STUDIES ON INORGANIC FRACTIONS AND EVALUATION OF CHEMICAL EXTRACTANTS FOR PHOSPHORUS IN TOBACCO GROWING SOILS

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Affectionately dedicated to

My Beloved Parents

Brothers

&

Sister

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
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CERTIFICATE

This is to certify that the thesis entitled, **"STUDIES ON INORGANIC FRACTIONS AND EVALUATION OF CHEMICAL EXTRACTANTS FOR PHOSPHORUS IN TOBACCO GROWING SOILS"** submitted by **Mr. NAGARAJA, M.P.** for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) IN SOIL SCIENCE** of the University of Agricultural Sciences, Bangalore, is a record of *bona-fide* research work done by him during the period of his study in this University under my guidance and supervision. This thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I INTRODUCTION

Phosphorus is an essential element for vital life process, such as photosynthesis and energy transformations It also has a significant role in sustaining and building up soil fertility, particularly under intensive system of agriculture.

Soils are known to vary widely in their capacities to supply phosphorus to crops mainly because of only a small fraction of the total phosphorus in soil is in a form available to crops. Thus, unless the soil contains adequate amount of plant available phosphorus, or is supplied with readily available (inorganic) phosphorus fertilizers, crop growth will suffer. Phosphorus content of Indian soils ranges from 0.006 to 0.5 per cent. Distribution of various forms of iron, aluminum and calcium and factors like soil age, drainage condition, mineralogical nature of soil as well as nature and amount of fertilizers applied are known to control phosphorus fractions in soil (Walsh and Beaten, 1973).

Soils of southern transitional zone of Karnataka, a narrow strip of about 50 km. wide from west to east and stretches from Shikaripura taluk of Shimoga district to Heddadevanakote (H.D. Kote) of Mysore are neutral to acidic in reaction derived from granites and gneiss. Nearly 57 and 24 per cent of the soils of this zone are medium and high in available phosphorus status, respectively (Gajanan *et al.*, 1987). This has been observed more continuously. Such a situation may be due to continuous application of high dose of phosphorus (80 kg.ha^{-1}) as against the low uptake of phosphorus (Gopalachari, 1984) resulting in phosphorus build up in soil.

Flue cured Virginia tobacco (FCV) is an important commercial crop of this zone occupying nearly 32,000 hectare area. For the production of FCV tobacco, emphasis is laid not only on the quantity but also on quality as it contributes to foreign exchange. A desirable growth with right quality can only be achieved through balanced and timely application of nutrients.

Availability of phosphorus is controlled by dynamic equilibrium among the different fractions of soil phosphorus where as the relative abundance of these chemical pool depends upon the physico-chemical properties of soil. Such information of soil phosphorus under tobacco cultivation is meagre. The investigation may therefore provide information regarding not only the extent of chemical pool of each fraction but also their relationship with soil properties.

Phosphorus being highly versatile element in its ability to chemically interact with soil mineral and organic components as well as precipitate in to insoluble phosphates. Several chemical extractants have been suggested from time to time to estimate available phosphorus, but all these extractants have to be verified for different soils and crop situation. Therefore information on the behavior of different chemical extractants for soils under tobacco cultivation needs to be assessed.

Keeping in view the above points , the present investigation has been taken up on soils under tobacco cultivation with the following objectives:

1. To study the status and relationship of inorganic fractions of soil phosphorus in relation to soil properties.
2. To find out the phosphorus availability by different extractants inrelation to its fractions.
3. To find out the suitable chemical extractant for available phosphorus in FCV tobacco growing soils.
4. To study the response of FCV tobacco to the application of phosphorus and its effect on content and uptake of other nutrients.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

There has been enormous research activity on phosphorus in soil and plant system ever since the definitive evidence for essentiality of plant for growth of higher plants was established. Phosphorus is not only involved in many kinds of reaction in soil but also play many vital physiological processes in plants. Owing to its importance in soil and plant system, voluminous literature has been accounted on various aspects of plant in recent years. In this chapter literature relevant to the present study have been briefly reviewed ;

2.1 Fractionation of Inorganic soil phosphorus

A knowledge of various forms of phosphorus present in soil is essential for assessing the phosphorus nutrition of plants. The availability of phosphorus depends on the amount of different phosphorus fractions and their solubility. Distribution of inorganic phosphorus fraction is related to the degree of chemical weathering.

Singh *et al.* (1968) reported that Bihar soils were found to contain inorganic phosphorus to the extent of 70 per cent of the total phosphorus and they indicated various components as Occluded Fe-P > Ca-P > Fe-P > Al-P > Occluded Al-P in sedentary soils and Ca-P > Occluded Fe-P > Fe-P > Occluded Al-P > Al-P in alluvial soils.

Lawrence *et al.* (1970) in an investigation demonstrated that newly applied phosphorus accumulated mainly in the NH_4F- soluble fraction in the soil, but substantial amounts were also recovered in the NaOH soluble fraction.

In an investigation conducted by Rajukkannu and Ravikumar (1975) revealed that Fe-P fraction was found to be the primary source of phosphorus in soil and it was available to the plants more easily. Al-P fraction was found to be less in red and alluvial soil, but spectacularly high in black soils. Fe-P fraction was found to be high in red, alluvial and lateritic soils but low in black soils.

Vig and Dev (1984) reported the phosphorus adsorption characteristics of some acid and alkaline soils of Punjab. Acid soils adsorbed more phosphorus as compared with the alkaline ones. In acid soils, more than 90 per cent of the adsorbed phosphorus was as Fe-P and Al-P and in alkaline soils, about 40 per cent was Saloid bound phosphorus.

Sharpley and Smyth (1985) revealed that the distribution of inorganic phosphorus in virgin non-calcareous soils was 2 per cent loosely bound, 52 per cent non-occluded and 46 per cent occluded. Cultivation resulted in an increase in non-occluded and decrease in occluded phosphorus.

Doddamani and Seshagiri Rao (1988) revealed that Ca-P was the dominant mineral form of phosphorus in Vertisols and Inceptisols and contributed 14.5 and 11.5 per cent of the total phosphorus in the soils respectively. Iron-P constituted 14.2, 9.1, 2.5 and 2.4 per cent of the total phosphorus in Oxisols, Alfisols, Vertisols and Inceptisols respectively.

Mishra (1994) analyzed the soil samples representing Western Uttar Pradesh for the different phosphorus forms. The amount of organic phosphorus varied widely i.e., 6.0-25.7 per cent of the total phosphorus, Ca-P was dominant inorganic phosphorus which constituted 14.3-48.0 per cent of total phosphorus, Al-P in these soils accounted for 3.0-12.2 per cent. Where as the Fe-P constituted 2.9-13.1 per cent of the total phosphorus.

2.2 Relationship of phosphorus fractions with soil properties

The form of phosphorus present in the soil depends on some of the soil physical or chemical properties existing in the particular soil. The relationship of these fractions with the phosphorus fractions were carried out by many of the workers, and some of them were presented below,

In a study conducted by Mishra and Ojah (1969) on phosphorus distribution in black and red soils of Uttar Pradesh, concluded that the organic matter, $CaCO_3$ and sesquioxides were found to be paramount importance in determining the distribution of phosphorus in soils.

Sacheti and Saxena (1973) reported that the correlations between pH and Saloid bound phosphorus were negatively significant for clay soils, while pH and Fe-P correlated negatively for sandy loam, sandy clay loam and clay soils. Significant correlations in case of organic carbon was recorded for Saloid bound phosphorus in sandy loam, aluminium bound in sandy clay loam, iron bound phosphorus in sandy loam, sandy clay loam, clay loam and clay soils. Forms of phosphorus in relation to physico-chemical properties of the soils of Uttar Pradesh were studied by Singh and Pathak (1973). They observed that the proportion of Ca-P in those soils was much higher in comparison to other form of soil- phosphorus. Fe-P and reductant soluble-phosphorus correlated positively with pH and organic matter. They also observed significant positive correlations between available phosphorus and Al-P, Fe-P, Reductant Soluble-P and Ca-P.

Goshal (1975) indicated that the concentration of phosphate ions in the soil solution was influenced by the rate and immobilization and reaction with the clay mineral fraction of soils, in turn the chemical fixation and release of phosphate was regulated by soil reaction and by the native content of clay minerals in the soil.

Uzu *et al.* (1975) reported that the total phosphorus content in the surface soils studied ranged widely from 120 to 1880 ppm. In most cases the relative abundance of the fractions of inorganic phosphorus was in the order of Occluded P > Fe-P > Al-P > Ca-P. Multiple correlation showed that organic phosphorus content was significantly correlated with soil pH, organic carbon content and total phosphorus content in the soils.

The distribution of phosphorus across the different fractions and their relationship to other soil chemical properties and to evaluate the effects of different soil development on P composition (Tiessen *et al.*, 1984) correlation and regression analysis of P distribution and chemical analysis confirmed the partial dependence of organic matter accumulation on available forms of P. They concluded that the relative proportions of available and stable as well as organic and inorganic P forms were dependent upon chemical properties and related to soil taxonomy.

Jaggi (1991) studied the relative properties of different forms of inorganic P influenced by different soil characteristics like pH, organic carbon, $CaCO_3$, CEC and texture in valleys of Himalaya. pH bears a significantly negative correlation (r=-0.60**), with Fe- P and significantly and positively correlated with Saloid-P and Al -P content.

The transformation and availability of phosphorus in some acid soils of Haryana depends upon the properties of the soil and some of P, clay and the organic matter content. Calcium carbonate content in case of alkaline soils and Al and Fe content in case of acid soils (Tek Chand *et al.*, 1992).

Patgiri Rao and Datta (1993) studied the forms and distribution of phosphorus in some Tea growing soils of Assam and stated that organic matter content of the soil contributed towards total P accumulation. There exists a positive correlation between Ca -P and RS -P with Organic P. RS - P negatively correlated with soil pH where as available P positively correlated with total P, and with Organic carbon.

Folle *et al.*, (1995) studied the effect of sludge on soil phosphorus fractions. The soils were adjusted to three pH levels of 5.8, 6.4 and 7.0 Water soluble P, Al-P, Ca-P, Fe-P, and total P were measured and higher soluble P was observed at soil pH of 7.0, Al-P and Fe-P at pH 5.8 and Ca-P at pH 6.4 and 7.0 Al-P and Fe-P was observed at pH 7.0.

2.3 <u>Evaluation of chemical extractants for available phosphorus</u>

The knowledge of the various forms of P present in soils and the condition under which these become available to plants is a pre-requisite for assessing the availability of P to the crop. And the phosphorus equilibrium is controlled by common ion principle, solubility product principle and by the adsorption of phosphorus on the surface of the particles (Ramamoorthy and Velayuthan, 1976).

Olusegun *et al.*, (1990) compared soil P extractants viz, Bray- Kurtz P1, Bray-Kurtz P2, Olsen and anion exchange resin (AERP) in ten

Michigan soils. Linear correlation coefficients among the Bray-Kurtz P1, and P2, Olsen P and AERP methods ranged from 0.79 to 0.99. The highest correlation was with Olsen extractant and lowest was with Bray- Kurtz P1.

Sanchez and Hanlon (1990) compared seven extractant viz., water, $NaHCO_3$, DTPA, EDTA, Mehlich-I and Mehlich-III for soil phosphorus test for a fast growing vegetable lettuce (*Luctuca satira*) on Florida Histosols. None of the extractants provided good correlations to lettuce response than water-P, although the Mehlich-III extractant gave similar correlations indicating that it may be suitable for use in Histosols.

Brar and Cox (1991) reported that the Olsen's solution is usually considered the best extractant for estimating phosphorus availability in calcareous soils. But predictability of response to P fertilizers is often low under field conditions.

Thirty two soils from Southern part of Guatemala was used to evaluate the chemical methods of phosphorus estimation viz., Bray 1, Mehlich 1, Pi strip and Resin strip. Bray 1 and Mehlich 1 readily dissolved Ca-P and over estimated available P. The Pi strip and Resin strip methods were more appropriate in estimating available phosphorus (Leal *et al.*, 1994).

Investigations carried out by Bhiyan and Sedberry (1995) on determination of extractable phosphorus with different extractants in soils of Louisiana, USA. Among the extractants Bray II extractant, in general extracted significantly larger quantities of phosphorus than did the other extractants.

Five reagents (modified Olsen, Mehlich 3, Mehlich 1, Bray 1 and modified Morgan) were tested for the determination of available P in soils of Costa Rica. The modified Olsen method was highly and significantly correlated with all the other methods for Ultisols and Andisols and slightly less for Inceptisols and Vertisols (Cabalceta, 1995).

Krishna and Satyanarayana, (1996) estimated soil - phosphorus by different methods like Bray No.1, Olsen, Truog, Datta and Kamath and Morgan in Vertisols located in different agro-climatic zone of northern Karnataka. The phosphorus extracting power of different extractants was in the order; Truog > Bray No.1> Olsen > Datta and Kamath > Morgan. Olsen and Bray No.1 extracts were more consistent in extracting P from specific phosphorus fractions than the other three extractants.

2.3.1 Suitability of chemical extractant for available phosphorus

Soil test data has to be verified with crop response and reliability of soil test methods for predicting critical levels of nutrient is important.

With this several workers studied many available soil phosphorus extractants for different crops and some of them were reviewed ;

Subramaniyan (1971) indicated that Bray's extractant (0.03 N NH_4F + 0.025 N HCl) was most suitable for acid soils of Malnad tracts of Karnataka. He found a critical soils test value of 2.5 ppm in an experiment with three levels of phosphorus and four extractants and wheat as a test crop.

Enwezer (1977) found that the phosphorus extraction with 0.03 N NH_4F + 0.1 N HCl had highest correlation with per cent yield (r = 0.74) in soils of south eastern Nigerian soils.

Mehlich (1978) found that phosphorus uptake by millet was highly correlated with phosphorus extracted by 0.2 N NH_4F+0.2 N HCl+0.03 N NH_4F and dilute acids 0.05 N HCl+0.025 N H_2SO_4. Mehlich followed by Olsen's extracted 0.5 M $NaHCO_3$ pH 8.5.

Panda (1982) reported that several extractants have been developed for estimation of available phosphorus. Bray's phosphorus and Olsen's phosphorus extractant are yet to be replaced taking into consideration of the case of analysis and time factor.

Menon *et al.* (1988) evaluated Pi paper test (Iron-hydroxide-impregnated filter paper test) with Bray-1, Bray-2, double acid, Olsen, water and resin extraction method in wide range of maize (*Zea maize*) growing soils of Hartsells and received highly significant correlations with crop response.

Bates (1990) compared five chemical soil phosphorus extractants on surface samples from 88 Ontario soils using maize in greenhouse. The correlation of extractable phosphorus to plant uptake resulted in r values of 0.74, 0.73, 0.54, 0.65 and 0.66 for $NaHCO_3$, AB-DTPA, Bray -Kurtz-P1, Bray-Kurtz-P2 and Mehlich-III.

Jaggi *et al.* (1990) in their studies, among seven phosphorus extraction methods using wheat growing soils in valleys of Himachal Pradesh. The Bray-P1 method was found to be best followed by Olsen method and Truog methods. The critical limits by these methods were 17.5, 7.4 and 7.2 ppm respectively.

Khadtar *et al.* (1991) compared suitability of soil test methods for available phosphorus in rice growing lateritic soils of South Konkan coastal zone of Maharastra. Among four methods , the Olsen-P and Bray-P2 method were superior to Truog and Bray-P1 for predicting available phosphorus status of these soils for rice under green house condition.

Naidu *et al.* (1991) reported a very close relationship between Plant-available P and resin extractable soil-P, in contrast to Olsen, Colwell, Bray-I , Bray-II while Mehlich-III extractable phosphorus were only weakly correlated with phosphorus uptake.

Thind *et al.* (1991) found that the amount of phosphorus extracted by different extractants decreased in the order of Mehlich-P > Hunter-P > Bray-P1 > Olsen-P . 0.01 M $CaCl_2$. Mehlich P extracted more of phosphorus from soil due to special property of complexing Al^{3+} and Fe^{3+} in ions in acid solution.

Simard *et al.* (1991) evaluated Sr-citrate extracting solution with water $NaHCO_3$, Bray-1, Bray-2, Mehlich-3 and 0.1 M HCl soil tests as extractants for soil-P, in Oat (*Avena sativa.* L) and Corn (*Zea maize* .L.) soils. The phosphorus extracted from 34 soils by Sr-citrate procedures was very closely related to that extracted by the six other solutions.

Dhillon and Sidhu (1992) compared different soil-P test methods in ground nut growing soils Ludhiana, the tests were Olsen, Datta and Kamath and Bray P1 and concluded that none of the methods correlated significantly with any of the yield parameters.

Bray's P1 extractant was rated as the most suitable method among the differentsoil-Ptest methods in Soybean growing valleys of Himachal Pradesh. The critical limit by this Bray's P1 method was 16.0 ppm.

Saloid-P fraction accounted for the major variation in available Phosphorus extracted by this extractant (Jaggi, 1992).

