SEASONAL CHANGES IN THE CARBOHYDRATE, PROTEIN AND NUTRIENT CONTENTS OF *PARKIA CLAPPERTONIANA* KEAY

BY

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THESIS APPROVAL

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TO

IFEYINWA

(My Wife)

AND

UGORIE EZE (MRS)

AKUNNE EGBOLUCHE (MRS)

OKWUCHUKWU

NDIBE

EGBUCHUNEM

(My Sisters & Brothers)

DECLARATION

I declare that this work is wholly the author's and has not been part of any presentation for any other qualification.

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ABSTRACT

The concentration and trend in seasonal changes of four food substances, five mecronutrients and five micronutrients were studied in eight organs of Parkia clappertoniana Keay.

All the constituents, except Cu, showed significant changes with time in the shoot (bark and leaves). Protein and nitrogen showed significant variation within each mature fruit part, between the floral stages and between the mature fruit parts.

As the young fruit developed there were significant decreases with time in the content of K and Mg. Similar observations were made for K and Pb in the husk. Calcium showed significant increases with time in the husk. There were significant decrease in pulp Pb and increase in seed Ca.

Starch and K in the bark and leaf starch varied significantly between trees and so did total soluble carbohydrates in the shoot, flowers and mature fruit. In the mature fruit reducing sugars, protein, nitrogen, Mg and Pb also showed significant differences between trees. Iron and Zn in the young fruit showed a similar observation.

Starch, total soluble carbohydrate, nitrogen, P, K and Mg were significantly higher in the young flower while the mature flower showed higher levels of Ca, Fe, Zn, Pb and Mn. In the mature fruit, the seed stored most of the starch, protein, nitrogen and

K while the pulp stored most of the total soluble carbohydrate and Pb.

The shoot showed significantly high levels of starch, total soluble carbohydrate, protein and nitrogen during the late rains. Reducing sugars were generally low in all the organs.

Phosphorus was significantly high in September (for bark) and between April and June (for leaves). In the stem, K was significantly high from June to October. High leaf K between June and August showed no significant differences between months. In the young fruit, K showed a similar trend from May to June.

Calcium was high in the bark during November to December, and Mg in August. Leaf Mg was generally high during the cold dry months (December - January) and during the early rains (May - June).

Iron showed high levels in the bark from November to December, and Zn from June to July. Iron in the bark was low in August and Zn was low in October. Leaf Fe and Zn did not show any significant variation between December and July.

In the bark, Pb and Mn were high in December and November respectively and low from June and July and between May and September respectively. Leaf Pb and Mn did not show significant changes between April and October.

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ABBREVIATIONS AND SYMBOLS USED IN THIS THESIS

AAS	= Atomic Absorption Spectrophotometer
Anova	= Analysis of Variance
Ca	= Calcium
cm	= centimetre
conc.	= Concentrated
Cu.	= Copper
Fe	= Iron
g	= gram
H_2SO_4	= Sulphuric acid
K	= Potassium
KH_2PO_4	= Potassium dihydrogen phosphate
LSD	= Least Significant Difference
Mg	= Magnesium
mg	= milligram
mgK	= milligram of potassium
mg/l	= milligram per litre
ml	= millimetre
Mn	= Manganese
N	= Nitrogen
$(NH_4)_2SO_4$	= Ammonium sulphate
nm	= nanometre
^oC	= Degrees Centigrade
%	= per cent
P	= Phosphorus
Pb	= Lead
ppm	= parts per million
PRT	= Protein
RS	= Reducing Sugars
S.E.	= Standard Error
SG	= Specific Gravity
$SnCl_2$	= stannous chloride
ST	= Starch
Syn.	= synonym
TSC	= Total Soluble Carbohydrates
Zn	= Zinc

CHAPTER ONE

INTRODUCTION

Members of the genus Parkia are all perennial trees of heights that range from 15-30 metres and 3-4 metres in girth (Grisebach, 1864; Oliver, 1871; Exell, 1944; Aubreville, 1950; Andrews, 1952; Hutchinson and Dalziel, 1954; Baker and Harris, 1957; Hutchinson and Dalziel, 1958; Irvine, 1961; Keay et al., 1964a; Campbell-Platt, 1980 and Hopkins, 1983). They are all legumes with spreading trunks and wide crowns.

The savanna species tend to shed and replace their leaves during the period of flowering in the first half of the dry season (Dalziel, 1936; Baker and Harris, 1957; Campbell-Platt, 1980 and Hopkins, 1983). In Zaria area the defoliation is more pronounced during March - April. It starts as the flowers open and continues up to fruit formation. Only some of the branches, especially those bearing the inflorescences, or the entire foliage may be defoliated (Baker and Harris, 1957 and Hopkins, 1983). This is followed by a vigorous development of new leaves. At Zaria, the plant flowered between January - May.

The flowers are borne on long peduncles of varying lengths (Baker and Harris, 1957; Irvine, 1961; Campbell-Platt, 1980 and Hopkins, 1983). The compound inflorescence bears 3-6 pendant capitula on a leaf-bearing branch or may develop from an axillary bud (Hopkins, 1983). The inflorescence frequently occurs at the edge of the foliage. Each capitulum bears about 2,000 - 2,400 small flowers tightly massed together on a knob-like receptacle (Baker and Harris, 1957).

There are both sterile and fertile flowers on the capitulum (Baker and Harris, 1957 and Harris, 1985). The sterile flowers are proximal and yield nectar which collects

in a groove formed between the two flower-types. The fertile flowers are stalkless (Keay et al.,1964a).

The flowers of some African species, e.g. Parkia clappertoniana Keay, are pollinated by fruit bats (Megachiroptera) (Baker and Harris, 1957 and Harris, 1985). Gledhill (1972) reported that bats visit the plant at night and may effect pollination. They are also visited by bees.

The fruit is a pod. Each hermaphrodite flower has the potential to form a pod after pollination. Out of the numerous flowers, each capitulum forms between 1-33 or more pods in a bunch. The pod measures 15-25 cm in length (Dalziel, 1936).

The seeds in the pod are surrounded by a yellowish mealy pulp; usually powdery when dry. Keay et al.(1964b) noted that the seeds do not show through the surface of fruit in P. clappertoniana as they do in Parkia bicolor A. Chev. In the latter species the seeds show slightly diagonal arrangement. The seed (a pulse) is covered by a hard black seed coat.

DISTRIBUTION OF PARKIA

Parkia species are widely distributed in the tropical regions of Africa, South East Asia and South America (Fig. 1) According to Baker and Harris (1957), 19 morphologically very diverse species are recorded from South America and West Indies;11 species from South East Asia and 5 morpholoically rather similar species from Africa. The species are clustered largely in West Africa (Africa), Amazonia (for South America) and the continental South East Asia. Hopkins (1983) also noted that the difference in species number for the three regions could be related to the amountof taxanomic work that has been done in each of them. The plant is found in both savanna and rain forest with the species manifesting variable characteristics in their different localities.

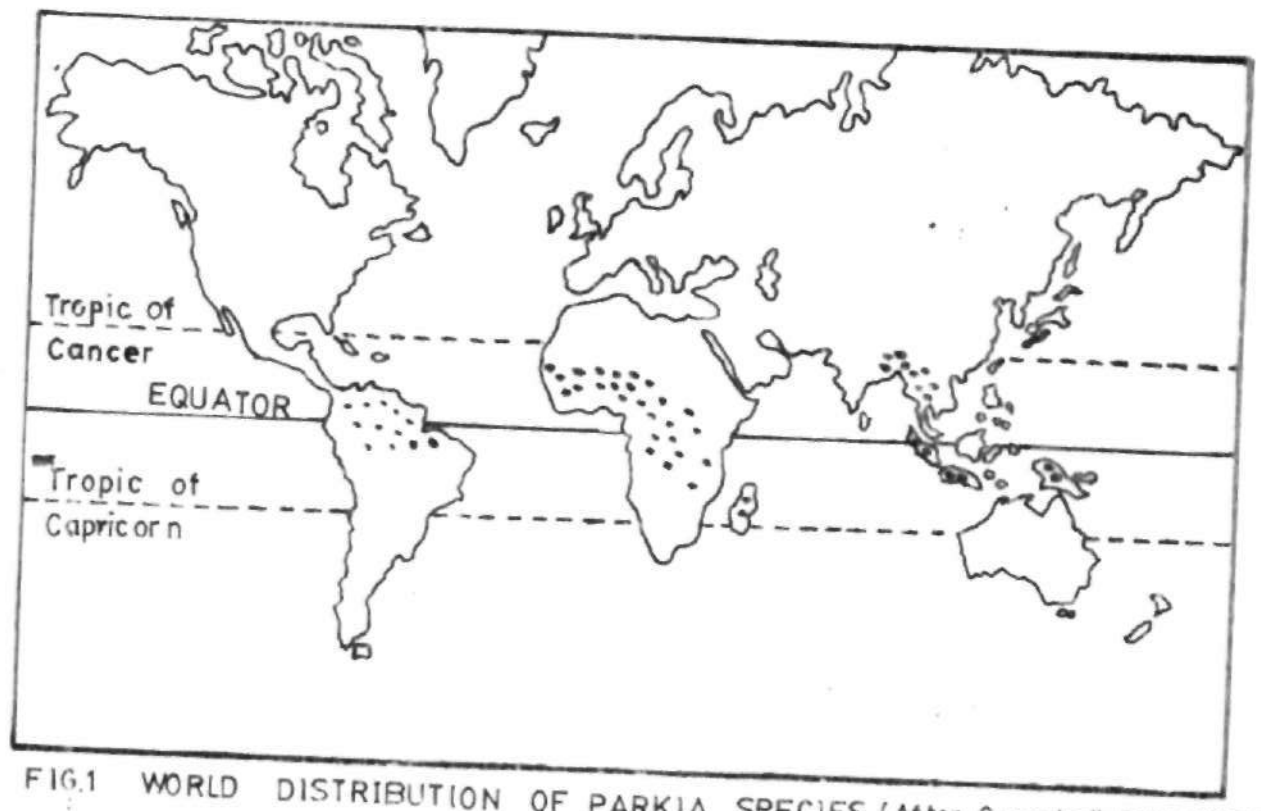


FIG.1 WORLD DISTRIBUTION OF PARKIA SPECIES (After Campbell-Platt,1980)

In Africa, Parkia is found mainly in the West, East and Central regions of the continent (Oliver, 1871; Exell, 1944; Aubreville, 1950; Hutchinson and Dalziel, 1958; Campbell-Platt, 1980 and Hopkins,1983). Parkia filicoidea Welw. ex Oliv. is found in the East and Central Africa (Brenan, 1959; Irvine, 1961; and Campbell-Platt, 1980). Exell (1944) and Keay (1955) described Parkia oliveri Mac. as endemic to Sao Tome; an island off the coast of Cameroon. Parkia madagascariensis R. Viguier was the only species recorded in the island of Madagascar; off the coast of Mozambique (Hopkins, 1983).

From the various accounts it appears that West Africa has the highest concentration and the widest distribution of Parkia trees. Baker and Harris (1957) reported that the Kew herbarium contains more materials of Parkia from Africa than from any other part of the world and that there is good reason to believe that comparatively speaking, the West African flora is particularly well known. All the species recorded as indigenous to Africa (Dalziel, 1936; Irvine, 1961; Campbell-Platt, 1980 and Hopkins, 1983) are all represented in the region. However Brenan (1959) reported that record of P. filicoidea for West Africa has probably always been in error.

P. bicolor, an evergreen forest species, occurs between Guinea and Gabon (Dalziel, 1936; Irvine, 1961; and Keay et al., 1964b). Irvine (1961) also reported that Parkia biglobosa Benth., a savanna species, occurs between Ghana and Sudan. Baker and Harris (1957) recorded the same species as distributed between the Guinea savanna and Sudan savanna in West Africa.

Keay (1957) and Keay et al. (1964a and 1964b) recorded two species of Parkia in Nigeria. These are P. bicolor and

P. clappertoniana. The former occurs in the rain forest belt, the latter is widely distributed in the savanna region.

P. clappertoniana is more abundant in the Northern States. It is a very common feature of the farmlands and avenue trees in Zaria, Katsina, Sokoto, Kano and Maiduguri (Dalziel, 1936; Hutchinson and Dalziel, 1958). This tree also occurs in large numbers in Kwara, Niger, Gongola, Bauchi, Benue and Plateau States (Keay et al. 1964a and 1964b; Gledhill, 1972).

THE ORIGIN OF PARKIA

There is not yet a definite account of the origin of the genus Parkia. Based on the various accounts of their distribution, early collections and nativity, one can only suggest their possible place(s) of origin. The plant occurs in the Neotropics and the old world.

