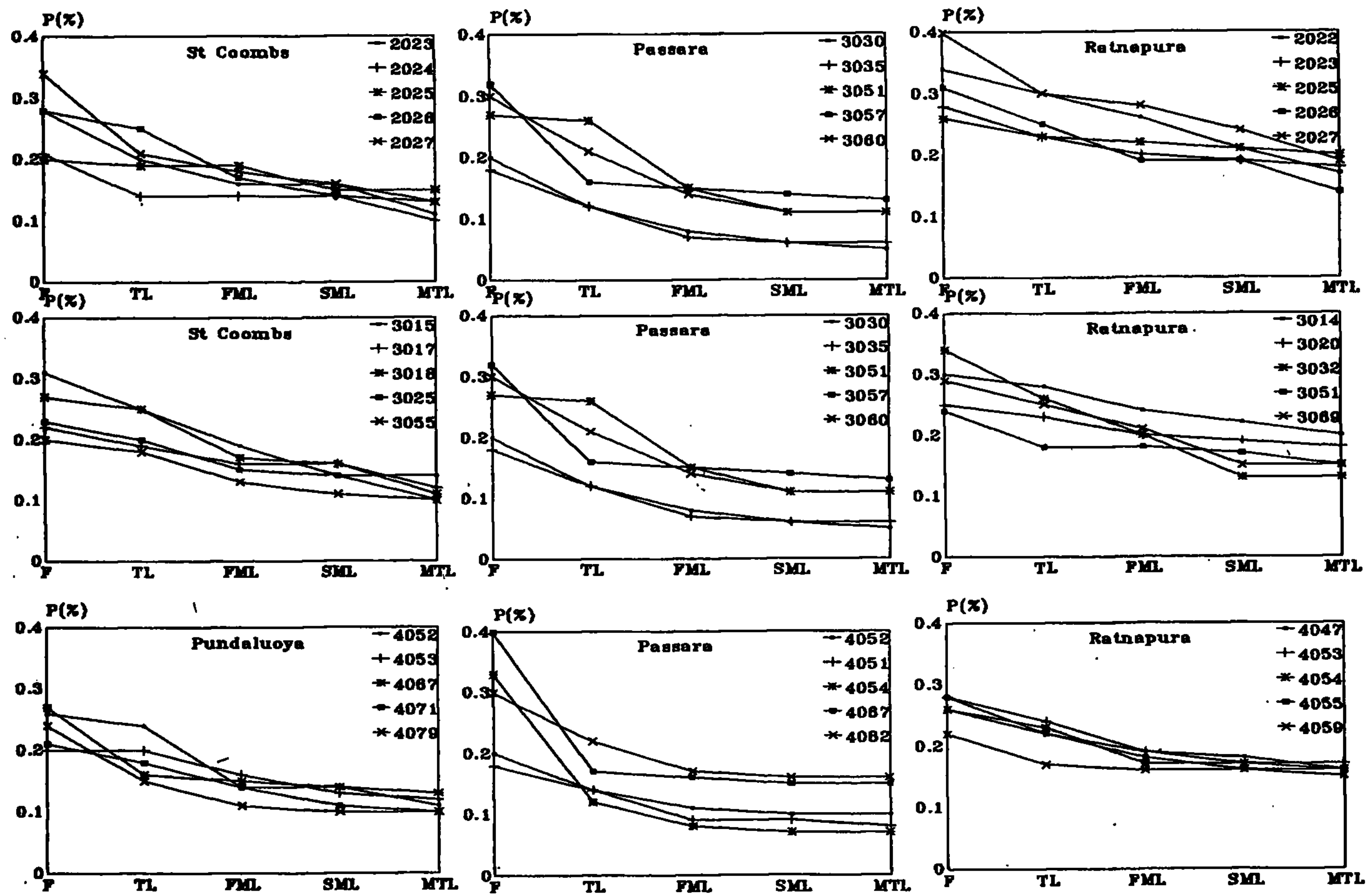

Fig. 5 – The relation between P% and leaf positon from three different tea-growing regions