Raghbir Singh *et al.* (1992) observed that the available soil P in barely growing soils of Haryana were in the order of Sulthanpur < Olsen < Morgan < Bray P1 < 1N NH_4F + 0.05 M EDTA < 1N $NaHCO_3$ + 0.05 1N EDTA and Olsen-P was correlated well.

Henry *et al.* (1993) compared phosphate extraction techniques (Truog, Bray 1 & 2 and Ambic) in a range of soils from Swaziland and South African sugar industries. The test crop was maize in green house, gave good results with 0.02 N H_2SO_4 (Truog method).

Available phosphorus test for Berseem (*Trifolium alexandrium*) were compared in fourteen soils from Haryana. The best results were obtained with the Olsen (r = 0.78) and modified Olsen (r = 0.80) extractants with critical limits of 8.0 and 7.5 kg phosphorus per ha respectively (Raghbir Singh *et al.* 1993).

Vinay Singh *et al.* (1993) determined available phosphorus by different soil-phosphorus estimation method in wheat growing soils of Uttar Pradesh. Among them Stewart, Morgan and 0.5 M NH_4HCO_3 (Datta and Khera, 1959) appeared most promising.

Adetunji (1994) studied phosphorus indices in maize growing soils of South Western Nigeria. The different methods viz., Bray-1, Bray-2, Olsen and resin-P . Olsen-P and resin-P has got good correlation with crop uptake.

Datta (1994) evaluated soil phosphorus extractants by using various extractants like Bray P1, Bray P2, North Carolina P and Spurway phosphorus in Ultisols of Tripura with Mung bean (V*igna radiata*) and Bray's method gave the good result.

Milap Chand and Dhillon (1994) evaluated ten rapid soil testing procedures for available phosphorus in greenhouse with wheat as a test crop. Among them phosphorus extracted by Olsen's method had the highest correlation with grain yield, relative yield and total phosphorus uptake by wheat. The critical level of soil phosphorus, with Olsen method was found to be 10 mg. P kg^{-1}.

Tehuenteu (1994) compared five chemical extractants for soil phosphorus estimation in 20 different acids soils of Cameroon. Among the different methods , Mehlich and double acid gave the best correlation with dry matter yield of maize.

Baljith Singh *et al.* (1995) evaluated Pi soil test method along with different extractants in wheat growing soils of Punjab. Among all the extractants, strip embedding phosphorus had the highest correlation co-efficient with dry matter yield. Phosphorus uptake followed by strip shaking phosphorus (Pi).

2.3.2 Relationship of chemical extractants with different fractions of soil phosphorus

The forms of soil phosphorus that are associated with Al, Fe, and Ca govern their solubility and potential availability determined by different extractants. The rate and quantity of phosphorus that can be solubilised by chemical extractants related to plant availability and represent the phosphorus fertility of soils. The previous work on relationship of various extractants with fractions of phosphorus were presented below,

Olsen's extractant removed most of its phosphorus from the Al-P fraction followed by the Ca-P fraction. studied the indices of phosphorus availability in some acid soils of Himalaya, Northern West India have indicated that the critical limit of available phosphorus for lentil crop was found to be 7 ppm. (Sharma and Tripathi, 1984).

Patiram *et al.* (1990) in their studies on forms of soil phosphorus in acid soils of Sikkim found that Al-P contributes more towards phosphorus availability to maize than Fe-P and Ca-P. The critical limits of available phosphorus by Bray P and Mehlich's extractants were 18 and 15 ppm respectively.

Kumaraswamy and Sreeramulu, (1991) studied some soils of Tamil Nadu for inorganic phosphorus fractions and its relationship with phosphorus extracted by some soil test chemical methods for rice. The result show that the Al-P and Fe-P contribute dominantly to the labile phosphorus pool in all the soils. Ca-P fraction appeared to contribute very small portion.

Verma *et al.* (1991) studied the relationship between available phosphorus and inorganic fractions in soils of eastern Uttar Pradesh. Al-P was found as the most abundant phosphorus fraction followed by Ca-P and Fe-P in Karail soils; while in red, alluvial soils and Tarai soils Ca-P is the most dominant fraction followed by Fe-P and Al-P. The correlation indicates that Olsen-P is closely and positively related with Al-P, Fe-P and Ca-P in all soils.

Reddy *et al.* (1991) studied the effect of long term application of phosphorus on the availability and forms of phosphorus in Coffee soils. Available phosphorus extracted by Bray-1 extractant and Al-Fe-P fractions were significantly positively correlated with dry matter yield and phosphorus uptake.

Patiram *et al.* (1993) reported that available phosphorus in Hilly soils of Meghalaya were in the order; Bray-2 > Mehlich > Olsen > Bray-1 and the inorganic phosphorus fractions was in the order; Reductant Soluble-P > Fe-P > Al-P > Ca-P, Al-P and Fe-P were the main source of available phosphorus in the soils.

Cujuste *et al.* (1994) conducted a laboratory and greenhouse experiment to study the relationship among phosphates fractions and phosphorus bio availability of tropical soils (Oxisols and Alfisols) in maize crop. They observed highly significant correlations for Bray-P versus resin-P and Bic-P, Olsen-P versus most phosphorus fractions and Mehlich's-P versus resin-P, Bic-P and residual-P.

Nagendra Rao and Chakrabarthy (1994) studied phosphorus indices with the extractants and evaluated in relation to inorganic P fractions in Tea growing soils of Himachal Pradesh. The relative abundance of inorganic phosphorus fractions form the order of RSP(reductant soluble P) > Fe-P > Ca-P > Al-P > Saloid-P. And the Mehlich 3 extractant was correlated well.

2.4 <u>Phosphate potential</u> (pP)

Most of the current methods measures the available soil phosphorus in terms of quantities by extracting different fractions of soil P. Schofield as early as in 1955 proposed the chemical potential for nutrient availability and suggested phosphate potential for P availability in relation to calcium.

According to Aslyng (1964) the total phosphorus uptake by plants is a linear function of potential. pP which expresses the work required for removal of phosphorus ions from the soil, when the phosphorus supply is the only limiting factor. Thus uptake was also a linear function of the application of dissolvable phosphate.

Elrashidi and Larsen (1978) reported that the increasing P additions to the soils resulted in decreasing phosphate potentials. the results that the P concentration in the soil solution was controlled by an adsorption type of mechanism.

Doddamani (1982) characterized Typical alluvial, black, red and laterite soil types of Karnataka for Phosphate potential and the data on pP values revealed that pP of black and alluvial soils was higher than that of red and laterite soils.

MATERIAL AND METHODS

III MATERIAL AND METHODS

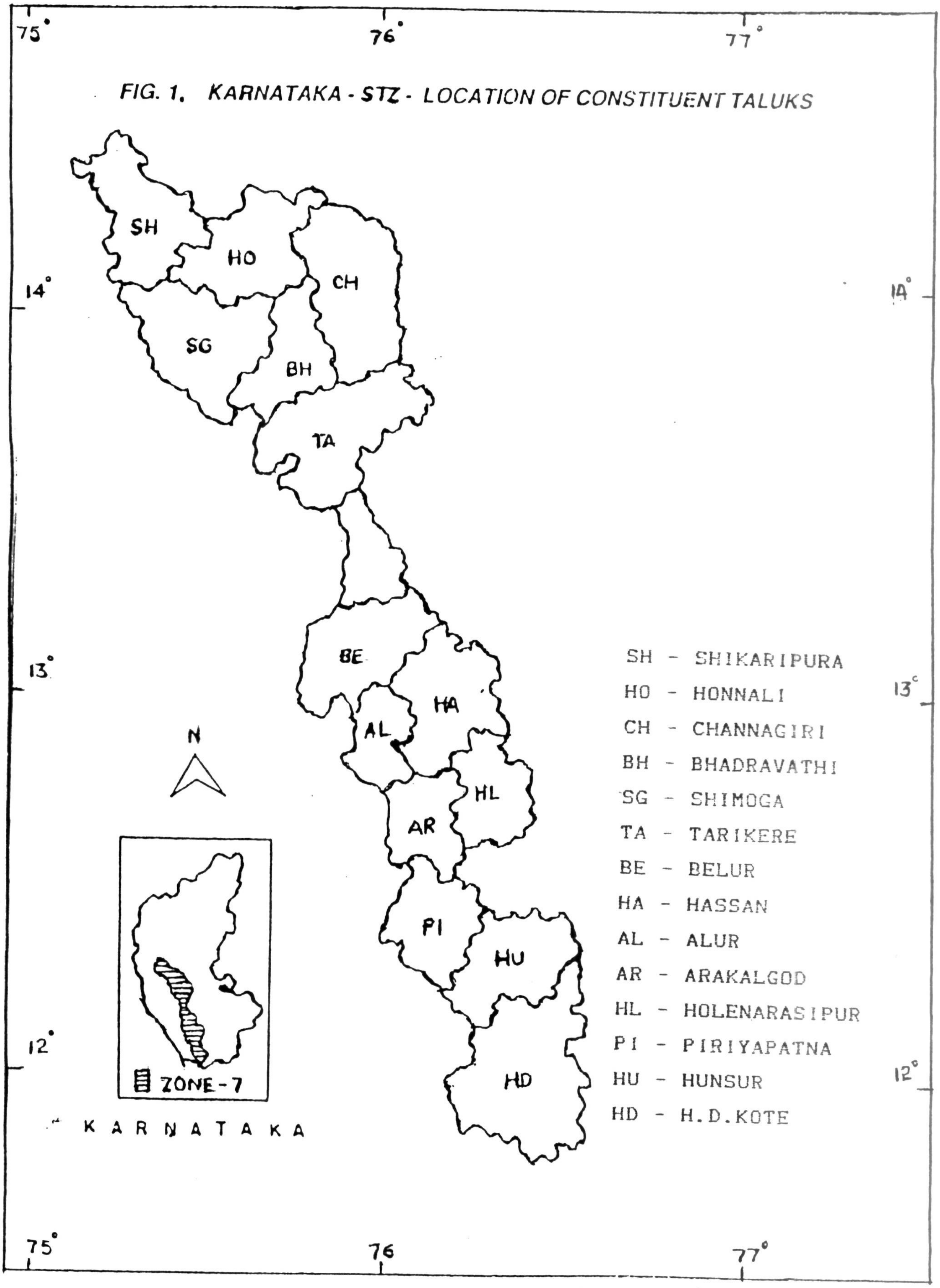
3.1 Collection and preparation of soil samples

The surface soil samples (0-20 cm)representing some important tobacco growing areas of Southern transition zone of Karnataka were collected by adapting standard procedures. The details of soils are furnished below and depicted in fig.1;

Sl.No.	District	Classification
1. Shikaripura	Shimoga	Typic Rhodustalfs
2. Abbligere	Shimoga	Typic Rhodustalfs
3. Navile	Shimoga	Typic Rhodustalfs
4. Tarikere	Chikmagalore	Typic Rhodustalfs
5. Arakalgud	Hassan	Typic Rhodustalfs
6. Ramnathpura	Hassan	Typic Rhodustalfs
7. Piriyapatna	Mysore	Rhodic Paleustalfs
8. Hunsur-1	Mysore	Rhodic Paleustalfs
9. Hunsur-2	Mysore	Rhodic Paleustalfs
10. H.D.Kote	Mysore	Rhodic Paleustalfs

The soil samples were dried in shade powdered with wooden mallet, passed through 2 mm sieve and preserved in polythene covers for further investigation.

FIG. 1. KARNATAKA - STZ - LOCATION OF CONSTITUENT TALUKS



3.2 Methods of Soil analysis :

3.2.1 Particle size analysis

The particle size analysis was estimated by the International pipette method as described by Piper (1950).

3.2.2 Soil reaction (pH)

The pH of soils were determined in 1:2 soil:water suspension by glass electrode using pH meter (Elico model LI-10 T) Jackson , (1973).

3.2.3 Electrical Conductivity (EC)

Electrical conductivity was determined in supernatant solution of 1:2 soil:water suspension using conductivity bridge (Elico type CM-82T) (Jackson, 1973).

3.2.4 Organic Carbon (OC)

Organic carbon content of the soil was determined by Walkley and Black's wet oxidation method (Jackson, 1973).

3.2.5 Cation Exchange Capacity (CEC)

The CEC was estimated by leaching the soil with neutral N NH_4OAC and replacing the absorbed NH_4 by K by leaching the soil with 1M KCl solution. The NH_4 in the leachate was estimated by distillation in a microjeldahl distillation (Jackson, 1973).

3.2.6 Exchangeable Cations

The exchangeable cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} were determined in the neutral N NH_4OAC extract as described by Jackson (1973). Exchangeable Ca and Mg were determined by standard versanate titration method and the exchangeable Na and K were estimated by using a flame photometer.

3.2.7 Extractable acidity (H + Al)

The extractable acidity was estimated by extracting the soil with 1 N KCl and titrated against standard EDTA solution as described by Hunter (1973).

3.2.8 Free Iron Oxides (Free Fe_2O_3)

Free iron oxides was extracted using sodium dithionite citrate buffer as described by Mehra and Jackson (1967). Iron in extract was determined colorimetrically at 510 nm using O-phenonthroline and hydroxylamine hydrochloride (Black, 1965).

3.3 Phosphate potential (pP)

The phosphate potential (1/2p Ca +1/2p H_2PO_4) was determined by equilibrating the soil samples with 0.01 M $CaCl_2$ solution as outlined by Aslyng (1954).

Fifty ml of 0.01 M $CaCl_2$ was added to 20g of soil in a 100 ml capacity test tube and shaken for a minute. The pH of the suspension was immediately measured using pH meter. Later the suspension was filtered through Whatman No.40 filter paper and the phosphorus concentration in the filtrate was determined by Chlorostannus reduced molybdophosphoric acid blue colour method in H_2SO_4 system as described by Jackson (1973). The concentration of Calcium in the filtrate was determined by standard versanate titration method using murexide indicator (Jackson, 1973).

3.4 Inorganic Phosphorus Fractionation

Soil inorganic phosphorus fractions were estimated by modified procedure of Chang and Jackson (1957) and after Peterson and Corey (1966) as outlined by Hesse, (1971).

The different inorganic phosphorus fractions estimated were saloid bound phosphorus (Saloid-P), aluminium bound phosphorus (Al-P), iron bound phosphorus (Fe-P), Calcium bound phosphorus (Ca-P), Occluded phosphorus (Occl-P) and Reductant soluble phosphorus (Red. Sol-P).

The Al-P fraction, Fe-P fraction and Ca-P fractions were determined by Chlorostannus reduced molybdophosphoric acid blue colour method in HCl system as outlined by Jackson (1973). The Saloid-P, Occl-P and Red.Sol-P fractions were determined by chlorostannus molybdophosphoric acid blue colour method in H_2SO_4 system (Jackson, 1973).

3.5 Available phosphorus

The available phosphorus content of soils were determined using five chemical extractants in order to identify the best extractant and to know their relationship with soil properties. The details of the procedures followed are as follows;

3.5.1 Bray No.:1 extractant

(0.03 N NH_4F + 0.025 N HCl) This extractant is usually used in acid soils. In this method three grams of soil was shaken with 30 ml of extractant for 5 minutes and filtered. The phosphorus extractant was determined by chlorostannus reduced molybdophosphoric blue colour method in hydrochloric acid medium. The intensity of blue colour was read at 660 nm using a spectrophotometer (Bausch and Lamb Spectronic 20-D model) (Bray and Kurtz, 1945).

3.5.2 Bray No.;2 extractant

(0.03 N NH_4F + 0.1 N HCl) The procedure followed was same as that of Bray's No.:1 method.

3.5.3 Truog's extractant

(0.002 N H_2SO_4 pH 2.4) was used to extract available phosphorus content of soils. Two grams of soil was shaken with 40 ml of extractant for 5 minutes and filtered. The phosphorus extracted was determined by chlorostannus reduced molybdophosphoric blue colour method in hydrochloric acid medium as described above (Truog, 1930).

3.5.4 Olsen's extractant

(0.5 M $NaHCO_3$ pH 8.5) Three grams of soil was treated with 30 ml of extractant and pinch of activated phosphorus free charcoal was added, shaken for 30 minutes. The contents were centrifuged and filtered to get a clear solution. The phosphorus in the filtrate was determined by method as described above (Olsen *et al*, 1954).

3.5.5 Mehlich exrtactant

(0.05 N HCl + 0.025 N H_2SO_4 pH 1) In this method, four grams of soil was shaken with 28 ml of extrtactant for 5 minutes and filtered. The phosphorus extracted was determined using molybdate-vanadate solution and the intensity of yellow colour was read at 420 nm using Spectrophotometer (Nelson, *et al*, 1953).

3.5.5 Total Phosphorus (Total P)

Total phosphorus was determined by digesting the soil with diacid mixture (Nitric acid and Perchloric acid) and estimated the quantity of phosphorus by vanado molybdate yellow colour method (Jackson, 1973).