While proposing the genus, Parkia, for the plant, Brown in 1926 made reference to a specimen collected from Bornu (now Borno State) in Nigeria by Clapperton (Keay, 1955). Brown named the first species Parkia africana but Keay (1955) later showed the name to be illegitimate. Hutchinson and Dalziel (1954) reported that the plant took its generic name after Mungo Park to commemorate his contributions to the study of the flora of West Africa. Mungo Park and Hugh Clapperton were both great European explorers to West Africa in the 18th and 19th Centuries respectively. Both men died in Northern Nigeria where P. clappertoniana abounds (Keay, 1955).

After a thorough taxanomic work Hopkins (1983) reported that three species are indigenous to Africa. These include P. bicolor, P. biglobosa and P. filicoidea. Brenan (1959) had recorded seven species for Africa and Madagascar. The

name clappertoniana is now dropped being synonymous with biglobosa (Hopkins, 1983). P. bicolor and P. biglobosa are found abundant in West Africa. P. filicoidea was reported to occur locally in Ivory Coast, Ghana - Togo highlands and eastern part of Nigeria (Hopkins, 1983). However, Brenan (1959) disagreed with record of the species from West Africa. The main Asian species, P. speciosa Hassk. is indigenous to Malaysia and Indonesia (Campbell-Platt, 1980) where it is also cultivated (Zeven and Zhukovsky, 1975).

Record of the use of Parkia as a cultivated crop is still scant. Brenan (1959) recorded that P. javanica (Lam.) (P. roxburghii G. Don.) was cultivated in Tanganyika (now Tanzania). During colonial times in Nigeria the local people were encouraged to plant Parkia seedlings and to raise them up to maturity (Harris, 1985). Parkia is likely to be planted in botanical gardens. The plant is planted in Achimota area of Ghana (Baker and Harris, 1957). Parkia up to the present time is planted in the farmlands for boundary demarcations in Zaria, Funtua, Katsina, Kano, Hadeija, Gashua, Sokoto, Malam Pateri areas in the Northern States of Nigeria (Personal Communication). In urban areas, the plant is planted as avenue trees. The plant however is still largely self-grown, left to grow and is usually tended when growing around homes.

It is possible to suggest, from the various accounts, that the genus Parkia has the tropical Africa as its place of origin. The plant shows the greatest variability in South America which has 19 species. Baker and Harris (1957) observed that although there are dangers in the assumption that the region in which a genus shows the greatest amount of variation is its centre of origin, it is at least unlikely

that the continent in which the fewest species with the least diversity occur will prove to be the cradle of that genus. Morphological variability decreases from South America through South East Asia to Africa. The great extent to which the Parkia plant and its products have been put into use, especially in West Africa, may support the suggestion of Africa as its place of origin. Throughout the savanna areas of West Africa the plant which is more commonly known as West African Locust Bean is an important grain legume. The major product of the plant is the seed used in preparing traditional food condiment known as dawa-dawa (Dalziel 1936 and Campbell-Platt, 1980). The pulp is used for a food drink known as Kunu by the Hausas. Various parts of the plant have local medicinal and other uses. The bark yields tannin (Dalziel 1936; Hutchinson and Dalziel, 1958; Irvine, 1961; Keay et al.,1964b and Fetuga et al.,1974). The bark is also used on floor and wall of mud houses and on wall of dyeing pits to prevent them from collapsing. The husk of the fruit is used as fish poison by fishermen (Brenan, 1959, Vickery and Vickery, 1979 and Personal Communication).

VARIABILITY IN THE AFRICAN SPECIES OF PARKIA

Hooker and Jackson (1895) in Index Kewensis and latter supplements recorded a total of 58 species to be in existence. Comparative studies have shown that these were not all separate species (Campbell-Platt, 1980). Account of the actual species indigenous to Africa is not yet conclusive. Keay (1955) recorded the number as four. Brenan (1959) recorded seven species for Africa and Madagascar, while Hopkins (1983) noted the number as three.

Many authors have at various times used different characters of the leaf and corolla lobes to differentiate

the species (Oliver, 1871; Aubreville, 1950; Keay, 1955 and Hopkins, 1983). This has led to dropping of earlier names e.g. P. clappertoniana and P. biglobosa which are regarded as synonyms. In arriving at their conclusions the authors have differed in the characters they emphasised.

In one of the most recent accounts, Hopkins (1983) has done a thorough analysis using the same characters employed by earlier authors. It was concluded that in floral characters the range of variation for P. oliveri, Mac. lies entirely within that of P. clappertoniana.

In leaf character she considered the concept of a 'cline' better than specific taxonomic groups to distinguish between P. biglobosa and P. clappertoniana. It was concluded that in their geographical distribution from East to West, the change in leaf character is rather gradual without discontinuities that could be exploited for taxonomic purposes. The African species were then listed as (1) P. biglobosa (2) P. bicolor (3) P. filicoidea. Parkia clappertoniana was regarded as synonymous with P. biglobosa.

PARKIA CLAPPERTONIANA Keay (Syn. PARKIA BIGLOBOSA (Jacq.) Benth.)

The species of Parkia selected for this work is Parkia clappertoniana Keay (Syn. P. biglobosa (Jacq.) Benth.) which grows abundantly in Zaria area. The name P. clappertoniana has been adopted as Hopkins work is yet subject to acceptance by other workers. The plant is a savanna species about 25 metres in height and 4 metres in girth (Keay, 1955 and Keay et al.,1964a and 1964b). It is found generally in the Guinea and Sudan savanna (Baker and Harris, 1957 and Irvine, 1961).

The tree has very high economic potential throughout

the sa anna regions of West Africa (Hopkins, 1983). It has both food and non-food values (Dalziel, 1936 and Campbell-Platt, 1980). It is carefully preserved by the natives as a valuable resource material.

The plant is owned by individuals on whose land it grows. Its destruction is prevented by local laws in some areas. They are deciduous at certain times of the year between the flowering and fruiting stages.

The plant is drought resistant. It produces dense and fresh foliage even in the heart of the dry season. Some products of the plant contain up to 36% of protein, 31% of sugar, 15% of starch and 23% of fat (Hill, 1952 and Fetuga et al.,1974).

The plant is a source of an important sulphur amino acid, lysine, which is generally limiting in West African diets (Annegers, 1974). Dalziel (1936) recorded that the yellowish mealy pulp is rich in assimilable carbohydrates. Oke and Umoh (1975) reported the true digestibility of the protein as being high; up to 76%. The leaves are rich in nitrogen and minerals. They may be collected and used as manure (Irvine, 1961). They add to the mineral and humus content of the soil when they fall. The pods are harvested from individual trees and removed for processing. The deeply fissured bark is rich in tannin.

CLIMATE AND SEASONS

The Zaria area has a tropical climate with marked rainy and dry seasons (Hore, 1970) in the year. The rainy season starts in May and ends in October (Kowal and Knabe, 1972). The mean monthly temperature, rainfall and relative humidity figures for the area during the study period (November, 1983 - October, 1984) are shown (Fig. 2).

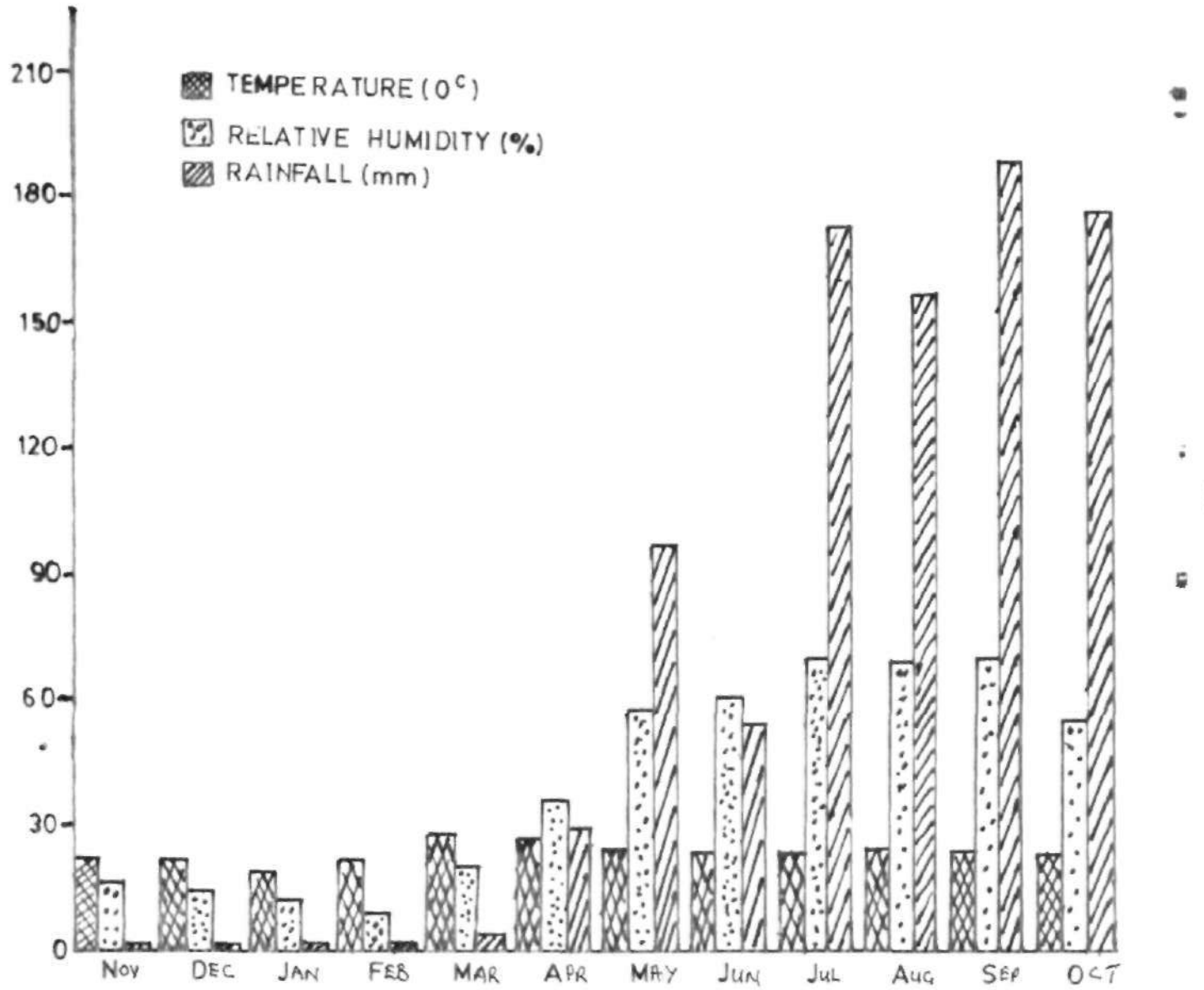


FIG. 2 MONTHLY MEANS OF TEMPERATURE, RELATIVE HUMIDITY AND RAINFALL IN ZARIA AREA DURING THE STUDY PERIOD (Nov. 1983 — Oct. 1984)
Source: Meteorological Unit, Soil Sci. Dept., I.A.R., A.B.U. Zaria.

OBJECTIVE OF THE STUDY

Most of the analytical studies on Parkia have been centred on the seed. This is the product of the plant mostly used as food in the areas where it grows. It has therefore attracted great attention for more investigation.

An attempt was made to investigate the trend of the seasonal variation of carbohydrates, protein and mineral nutrients in the different parts of the plant.

In addition, the biology of the plant was also studied. The study will provide greater insight into the pattern of nutrition of this very important tree crop. It will also help to determine the relative importance of the plant parts on the basis of their food contents and mineral nutrients.

CHAPTER TWO

REVIEW OF LITERATURE

Considerable work has been done on the West African Locust Bean (Parkia clappertoniana Keay (Synonym P. biglobosa (Jacq.) Benth.) to determine the nutritional status and food value of the seeds. The protein content, though of poor quality (Fetuga et al.,1974), has been found to be as high as 36% (Hill, 1952) and 303 g/kg (Fetuga et al.,1974) in the seeds. Fetuga et al. (1974) also observed that the quality of the protein could be improved by cooking the seeds, by removing the testa, or by supplementing it with methionine.

Annegers (1973) reported that those diets of the arid region which include Parkia products have a high protein: calorie ratio. According to Fetuga et al. (1973a and 1973b) the high fibre yield could make Parkia seeds a source of useful animal feeding stuff. Annegers (1974) observed that Parkia seed is a rich source of lysine which is a sulphur amino acid known to be limiting in West African diets.

PLANT NUTRITION AND PLANT ENVIRONMENT

The plant is surrounded above by the atmospheric environment and below by the soil. Both environments exert some influence on the nutrition of the plant and the distribution of food substances and nutrients in plants. Certain variations in the conditions of the atmosphere may cause the plant to shed its leaves. Differential defoliation was observed to reduce pod yield in three varieties of dwarf beans (Appadurai and Rajakaruna, 1967). Totally defoliated plants produced one-tenth of the yield produced by undefoliated plants.