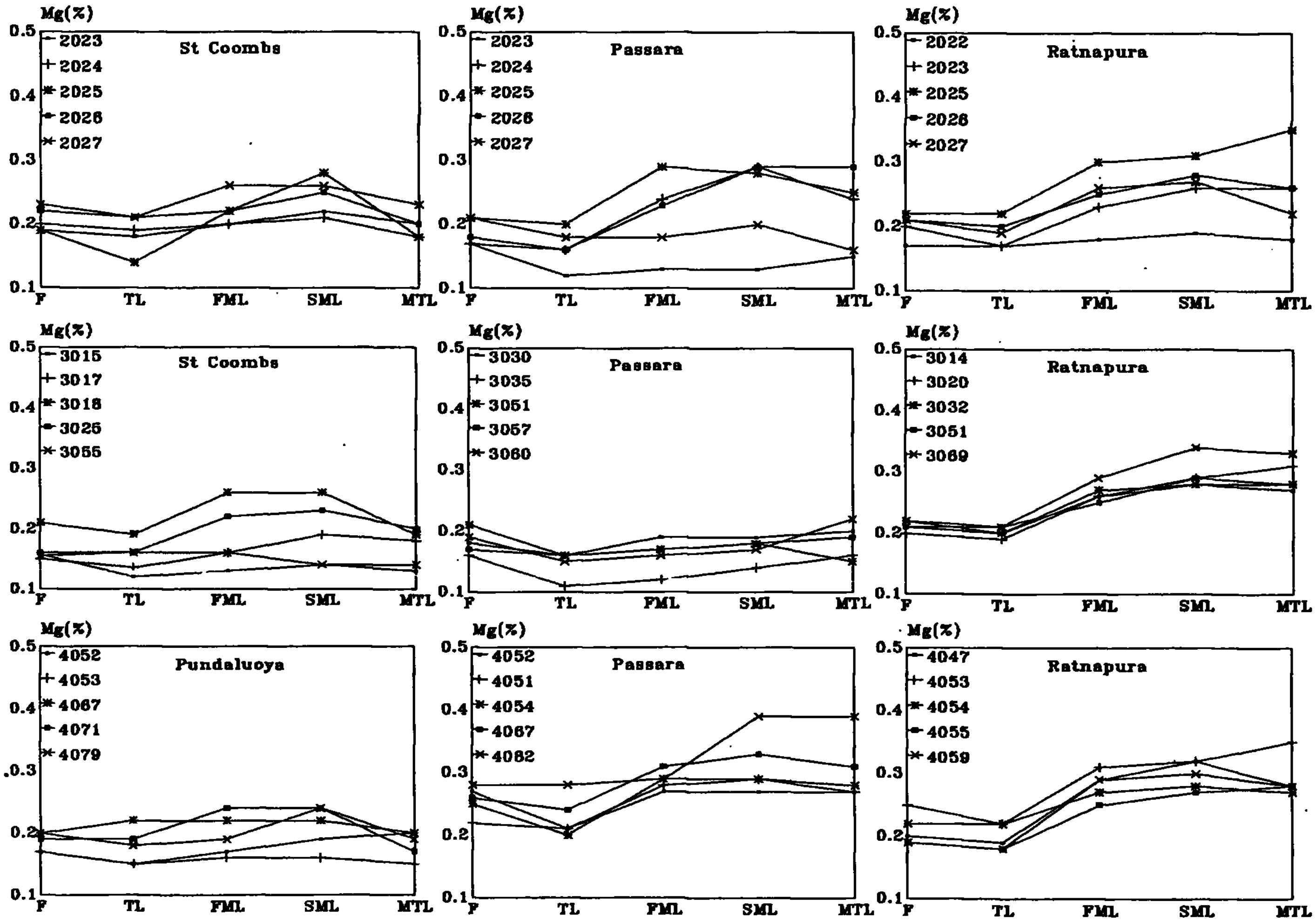

Fig. 6 – The relation between Mg% and leaf position from three different tea-growing regions