3.6 Field Experiment

A long term experiment on the effect of reduced level (instead of 80 $Kg.ha^{-1}$ recommended) of phosphorus on yield and quality of FCV tobacco started in the year 1993 on phosphorus buildup soils of Regional research station, Navile, Shimoga. The following were the treatments included in the experiment

T1	:	Control. No application of phosphorus.
T2	:	30 Kg. P_2O_5. ha^{-1} applied every year.
T3	:	30 Kg. P_2O_5. ha^{-1} applied once in two year.
T4	:	30 Kg. P_2O_5. ha^{-1} applied once in three year.
T5	:	60 Kg. P_2O_5. ha^{-1} applied every year.
T6	:	60 Kg. P_2O_5. ha^{-1} applied once in two year.
T7	:	60 Kg. P_2O_5. ha^{-1} applied once in three year.

The experiment on tobacco (Variety FCV Special) was laid out in randomized block design with four replications adapting 0.9 m x 0.6m spacing and the plot size was 4.8m x 3.6m.

Soil samples were collected at a depth of 0-20 cm. In all the plots before imposal of the treatment. Recommended dose of N (40 $kg.ha^{-1}$) and K (80 $kg.ha^{-1}$) were given to all the plots.

After harvesting, cured leaf were graded as per the standard procedure (CTRI, 1984). Leaf samples viz., X group (lugs and cutters comprising 4 to 12 leaves), L (leaf comprising 13^{th} to 17^{th} leaf) and tips (18^{th} to 22^{nd} leaf) were collected besides stalk and root samples were also collected from all the plots for further analysis.

3.7 Analysis of Plant samples

The tobacco plant samples collected from different parts (X, L, Tips, Stalks and Roots) dried in an oven at 60° C. These dried samples were powdered in Willey Mill and analysed. The quality parameter viz., nicotine, reducing sugar and TGE were carried for leaf samples (X and L). Major, secondary and micronutrients were also estimated for these samples.

3.7.1 Total Nitrogen

The nitrogen contents in samples were determined by digesting the samples using concentrated H_2SO_4 and digestion mixture consisting of K_2SO_4, $CuSO_4$ and Se and then distilled in alkaline medium as per the standard procedure described by Jackson, (1973).

3.7.2 Nicotine

The nicotine content was estimated in the Benzene chloroform mixture and estimated titrating against standard perchloric acid solution by the method described by Murty *et al*, (1986).

3.7.3 Reducing Sugar

The reducing sugar of tobacco leaf estimated using Copper iodometric microreagent as described in ISI procedure. Murty *et al,* (1986).

3.7.4 Top Grade Equivalent (TGE)

The TGE was calculated by multiplying the different grades of cured leaf yield with corresponding grade index for FCV tobacco (Southern transition zone) as described by CTRI, (1984).

Wet Ashing

Mineral elements in the plant samples were determined by wet oxidation method. One gram powdered, well mixed plant samples were predigested with concentrated nitric acid mixture (10: 4 ratio). After digestion, white residue was left. This was cooled, made upto a known volume with distilled water. A blank was also run simultaneously to account for the contamination during estimation and used for further analysis.

3.7. 5 Phosphorus

Phosphorus was estimated by Vanado-molybdophosphoric acid yellow colour method. The intensity of yellow colour was read using Spectronic-20 D spectrophotometer at 430 nm. wave length (Jackson, 1973).

3.7.6 Potassium

Potassium content in plant sample was determined using flame photometer (Jackson, 1973).

3.7.7 Calcium and Magnesium

Calcium and Magnesium were determined from the digested sample, by titrating an aliquot against standard EDTA solution using suitable indicator (Jackson, 1973).

3.7.8 Sulphur

In the digested sample, sulphur was determined by turbidometric method (Jackson, 1973).

3.7.9 Micronutrient Analysis

Digested plant extracts were analysed for micronutirents viz., Copper, Zinc, Manganese and Iron (ppm) by using Atomic absorption spectro-photometer (Model, GBC 904 AA).

3.8 Uptake of Plant Nutrients

After the determination of the nutrient concentration in the plant sample, the values were multiplied by the corresponding dry matter yield to get uptake by leaf and stalks.

3.9 Statistical analysis and Interpretation of results

The relationship of soil properties with inorganic phosphorus fractions, available phosphorus extraction with different extractants were worked out by correlation and multiple regression analysis. Also the correlation between uptake of phosphorus with available phosphorus by different extractants was carried out. This results were reported at 5 and 1 percent level of significance (Sunderaraj *et al.*, 1972).

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Results of the studies on inorganic fractions of phosphorus and evaluation of different extractants for the determination of available phosphorus in tobacco growing soils are presented in this chapter.

4.1 Physico - chemical properties of soils

The physico-chemical properties of the soils for the study are given in Table 1.

4.1.1 Particle size analysis

The data revealed that almost all the soils containing higher percentage of sand ranged from 66.5 (H.D. Kote) to 81.5 per cent (Hunsur - 2). The texture of the soil varied from Loamy sand to Sandy loam. The clay content was ranging from 9.5 to 17.8 per cent in Navile and H.D.Kote soils respectively.

4.1.2 Soil reaction and Electrical conductivity

The soil reactions were found to be moderately acidic and pH ranged from 5.22 (Arakalgud) to 6.37 (Tarikere). EC of the soils varied from 0.05 to 0.22 dSm^{-1} and the highest EC was found in Ramnathpura soil and the lowest was noticed in Arakalgud. Almost all the soils were found to be low in electrical conductivity indicating low salt content of the soil.

4.1.3 Organic carbon

The Organic carbon content of the soils ranged from 0.35 per cent (Navile) to 0.88 per cent (H.D.Kote).

4.1.4 Cation exchange capacity

The CEC values of most of the soils studied were in the range 8.18 to 14.25 C.mol (P^+) kg^{-1} for Piriyapatna and Hunsur-1. But with the exception of H.D. Kote soil recorded highest CEC [18.03 C.mol (P^+) kg^{-1} .

4.1.5 Exchangeable cations

The exchangeable cations viz., Ca^{2+}, Mg^{2+}, Na^+ and K^+ contents were found to be lowest in Piriyapatna soils (0.59, 0.31, 0.14 and 0.15 C.mol (P^+) kg^{-1}) while, the soil of H. D. Kote was found to be highest (4.07, 1.20, 0.54 and 0.46 C.mol (P^+) kg^{-1} indicating soil are low in base saturation.

Table 1. Physico-chemical properties of tobacco soils.

Soils	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Tex. class	pH 1:2 water	EC dSm^{-1}	OC (%)	CEC	Extractable acidity	Exch. cations Ca	Mg	Na	K	Free Fe_2O_3 (%)	pP
									←	[Cmol.$(P^+)kg^{-1}$]				→		
Shikaripura	31.6	45.7	10.2	11.6	LS*	6.10	0.08	0.60	11.60	0.35	1.60	0.49	0.22	0.22	0.79	5.55
Abbligere	46.8	25.0	13.2	12.6	LS	5.24	0.08	0.49	12.60	0.67	1.30	0.40	0.23	0.29	0.43	5.74
Navile	35.0	40.2	13.4	9.5	LS	5.44	0.09	0.35	9.50	0.43	0.80	0.18	0.19	0.25	0.43	5.08
Tarikere	44.3	30.4	12.5	12.0	LS	6.37	0.08	0.73	12.00	0.43	2.12	0.93	0.23	0.24	0.68	5.41
Arakalgud	50.5	22.1	13.1	13.4	LS	5.22	0.05	0.54	13.36	0.55	1.20	0.20	0.17	0.20	0.42	5.07
Abbligere	46.8	25.0	13.2	12.6	LS	5.24	0.08	0.49	12.60	0.67	1.30	0.40	0.23	0.29	0.43	5.74
Ramnathpura	41.2	31.2	10.2	14.8	LS	5.73	0.22	0.73	12.08	0.37	2.39	0.78	0.34	0.48	0.81	5.23
Piriyapatna	55.2	21.1	8.2	10.2	LS	5.72	0.05	0.38	10.15	0.38	0.59	0.31	0.14	0.15	0.33	5.56
Hunsur-1	47.5	21.8	12.2	16.3	SL*	6.30	0.10	0.81	14.25	0.32	2.65	0.57	0.26	0.29	0.89	5.41
Hunsur-2	44.3	37.2	6.6	10.3	LS	5.83	0.08	0.42	10.25	0.44	1.87	0.63	0.22	0.22	0.52	5.84
H.D.Kote	41.0	25.5	14.2	17.8	SL	5.96	0.16	0.88	17.80	0.38	4.07	1.20	0.54	0.46	0.62	5.73

LS* = Loamy sand SL* = Sandy loam.

4.1.6 Extractable acidity

Extractable acidity includes H^+ and Al^{3+} of the soils ranging from 0.32 to 0.67 C.mol (P^+) kg^{-1}. The highest recorded in soils of Arakalgud and the lowest value was in Hunsur-1.

4.1.7 Free iron oxides

The free Iron oxides of the soils varied from 0.33 per cent (Piriyapatna and Navile) to 0.89 per cent (Hunsur-1).

4.1. 8 Phosphate potential

The Phosphate potential was in the range of 5.08 (Navile) to 5.84 (Hunsur-2) indicating that the soils studied have less difference in phosphate potential.

4.2 Inorganic phosphorus fractions

The results of the inorganic phosphorus fractions and their contribution to total phosphorus in soils are presented in Table 2.

4. 2.1 Saloid bound phosphorus

The Saloid P varied from 2.1 to 8.5 ppm in the soils. The highest Saloid-P was recorded in Hunsur-2 while lowest per cent of P to total P was recorded in case of Shikaripura (0.5) and highest in case of Tarikere (2.3).

4.2.2 Aluminium phosphorus

Al - P fraction in the soil was in the range of 24.6 to 97.3 ppm. The highest was in Abbligere and the lowest was in case of Shikaripura. The Al - P was accounted for 6.1 per cent (Shikaripura) to 26.3 per cent (Arakalgud) to total phosphorus.

4.2.3 Iron phosphorus

The data show that Fe-P fraction recorded highest concentration compared to other inorganic fractions studied. Fe-P was in the range of 52.1 ppm (Shikaripura) to 131.0 ppm (Abbligere). The contribution of this fraction to total phosphorus was 12.9 to 32.9 per cent for Shikaripura and Arakalgud soils.

4.2.4 Calcium phosphorus

The Ca-P of the soils ranging from 18.5 to 35.9 ppm. The highest value was found in case of Hunsur-2 while lowest was found in Ramnathpura. The Ca-P contribution to total phosphorus was 4.4 to 12.3 per cent in Ramnathpura and Piriyapatna respectively.

Table 2. Inoganic fractions and total phosphorus (ppm) of tobacco soils.

Soil	Saloid-P	Active-P			Occl-P	Red.Sol-P	Total-P
		Al-P	Fe-P	Ca-P			
Shikaripura	2.1 (0.5)	24.6 (6.1)	52.1 (12.9)	29.6 (7.3)	14.4 (3.6)	43.4 (10.7)	404.5
Abbligere	7.6 (1.4)	97.2 (18.0)	131.0 (25.0)	27.5 (5.3)	35.7 (6.8)	46.3 (8.8)	523.0
Navile	6.9 (1.9)	60.9 (12.6)	79.1 (16.3)	24.0 (5.0)	21.5 (4.4)	39.8 (8.2)	484.5
Tarikere	4.9 (2.3)	26.4 (12.7)	53.2 (24.7)	21.1 (9.8)	20.4 (9.4)	41.2 (19.1)	216.0
Arakalgud	6.2 (1.9)	87.0 (26.3)	108.8 (32.9)	34.6 (10.4)	15.4 (4.7)	54.8 (16.5)	331.3
Ramnathpura	4.0 (1.0)	40.5 (9.7)	90.6 (23.6)	18.5 (4.4)	3.2 (0.8)	45.0 (10.8)	417.0
Piriyapatna	2.9 (1.3)	39.3 (17.2)	36.6 (16.0)	28.2 (12.3)	21.9 (9.6)	39.5 (17.3)	228.5
Hunsur-1	6.3 (1.8)	63.9 (18.7)	96.7 (28.2)	27.2 (7.9)	6.2 (1.8)	57.7 (16.8)	342.5
Hunsur-2	8.5 (2.1)	78.9 (19.7)	122.1 (30.5)	35.9 (9.0)	19.3 (4.8)	56.5 (14.1)	400.0
H.D.Kote	3.3 (0.8)	34.6 (8.2)	103.4 (24.4)	19.7 (4.6)	22.7 (5.3)	36.9 (8.7)	424.0

* Percentage contribution to total-P is given in parenthesis.

4.2.5 Occluded phosphorus

The Occl-P fraction of the soils ranging from 3.2 (Ramnathpura) to 35.7 ppm (Abbligere) and its contribution towards total phosphorus was 0.8 (Ramnathpura) to 4.6 per cent (Piriyapatna).

4.2.6 Reductant soluble phosphorus

The Red.Sol-P content of the soils were ranging from 36.9 to 57.7 ppm H.D.Kote and Hunsur-1 soils respectively. This fraction contributed to an extent of 8.2 (Navile) to 19.1 per cent (Tarikere) in total phosphorus.

4. 3 Total phosphorus

The total-P varied from 216.0 (Tarikere) to 523.6 ppm (Abbligere) and were lowest and the highest respectively. (Table 2)

4.4 Relationship of inorganic phosphorus fractions with soil properties

The data presented in Table 3 show that none of the soil properties had significant correlation with Saloid-P. The Al-P fraction was significantly and negatively correlated with pH (r=-0.648), OC (r=-0.470), Free Fe_20_3 (r=-0.517) and positively with extractable acidity (r=532).

The correlation coefficients for Fe-P was negatively significant with pH (r=-0.461) and other soil properties were found to be non significant.

Significant correlation was recorded in case of Ca-P with OC (r=-0.514) while other properties were found to be non significant. It was observed that significant negative correlation between Occl-P and free Fe_2O_3 (r=0.500) and positive correlation with extractable acidity (r= 0.705) and phosphate potential (r=0.465). The Red. Sol -P was correlated significantly with none of the soil properties. And the total phosphorus was correlated non significantly with all soil properties except pH (r= 0.472).

4.5 Available phosphorus by different extractants

The results of the available phosphorus extracted by different chemical extractants are present in Table 4.

4.5.1 Bray No.:1

The available phosphorus extracted by Bray No.:1 extractant varied from 4.1 to 37.1 ppm in Shikaripura and Hunsur-2 as lowest and the highest values respectively.

4.5.2 Bray No.:2

The available phosphorus extracted by Bray No.:2 extractant was in the range of 5.3 (Shikaripura) to 41.7 ppm (Hunsur-2). Thus this extractant extracted more available phosphorus than other extractants.

4.5.3 Truog's extractant

The Truog's extractant extracted the available phosphorus varied from 3.3 to 37.3 ppm in Shikaripura and Hunsur-2 as the lowest and the highest value respectively.

4.5.4 Mehlich's extractant

The available phosphorus extracted by Mehlich's extractant was found to be lowest among the extractants. This was ranging from 2.8 (Shikaripura) to 12.1 ppm (Husnur-2).

4.5.5 Olsen's extractant

The available phosphorus extracted by Olsen's method varied from 3.7 to 28.5 ppm in H.D. Kote and Abbligere respectively.

4.6 Relationship between Inorganic fractions and phosphorus extractants

The results of the correlation study presented in Table 5 show that all the inorganic phosphorus fractions except Occl-P correlated positively with all the phosphorus extractants.

The Saloid-P correlated positively significantly with Bray-No.:1 (r=789), Bray-No.:2 (r=0.772), Truog-P (r=0.849), Mehlich-P (r= 0.787) and

Table 3. Correlation coefficients (r) between inorganic fractions, total-phosphorus and soil properties.

Soil properties	Inorganic P fractions						
	Saloid-P	Al-P	Fe-P	Ca-P	Occl-P	Red.Sol-P	Total-P
pH	-0.404	-0.645*	-0.461*	-0.276	-0.388	-0.011	-0.472*
Organic carbon	-0.318	-0.470*	-0.030	-0.514*	-0.423	-0.022	-0.126
Clay	-0.162	-0.188	0.228	-0.400	-0.319	0.091	0.093
CEC	-0.153	-0.339	0.096	-0.352	-0.280	0.028	0.083
Extractable acidity	0.194	0.532*	0.286	0.349	0.705**	-0.046	0.012
Free Fe_2O_3	-0.283	-0.517*	-0.073	-0.436	-0.501*	0.030	-0.001
Phosphate potential	0.134	-0.040	0.166	0.133	0.465*	-0.040	0.113

* Significant at 5 per cent
** Significant at 1 per cent

Table 4. Available phosphorus content (ppm) extracted by different chemical extractants in tobacco soils.

Soils	Bray No.1	Bray No.2	Truog P	Mehlich P	Olsen P
Shikaripura	4.1	5.3	3.0	2.8	7.0
Abbligere	26.5	29.3	33.0	10.3	28.5
Navile	28.6	35.0	24.8	10.7	20.6
Tarikere	7.1	11.0	9.3	10.3	10.3
Arakalgud	33.9	41.5	27.0	8.7	23.8
Ramnathpura	10.1	14.0	6.9	6.3	12.5
Piriyapatna	11.9	14.2	9.9	5.4	11.1
Hunsur-1	21.4	26.7	20.1	7.6	22.5
Hunsur-2	37.1	41.7	37.8	12.1	26.9
H.D.Kote	4.5	9.1	3.3	3.6	3.7

Olsen P (r=0.686). Significant positive correlations were observed between Al-P and all the extractants tried thus indicating good relationship with all the extractants.