Plant mineral nutrition involves the extraction of mineral elements from the soil by the plant. Several elements have been reported as essential to plant growth and development. They include nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca) and magnesium (Mg.). These are described as macronutrients as the plant usually requires them in larger quantitites than other elements (Pandey and Sinha, 1972; Delvin, 1975 and Kramer and Kozlowski, 1979). Other elements are often required in small amounts by the plant. They include Iron (Fe), Zinc (Zn), Lead (Pb), Manganese (Mn) and Copper (Cu). They are described as micronutrients.

For proper growth and development the necessary minerals must be supplied in soluble forms and in adequate amounts. Solutions of the mineral nutrients are formed in the soil environment from where the plant obtains them through the roots by absorption. Nutrient uptake is directly dependent upon water intake. Water stress is generally noted to reduce rates of translocation, and nutrient uptake is retarded under the same condition (Erdei et al., 1983).

PRODUCTS OF PLANT NUTRITION

1. Carbohydrates

Carbohydrates are direct products of photosynthesis. They are the most abundant chemical constituents of plants and make up 60-90% of their dry matter. Salisbury and Ross (1978) showed that sucrose is the most abundant sugar transported in the phloem sieve tubes of most plants. Priestley (1962) recorded that carbohydrates are usually stored in the form of starch.

Production of carbohydrates by photosynthesis involves the assimilation of carbon in the form of carbon dioxide (CO_2). Ormrod (1964) observed that net assimilation of CO_2 decreased at the onset of fruiting in Phaseolus vulgaris L. In adult trees aerial parts are the main reservoir for carbohydrates as they make up more of the total dry weight of a tree than the roots (Kramer and Kozlowski, 1979).

Priestley (1962) recorded that analyses of carbohydrate resources in fruit and other trees showed a drop in carbohydrate content of the older regions with the start of growth. This drop increased with shoot extension. During growth the reserves were transformed and translocated to the growing regions causing depletion in reserves. In times of fruiting or seed production a very large percentage of carbohydrate supply is diverted from vegetative to reproductive parts of the plant (Kramer and Kozlowski,1979). They also stated that recurrently flushing tropical trees show some drop in overall carbohydrate content of the foliage with each growth flush.

Studies have been carried out on the distribution of carbohydrates in different plants and their parts under various conditions. Hilgeman et al. (1967) studied the effect of time of harvest on leaf carbohydrate content in "Valencia" oranges between February and July. They observed that leaf carbohydrates, on trees with mature fruit, decreased between February and June. They attributed higher leaf carbohydrate level in May for harvested trees to increased set of young fruit.

Fahmy (1958) determined changes in reducing and non-reducing sugars and starch contents of "Souri" olive trees during the bearing year of 1956 and the non-bearing year of 1957,

and reported significant seasonal changes. During the period of flowering and fruit-setting, leaf starch was significantly higher in the bearing year than in the non-bearing year. It was also reported that any change in leaf carbohydrates was a direct result of a change in starch content of the leaves. Wood and McMeans (1981) reported that leaf starch generally declined during kernel growth in the Pecan tree (Carya illinoensis Wang. Koch).

Suryanarayana (1978) studied seasonal changes of carbohydrates in the shoots of regular and irregular bearing cultivars of mango for two seasons. It was reported that glucose and fructose decreased in shoots of all the cultivars at the time of flower bud formation. They rose sharply during inflorescence development and emergence. It was also noted that starch content reached the highest level during flower bud formation.

Sucrose and starch were found as the principal storage carbohydrates in the living bark of black locust tree (Robinia sp.) (Siminovitch et al., 1953). Both carbohydrates depleted in late spring by the flush of new growth. They observed that starch did not appear in the bark as a storage product until late in the summer and reached a maximum in early fall. It disappeared in the cold weather in the late fall. Reducing sugars were in low amounts throughout the year with the maximum in late winter. They argued that the observations on seasonal and unseasonal variations in the carbohydrates of black locust tree suggested that a temperature-sensitive reversible enzymatic process was operating in the bark of the tree. They observed that this process may be dependent on the state of hydration of the cells of the bark tissues.

Eaton and Ergle (1953) reported that the carbohydrate levels in the middle third of cotton stems increased from mid-July, when nearly most of them were being shed.

Quantitative starch and soluble sugars were determined in tissue samples collected biweekly from twigs, scaffold limbs and trunks of five-year old peach trees (Dowler and King, 1966). Carbohydrate content in all tissues was highest in October and November and decreased rapidly until January and then remained relatively constant until March. Total carbohydrate changed a little during the dormant period except in the twigs.

In Rhamnus frangula L., the highest total sugar in the stem occurred in April while the highest starch also in the stem was found in early May (Smith et al.,1966). In the bark of the peach plant, sucrose, fructose and glucose were found to increase significantly from August to January (Rohrbach and Luepschen, 1968).

Crane et al. (1976) reported rapid accumulation of sugars and their conversion to fat in the nuts of pistachio (Pistacia vera L.) during the months of July and August. Lasheen and Chaplin (1977) compared levels of soluble sugars in the bark, leaves, leaf buds and flower buds of two cultivars of peach (Prunus percia L. (Batsch)) differing in cold hardiness for one year. They observed that oligosaccharides accumulated generally in the bark during fall and winter. Monosaccharides accumulated during periods of active growth.

2. Protein

Nitrogen has been noted as one of the essential elements in plant nutrition. It affects plant growth and development more than any other element (Hesse, 1971). It is found in the

soil mainly in organic form and made available to plants in inorganic forms such as nitrate (NO_3^-) and ammonium(NH_4^+) compounds. Elemental nitrogen from the large reservoir in the atmosphere is transformed into the utilisable forms mainly by the nitrogen fixing bacteria, and also by other agents in the nitrogen cycle.

The principal initial products of nitrogen assimilation are amino acids. Pate (1973) noted that roots of herbaceous and woody plants can manufacture organic nitrogenous compounds from the nitrate or other inorganic forms of nitrogen they absorb from the medium. The amino acids form the basic units from which proteins are built (Ting, 1982).

Hay *et al*. (1953) reported that total N decreased in all vegetative parts of the corn plant (*Zea mays*) from pollination to maturity. The grain contained a little more than twice as much N at maturity as did the vegetative parts. Herridge and Pate (1977) observed that assimilation was used most efficiently for N fixation in late vegetative growth in an annual legume when nodules were most active and their carbohydrate supply still adequate. Weinhaum *et al*. (1978) reported that nitrogen absorbed from fertiliser was rapidly mobilised by swelling buds and rapidly elongating shoots of non-bearing prune trees. Rapid shoot elongation was primarily dependent on the redistribution of nitrogen.

The total nitrogen content was fairly constant during autumn and the beginning of winter, in the xylem sap of *Citrus* (Moreno and Garcia-Martinez, 1983). There was a progressive increase in total N content afterwards until the beginning of the spring flush. This was followed by a progressive decrease, reaching the lowest content of the cycle in summer.

This indicated an increase in the transport of N nutrients to the aerial parts of the plant during the spring flush.

Protein-nitrogen increased in early fall and decreased briefly during the period of rapid cold acclimation in the living bark of young twigs of red-osier dogwood (Cornus stolonifera Michx). It then increased gradually during late fall (Li et al.,1965).

Fahmy (1958) observed significant seasonal changes in leaf nitrogen content of "Souri" olive. The highest occurred during winter preceding the bearing year, dropped after fruit set in summer. The leaf nitrogen content was low in the winter preceding the non-bearing year. He also reported that the nutritional status of the trees, as revealed by their leaf-nitrogen content, showed a relatively high nitrogen concentration in the winter months before initiation of active growth early in the spring of the bearing year. Morrison and Pirie (1961) found that protein content of a leaf tends to diminish as the leaf matures. They observed that as far as protein is involved it is possible that this variation in protein concentration is enough to account for such differences in the feeding value of different forages.

3. Mineral Elements

Mineral elements have been shown as important to the nutrition of plants. They are primarily obtained from the soil by asborption (Gauch, 1972). The bulk of nutrients absorbed through the roots goes into the leaves where concentration and elaboration take place (Humphries, 1956). From the leaf, most of the materials may be re-exported via the phloem to other parts of the plant. In the developing foliage and fruits, such imported nutrients are used for

growth and storage. The bark of trees appears to act as temporary storage reservoir for mineral elements (Humphries, 1956).

Batista (1974) reported that concentrations of Cu, Zn and Mn in the stem of P. vulgaris varied with the season. Immature leaves of young "Golden Delicious" apple trees were better index of phosphorus nutrition than mature leaves (Benson and Covey, 1979).

Bengtsson and Jensen (1983) analysed cucumber (Cucumis sativa) grown in nutrient solution at different ages for the distribution of nutrients. The concentration of K was about the same in both roots and shoots. Its content decreased with leaf age except in older plants with flowers and fruits where it increased in the youngest leaves. On a whole-organ basis, K was equally distributed in roots and shoots. Jensen (1978) made similar observations for wheat shoots of the same age.

Sparks (1968) studied changes in mgk and %k in leaves, shoots and branches of non-fruiting mature pecan trees (C. illinoensis) as a function of physiological development throughout the growing season. In all organs the highest rate of accumulation of K occurred during the period immediately following bud break. This was greatest in the leaves, shoots and branches in that order. At about the time dry weight of the branches, shoots and leaves reached a maximum, there was a net loss of K, apparently to other parts of the tree. He also reported that mgk was highest in the leaves, branches and shoots over most of the sampling period. Gallo and Miyaska (1961) observed that K content was higher in the leaves than in other parts of the bean plant (P. vulgaris).

Calcium is one of the essential elements required by

plants. The order of increasing Ca concentration in bean plant parts (P. vulgaris) was observed as roots < stem < trifoliate leaves < primary leaves (Biddulph et al., 1959). When the entire root system was involved in Ca uptake, the amount of the element transported to the shoot increased with age of the plant (Al-Ani and Koontz, 1969).

Calcium uptake appeared to be related to the amount of P in the medium (Ehrler et al., 1958). Movement of Ca involved distribution and redistribution. Under Ca stress the amount of Ca deposited in primary leaves subsequent to absorption through the root was redistributed to the newly formed tissues independent of Ca status of P. vulgaris (Greene and Bukovac, 1968).

Leaf content of all elements except iron varied with cultivar in apples (Nagai and Ishii, 1979). Mulder (1950) attributed zinc deficiency in fruit trees to the phosphorus content of the soil.

Several studies have been made in various plants to investigate the composition of mineral elements, and their variation and distribution over the seasons. For purposes of convenient comparison, the minerals have been grouped according to the similarity in their composition, variation or distribution among the different plant parts.

MINERAL DISTRIBUTION IN THE REPRODUCTIVE ORGANS

Albregts and Howard (1978) studied the content of N, P, K, Ca, Mg, Fe, Zn, Mn, and Cu in the fruit and calyx of four clones of strawberry (Fragaria ananassa Duch) for two seasons. They observed that contents of the elements varied with the year, the clone and the time of the season. The concentration of the elements in the fruit decreased in the

order of K, N, P, Ca, Mg, Fe, Mn, Zn, and Cu. The elements occurred at higher concentrations in the calyx than in the fruit. They suggested that this could be due to the much higher dry weight content of the calyx.

Painter and Raese (1956) determined the mineral composition of the hulls, shells and kernels of Persian walnuts (Juglans regia L.) from eight different locations. The hulls contained the highest concentration of K and Ca. The shell contained the highest N and Mg. Davies and Kempton (1976) harvested fully opened flowers and the fruit of female cucumber and analysed their mineral composition at intervals of 2-28 days. Sigmoidal curves were obtained for the total content per fruit of the major nutrients, N, P, and K.

MINERAL DISTRIBUTION IN THE FOLIAR ORGANS

A weekly tissue analysis of greenhouse tomatoes showed a general decline in nutrients as the season progressed (Maclean et al., 1968). High nutrient demand occurred during certain stages of the plant growth and production.

The concentrations of several mineral elements in leaflets of Pistacia ("Kerman") studied by Uriu and Crane (1977) did not differ significantly with leaf position. Nitrogen, P, and Zn concentrations were relatively high initially, but rapidly dropped during leaf expansion and reached a steady state in summer. Manganese increased from an initially low level and then remained fairly constant. Potassium and Mg behaved similarly to Mn but reached constant levels later in the season. The study also showed that leaves from bearing branches were lower in N and P but higher in K than leaves from non-bearing branches.

Labanauskas et al. (1961) studied the seasonal changes in concentrations of micronutrients in leaves of "Fuert"

avocado over a 12-month period for three years. They observed significant curvilinear regressions of the Mn and Fe concentrations on age of leaves, in all the three years.

Bradford et al. (1963) made a comparison between the micronutrient content of orange (Citrus) leaves (4-6 months old) taken from non-fruiting and fruiting terminals of the same trees from 22 representative orchards. Non-fruiting terminals showed significantly higher amounts of Cu than fruiting terminals. No significant differences were found in the amounts of Fe, Pb, and Zn.

Poling and Oberly (1979) recorded significant differences in the levels of Mg, Ca, Fe and Mn in leaves of "McIntosh" apple (Malus domestica Barkh).