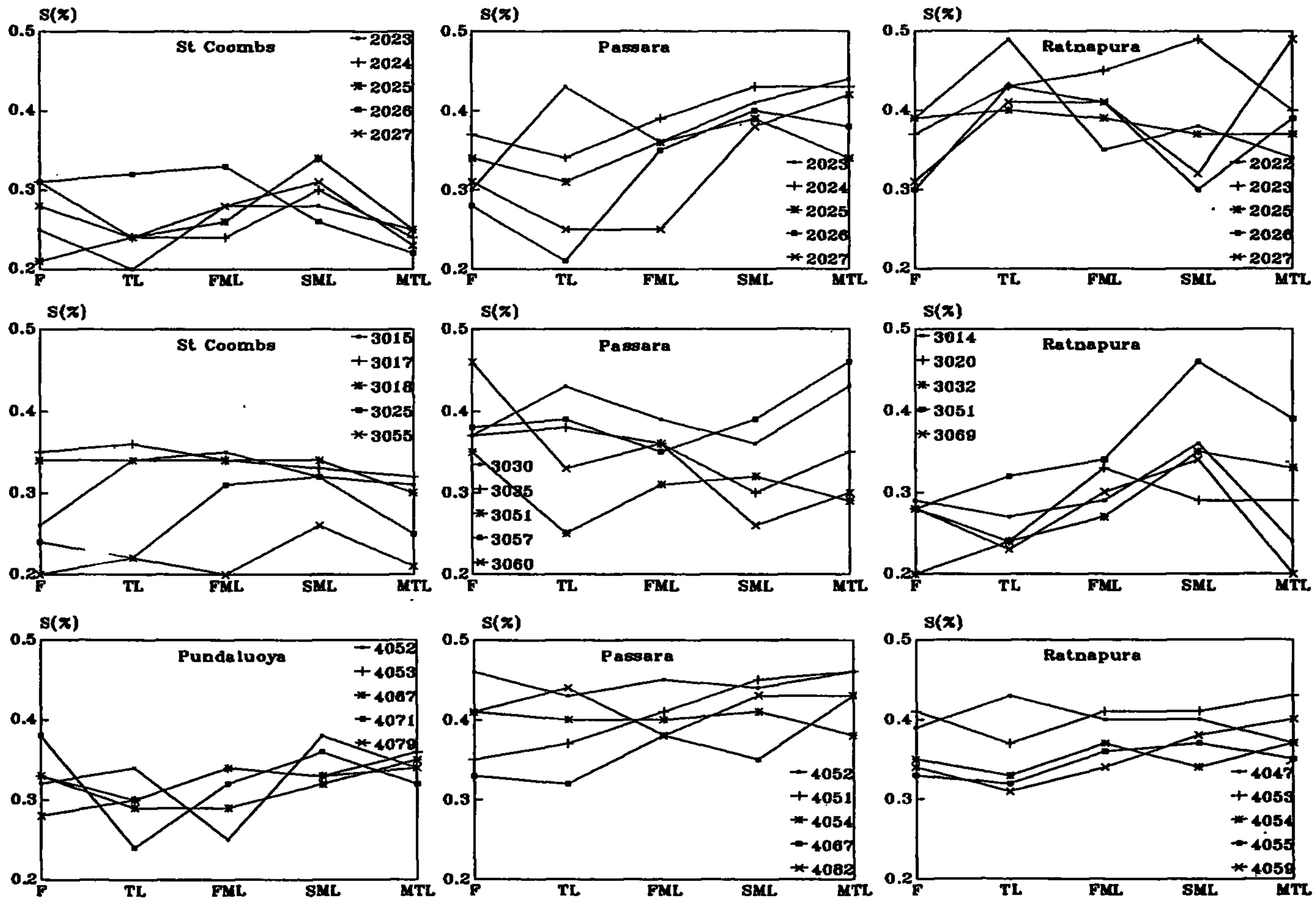

Fig. 7 – The relation between leaf S% and leaf position from three tea-growing regions