The correlation study indicated that the Fe-P was significantly correlated with Bray-No.:1 (r=0.650), Bray-No.:2 (r=0.633), Truog-P (r=0.730), Mehlich-P (r=0.673) and Olsen-P (r= 0.660). Ca-P also correlated significantly with al the extractants tried.

The Occl-P was correlated significantly with none of the phosphorus extractants. And the Red.Sol-P correlated significantly and positively with Bray-No.:1 (r=0.657), Bray-No.:2 (r=0.651), Truog-P (r= 0.622), Mehlich-P (r=0.554) and Olsen-P (r=0.678).

4.7 Extraction of available phosphorus in soils under different levels of phosphorus treatments

Perusal of data in Table 7 indicate that among the extractants Bray-No.:2 extracted highest amount of available phosphorus in all the treatments. While, lowest amount of available phosphorus was recorded in case of Mehlich-P. Treatmental effect was not noticed in available phosphorus extracted by different extractants except Truog-P and Olsen-P.

Table 5. **Correlation coefficients (r) between phosphorus extracted by chemical extractants and inoganic fractions.**

Phosphorus extractants	Inorganic phosphorus extractants					
	Saloid-P	Al-P	Fe-P	Ca-P	Occl-P	Red.Sol-P
Bray-No.1	0.789**	0.909**	0.650**	0.626**	0.183	0.657**
Bray-No.2	0.772**	0.887**	0.633**	0.602**	0.137	0.651**
Truog-P	0.849**	0.929**	0.730**	0.600**	0.355	0.622**
Mehlich-P	0.787**	0.881**	0.673**	0.476*	0.198	0.554*
Olsen-P	0.686**	0.845**	0.660*	0.647**	0.081	0.678**

* Significant at 5 per cent
** Significant at 1 per cent

Table 6. Multiple regression equations for available phosphorus extractants and inorganic fractions.

Bray-No.1 (Y_1)

$$Y_1 = 15.923 + 2.693^{**}(X_1) + 0.387^{**}(X_2) + 0.082(X_3) + 0.201(X_4) + 0.439^{**}(X_5) + 0.516^{**}(X_6) \quad (R^2 = 0.948^{**})$$

Bray-No.2 (Y_2)

$$Y_2 = 22.977 + 2.825^{*}(X_1) + 0.454^{**}(X_2) - 0.124(X_3) + 0.129(X_4) - 0.496^{**}(X_5) - 0.578^{*}(X_6) \quad (R^2 = 0.918^{**})$$

Truog-P (Y_3)

$$Y_3 = 5.102 + 2.274^{**}(X_1) + 0.353^{**}(X_2) - 0.060(X_3) + 0.179(X_4) - 0.065(X_5) - 0.375^{*}(X_6) \quad (R^2 = 0.949^{**})$$

Mehlich-P (Y_4)

$$Y_4 = 12.355 + 0.596(X_1) + 0.145^{**}(X_2) - 0.052^{*}(X_3) - 0.074(X_4) - 0.094(X_5) - 0.171^{*}(X_6) \quad (R^2 = 0.849^{**})$$

Olsen-P (Y_5)

$$Y_5 = -16.499 + 0.849(X_1) + 0.247(X_2) + 0.049(X_3) + 0.499(X_4) - 0.240(X_5) + 0.062(X_6) \quad (R^2 = 0.793^{**})$$

Where, X_1 = Saloid-P, X_2 = Al-P, X_3 = Fe-P, X_4 = Ca-P, X_5 = Occl-P, X_6 = Red.Sol-P

* Significant at 5 per cent

** Significant at 1 per cent

Table 7. Available phosphorus extracted (ppm) by different chemical extractants of Navile soil underdifferent levels of phosphorus application.

Treatment	Bray No. 1	Bray No. 2	Truog-P	Mehlich-P	Olsen-P
Control	29.1	35.7	25.7	10.8	14.5
30 kg. P_2O_5 ha^{-1} every year	29.9	37.0	26.7	11.6	15.0
30 kg. P_2O_5 ha^{-1} once in 2 year	29.1	37.8	26 3	12.2	16.2
30 kg. P_2O_5 ha^{-1} once in 3 year	26.6	34.0	29.4	11.6	14.8
60 kg. P_2O_5 ha^{-1} every year	29.6	32.8	33.5	13.0	17.9
60 kg. P_2O_5 ha^{-1} once in 2 year	29.1	35.2	33.5	12.0	17.3
60 kg. $P_{20}5$ ha^{-1} once in 3 year	30.8	33.3	33.2	13.2	20.3
SEm ±	1.13	1.44	2.18	0.73	0.78
CD at 5 %	ns	ns	6.49*	ns	2.33**
CV %	7.72	8.20	14.69	12.08	9.45

* Significant at 5 per cent.
** Significant at 1 per cent.

Crop response study

4.8.1 Yield parameters

The data pertaining to leaf yields of FCV Tobacco as influenced by different levels of phosphorus are presented in Table 8 and depicted in Fig 4.

The Green leaf and cured leaf yields were in the range 7915 (T3) to 8643 (T4) kg. ha^{-1} and 1067 (T2) to 1210 (T4) $kg.ha^{-1}$ respectively indicating that the difference in yield was non significant. The top grade equivalent; quantity parameter decreased from 582 (T1) to 503 (T2) but the dense was found to be non significant.

4.9 Relationship between phosphorus availability with plant parameters

The correlations between the soil test values with yield, phosphorus content and phosphorus uptake by FCV tobacco as influenced by the different levels of phosphorus application are presented in Table 9.

Almost all the extractants were correlated non significantly with many of the plant parameters except Truog and Olsen . Truog correlated significantly positively with TGE (r=0.408), root P content (r=0.582) and stalk uptake (r=0.441). Olsen's extractant correlated negatively significantly with L position phosphorus concentrations (r=-o.496) and positively with

Table 8. Different level of phosphorus on yield parameters (kg/ha) of FCV Tobacco (Var. FCV Spl.)

Treatments	Green leaf yield	Cured leaf yield	TGE
Control	8135	1178	582
30 kg P_2O_5 /ha every year	8193	1067	503
30 kg P_2O_5 /ha once in 2 year	7915	1091	553
30 kg P_2O /ha once in 3 year	8643	1210	530
60 kg P_2O_5 /ha every year	8513	1146	579
60 kg $P_{20}5$ /ha once in 2 year	8555	1161	575
60 kg P_2O_5 /ha once in 3 year	8190	1147	509
SEm $\pm$	23	63	29
CD at 5%	ns	ns	ns
CV%	8.6	11.1	10.6

Table 9. Correlation coefficients (r) of soil test values for P with Yield, P content and P uptake by FCV tobacco.

Plant parameters	Bray-P1	Bray-P2	Truog-P	Mehlich-P	Olsen-P
A. Yield					
1. Green leaf yield	-0.104	0.010	0.220	0.220	0.302
2. Cured leaf yield	-0.084	0.197	0.030*	-0.157	0.151
3. TGE	-0.012	-0.191	0.408*	0.384*	0.197
B P content					
1. X-position	0.040	-0.243	-0.271	-0.346	0.066
2. L-position	-0.091	-0.241	-0.384*	-0.271	-0.496**
3. Tips	0.179	0.101	0.107	0.339	0.066
4. Stalks	0.165	-0.110	0.039	0.009	0.183
5. Roots	0.179	-0.102	0.582**	0.243	0.640**
C. P uptake					
1. Leaf	0.088	-0.221	-0.294	-0.163	-0.303
2. Stalk	0.165	-0.187	0.441*	0.393	0.726**
3. Total	0.115	-0.245	-0.223	-0.092	-0.189

* Significant at 5 per cent
** Significant at 1 per cent

root phosphorus content (r=0.640) and stalk uptake. But total phosphorus uptake was correlated non significantly with all the extractants. However, Bray-No.:1 extractant correlated positively.

4.10. Quality attributes of FCV tobacco

The data in Table 10 show that nicotine content of X position leaves less than L position ranging from 1.83 (T1) to 2.10 (T5) per cent and 2.06 (T1) to 2.55 (T5) per cent in L position. The difference in nicotine content due to treatment was non-significant.

Reducing sugar content was ranging from 11.1 to 14.2 per cent in T2 and T3 at X-leaf position .In L position, reducing sugar was ranging from 10.8 to 12.7 per cent in T5 and T2. Reducing sugar content of X-leaf position was observed higher than L position leaves. The difference in reducing sugar content was non-significant.

Nitrogen content was in the range of 1.88 (T3) to 2.08 (T2) per cent in case of X-leaf position while 2.01 (T3) to 2.21 (T6) per cent in L position and both are non-significant.

Table 10. Quality of tobacco as influenced by different levels of phophorus treatments.

Treatments	Nicotine (%)		Reducing sugar (%)		Nitrogen (%)	
	X	L	X	L	X	L
Control	2.18	2.06	11.4	11.9	2.01	2.07
30 kg P_2O_5 /ha every year	2.01	2.40	11.1	12.7	2.08	2.17
30 kg P_2O_5 /ha onec in 2 year	1.99	2.35	14.2	11.0	1.88	2.01
30 kg P_2O_5 /ha once in 3 year	2.10	2.31	13.0	12.0	2.03	2.10
60 kg P_2O_5 /ha every year	1.89	2.55	11.3	10.8	2.04	2.05
60 kg P_2O_5 /ha once in 2 year	1.83	2.30	12.5	11.5	1.99	2.21
60 kg P_2O_5 /ha once in 3 year	2.02	2.34	13.7	12.0	1.94	2.01
Acceptable limit	(0.7 - 3.0 %)		(8 - 24 %)		(1 - 3 %)	
SEm ±	0.16	0.16	1.30	1.16	0.09	0.06
CD at 5%	ns	ns	ns	ns	ns	ns
CV%	15.8	13.9	19.4	19.4	8.53	5.85

4.11 Chemical composition of FCV tobacco

4.11.1 Nitrogen content and uptake

The data presented in Table 12 show that nitrogen content of leaves and stalk varied from 2.06 (T7) to 2.14 (T6) per cent and 0.6 (T1 and T7) to 0.81 (T5) per cent. While the uptake of nitrogen was ranging from 23.6 (T7) to 25.5 (T4) kg.ha^{-1} and 3.1 (T1) to 4.5 (T5) kg.ha^{-1} respectively. The difference was found to be non-significant with the varied level of phosphorus.

4.11.2 Phosphorus content and uptake by FCV tobacco

The effect of different level of phosphorus on the phosphorus content at different positions and the uptake by the plant are presented in Table 11(a) and 11(b).

The phosphorus removed by leaves and stalks were ranged from and the total uptake was 4.7 to 5.3 kg.ha^{-1} as lowest (T3) and highest the highest values (T5 and T7).

4.11.3 Potassium content and uptake

The potassium content (Table 12) of leaves and stalks were ranging from 2.22 (T7) to 2.43 (T1) per cent and 1.33 (T1) to 1.54 (T2) per cent where the uptake varied from 24.7 (T2) to 28.7 (T1) kg.ha^{-1} and 3.1 (T1) to

Table 11(a). Phosphorus content (%) of FCV tobacco at different parts as influenced by different levels of phosphorus application.

Treatments	X	L	Tips	Stalks	Roots
Control	0.42	0.38	0.36	0.06	0.05
30 kg P_2O_5 /ha every year	0.44	0.41	0.41	0.06	0.06
30 kg P_2O_5 /ha once in 2 year	0.46	0.34	0.34	0.05	0.06
30 kg P_2O_5 /ha once in 3 year	0.39	0.37	0.37	0.06	0.05
60 kg P_2O_5 /ha every year	0.45	0.36	0.36	0.08	0.07
60 kg P_2O_5 / ha once in 2 year	0.44	0.40	0.40	0.09	0.07
60 kg P_2O_5 /ha once in 3 year	0.49	0.36	0.36	0.09	0.07
SEm ±	0.04	0.04	0.01	0.01	0.01
CD at 5%	ns	ns	0.04*	0.02**	ns
CV%	18.9	20.9	7.6	21.6	20.4

* Significant at 5 per cent
** Significant at 1 per cent

Table 11(b). Phosphorus uptake (kg/ha) of FCV tobacco as influenced by different levels of phosphorus application.

Treatments	Leaves	Stalks	Total-P
Control	4.6	0.32	4.9
30 kg P_2O_5 /ha every year	4.5	0.35	5.0
30 kg P_2O_5 /ha once in 2 year	4.5	0.38	4.8
30 kg P_2O_5 /ha once in 3 year	4.6	0.44	5.0
60 kg P_2O_5 /ha every year	4.8	0.44	5.3
60 kg P_2O_5 / ha once in 2 year	4.7	0.50	5.2
60 kg P_2O_5 /ha once in 3 year	4.8	0.52	5.3
SEm $\pm$	0.22	0.15	0.24
CD at 5%	ns	ns	ns
CV%	9.72	11.50	9.72

* Significant at 5 per cent
** Significant at 1 per cent

4.5 (T5) $kg.ha^{-1}$ respectively. The difference in the treatments was found to be non significant.

4.11.4 Calcium content and uptake

The perusal of data in Table 12 show that the calcium content of leaves and stalk were ranged from 1.38 (T1) to 1.48 (T4) and 0.59 (T5) to 0.65 (T1) per cent respectively. With the uptake varied from 14.4 (T4) to 16.5 (T6) $kg.ha^{-1}$ and 3.2 (T4) to 3.5 (T7) $kg.ha^{-1}$ respectively and found to be non significant among the different treatments.

4.11.5 Magnesium content and uptake

The magnesium content of leaves and stalk varied from 0.29 (T3) to 0.38 (T1) and 0.20 (T3) to 0.29 (T7) per cent. The uptake ranged from 3.2 (T3) to 4.4 (T1) and 1.0 (T3) 1.6 (T7) $kg.ha^{-1}$ respectively. They are non significant with different levels of phosphorus applications (Table 12).

4.11.6 Sulphur and uptake

The Table 12 shows that the sulphur content was ranging from 0.14 (T2) to 0.17 (T5) and 0.07 (T1 and T5) to 0.09 (T6) per cent in leaves and stalk respectively, while the uptake varied from 1.5 (T2) to 1.9 (T4, T5 and T6) $kg.ha^{-1}$ in leaves and in stalk. The sulphur content was 0.4 $kg.ha^{-1}$

all the treatments except T6 (0.5 kg /ha). The difference due to application of various levels of phosphorus was found to be non significant.

4.12 Micronutrient content and uptake

The data presented in Table 13 shows that the some important micro nutrient content and uptake of FCV tobacco leaves and stalk with different levels of phosphorus application.

4.12.1 Copper content and uptake

The copper content was the least concentration among the four micro nutrients studied. The range in leaves and stalk varied from 14.0 (T4) to 17.4 (T1) and 6.8 to 10.3 (T4) ppm respectively. While the uptake ranges from 15.4 (T2) to 24.5 (T1) and 3.5 (T3) to 5.6 (T4) $g.ha^{-1}$ respectively.

4.12.2 Zinc content and uptake

The zinc content of tobacco leaves and stalk were in the range of 28.9 (T5) to 32.4 (T6) and 5.5 (T3) to 7.6 (T5) ppm , while uptake 32.0 (T2) to 37.4 (T1) and 2.9 (T3) to 4.7 (T6) $g.ha^{-1}$ respectively.

4.12.3 Manganese content and uptake

The manganese content of leaves and stalk varied from 162.7 (T3) to 56.3 (T6) and 180.4 (T3) to 229.7 (T5) ppm. While the uptake 180.4 (T3) 229.7 (T5) and 12.6 (T3) to 30.1 (T6) $g.ha^{-1}$ respectively.

4.12.4 Iron content and uptake

The iron content of leaves and stalk ranged from 518.0 (T6) to 554.0 (T5) and 406.5 (T2) to 641.3 (T4) ppm. The uptake of leaves and stalk varies from 555.0 (T2) to 641.3 (T4) and 212.8 (T1) to 336.8 (T5) respectively.

Table 12. Nutrient content (%) and uptake (kg/ha) by leaves and stalks of FCV tobacco as influenced by different phosphorus treatments.