McClung and Lott (1956) studied the mineral nutrient composition of peach leaves, as a function of time, during the growing season of the tree (between June and September). They reported that the percentages of N, P, Zn, Cu, and K were highest in early June and declined for the season as a whole with a tendency to level off in late July and August. The percentages of Ca, Mg, Mn, and Fe increased for the season as a whole. They also remained relatively constant during the later part of the period. The percentage of K was much higher and Ca and Mg lower for leaves from trees without a crop. Analysis of leaf samples from 79 sweet cherry orchards showed that N, P, K levels decreased in the foliage on a percentage basis as the season progressed (Christensen and Walker, 1964).

Nitrogen and K decreased in concentration with time in leaves from selected species of woody ornamental plants (Davidson, 1961). In the same study Ca, Mg, Fe and Mn increased with time while Cu exhibited no significant change with time.

The concentrations of Cu and Zn tended to decrease with age of the leaf through the seasons until mid-winter in leaves of Washington Navel orange (Citrus) over a period of 12 months (Labanauskas et al.,1959). The levels of Mn and Fe on the other hand tended to increase. Zinc, Cu and Mn decreased slightly during blooming and initiation of new flush at the end of the growing season. Iron increased in concentration with leaf age throughout the growing season with no apparent indication of outward movement of the element at any time, There were downward linear trends for Zn and Cu which were highly significant throughout the season. Iron and Mn showed significant upward linear trends.

Spiers (1982) obtained leaf samples from "Tifblue" rabbiteye blueberry (Vaccinium ashei) at two-week intervals during the growing season of 1979 and 1980. Each sample was analysed for five macronutrients and five micronutrients and it was observed that the elemental content patterns correlated closely between the years except for iron. Nitrogen, P and Zn were highest in the early part of the season. They decreased until harvest and levelled off as the growing season progressed. Levels of Ca and Mg remained relatively constant throughout the season, with lowest percentages during the harvest. Potassium and Mn were high during April and early May and were low during harvest and high again in October.

Nwoboshi (1974) studied the seasonal variation in nutrient concentrations in teak (Tectona grandis) using leaf samples from different regions of the crown. For the two-year study period, he observed that N, K, Ca and Mg were greater at the bottom than at the top of the crown, whereas P concentrations showed the reverse. Phosphorus and K levels generally decreased

with growth and maturation of the leaf while that of Ca increased. Phosphorus and K approached a near constant value in June and from mid-November to mid-December. Nitrogen remained more or less constant throughout the growing season. He reported that observations for the two years showed similar trends but nutrient content values showed distinct variations.

MINERAL DISTRIBUTION ON A WHOLE PLANT BASIS

Furuta et al. (1963) determined the influence of leaf position with regard to height from the ground, position on the shoot and compass direction on some mineral contents of leaves of Magnolia (Magnolia grandiflora) in June and August. All positions influenced leaf composition of one or more elements at both sampling dates. Interactions occurred to influence composition of the leaves in June but not in August. They also reported significant variations from tree to tree.

The presence of a fruit crop exerted very little influence on the shapes of the nutrient composition-time curves (McClung and Lott, 1956). Differences between trees with and without a crop were largely expressed by the first sampling date.

In a study of the effect of retaining fruit on the induction of scorch and defoliation, and on the nutrient status of pecan (C. illinoensis), Sparks (1977) reported that fruiting suppressed accumulation of N, P, and Zn in leaves. Loss of K from the leaves was associated with a high content of the element in the shuck.

Impens (1966) stated that leaf conductance also plays a role in mineral distribution in the entire plant. Robblin et al. (1983) studied the distribution of mineral nutrients in Mimosa pudica. They reported low Ca concentrations

in parts of the plant with high plasticity.

The leaf plays an important part in the distribution and redistribution of materials in the plant. The size and development of foliage can influence the concentration and distribution of mineral elements in the entire plant.

CHAPTER THREE

MATERIALS AND METHODS

LOCATION OF EXPERIMENTAL PLANTS

Five trees of Parkia clappertoniana Keay were chosen as the experimental plants. They were located as follows, within the main campus of the Ahmadu Bello University, Samaru Zaria:

1. At the end of block B of Ribadu Hall, facing the Department of Microbiology.
2. At the end of Wing B, Department of Biological Sciences.
3. Near the entrance to Institute for Agricultural Research (IAR) Library.
4. At the end of the Staff School block adjacent the Staff Club.
5. At the entrance to the Department of Architecture.

ORGANS OF THE PLANT SAMPLED

Samples of the following organs were obtained from each tree at two-weekly intervals:

1. The bark of the stem 3-4mm thick
2. The leaves
3. The young (or early) flower
4. The mature (or late) flower
5. The young (or early) fruit
6. The mature (or late) fruit

Samples were harvested throughout the study period of 12 months beginning November 1983 to October 1984. Monthly means of the substances determined were used for

statistical analyses. Flowers and fruits were harvested only during the period of production within the duration. For the flower and fruit samples, an attempt was made to differentiate clearly between young and mature stages. The flowers were considered mature when the individual flowers were open and turning red. The fruit was considered mature when the husk was dry, turning from green to brown and the white solid pulp became powdery and yellow in colour.

GENERAL PREPARATION OF SAMPLES

1. STEM

   The bark of the branch stem (3-4 mm thick) was obtained by scrapping it off the sample using a sharp knife. The wood was discarded.

2. LEAVES

   The leaf samples were separated into the leaflets. The petiole and rachis were discarded.

3. FLOWERS

   Only the florets were used. The peduncle and the swollen receptacle were discarded.

4. FRUITS

   The entire young fruit was used while the mature fruit was separated into husk, pulp and seeds before treatment and analysis.

After harvest, each sample was dried in an oven at $60^{o}C$ till constant weight. Dried samples were ground in a Cassella mill.

EXTRACTION OF TOTAL SOLUBLE CARBOHYDRATES (TSC)

The extraction was done with hot 80% ethanol (McCready et al., 1950). 0.2 g of the finely ground sample was weighed into a 50 ml centrifuge tube. Three drops of 80% ethanol were added to prevent clumping.

Then 5 ml water and 25 ml hot 80% ethanol were added. The content of the tube was stirred to mix thoroughly. The tube was allowed to stand for five minutes and centrifuged at 2,000 rpm for ten minutes.

The supernatant (the alcohol extract) was decanted into a storage bottle. 30 ml of fresh hot 80% ethanol was then added to the residue. This was stirred and centrifuged as before. The washing was done three times. After the third washing and filtration, the combined filtrate was made up to 100 ml with 80% ethanol. The residue was preserved in centrifuge tube. The alcohol extract was used for analysis.

ESTIMATION OF TSC

The total soluble carbohydrates (TSC) were extracted and estimated as a single fraction using the anthrone method described by Witham et al. (1971). 1 ml of the alcohol extract was pipetted into a test tube. 6 ml of the anthrone reagent was added and heated in a boiling water bath for three minutes. It was then cooled in a cold water bath. To another test tube, 1 ml of water and 6 ml of anthrone reagent were added. This served as a blank.

The amount of TSC in the sample was measured by obtaining the absorbance at 600 nm using Bausch-Lomb Spectronic 20 colorimeter and colorimeter tube of 1 cm path-length. The blank was used to zero the instrument. Each determination was done in triplicate. The concentration of TSC was estimated by comparing the mean absorbance with the standard curve (see page 35).

EXTRACTION OF STARCH

Starch was obtained by further treatment of the residue preserved after the extraction of TSC described above. After the third washing, 5 ml of water was added to the residue and stirred. While stirring 6.5 ml of 52% perchloric acid was added to the tube.

The mixture was stirred for five minutes with a glass rod and then left to stand for 15 minutes with occasional stirring. 20 ml of water was then added to the tube and centrifuged as before. The aqueous starch solution was decanted into a 100 ml calibrated flask.

5 ml of water was again added to the residue in the tube and allowed to stand for 30 minutes with occasional stirring. The contents of the tube were then washed into the flask containing the first extract. The combined solution was then made up to the mark with deionised water. The solution was then filtered, discarding the first 5 ml of the filtrate. The filtrate is the starch extract in solution.

ESTIMATION OF STARCH

The starch concentration was estimated by the anthrone method (McCready et al., 1950 and Plummer, 1978). After a preliminary run, the extract was diluted so as to obtain a dilution factor of 2, 3, 5, 6 and 10 for young flower, husk, young fruit, pulp and seed respectively.

5 ml of the diluted solution in a boiling tube was placed in a cold water bath. 8 ml of the anthrone reagent was added to the tube which was then covered with parafilm to prevent evaporation. The tube was heated for 7.5 minutes at 100°C and cooled rapidly to 25°C. A reagent blank was prepared in the same manner and used to zero the instrument.

The contents of the tube were transferred into a colorimeter tube with 1 cm path length and the extinction read at 620 nm in a Bausch-Lomb Spectronic 20 colorimeter. Each determination was done in triplicate. The concentration of glucose was obtained by comparing the mean absorbance reading of sample with a standard curve(see page 36). The amount of starch was calculated by multiplying the amount of glucose obtained by a factor of 0.90.

DETERMINATION OF REDUCING SUGARS (RS)

The amount of reducing sugars (RS) in the sample was estimated based on the method of Lindsay (1973). 1 ml of water and 2 ml of 3, 5-dinitrosalicylic acid reagent were added to 50 mg of the sample in a test

tube. The tube was then placed in a boiling water bath and heated for ten minutes with occasional shaking. A blank solution was prepared in a similar manner and used to zero the instrument.

The test tube was allowed to cool and 6 ml of water added. The contents were then transferred into a colorimeter tube and the absorbance measured at 570 nm wavelength in a Bausch-Lomb Spectronic 20 colorimeter. Each determination was done in triplicate. The amount of reducing sugars was estimated by comparing the mean absorbance with a standard curve (see page 36).

DIGESTION OF SAMPLES

Digestion of the sample was based on the methods of Bould *et al.* (1960) and Williams (1964). The samples were digested with concentrated sulphuric acid and a digestion mixture of anhydrous sodium sulphate and selenium, until the solution was clear.

0.5 g of the sample was weighed into a 300 ml Kjeldahl flask. 20 ml of conc. H_2SO_4 (S.G.1.84) and 10 g of the digestion mixture were added to the flask. The digestion, carried out in a fume chamber at 60°C, was allowed to continue for 30 minutes after the solution was clear, The flask was then allowed to cool.

Contents of the flask were filtered into a 200 ml calibrated flask using Whatman filter paper No.40. The filtrate was then diluted to the mark with deionised water. The digest was used for the determination of the various mineral elements including nitrogen and phosphorus.

It shall henceforth be referred to as "the digest".

DETERMINATION OF NITROGEN

The total nitrogen in the sample was estimated using the method described by Williams (1964). 1 ml of the digest was transferred to a 50 ml calibrated flask and diluted with 30 ml of deionised water. 2 ml of the Nessler's reagent was added to the solution and made up to the mark with deionised water. This gave a dilution factor of 50. The flask was allowed to stand for 20 minutes for full colour development.

After shaking, some of the solution was transferred to a colorimeter tube and the absorbance was measured at 430 nm wavelength in a Bausch-Lomb Spectronic 20 colorimeter. A blank, simiarly prepared, was used to zero the instrument. Each determination was done in triplicate. The mean absorbance was compared with a standard curve (see page 37). to calculate the amount of nitrogen. The seed samples which had a higher concentration of nitrogen from a preliminary run, were diluted by a factor of 100.

LETERMINATION OF PROTEIN

The protein content was measured indirectly. An empirical factor of 6.25 was used to convert the nitrogen into protein (Mckee, 1962 and Osborne and Voogt, 1978). Thus protein content was calculated as N X 6.25, and was finally converted to g/100 g.

DETERMINATION OF PHOSPHORUS

Phosphorus was determined as described by Humphries (1956). The method depends on the formation of a blue complex between phosphate and molybdic acid in the presence of a reducing agent (Stannous chloride, $SnCl_2$).

1 ml of the digest was measured into a 50 ml calibrated flask and 3 ml of deionised water added, followed by 1 ml of ammonium molybdate solution and 1 ml of stennous chloride.

After shaking, the mixture was made up to the mark with deionised water and allowed to stand for 20 minutes. A blank solution was similarly prepared and was used to zero the instrument.

The solution was transferred into a colorimeter tube and the absorbance obtained at 360 nm wavelength in a Bausch-Lomb Spectronic 20 colorimeter. Each determination was done in triplicate. The amount of phosphorus in the sample was determined by comparing the mean absorbance with a standard curve (see page 38).

ANALYSIS OF THE MINERAL ELEMENTS

The concentration of potassium was determined by the flame photometric method. All other elements (Mg, Ca, Fe, Zn, Pb, Mn and Cu) were measured using the atomic absorption spectrophotometer. The flame photometer consists of a sensor, atomiser, filter, a screen and a meter. It measures the intensity of light (the flame) emitted by the element in the solution when the appropriate filter is used. The solution is atomised into an air-acetylene flame. The filter

narrows down the wavelength field while the emission is registered in the meter.