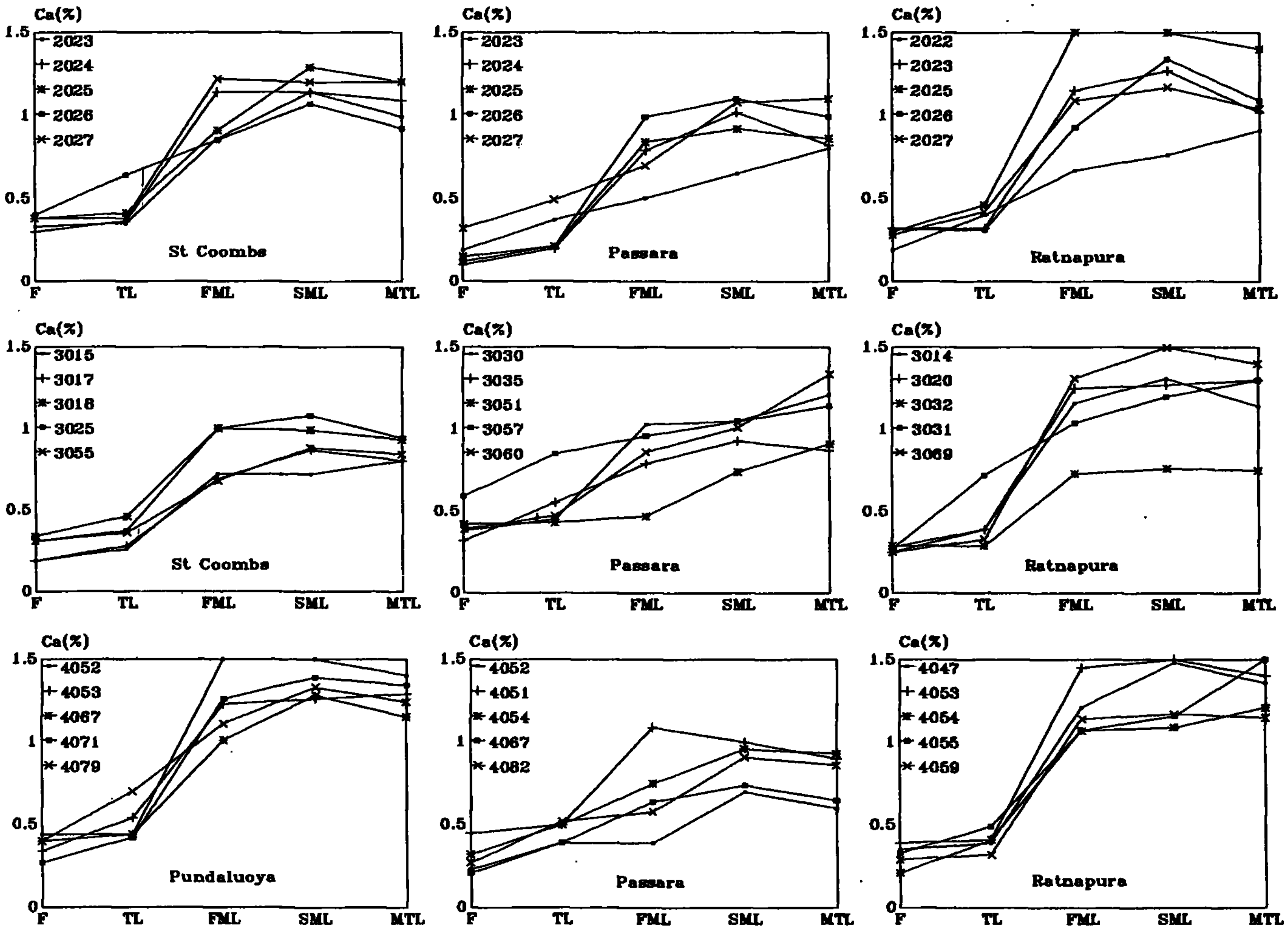

Fig. 8 – The relation between Ca% and leaf position from three different tea-growing