Treatments	Nitrogen				Potassium				Calcium				Magnesium				Sulphur			
	Content		uptake		Content		uptake		content		uptake		content		uptake		content		uptake	
	L*	S*	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
T1	2.13	0.59	24.6	3.1	2.43	1.34	28.7	7.0	1.38	0.65	16.2	3.4	0.38	0.23	4.5	1.2	0.14	0.07	1.7	0.4
T2	2.13	0.73	22.5	3.8	2.41	1.54	25.7	7.9	1.46	0.64	15.5	3.3	0.32	0.25	3.4	1.3	0.14	0.08	1.5	0.4
T3	2.08	0.61	22.7	3.2	2.29	1.53	25.0	7.9	1.47	0.63	16.1	3.3	0.29	0.20	3.2	1.1	0.15	0.08	1.7	0.4
T4	2.10	0.66	25.5	3.6	2.33	1.43	28.0	7.6	1.48	0.60	18.2	3.3	0.32	0.20	3.9	1.1	0.15	0.08	1.9	0.4
T5	2.15	0.73	25.3	4.0	2.26	1.50	26.3	8.0	1.42	0.58	16.4	3.2	0.33	0.25	3.8	1.4	0.17	0.07	1.9	0.4
T6	2.15	0.73	25.3	4.0	2.26	1.50	26.3	8.0	1.41	0.61	16.5	3.4	0.36	0.25	4.2	1.3	0.16	0.09	1.9	0.5
T7	2.08	0.58	23.6	3.2	2.22	1.48	25.7	8.2	1.42	0.63	16.3	3.5	0.34	0.28	3.9	1.6	0.16	0.08	1.8	0.4
SEm±	0.1	0.1	1.6	0.4	0.1	0.1	1.8	0.3	0.1	0.1	1.6	0.4	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1
CD at 5%	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	5.4	19.4	13.1	22.6	8.8	11.8	13.6	8.6	9.8	17.4	18.3	21.2	12.7	36.4	17	37.4	10.5	20.1	14.8	21.3

L* = Leaves. S* = Stalks.

Table 13. Micronutrient content (ppm) and uptake (g/ha) of leaves and stalks of FCV tobacco as influenced by different phosphorus treatments.

Treatments	Copper				Zinc				Manganese				Iron			
	Content		uptake		content		uptke		content		uptake		content		uptake	
	L*	S*	L	S	L	S	L	S	L	S	L	S	L	S	L	S
T1	17.4	7.8	20.5	4.1	31.7	6.5	37.4	3.5	179.4	38.0	212.0	20.2	525.8	406.5	614.0	212.8
T2	14.5	7.8	15.4	4.0	30.0	6.3	32.0	3.2	183.3	48.0	194.7	24.9	521.3	493.0	555.0	245.8
T3	15.4	6.8	16.8	3.5	29.9	5.5	32.3	2.9	165.0	24.3	180.4	12.6	540.0	446.8	586.5	237.8
T4	14.0	10.3	6.8	5.6	29.8	7.5	36.1	4.0	162.7	37.5	194.7	19.5	527.8	594.0	641.3	326.3
T5	15.3	9.3	17.7	5.1	28.9	7.6	33.6	4.3	199.4	49.3	229.7	27.2	552.8	507.5	627.0	366.8
T6	15.9	7.8	18.3	4.2	30.2	7.0	35.0	4.7	174.6	56.3	201.4	30.1	518.0	614.3	601.5	330.8
T7	14.9	7.5	17.0	4.2	30.5	6.8	34.9	3.8	187.0	38.8	214.6	21.4	537.8	523.8	618.5	290.5
SEm ±	0.7	0.9	1.3	0.6	1.3	0.7	2.3	0.4	11.6	7.3	17.6	3.8	20.7	74.5	43.8	42.3
CD at 5%	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	9.8	21.8	14.6	28.3	8.4	14.6	13.5	22.9	12.9	34.9	17.2	33.7	7.8	28.9	14.4	29.5

L* = Leaves. S* = Stalks.

DISCUSSION

V DISCUSSION

Studies on phosphorus inorganic fractions and available phosphorus with different chemical extractants and other related aspects of phosphorus in soils shall provide an useful information of the extractant. The results of the present investigation are discussed in this chapter.

5.1 Inorganic phosphorus fractions

5.1.1 Saloid phosphorus

The Saloid-P content varied from 2.1 to 8.5 ppm and was found to be lowest (0.5 to 2.3%) among the different forms of phosphorus (Table 2 and fig.1). The lowest content of Saloid-P may be due to the transformation of soluble forms of phosphorus into relatively less soluble form with the lapse of time. Similar results were also reported by Doddamani and Seshagiri Rao, 1988 in Alfisols, Dakhore *et al.* 1993 in Sandy clay Entisols and also Nagendra Rao and Chakrabarthy, 1994 in Alfisols. Generally Saloid-P were very low in red soils (Subramanian *et al.*, 1987) but Saloid-P was comparatively more in soils studied. This may be due to continuous application of phosphoric fertilizers.

Further, the correlation studies revealed that the non-significant negative correlation between Saloid-P and soil properties indicated that Saloid-P was not influenced by any of the soil properties studied (Table 3).

5.1.2 Aluminium phosphorus

The Al-P content of the soil varied from 24.6 to 97.2 ppm and contributed 5.9 to 26.6 per cent to total-P (Table 2 and fig 2).

The higher content of Al-P in highly acidic soils was recorded as compared to the soils of slightly acidic or neutral. This may be due to phosphorus get immobilized and accumulated as Al-P in acid soils (Lawrence *et al.*, 1970). Doddamani and Seshagiri Rao (1988) also reported that the higher Al-P in Alfisols soils may be due to the chemical indices of weathering of mineral and concomitant release of aluminium, favouring the conversion to Al-P.

The correlation study also indicated that Al-P was significantly correlated with pH (r=-0.648) and extractable acidity (r=0.532). Al-P found to be negatively correlated with OC (r=-0.470), free Fe_2O_3 (r=-0.517). This is in agreement with Doddamani and Seshagiri Rao (1988). Significant negative correlation with organic matter suggests that organic matter reduces precipitation of phosphorus in to sparingly soluble hydroxy phosphates of Aluminium (Bolt and Bruggenwert, 1976). (Table 3).

5.1.3 Iron Phosphorus

The content of Fe-P ranged from 52.1 to 131.0 ppm and contributed to an extent of 12.4 to 32.9 percent to total-P (Table 2 and fig 2). The content of Fe-P was high in the soils which may be ascribed to low pH, addition of fertilizer and manures to the soil as reported by Sacheti and Saxena (1973) and Subramanian *et al.* (1987). The high Fe-P and Al-P content in red soils indicated the intense weathering of these soils. The dominance of a particular form of phosphorus in a soil depends on the chemical weathering sequence as suggested by Chang and Jackson (1958). Rajukkannu and Ravi Kumar (1975) also reported that Fe-P fraction was found to be high in red soils.

It is apparent from the data in Table 3 that the Fe-P correlated negatively with pH (r=-0.461) and none of the other soil properties significantly correlated with Fe-P. Similar result was reported by Jaggi (1991).

5.1.4 Calcium phosphorus

The content of Ca-P ranged from 19.7 to 35.9 ppm and accounted for 4.4 to 12.3 per cent of total-P (Table 2 and fig 2). The lower content of Ca-P compared to Al and Fe-P in the soils studied may be due to acidity / low base saturation. In acid soils, iron and aluminium phosphorus are normally dominant fraction (Sacheti and Saxena, 1973).

The correlation studies between forms of phosphorus and various soil properties (Table 3) indicated that the Ca-P was negatively correlated with OC (r=-0.514). Similar results were observed by Doddamani and Seshagiri Rao (1988).

5.1.5 Occluded phosphorus

The content of Occl-P ranged from 3.2 to 35.7 ppm and contributed 0.8 to 9.6 per cent of total-P (Table 2 and fig 2). This fraction was found to be lowest among the fraction except Saloid-P indicating less amount of phosphates are occluded in oxides of iron and aluminium (Sharpley and Smyth, 1985).

The correlation coefficients between Occl-P and soil properties were presented in Table 3. The perusal of data also shows that Occl-P was negatively correlated with free Fe_2O_3 (r=-0.500) and positively with extractable acidity (r=0.705) and phosphate potential (r=0.465).

5.1.6 Reductant Soluble Phosphorus

The Red.Sol-P content ranged from 36.9 to 57.7 ppm and contributed to an extent of 8.2 to 19.1 per cent to total-P (Table 2 and fig 2). Chang and Jackson (1958) observed that highly weathered soils always contained appreciable amount of Red.Sol-P and Occluded forms of phosphorus. Kanwar *et al.* (1983) and Subraminan *et al.* (1987) noticed that Red.Sol-P fraction as one of the major inorganic soil phosphorus fraction in the Alfisols.

The Red.Sol-P fraction correlated significantly with none of the soil properties, which is in contrast to the findings of Kothandaraman and Krishnamoorthy (1979).

LEGANDS

1. Shikaripura
2. Abbligere
3. Navile
4. Tarikere
5. Arakalgud
6. Ramnathpura
7. Piriyapatna
8. Hunsur-1
9. Hunsur-2
10. H.D.Kote

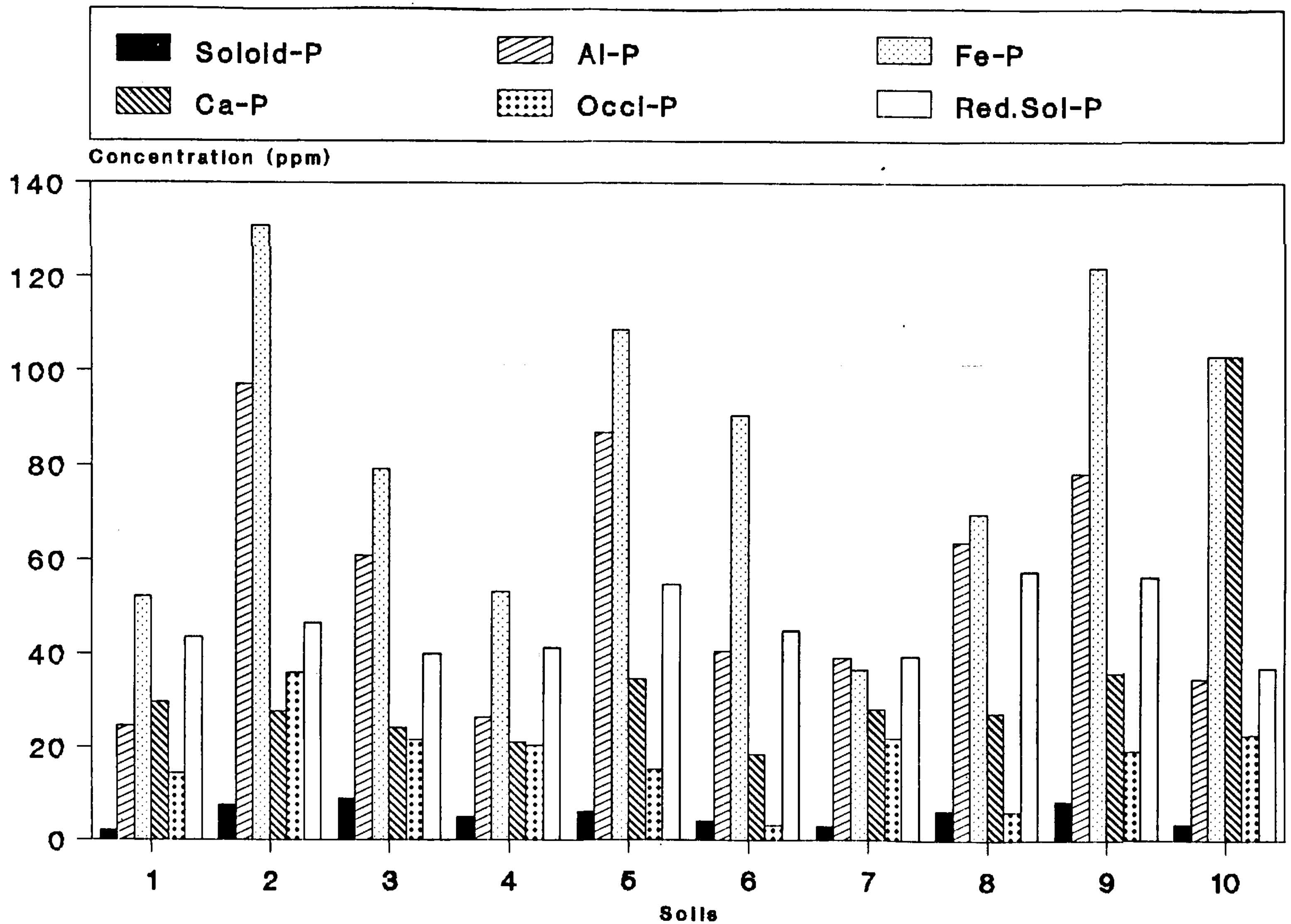


Fig.2: Inorganic fractions of soil phosphorus.

5.2 Total phosphorus

The total-P content of the soils ranged from 216.0 to 523.6 ppm (Table 2). The high content of total-P in soils may be due to the addition of fertilizers/manures. The results of the study corroborated with the findings of Gupta and Singh (1972), Chandrabhan and Harishankar (1973) and Ruhal and Ram Deo (1979).

The total-P correlated negatively (Table 3) with pH (r=-0.472). The result was in accordance with those reported by Giridhara Krishna (1993).

5.3 Phosphate potential

The lower phosphate potential (Table 1) in case of Navile soil (5.08) indicating more weakly the phosphorus held compared to other soils. In otherwards the higher the phosphate potential as in case of Hunsur-2 (5.84) the more difficult for phosphate to enter into the solution (Orlov, 1992). Beckett and White (1964) revealed that the surfaces of calcium, iron and aluminium depending on the pH, which influences the variations in phosphate potential.

5.4 Evaluation of chemical extractants

Phosphorus occurs in soil in both organic and inorganic forms and the chemical soil testing procedures measures only the latter using a particular extractant depends on the nature of soil and kinds of compounds found in the soil. The phosphorus extracted by different extractants in tobacco growing soils were presented in Table 4 and fig 3 and their relationship with the inorganic phosphorus fractions were presented in Table 5.

5.4.1 Bray-No.:1 extractant

The fluoride ions in Bray-No.:1 has the special property of complexing Al^{3+} and Fe^{3+} ions in acidic solution with consequent release of phosphorus held in the soil by these trivalent ions. Inclusion of dilute acid in the extractant results in the dissolution of the more active calcium phosphate and prevents the precipitation of phosphate much soluble (Jackson, 1958).

The available phosphorus extrtacted by Bray-No.1 stands second among the other phosphorus extractants and highest available phosphorus was recorded in soils of Hunsur-2 and Arakalgud. This may be attributed to the large amount of phosphorus present in iron and aluminium fractions in these soils.

Correlation study revealed that significant positive correlation were observed between Bray-No.:1 with all the fractions except Occl-P. This suggests that Bray-No.:1 might not extracted phosphorus present in Occluded form..

5.4.2 Bray-No.:2 extractant

The Bray-No.:2 extractant extracted highest amount of phosphorus from the soils (5.3 to 41.7 ppm) when compared to other phosphorus extractants. The higher extraction of available phosphorus is because of its composition (0.03 N NH_4F + 0.1 N HCl). Here the fluoride ion displaces phosphates from iron and aluminium phosphate (Swenson *et al.*, 1949) and the dilute hydrochloric acid present helps in dissolving calcium phosphates. The extraction pattern of this extractant is similar to that of Bray-No.:1. However, the higher solubility of phosphorus in Bray-No.:2 than Bray-No.:1 was due to its relatively higher acidic strength and also complexing nature of phosphorus adsorbed by these trivalent ions as reported by Ballard (1974) and Bhiyan and Sedberry (1995).

The correlation between the Bray-No.:2 extractant and the inorganic phosphorus fractions presented in Table 6 shows that Bray-No.:2 is similar to Bray-No.:1 significantly with Saloid-P, Al-P, Fe-P, Ca-P and Red.Sol-P but Occl-P has got non-significant with Bray-No.:2 extractant. Similar findings was reported by Jaggi (1992).

5.4.3 <u>Truog's extractant</u>

The quantity of available phosphorus extracted by Truog's (3.0 to 3.7 ppm) extractant was found to be next to Bray-No.:2 and on par with Bray-No.:1 extractant. The higher extraction of available phosphorus may be due to solubility of Ca-P due to the increased hydrogen ion activity since the extractant contains dilute sulphuric acid with high acidic strength (pH 3.0) (Ballard, 1974).

Similar to other extractants Truog-P also was significantly correlated with all the fractions except with Occl-P.

5.4.4 Mehlich's extractant

The available phosphorus extracted by Mehlich's extractrant shows that this extractant extracts the least (2. 8 to 12.1 ppm) amount of available phosphorus among the extractants. Similar results were reported by Menon *et al.* (1988) and Menon *et al.* (1990).

The data on relationship between Mehlich's extractant and inorganic phosphorus fractions indicated that this extractant was significantly correlated with all the extractants except Occl-P. This extractnat might have received phosphorus largely from Al-P, Saloid -P and Fe-P but less with Ca-P. This may be due to the extraction of higher portion from dominant inorganic fractions in the soil (Nelson *et al.*, 1953).

5.4.5 Olsen's extractant

The available phosphorus extracted by Olsen's extractant was next only to Truog. The low extraction of available phosphorus by Olsen-P may be due to the soils studied were acidic with low calcium activity. Similar results were reported by Thind *et al.* (1991).