The atomic absorption spectrophotometer (AAS) is based on the same principle except that the radiation is absorbed rather than emitted (Whiteside, 1975). In AAS, the sample solution is sprayed into a flame. The atoms held in the flame are irradiated with light from a cathode lamp made of the same element as is the one being determined in the sample. The atoms held in the flame absorb some of the incident radiation. The amount of radiation absorbed is proportional to the concentration of the element in the sample solution.

DETERMINATION OF POTASSIUM (K)

Potassium was determined using Corning-EEL flame photometer. Lithium chloride was added to the digest to prevent the ionisation of potassium during determination which would have led to lower values. All determinations were done against a reagent blank and in triplicate. The amount of K was determined by comparing mean sample reading with a standard curve (see page 39).

DETERMINATION OF Mg, Ca, Fe, Zn, Pb, Mn and Cu

Other minerals were determined using the Unicam Atomic Absorption Spectrophotometer at the appropriate wavelength. A solution of strontium chloride was added to the digest to reduce any interference by aluminium and phosphorus during the determination of Ca and Mg.

Each determination was done against a reagent blank and in triplicate. A standard curve was prepared

for each element using their standard solutions. Concentration of the element in the sample was determined by comparing the mean AAS reading with the standard curve (See page 38).

PREPARATION OF STANDARD CURVES

1. Standard Curve for Total Soluble Carbohydrates (TSC) (See p.71)

0.20 ml, 0.40 ml, 0.60 ml, 0.80 ml and 1 ml of a standard glucose solution were pipetted into a series of five test tubes. Each aliquot was made up to 3 ml by addition of deionised water. A sixth test tube was prepared to contain only 3 ml of deionised water. This was the blank.

6 ml of the anthrone reagent was added to each test tube in a cold water bath and then placed in a boiling water for three minutes. After heating they were cooled in a cold water bath. The blank was used to zero the instrument. The content of each tube was transferred to a colorimeter tube and the absorbance measured at 600 nm wavelength in a Bausch-Lomb Spectronic 20 colorimeter. Each measurement was done in triplicate.

The standard (or calibration) curve was obtained by plotting the absorbance (Y-axis) against the glucose concentration (X-axis). The line was regressed (i.e. a regression equation was derived and used to draw a straight line).

2. Standard Curve for Starch (see page 71)

Into a series of five test tubes, 0.40 ml, 0.80 ml, 1.20 ml, 1.60 ml and 2.00 ml of a glucose standard solution were transferred. The solution in each tube was made up to 2 ml by adding the corresponding volume of deionised water. A sixth tube (blank) contained only 2 ml of water.

The test tubes in a rack were placed in a cold water bath and then 8 ml of the anthrone reagent was added to each. The precaution ensures a similar heating treatment for all the tubes in the series (Pucher et al., 1948). It prevents erratic results from the heat developed by the water-sulphuric acid (from the anthrone reagent) reaction.

The tubes were then agitated, to mix the contents thoroughly, and covered with parafilm. They were heated together in a boiling water bath for 7.5 minutes. The tubes were later cooled rapidly to room temperature.

The content of each tube was transferred into a colorimeter tube, and the absorbance measured at 620 nm wavelength in a Bausch-Lomb Spectronic 20 colorimeter. The blank was used to zero the instrument. The mean absorbance values were plotted against the glucose concentrations. The curve was regressed.

3. Standard Curve for Reducing Sugars (RS) (see page 77)

To a series of five test tubes, 0.40 ml, 0.80 ml, 1.20 ml, 1.60 ml and 2.00 ml of a standard glucose solution were added. Each (except the fifth tube) was then made up to 2 ml of solution by adding the appropriate

volume of deionised water. The sixth tube (blank) contained only 2 ml of water.

4 ml of the 3, 5-dinitrosalicylic acid reagent was added to each tube. They were covered with parafilm and heated for four minutes in a boiling water bath, then cooled to room temperature. 4 ml of deionised water was added to each tube and the content transferred to a colorimeter tube. The absorbance was then measured at 570 nm wavelength in a Bausch-Lomb Spectronic 20 colorimeter. The blank was used to zero the instrument and each measurement was in triplicate. The standard curve was obtained by plotting the mean absorbance against the glucose concentration. The curve was regressed.

4. Standard Curve for Nitrogen (N) (see p.76)

0.20 ml, 0.60 ml, 1.00 ml, 1.40 ml and 1.80 ml of a standard nitrogen ($(NH_4)_2SO_4$) were pipetted into a series of five 50 ml calibrated flasks. They were made up to 30 ml of solution with deionised water. A sixth flask (blank) contained only 30 ml of water.

2 ml of Nessler's reagent was added to each and made up to the mark with water. After shaking to mix well, the solution was allowed to stand for 20 minutes.

The content of each flask was transferred to a colorimeter tube and the absorbance measured at 430 nm in a Bausch-Lomb Spectronic 20 colorimeter. The blank was used to zero the instrument. The measurement was done in triplicate. The mean absorbance was then plotted against the concentration. The graph was regressed.

5. Standard Curve for Phosphorus (P) (see p.77)

0.10 ml, 0.30 ml, 0.50 ml, 0.70 ml and 1.00 ml of stock potassium dihydrogen phosphate (KH_2PO_4) solution was transferred to a series of five 50 ml calibrated flasks. Each (except the fifth) was made up to 1 ml by adding the corresponding volume of deionised water. A sixth flask (blank) contained only water.

1 ml of ammonium molybdate solution was added to each flask, followed by 1 ml of stannous chloride solution. The solution was mixed thoroughly by shaking and then made up to the mark with deionised water.

The flasks were allowed to stand for 20 minutes for full colour development. The solution was then transferred to a colorimeter tube and the absorbance measured at 360 nm in Bausch-Lomb Spectronic 20 colorimeter. The blank was used to zero the instrument and each measurement was in triplicate. The mean absorbance was plotted against the phosphorus concentration. The curve was regressed.

6. Standard Curve for the Mineral elements (see pp.73,74,75,76)

Standard solutions of the different elements were prepared to contain 1,000 ppm (1,000 mg/l) of the element. From the stock solutions, serial dilutions were made in each case to contain a range of concentrations of the element.

Absorbance readings were obtained in triplicate for each concentration at the wavelength appropriate for the element (with the exception of K) and against a reagent blank.

In the case of potassium, the emission readings were obtained using a Corning-EEL Flame photometer and a potassium filter. All the other mineral elements were measured using the Unicam SP 1900 Atomic Absorption Spectrophotometer and the appropriate cathode tube.

The standard curve was obtained by plotting the absorbance (emission for K) against the concentration of the element. The curve was regressed in each case.

CONVERSION OF ABSORBANCE/EMISSION UNITS

The substances were obtained in mg/l or ppm. The results were then converted to mg/100 using the following relationship:

$$\text{mg/l (or ppm)} = \frac{(a-b)\ V}{10W} \quad \text{mg/100 g}$$

where a = standard curve reading of the sample

b = standard curve reading of the blank (= 0)

V = final volume to which the final extract of the sample was diluted.

W = Initial weight of sample used for extraction or ashing.

To convert to g/1000 g, the mg/100 g value was divided by 1,000.

Reducing sugars were expressed in percentage based on the method of Lindsay (1973).

STATISTICAL ANALYSIS

An analysis of variance model was used to detect differences in levels of the substances. Sources of variation for the analysis of each substance were as follows: plant, month, plant organ, plant organ x plant organ and residual.

Least significant difference (LSD) was applied to detect points of differences in each factor but only following a significant F-test in the analysis of variance. All tests were done at 5% significance level. Only differences that were significant at this level are discussed.

FIELD OBSERVATIONS

Field trips were undertaken to the town and rural areas of Zaria and to some towns nearby. This was done at different times during the period of the study. The areas visited included Funtua town and environs (December, 1983), Katsina-Dawakin-Tofa-Kano-Zaria (January, 1984), Zaria-Pambegua-Kayarda-Saminaka (March, 1984), Zaria-Kano by rail, and Kaduna (June-July, 1984). Observations were also made in the towns and villages along Kaduna-Abuja-Okene-Uromi road.

The observations included the density of the plant (P. clappertoniana) among the vegetation and its frequency of occurrence. Interviews were also held with the people in the different areas in order to find out more of the local uses of the plant and its products, the amount of importance attached to its ownership and the possibility of its cultivation. Observations were also made on the plant's phenology and the characteristics it displayed generally during the period of the study.

CHAPTER FOUR

RESULTS

CARBOHYDRATES

1. Starch

The results of starch content in the bark are presented in Fig. 3. It showed a slight decrease in December after which it increased until it reached its first peak (3.34 g/100 g) in April. It then started to drop in the subsequent months and reached to its lowest level (1.94 g/100 g) in July. Thereafter it showed a sharp increase and reached its second peak (3.90 g/100 g) in September. In the bark, starch content varied significantly with months ($P = 0.05$).

Leaf starch also showed two peaks, one in February (3.20 g/100 g) and the other (3.73 g/100 g) in August (Fig. 3). It also varied significantly with months ($P = 0.05$).

In the young and mature flowers starch showed relatively constant levels throughout their period of production (Fig. 4 and Appendix 3). The young flower showed significantly higher content of starch than the mature flower. It also showed significant changes with months ($P = 0.05$).

In the young fruit, starch content increased from 16.20 g/100 g in March through July (17.30 g/100 g) with a slight drop in May (16.70 g/100 g) (Fig. 5 and Appendix 4). It showed significant changes with months ($P = 0.05$).

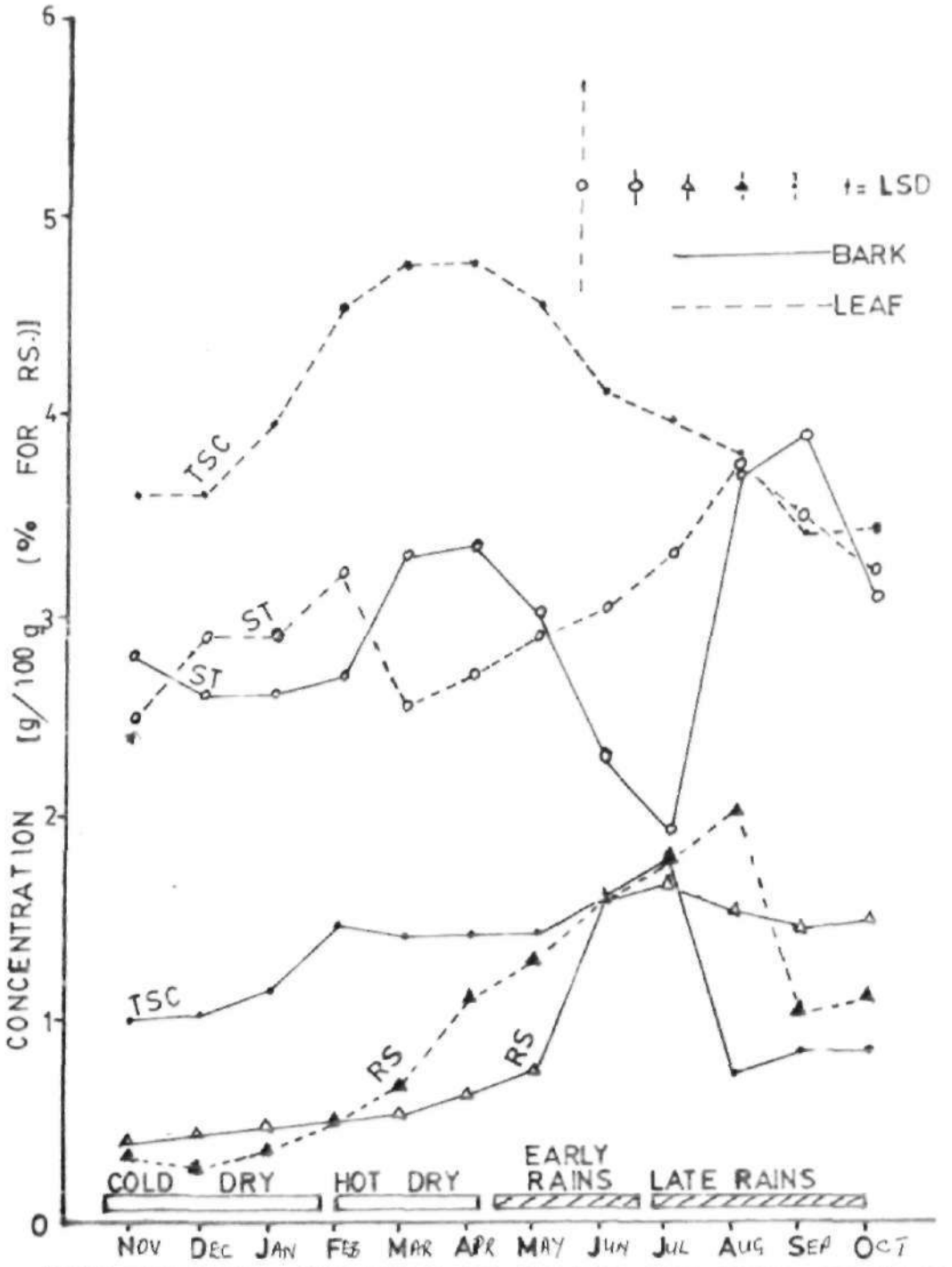


FIG.3 SEASONAL VARIATION OF STARCH (ST), TOTAL SOLUBLE CARBOHYDRATES (TSC) AND REDUCING SUGARS (RS) IN THE BARK AND LEAF. (LSD IS INDICATED, P = 0.05.)