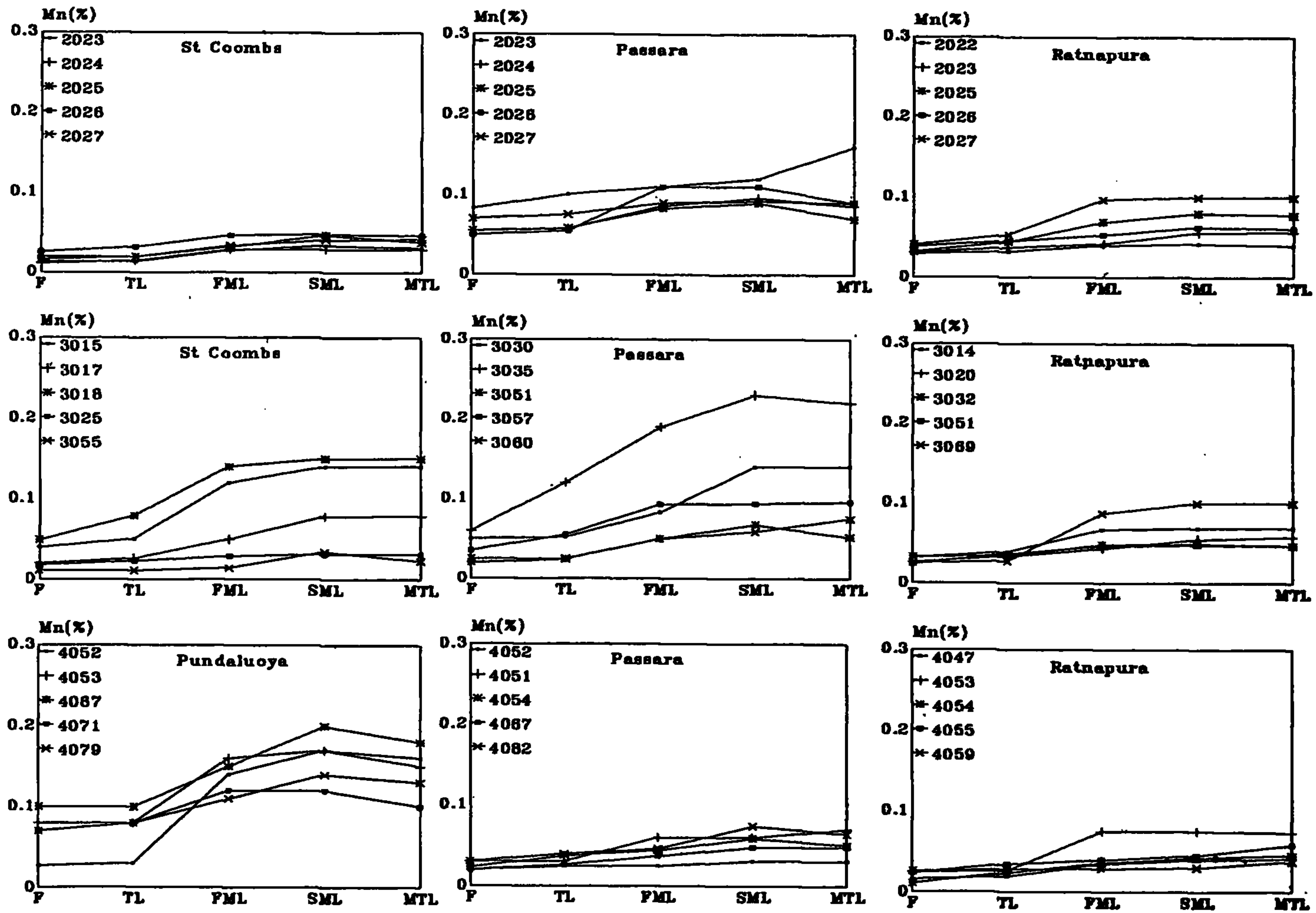

Fig. 9 – The relation between leaf Mn% and leaf position from three different tea-growing regions