The relationship between Olsen's method and the inorganic phosphorus fractions show that the Olsen's extractant was significantly correlated with all the fractions except Occl-P. The results are in agreement with the findings of Nagendra Rao and Chakraborty, (1994).

LEGANDS

1. Shikaripura
2. Abbligere
3. Navile
4. Tarikere
5. Arakalgud
6. Ramnathpura
7. Piriyapatna
8. Hunsur-1
9. Hunsur-2
10. H.D.Kote

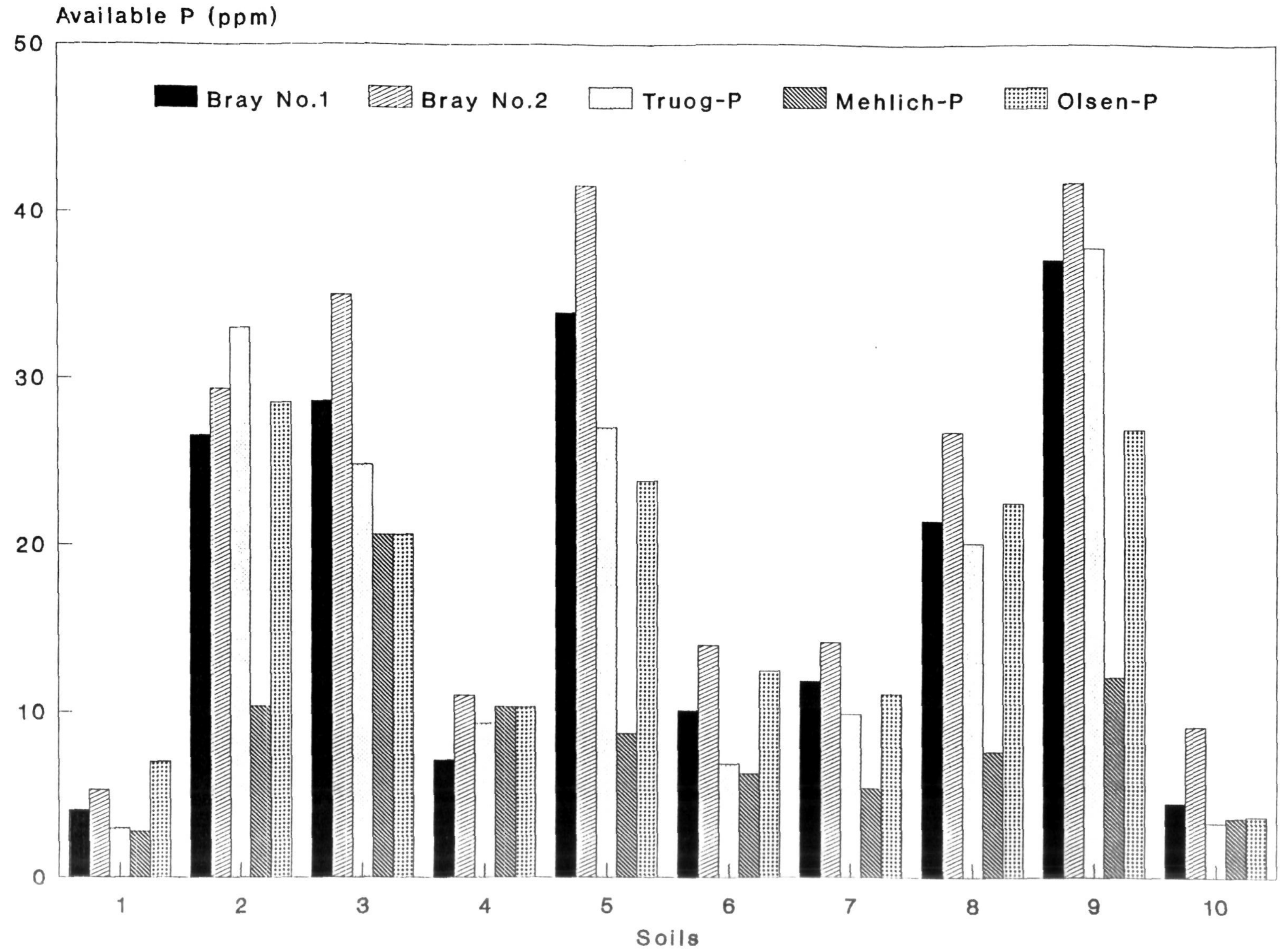


Fig.3: Available phosphorus extracted by different chemical extractants.

Multiple regression equations for available phosphorus extractants presented in Table 6 show that Saloid-P, Al-P, Fe-P, Occl-P, and Red. Sol-P fractions were individually accounted for 94.8, 91.8, 94.9, 84.9 and 79 per cent variations among Bray-No.:1, Bray-No.:2, Truog-P, Mehlich-P and Olsen-P indicating that Bray-No.:1, and Truog-P are very much influenced by these fractions but Olsen-P was not shown higher variation. However, Al-P and Saloid-P were the important fractions found to be associated with available phosphorus extracted by all the extractants except Olsen-P. This may be due to the higher content of Al-P in red soils Debnath and Mandal, (1982) also reported that Al-P was one of the important fractions as the main source of available phosphorus in soils of West Bengal. Jaggi *et al.* (1990) considered the Al-P as a major contributor for available phosphate in soil.

5.5 Suitability of chemical extractant for the extraction of available hosphorus

The phosphorus extracted by different phosphorus extractants in the soils with different levels of phosphorus applied in a long term experiment were presented in Tale 7 and fig 4. The extraction pattern by different extractants followed the same trend described earlier. The extraction of available phosphorus was in the order of Bray No.:2 > Bray-No.:P1=Truog-P > Olsen-P > Mehlich-P. The higher available phosphorus was observed in the phosphorus applied treatment due to the higher application of fertilizers for a longer time. However, Treatmental difference was found to be non significant except Truog-P and Olsens-P. At the same level of phosphorus treatment, there was no difference in available phosphorus extracted by all

LEGANDS

T1 : Control. No application of phosphorus.

T2 : 30 Kg. P_2O_5. ha^{-1} applied every year.

T3 : 30 Kg. P_2O_5. ha^{-1} applied once in two year.

T4 : 30 Kg. P_2O_5. ha^{-1} applied once in three year.

T5 : 60 Kg. P_2O_5. ha^{-1} applied every year.

T6 : 60 Kg. P_2O_5. ha^{-1} applied once in two year.

T7 : 60 Kg. P_2O_5. ha^{-1} applied once in three year.

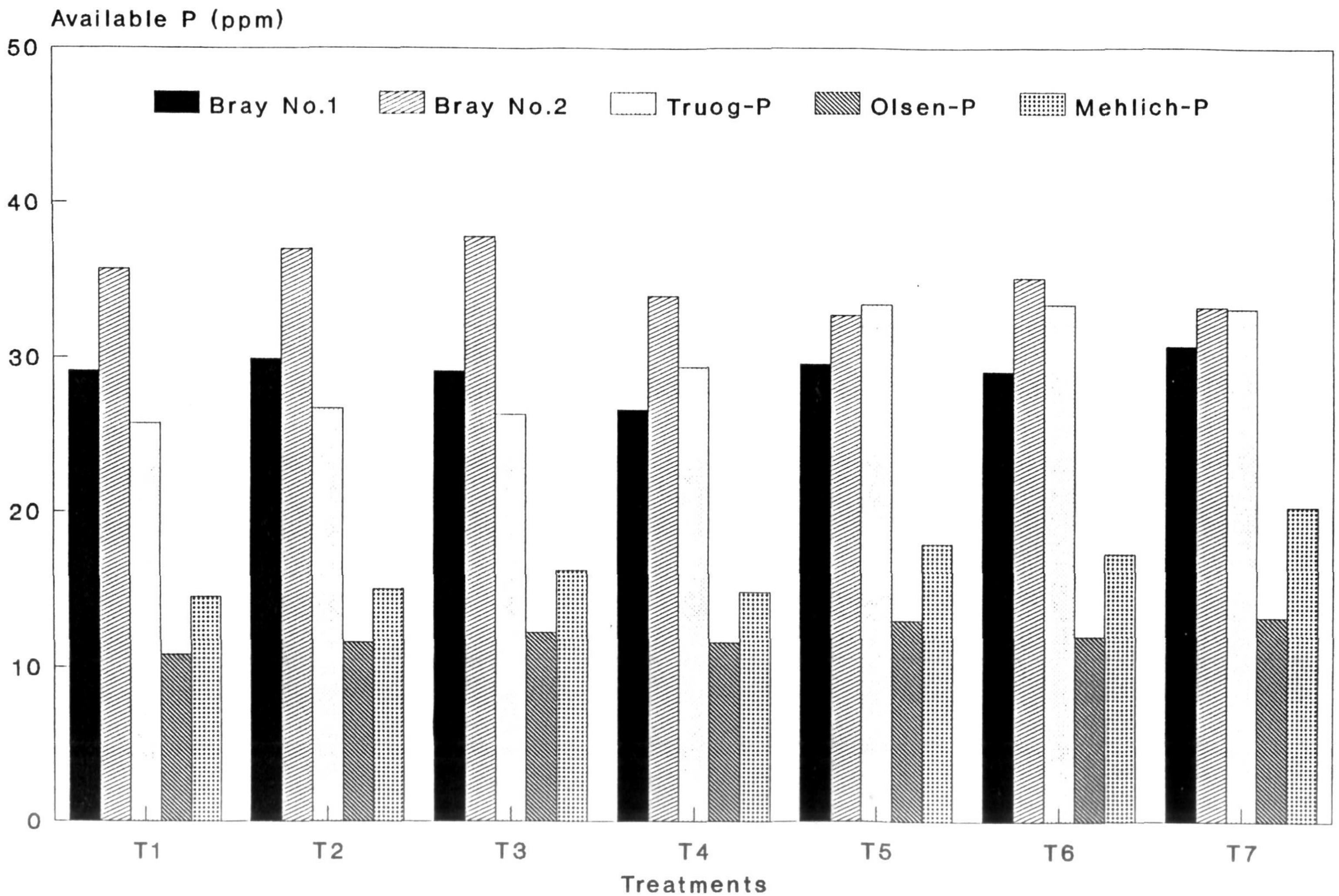


Fig.4: Available phosphorus as influenced by different levels of phosphorus treatments

the extractants indicating marked depletion of available phosphorus either due to omission or reduced level of phosphorus application was not noticed.

5.6 Yield Parameters

The green leaf, cured leaf yield and TGE (Top grade equivalent) of FCV tobacco as influenced by the different levels of phosphorus application were presented in Table 8 and depicted in fig 5.

The Green leaf yield was ranging from 7915 to 8643 $kg.ha^{-1}$. Perusal of data indicate that treatmental effect was not significant on both Green leaf and cured leaf yield. However , 30 Kg P_2O_5 ha^{-1} once in three year treatment recorded numerically higher cured leaf yield.

The data also show that the response to phosphorus application at the rate of 60 Kg ha^{-1} applied every year produced slightly less yield. Similar observations were also reported by earlier workers (Gopinath, 1965 ; Gopalachari and Manga Reddy, 1972 and Sanibabu and Krishamurthy, 1984). The results also indicated that the omission of phosphorus at the same level of phosphorus application did not significantly influence the yield parameters. The research conducted at CTRI (1992) also revealed that omission of phosphorus in fertilizer schedule on FCV tobacco in Vertisols of Andhra Pradesh for once in three year or six year did not significantly influence the green leaf and cured leaf yields.

LEGANDS

T1	:	Control. No application of phosphorus.
T2	:	30 Kg. P_2O_5. ha^{-1} applied every year.
T3	:	30 Kg. P_2O_5. ha^{-1} applied once in two year.
T4	:	30 Kg. P_2O_5. ha^{-1} applied once in three year.
T5	:	60 Kg. P_2O_5. ha^{-1} applied every year.
T6	:	60 Kg. P_2O_5. ha^{-1} applied once in two year.
T7	:	60 Kg. P_2O_5. ha^{-1} applied once in three year.

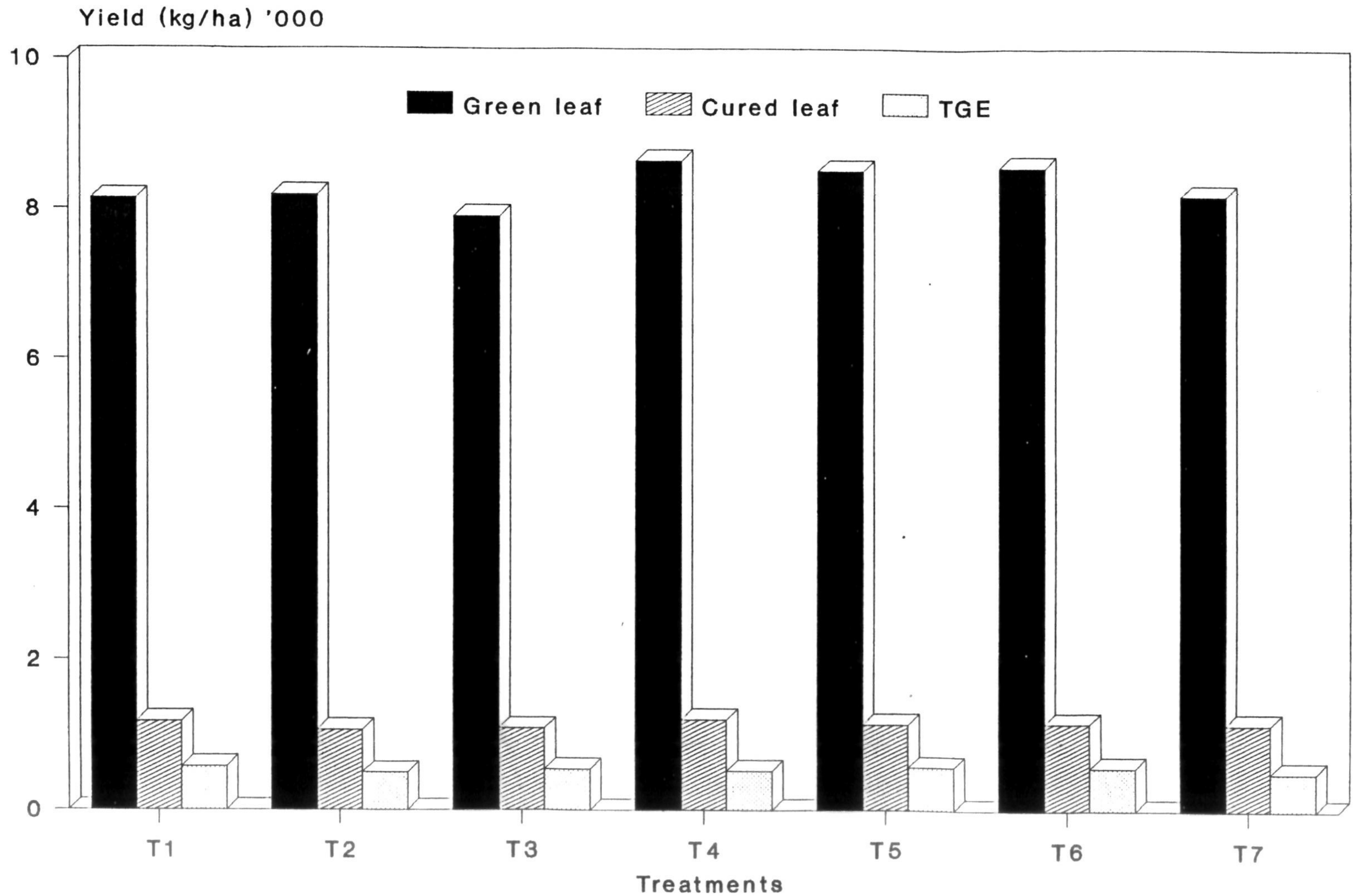


Fig.5: Different levels of phosphorus on yield parameters of FCV tobacco (FCV Spl.)

Top grade equivalent (TGE) which reflects the quality of cured leaf with respect to colour, spots / blemish, texture, and body condition, was not improved either due to reduced level or omission of phosphorus application. This implies that there was not much difference in producing bright grades of Tobacco by phosphorus levels. Similar results on bright leaves due to phosphorus application was reported by Patel (1965).

5.7 Relationship between available phosphorus and plant parameters

The data presented in Table 9 show that the relationship between the phosphorus extractants and the effect of different phosphorus treatments on different plant parameters does not significantly correlated and also with total phosphorus uptake. However, Bray-P1 better correlated with total phosphorus uptake indicating that all the extractants tried were on par with regards to extraction of available phosphorus.

5. 8 Quality attributes of FCV Tobacco

Tabacco quality is a relative term which was defined by Padilla (1965) as the sum of physico-chemical, organoleptical and economical properties possessed by the leaf that make it desirable or undesirable for specific purposes. In the present experiment quality attributes such as nicotine, total nitrogen, and reducing sugar were presented in Table 10 and depicted in fig. 6(a) and 6(b).

The data pertaining to nicotine content, reveal that there was no significant variation among the treatments due to different levels of

LEGANDS

T1 : Control. No application of phosphorus.

T2 : 30 Kg. P_2O_5. ha^{-1} applied every year.