	MATURE FRUIT PART														
	HUSK					PULP					SEED				
CONSTITUENT	May	Jun	Jul	SE	LSD	May	June	Jul	SE	LSD	May	Jun	Jul	SE	LSD
1. Starch (g)	7.30a	7.16a	6.75a	0.13	0 72	22.30a	22.4a	23.1	0.21	0.72	42.00	42.95	43.70	0.40	0.72
2. Total Soluble carbohydrates (g)	1.74a	1.77a	1.84	0.02	0.09	7.17a	7.33	7.24a	1.97	0.09	4.67a	4.63a	4.67a	0.02	0.09
3. % Reducing sugar	2.35	1.99	1.62	0.17	0.30	1.13e	1.27	0.95e	0.08	0.30	0.30	0.40	0.45	0.04	0.30
4. Protein (g)	3.22a	3.63a	2.51	0.27	0.53	3.53a	3.53a	2.65	0.22	0.53	32.19	32.57	29.76	0.79	0.53
5. Nitrogen (g)	0.65a	0.58a	0.38	0.04	0.16	0.59a	0.57a	0.40	0.04	0.16	5.05	5.27	4.71	0.12	0.16

Table 1: MONTHLY MEANS OF CARBOHYDRATES, PROTEIN AND NITROGEN CONTENTS (PER 100 g DRY WEIGHT) OF THE HUSK, PULP AND SEED OF THE MATURE FRUIT. (MEANS BEARING THE SAME LETTER ALONG EACH ROW ARE NOT SIGNIFICANTLY DIFFERENT FOR EACH MATURE FRUIT PART) P = 0.05).

In the mature fruit parts (Table 1), starch decreased in the husk from 7.30 g/100 g in May to 6.75 g/100 g in July. There was a slight increase in the seed from 42 g/100 g in May to 43.70 g/100 g in July. Starch showed significant changes in the pulp and seed with months and between the mature fruit parts ($P = 0.05$).

2. Total Soluble Carbohydrates (TSC)

The seasonal variation of TSC in the bark is portrayed in Fig. 3. It increased to its dry season peak (1.46 g/100 g) in February, then decreased slightly during the subsequent two months. From May it increased gradually (1.42 g/100 g) and reached a wet season peak (1.79 g/100 g) in July and then dropped sharply in August (0.74 g/100 g). It rose again in the subsequent month to a constant level (0.85 g/100 g) until October. It showed significant variation with months ($P = 0.05$).

Leaf TSC showed steady increase and reached its peak in March and April (4.75 g/100 g) (Fig. 3 and Appendix 2). Thereafter it declined until the lowest (3.40 g/100 g) in September. It then increased slightly in October. There was significant monthly variation in leaf TSC ($P = 0.05$).

The data presented in Fig. 4 and Appendix 3 showed changes in the TSC content of the young and mature flowers. In the young [illegible] flower it showed very slight increase between January (0.98 g/100 g) and May

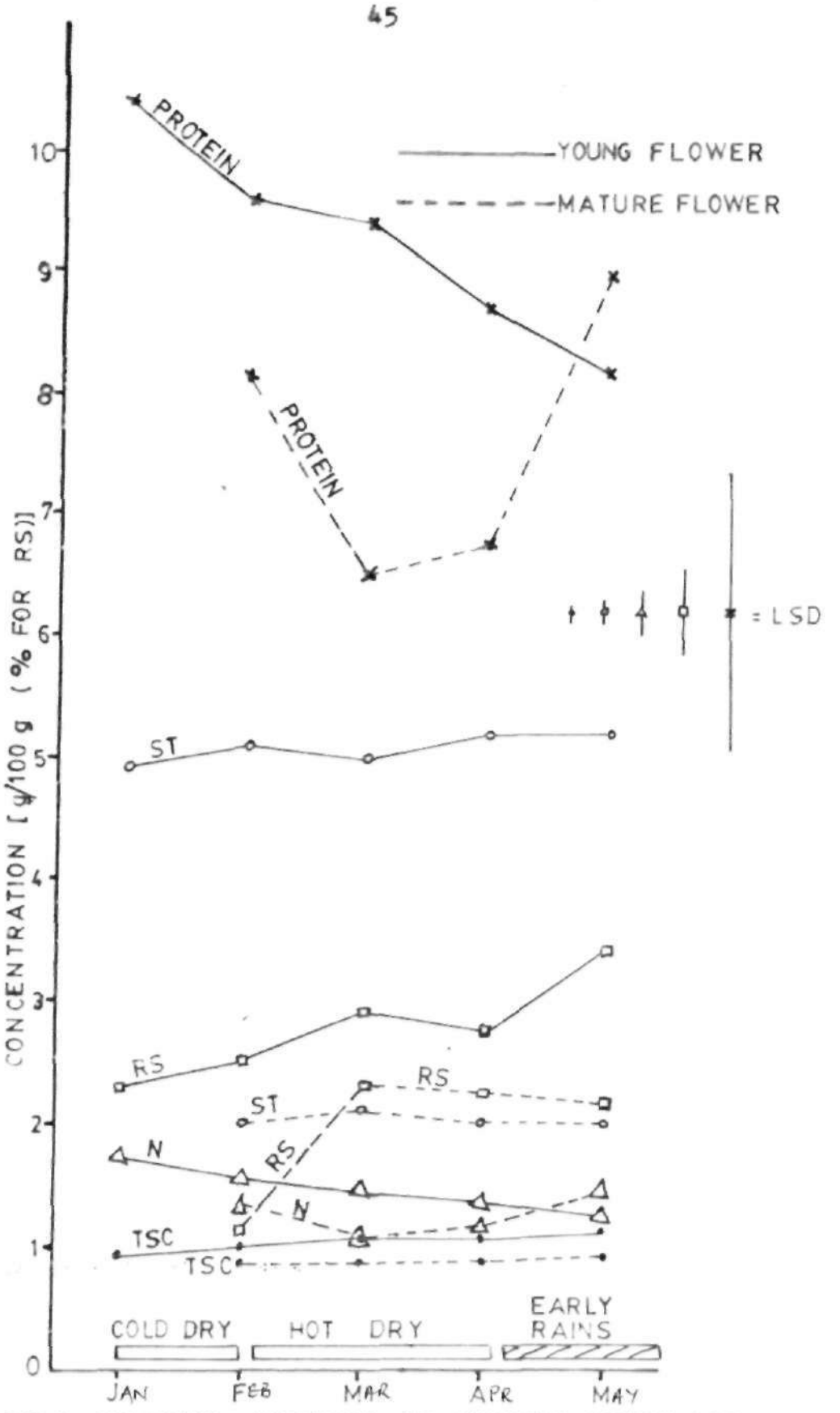


FIG. 4 SEASONAL VARIATION OF PROTEIN, STARCH (ST), REDUCING SUGARS (RS), TOTAL SOLUBLE CARBOHYDRATES(TSC) AND NITROGEN (N) IN THE YOUNG AND MATURE FLOWERS. (LSD IS INDICATED) P = 0·05

(1.12 g/100 g). In the mature flower the TSC level remained relatively constant between February (0.87 g/100 g) and May (0.89 g/100 g). There was significant variation in TSC level with months in the young flower and between the two floral stages (P = 0.05).

The results presented in Fig. 5 and Appendix 4 showed that TSC content of the young fruit declined from March (10.85 g/100 g) to July (5.74 g/100 g) with a slight increase (6.01 g/100 g) in June. It varied significantly with months (P = 0.05).

Among the mature fruit parts (Table 1) TSC level increased only slightly in the husk and remained relatively constant in the pulp and seed. It showed significant differences between the mature fruit parts and within the husk (P = 0.05).

3. Reducing Sugars (RS)

Reducing sugars in the bark showed a progressive increase from January (0.48%) to May (0.75%) and then increased sharply to its peak (1.69%) in July (Fig. 3 and Appendix 1). Thereafter it declined slowly until September (1.46%). It varied significantly with months (P = 0.05).

Leaf RS (Fig. 3 and Appendix 2) increased steadily from December (0.26%) until its peak (2.06%) in August. It dropped (1.03%) in September and increased slightly later in October. It showed significant changes with months (P = 0.05).

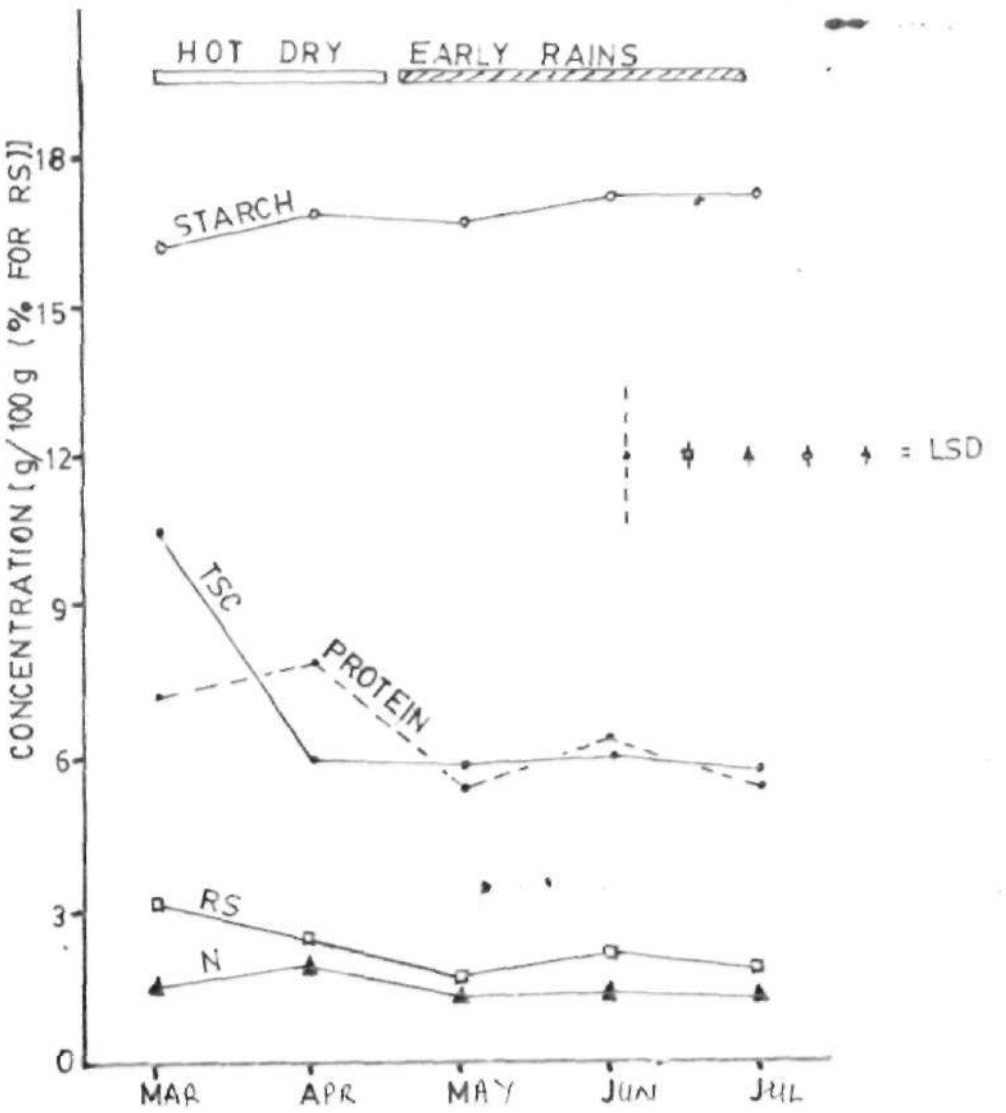


FIG. 5 SEASONAL VARIATION OF STARCH, TOTAL SOLUBLE CARBOHYDRATES (TSC), PROTEIN, REDUCING SUGARS (RS) AND NITROGEN (N) IN THE YOUNG FRUIT. (LSD IS INDICATED, P = 0·05)

In the young flower (Fig. 4 and Appendix 3) RS content increased from January (2.34%) to May (3.4%) with a drop (2.90%) in March. In the mature flower it rose sharply to 2.30% in March and declined gradually in the subsequent months. It varied significantly with months in the young flower (P = 0.05).