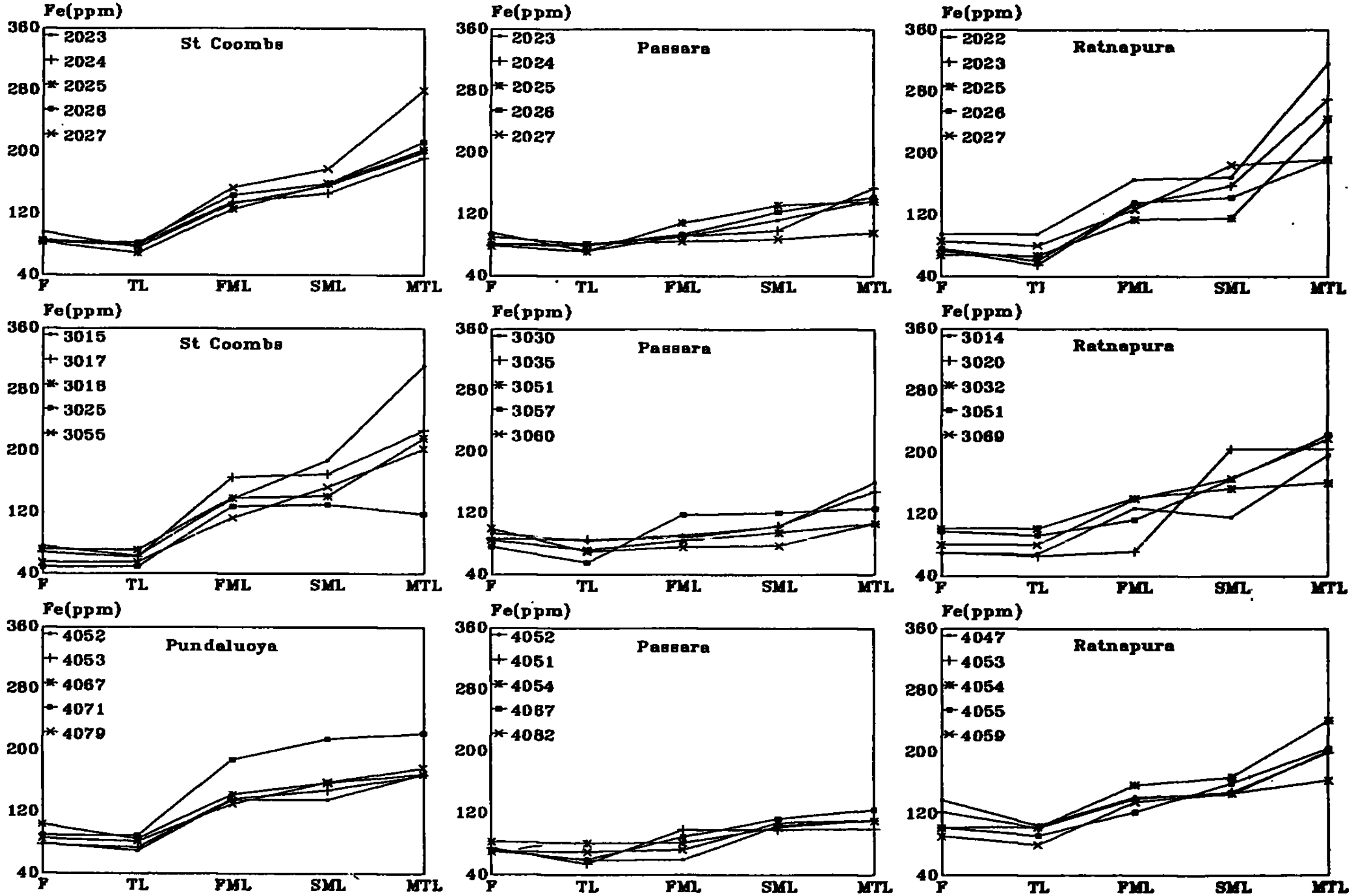

Fig. 10 – The relation between leaf Feppm and leaf position from three different tea-growing regions