T3 : 30 Kg. P_2O_5. ha^{-1} applied once in two year.

T4 : 30 Kg. P_2O_5. ha^{-1} applied once in three year.

T5 : 60 Kg. P_2O_5. ha^{-1} applied every year.

T6 : 60 Kg. P_2O_5. ha^{-1} applied once in two year.

T7 : 60 Kg. P_2O_5. ha^{-1} applied once in three year.

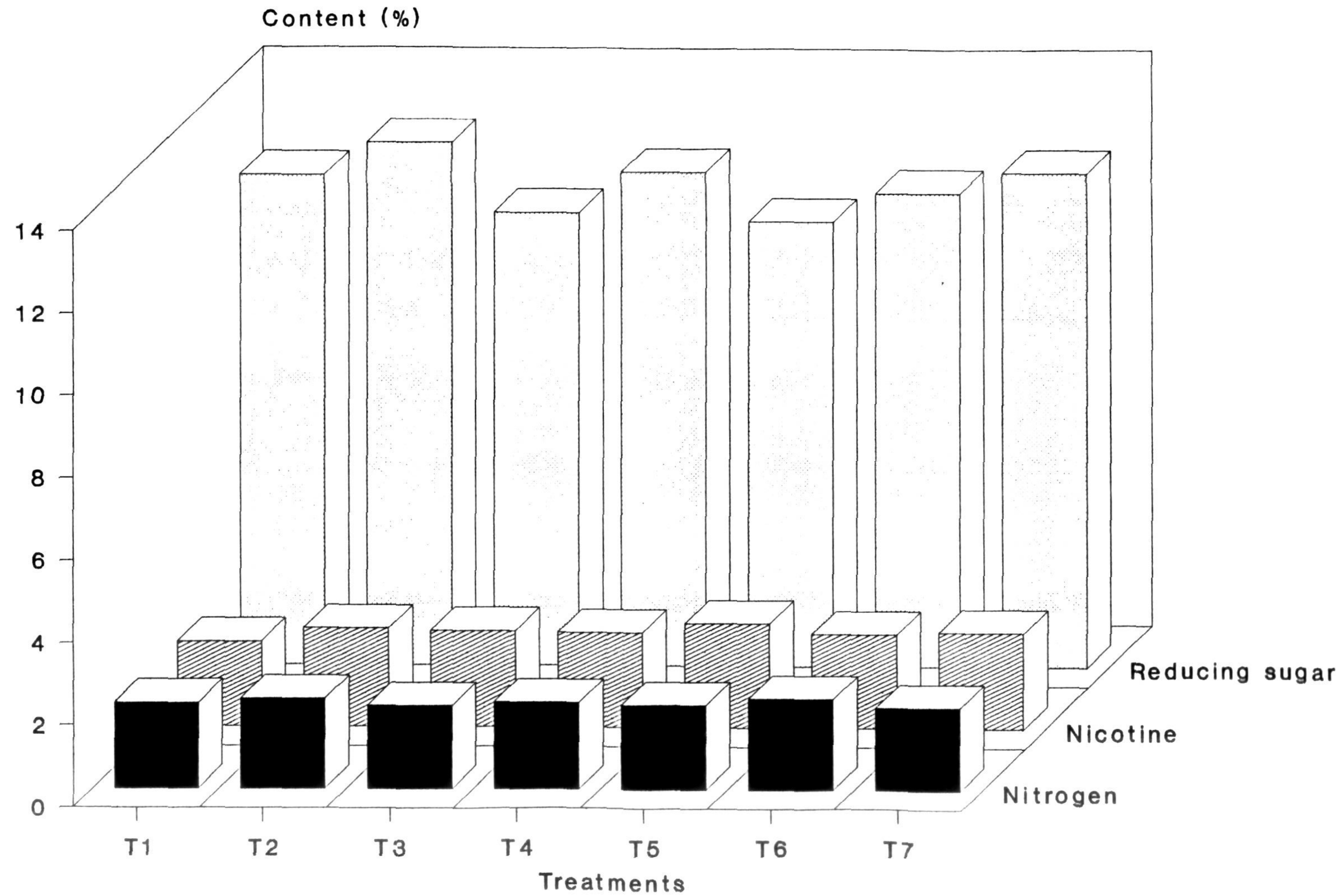


Fig.6(a): Quality of tobacco leaf (L-position) as influenced by different phosphorus levels.

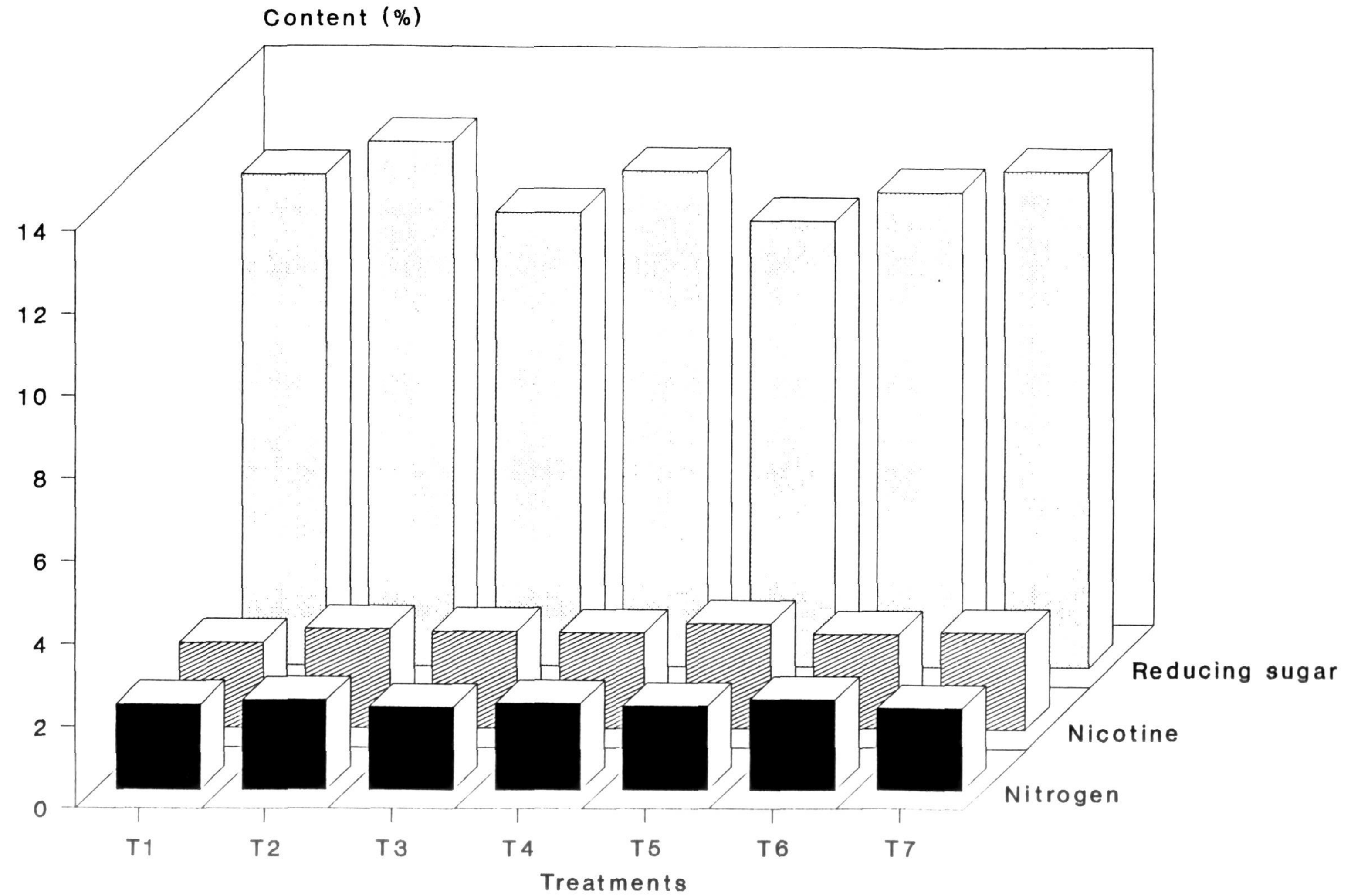


Fig.6(b): Quality of tobacco leaf (L-position) as influence by different phosphorus levels.

phosphorus application. This implies that nicotine was independent of phosphorus level in the leaf. The range was (1.83 to 2.18 %) in X position and (2.06 to 2.55%) in L position. The L position leaves was observed the higher nicotine content than X position. The values were within the acceptable range (0.75 to 3.00%). Leong (1978) and Oliveira *et al.*, (1983) also reported that application of phosphorus did not affect the nicotine content of leaves.

The reducing sugar content of FCV tobacco was also not influenced significantly with different levels of phosphorus application. The range in X position was 11.1 to 14.2 per cent and in L position 10.8 to 12.7 percent. However, the reducing sugar content of all the treatments were in the acceptable range (8.24%) of desirable quality.

The total nitrogen content of FCV tobacco was not influenced by different phosphorus levels ranging from 1.88 to 2.01 per cent and 2.01 to 2.21 per cent in X and L position respectively. However, the nitrogen content in all the treatments were with in the acceptable range of 1.0 to 3.0 per cent. The above results were also reported by CTRI (1992).

5.9 Phosphorus content in different positions and Total -P uptake by FCV tobacco

The phosphorus content of FCV tobacco as influenced by different levels of phosphorus application was presented in Table 11(a) and 11(b).

LEGANDS

T1	:	Control. No application of phosphorus.
T2	:	30 Kg. P_2O_5. ha^{-1} applied every year.
T3	:	30 Kg. P_2O_5. ha^{-1} applied once in two year.
T4	:	30 Kg. P_2O_5. ha^{-1} applied once in three year.
T5	:	60 Kg. P_2O_5. ha^{-1} applied every year.
T6	:	60 Kg. P_2O_5. ha^{-1} applied once in two year.
T7	:	60 Kg. P_2O_5. ha^{-1} applied once in three year.

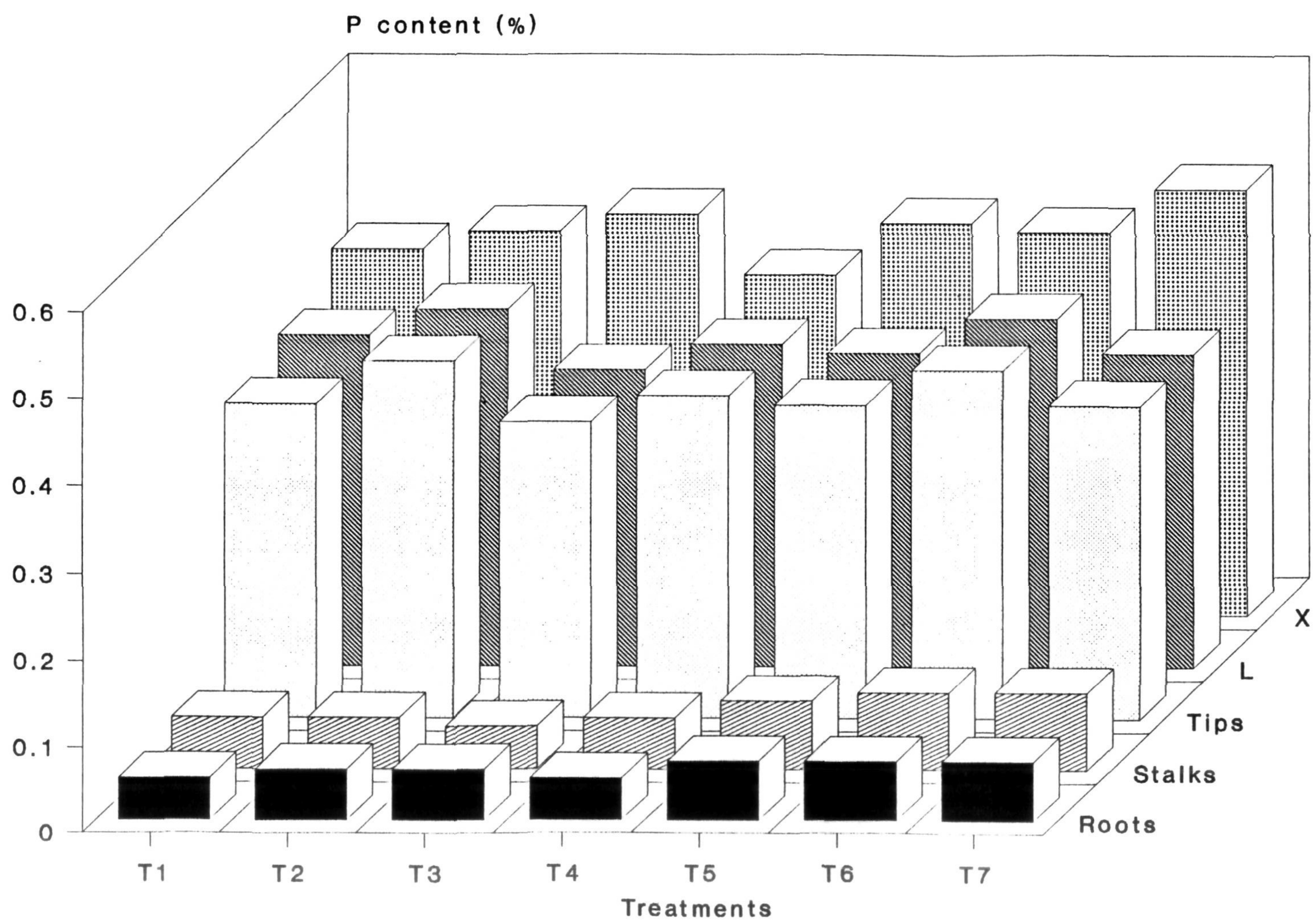


Fig.7: Phosphorus content of tobacco as influenced by different phosphorus treatments.

The phosphorus content of leaf in X, L ,Tips positions, stalks and roots were found to be higher in the treatment with 60 Kg $P_2 O_5$ ha^{-1} once in three year and lowest in the treatment 30 Kg P_2O_5 ha^{-1}. once in three year, However , the differnce due to the treatments was found to be non significant (fig.7).

The total uptake, due to different phosphorus level were ranging from 4.8 to 5.3 Kg ha^{-1} phosphorus uptake was found to be more in case of 60 Kg P_2O_5 ha^{-1} every year and once in three year. However, the total uptake was non significant indicating that the depletion of phosphorus in the form of uptake was almost same in all the treatments. This is in agreement with the findings of CTRI (1961-62) and CTRI (1992) [fig.8(a)].

5.10 Influence of phosphorus application on contents and uptake of nutrients.

The influence of different levels of phosphorus treatment on chemical composition and removal of leaves and stalks of FCV tobacco were presented in Table 12 and fig 8(a) and 8(b).

The nitrogen content in leaves and stalks were ranging from 2.68 to 2.15 per cent ad 0.58 to 0.81 per cent respectively. The leaves contained more of nitrogen than stalk. The uptake of nitrogen was next only to potassium in quantity and was ranging from 22.5 to 25.5 and 3.1 to 4.5 Kg ha^{-1} in leaves and stalks respectively. However, the nitrogen content and uptake were found to be non significant with different levels of phosphorus application. This is in accordance with the results of Gopalachari *et al.* (1978).

Potassium content and uptake found to be highest among the chemical nutrients studied in leaves and stalks of FCV tabacco. The content ranged from 2.22 to 2.43 and 1.34 to 1.54 per cent in and uptake was 25.7 and 25.7 and 7.0 to 8.3 Kg ha^{-1} in leaves and stalk respectively. The uptake was found to be high when compared to nitrogen and phosphorus indicating requirements of potassium is relatively higher than nitrogen and phosphorus (Garner, 1951). However, the tretmental deference was non significant.

The Calcium content and uptake by FCV tabacco due to different phosphorus treatments were found statistically non significant. The content of Calcium in leaves and stalk were 1.38 to 1.48 and 0.58 to 0.65 per cent and uptake 15.5. to 18.2 and 3.2 to 3.5 Kg ha^{-1} in leaves and stalks respectively. Among the secondary nutrients calcium content and uptake was found to be more and next to nitrogen and potassium indicating that calcium is the second most important constituent of ash (Hewitt, 1963).

The Magnesium stands next only to calcium content and uptake by leaves and stalks. However, the content in leaves (0.29 to 0.38%) and stalks (0.20 to o.28%), uptake in leaves (3.2 to 4.5 Kg ha^{-1}) and stalks (1.1 to 1.6 Kg ha^{-1}) respectively. The data show that effect of phosphorus on magnesium content and uptake was not significant. Similar results were reported by Gopalachari, *et al.* (1984).

LEGANDS

T1 : Control. No application of phosphorus.

T2 : 30 Kg. P_2O_5. ha^{-1} applied every year.

T3 : 30 Kg. P_2O_5. ha^{-1} applied once in two year.

T4 : 30 Kg. P_2O_5. ha^{-1} applied once in three year.

T5 : 60 Kg. P_2O_5. ha^{-1} applied every year.

T6 : 60 Kg. P_2O_5. ha^{-1} applied once in two year.