In the young fruit, RS content showed a steady decline from March (3.18%) until July (1.90%) with a slight increase (2.13%) in June (Fig. 5 and Appendix 4). It showed significant variation with months (P = 0.05).

In both the husk and pulp of the mature fruit (Table 1) RS content decreased between May and July with a slight increase in June for pulp. In the seed there was slight increase in RS level during these months. There was significant difference in RS level of the mature fruit parts and within the husk and pulp (P = 0.05).

PROTEIN

The data in Fig. 6 and Appendix 1 showed that protein content in the bark decreased sharply until March (2.31 g/100 g) with a little increase (3.04 g/100 g) in February. Thereafter it rose sharply, with a drop (2.80 g/100 g) in May, until the peak (6.20 g/100 g) in September. It then dropped (4.33 g/100 g) in October. It varied significantly with months (P = 0.05).

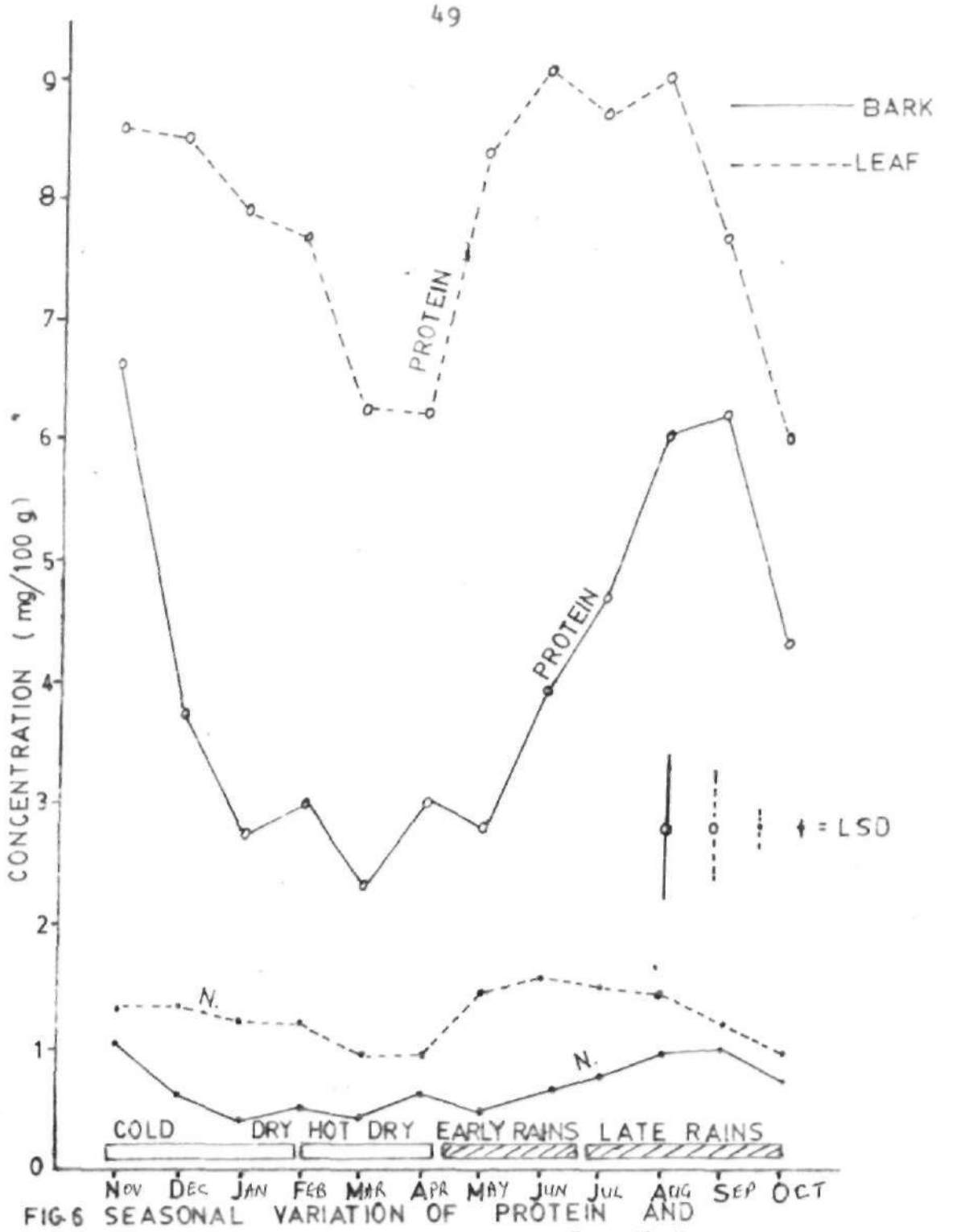


FIG-6 SEASONAL VARIATION OF PROTEIN AND NITROGEN (N) IN THE BARK AND LEAF.
(LSD IS INDICATED, P = 0·05.)

Leaf protein (Fig. 6 and Appendix 2) declined steadily until the lowest level (6.21 g/100 g) in April. It then rose sharply to its peak (9.17 g/100 g) in June. Thereafter it decreased, with a slight increase (9.09 g/100 g) in August, until October. It varied signifieantly with months (P = 0.05).

The protein level (Fig. 9 and Appendix 3) decreased steadily in the young flower between January (10.42 g/100 g) and May (8.20 g/100 g). In the mature flower it decreased sharply in March (6.51 g/100 g) and then increased rapidly until May (9.00 g/100 g). In the mature flower protein level showed significant differences with months (P = 0.05).

In the young fruit (Fig. 5 and Appendix 4) protein content fluctuated between May (7.18 g/100 g) and July and eventually dropped in the latter month (5.40 g/100 g).

The data in Table 1 showed that protein content increased in the husk (3.63 g/100 g) in June and dropped (2.51 g/100 g) later in July. In the pulp it decreased between May (3.53 g/100 g) and July (2.65 g/100 g). It showed a similar trend in the seed. Protein content showed significant differences between the mature fruit parts and with months within each part (P = 0.05).

MACRONUTRIENTS

1. Nitrogen (N)

Nitrogen showed the same trend of changes as protein in all the organs (Figs. 6, 4 and 5 and Table 1).

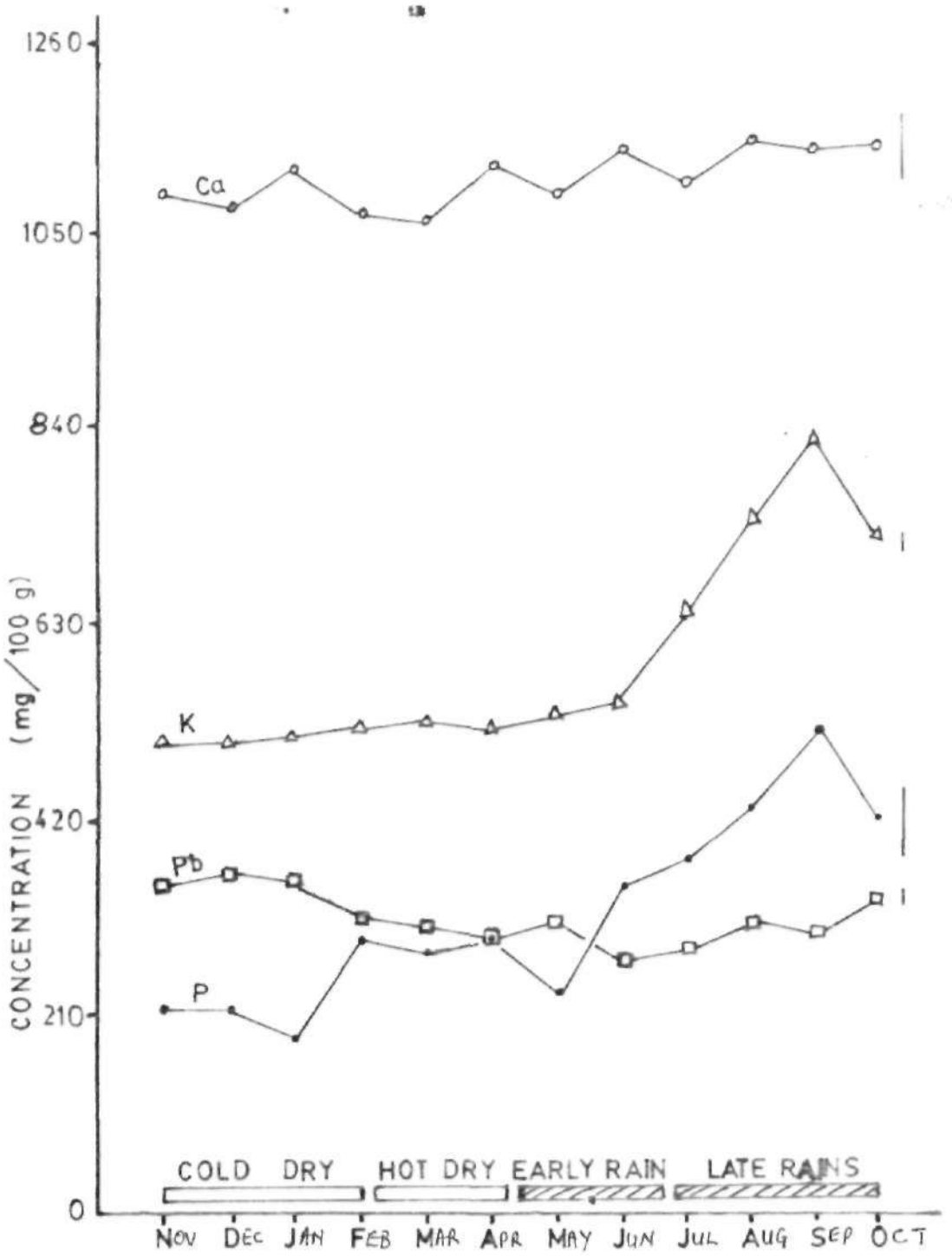


FIG. 7 SEASONAL VARIATION OF Ca, K, Pb AND P IN THE BARK. (LSD IS INDICATED, P = 0 05)

2. Phosphorus (P)

The P content and its seasonal variation in the bark are shown in Appendix 1 and Fig. 7 respectively. It dropped (189 mg/100 g) in January and then increased until April (301 mg/100 g) with a slight drop (232 mg/100 g) in May and then rose rapidly to its peak (526 mg/100 g) in September. It dropped again (423 mg/100 g) in October. It varied significantly with months (P = 0.05).

Leaf P (Fig. 8 and Appendix 2) dropped sharply (509 mg/100 g) in January and then increased rapidly until the peak (1058 mg/100 g) in May. Thereafter it dropped steadily until the lowest level (409 mg/100 g) in October. It showed significant differences between months (P = 0.05).

In the young flower (Fig. 9 and Appendix 3) P level increased in February (664 mg/100 g) and April (670 mg/100 g) and decreased in March (620 mg/100 g) and May (631 mg/100 g). In the mature flower P declined gradually until April (480 mg/100 g) and then increased (510 mg/100 g) in May. It varied significantly between the two floral stages (P = 0.05).

In the young fruit (Fig. 10 and Appendix 4) P content generally dropped between March (773 mg/100 g) and July (765 mg/100 g) with slight increase in May (780 mg/100 g).