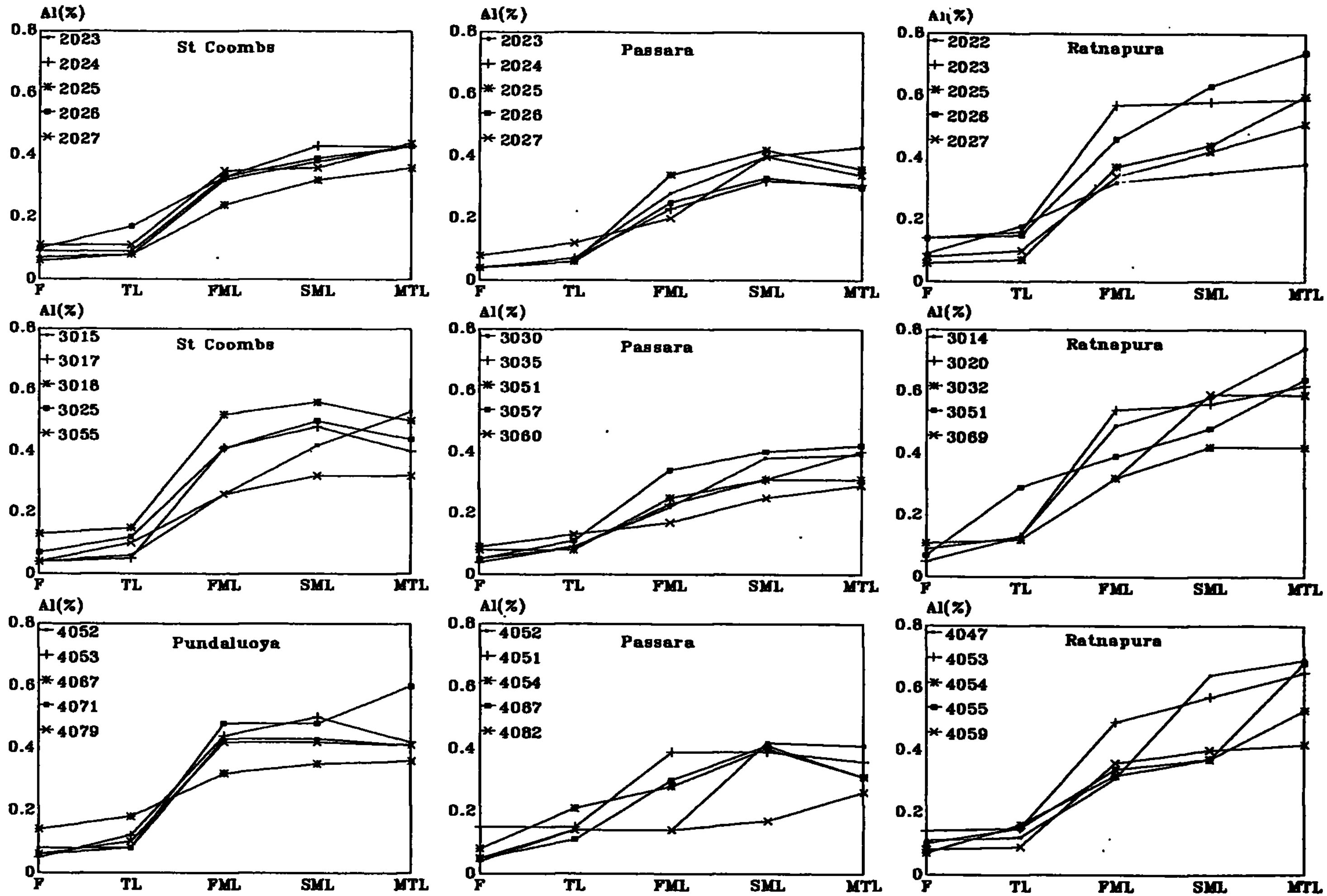

Fig. 11 – The relation between leaf Al% and leaf position from three different tea-growing regions