T7 : 60 Kg. P_2O_5. ha^{-1} applied once in three year.

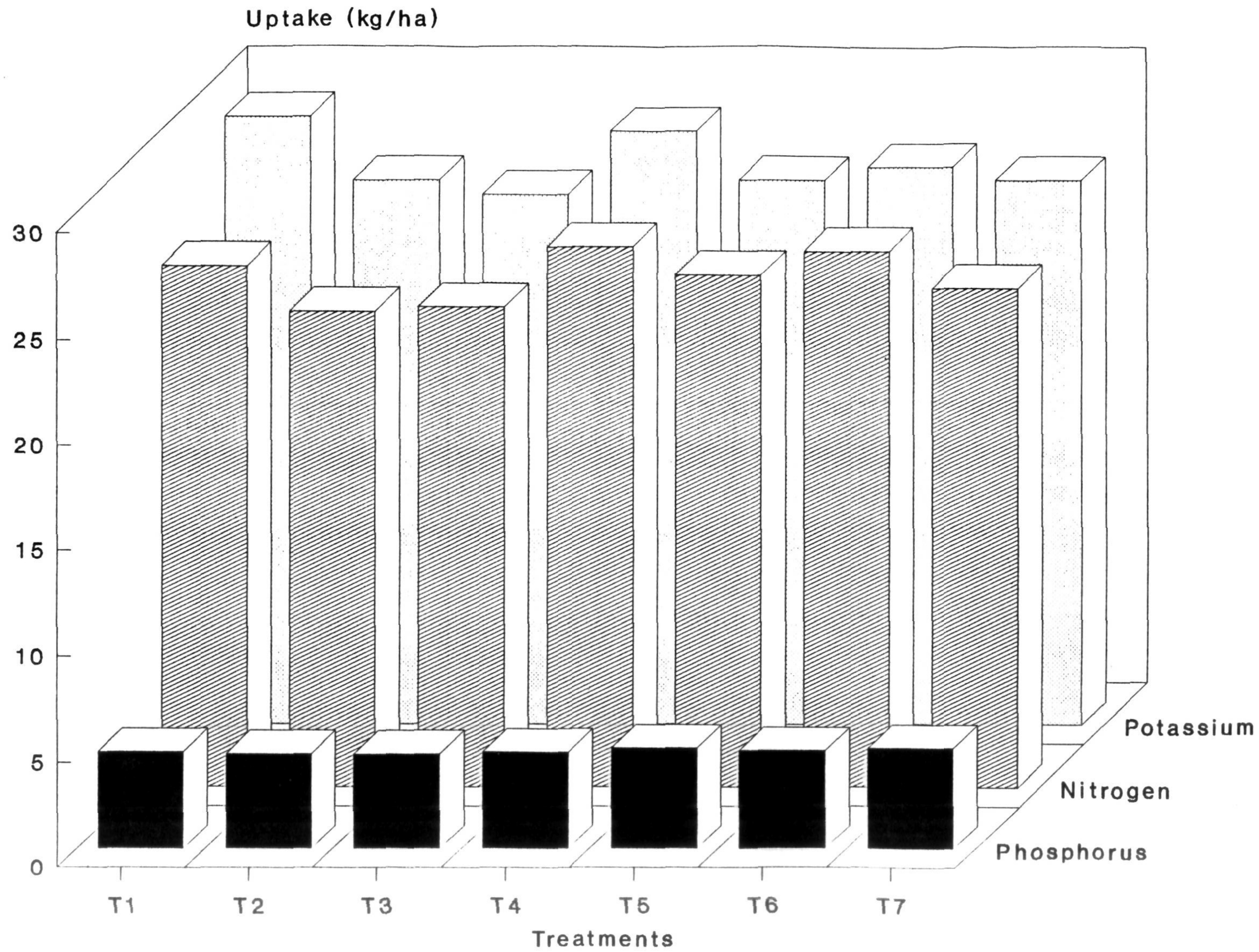


Fig. 8(a): Effect of phosphorus on uptake of major nutrient on tobacco.

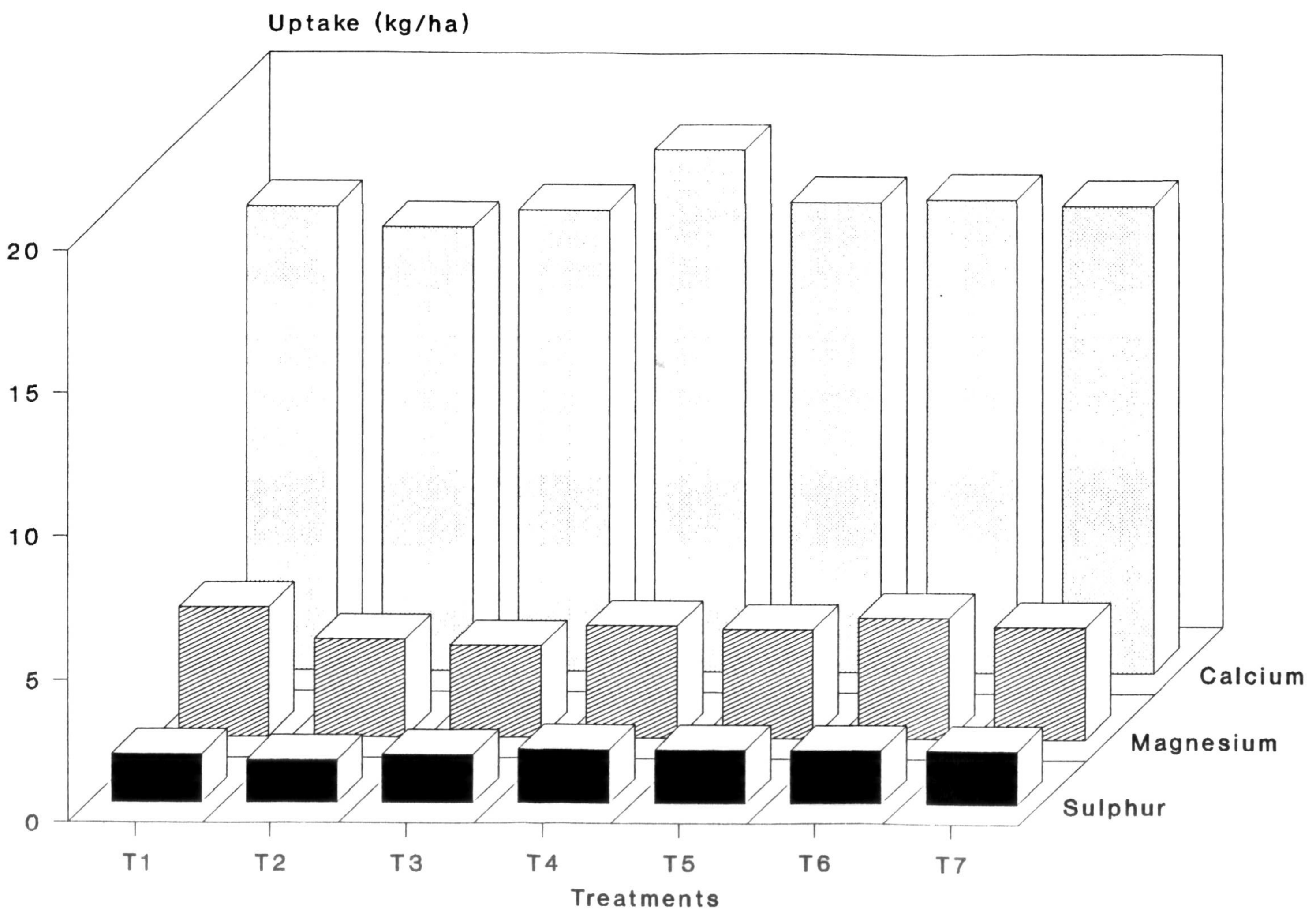


Fig. 8(b): Effect of phosphorus on uptake of secondary nutrients on tobacco.

The Sulphur found to be least in content and uptake among the secondary nutrients studied. However, ranged from 0.14 to 0.17 and 0.07 to 0.09 per cent; 1.5 to 1.9 and 0.4 to 0.5 Kg ha^{-1} in leaves and stalks respectively. The variation due to phosphorus application was found to be non significant. The above results were in agreement with findings of earlier reports (Lalas *et al.*, 1978 and Oliveira *et al.*, 1983).

5.11 <u>Micronutrient content and removal as influenced by phosphorus application</u>

The perusal of the data presented in Table 13 and figure 8(c) regarding the micronutrients content and uptake by FCV tobacco show that the copper was found to be lowest in concentration and uptake by leaves and stalk. Iron was found to be highest among the micronutrients studied and the effect of these micronutrients due to different levels of phosphorus applications was non significant. This is in agreement with the reports by Garner (1951) and Murthy *et al.* (1986).

LEGANDS

T1	:	Control. No application of phosphorus.
T2	:	30 Kg. P_2O_5. ha^{-1} applied every year.
T3	:	30 Kg. P_2O_5. ha^{-1} applied once in two year.
T4	:	30 Kg. P_2O_5. ha^{-1} applied once in three year.
T5	:	60 Kg. P_2O_5. ha^{-1} applied every year.
T6	:	60 Kg. P_2O_5. ha^{-1} applied once in two year.
T7	:	60 Kg. P_2O_5. ha^{-1} applied once in three year.

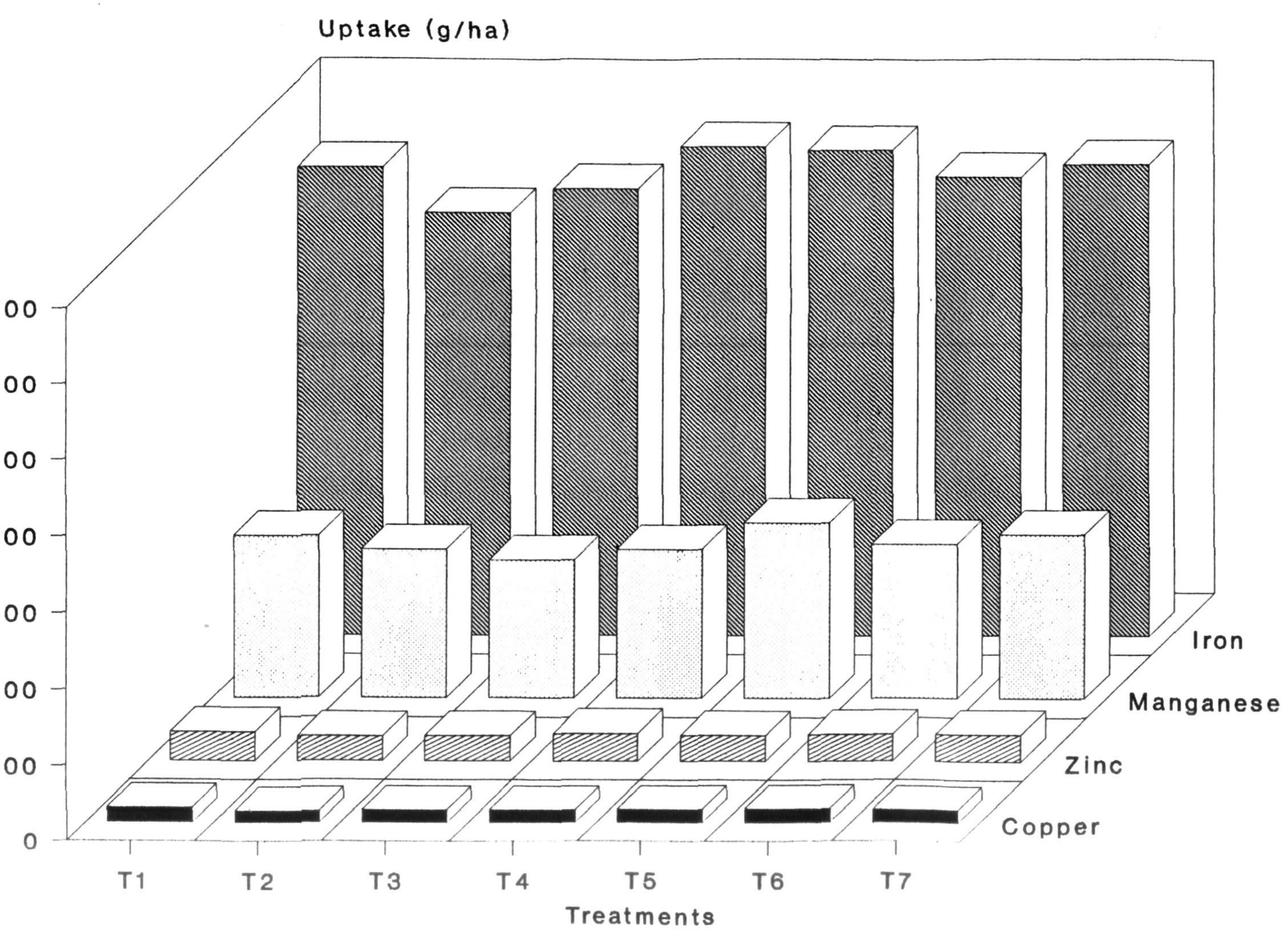


Fig. 8(c): Effect of phosphorus on uptkae of micronutrients on tobacco.

FUTURE LINE OF WORK

- Depletion pattern of phosphorus in phosphorus build up soils have to be worked out.
- Identification of chemical compounds/species that are formed in soils due to P build up and their solubility for the contribution to available pool.
- Necessary to work out the contribution of different fractions of P to the uptake.
- Phosphates activity influenced by P-Solubilising micro organisms.

SUMMARY

VI SUMMARY

An investigation on soil inorganic phosphorus fractions and their relationship with soil properties and available phosphorus extracted by different extratants was carried out in soils under tabacco cultivation of Southern transitional zone of Karnataka. An attempt has been made to find out a suitable extractant for available phosphorus under different levels of phosphorus application in a long term experiment on tobacco laid out in high phosphorus build up soils of Regional research station, Navile, Shimoga. The out come of the investigation are summarized below,

Inorganic soil phosphorus fractionation study revealed that Saloid -P fraction was the least (2.1 to 8.9 ppm) and its contribution to total phosphorus was to the extent of 0.5 to 2.3 per cent.

The Al-P and Fe-P were the two dominant fractions of soil phosphorus observed in Alfisols under tobacco cultivation. The concentration and contribution of each fraction to total phosphorus was in the following order of Saloid-P < Occl-P < Ca-P < Red.Sol -P < Al-P < Fe -P.

Among the soil, pH, OC and free Fe_2O_3 are found to be dominant characters influencing most of the phosphorus fractions.

Study on extraction of available phosphorus extracted by different chemical extractants revealed that majority of the soils under tobacco cultivation found to be very high in available phosphorus content.

Bray-No.:2 has extracted more available soil phosphorus among the extractants tried and observed following order of extraction; Bray-No.:2 > Bray-No.:1 = Truog-P > Olsen-P > Mehlich-P.

None of the extratants found to be significantly correlated with phosphorus uptake by Tobacco. However, better correlation was observed with Bray-No.:1.

Significant positive correlations were observed between the extractants tried and the inorganic fractions except Occl -P.

The multiple regression equations for inorganic phosphorus fractions and the extractants revealed that the variation due to Saloid-P, Al-P and Fe-P were found to be large with all the extractants.

There was no much variation in phosphorus potential for the soils studied, However, Navile soil was observed the least (5.08) indicating more weakly the phosphorus held compared to other soils.

Response of phosphorus application to tobacco revealed that there was no significant differnce in tobacco yield either due to reduction in phosphorus level and due to omission of phosphorus at the same level of phosphorus application.

Quality attributes of tobacco Viz., nicotine, reducing sugar and total nitrogen were in a acceptable limits and not affected due to different levels of phosphorus application.

Phosphorus application did not influence to the content and removal of nitrogen, potassium, secondary and micronutrients.

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VII REFERENCES

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* Orignial not seen.

APPENDIX

APPENDIX - I

Flow chart for Soil P fractionation System

(Peterson & Corey., 1966 as outlined by Hesse , 1971) .

0.5 gm Sample

Extract with 25cc 1N NH_4Cl, 1/2 hour shaking and centrifuge

Solution A → Saloid -P

Soil

Extract with 25 cc 0.5 N NH_4F, 1 hour shaking and centrifuge

Solution B → Al-P

Soil

Wash twice with 25cc Sat. NaCl and extract with 25 cc 0.1 N NaOH. 16 hour shaking and centrifuge

Solution C → Fe-P

Soil

Wash twice with 25cc Sat. NaCl Add 12.5 cc 0.3 M NaC_2O_4. $Na_2S_2O_3$ & shake for 15 minutes. Heat to 80° C, dilute to 25cc centrifuge.

Solution D → Reductant soluble-P

Soil

Wash twice with 25cc Sat. NaCl Add 25 cc 0.1 M NaOH, shake for 1 hour and centrifuge

Solution E → Occluded -P

Soil

Wash twice with Sat. NaCl, Add 25 cc 0.2 M H_2SO_4, shake for 1 hour & centrifuge

Solution F → Ca -P

Discard the Soil