In the mature fruit (Fig. 11 and Appendix 5) P dropped gradually in the husk (670 mg/100 g) in June

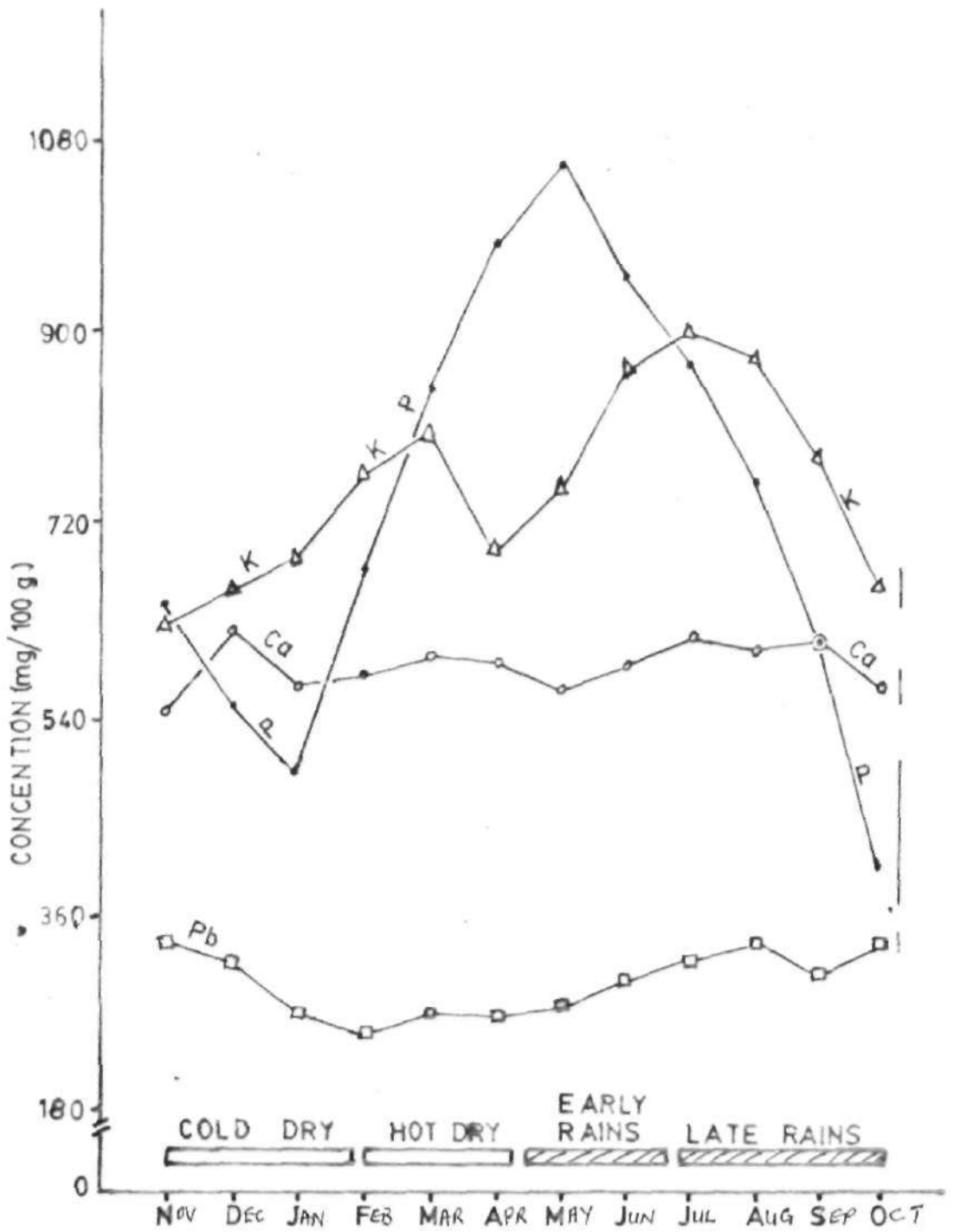


FIG. 8 SEASONAL VARIATION OF K, Ca, P AND Pb IN THE LEAF. (LSD IS INDICATED, P = 0·05)

and rapidly in July (631 mg/100 g). In the pulp it dropped steadily during the months and increased between May (726 mg/ 100 g) and July (825 mg/100 g) in the seed.

3. Potassium (K)

The data in Appendix 1 showed the K content of the bark while Fig.7 illustrates the seasonal variation. It increased gradually between December (506 mg/100 g) and June (551 mg/100 g) with a slight drop (519 mg/100 g) in April. Thereafter it increased to its peak (836 mg/100 g) in September and then dropped in October (726 mg/100 g). It showed significant differences between months (P = 0,05).

Leaf K (Fig.8 and Appendix 2) increased steadily to its first peak (799 mg/100 g) in March and then dropped in the following month to 700 mg/100 g. It then increased rapidly to its second peak (902 mg/100 g) in July and dropped sharply until October (657 mg/100 g). It showed significant differences between months (P = 0.05).

In the young flower (Fig. 9 and Appendix 3) K content increased until March (685 mg/100 g). It declined (679 mg/100 g) in April and increased slightly again in May (682 mg/100 g). In the mature flower it increased until April (569 mg/100 g) and remained relatively constant until May (568 mg/100 g).

In the young fruit (Fig. 10 and Appendix 4) K content increased until May (714 mg/100 g) and then declined until July (9 mg/100 g). It varied significantly between months (P 0.05).

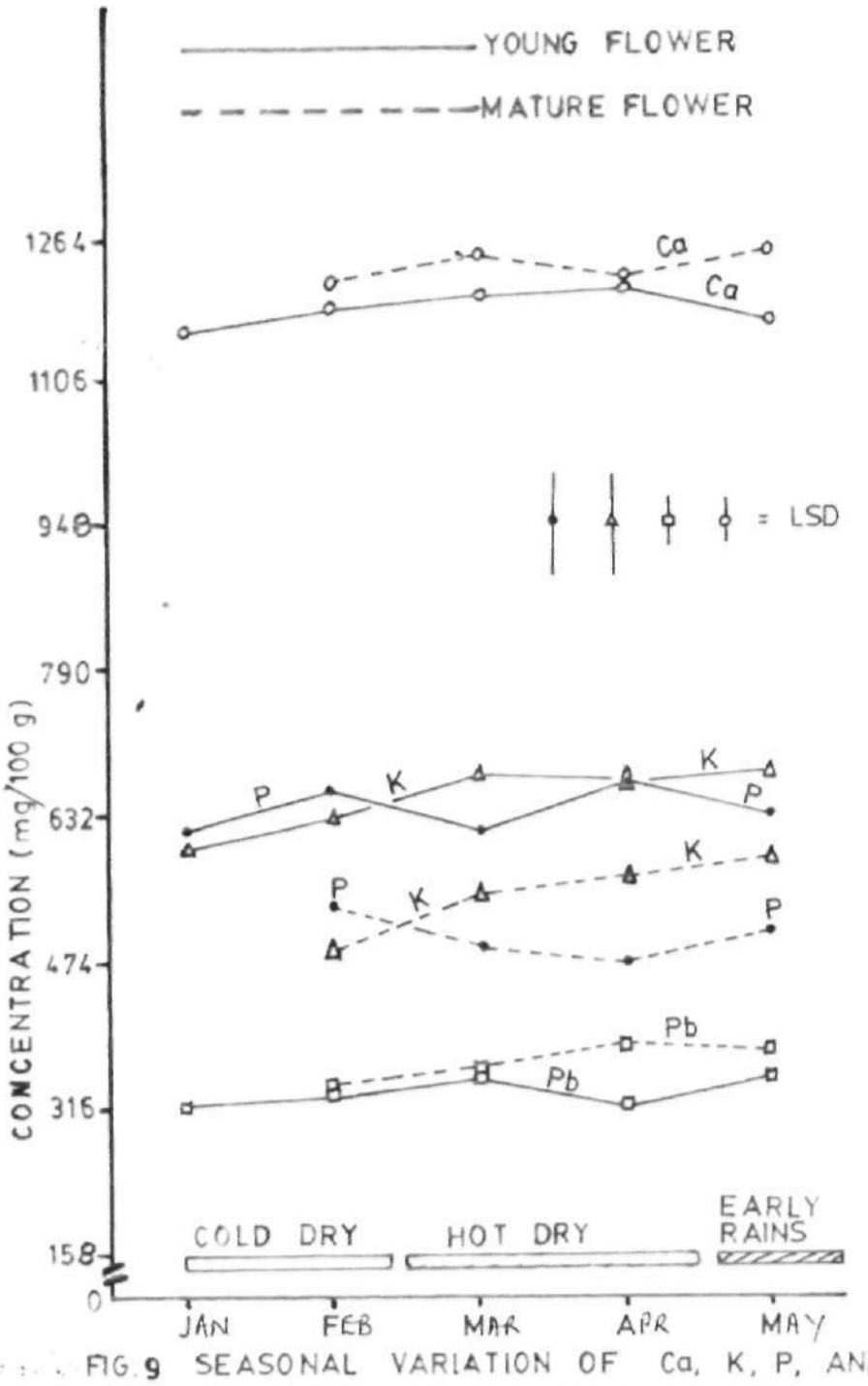


FIG. 9 SEASONAL VARIATION OF Ca, K, P, AND Pb IN THE YOUNG AND MATURE FLOWERS. (LSD IS INDICATED, P = 0·05)

In the husk of mature fruit (Fig. 11 and Appendix 5) K level declined between May (709 mg/100 g) and July (524 mg/100 g). In the pulp it was relatively constant until June and declined in July (586 mg/100 g). In the seed it dropped to a constant level between May (1035 mg/100 g) and July (1006 mg/100 g). It showed significant variation between months in the husk and seed ($P = 0.05$).

4. Magnesium (Mg)

The results presented in Fig.12 and Appendix 1 showed that Mg dropped in the bark between December (18 mg/100 g) and February (13 mg/100 g). After a slight increase (14 mg/100 g) it declined steadily until July (11 mg/100 g). It increased again until September (13 mg/100 g) and dropped in October. It showed significant changes between months ($P = 0.05$).

In the leaf (Fig.13 and Appendix 2) Mg content fluctuated between 8.4-11 mg/100 g throughout the season. It showed significant variation with months.

In the young flower (Fig.14 and Appendix 3) Mg level dropped slightly (9 mg/100 g) in May. In the mature flower it dropped to a constant level (7 mg/100 g) until May. It showed significant difference between the two floral stages ($P = 0.05$).

The level of Mg in the young fruit (Fig. 15 and Appendix 4) increased in April (11 mg/100 g) and then declined until July (9 mg/100 g). It varied significantly between months ($P = 0.05$).

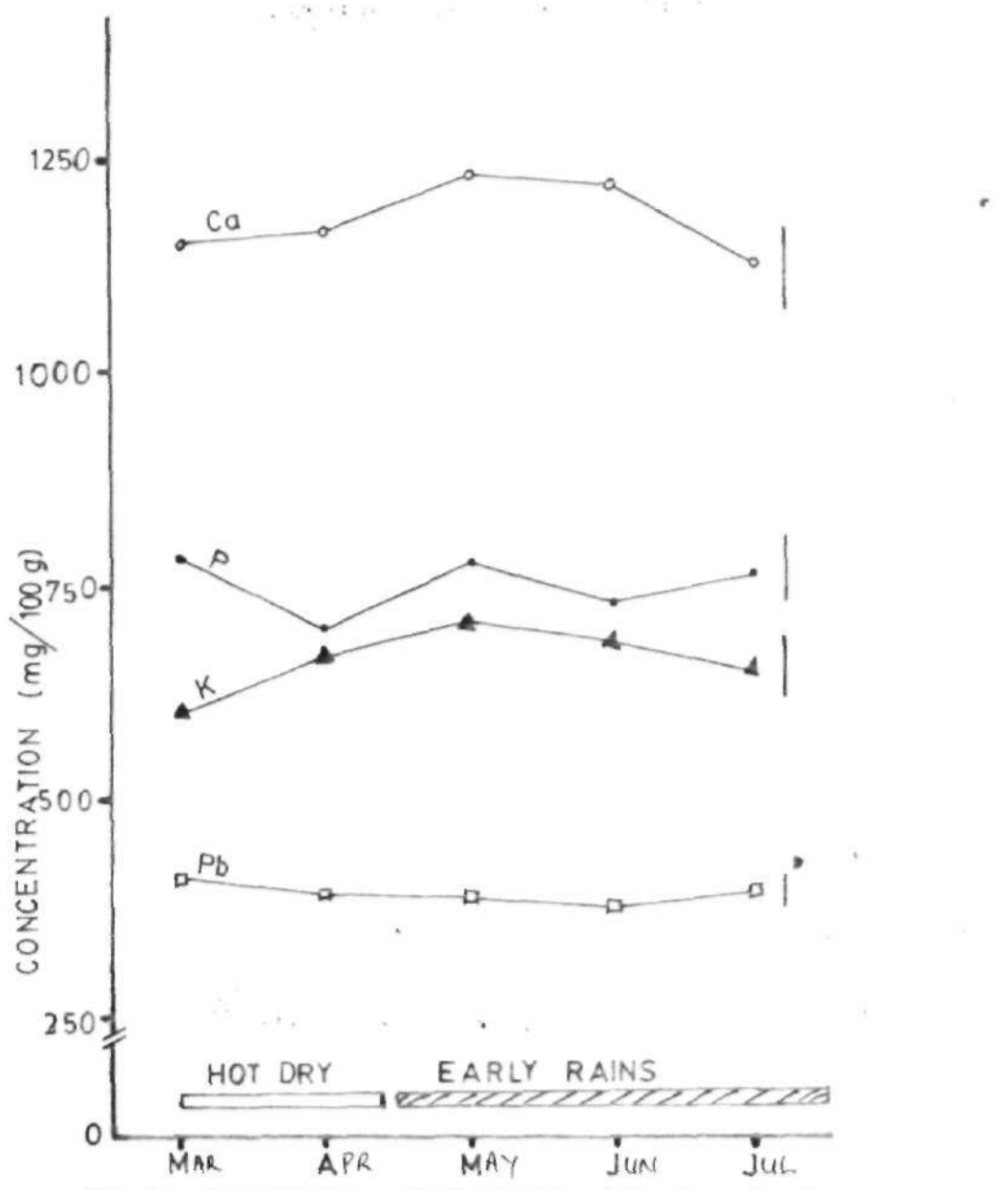


FIG.10 SEASONAL VARIATION OF Ca, P, K AND Pb IN THE YOUNG FRUIT. (LSD IS INDICATED, P = 0·05)

The data in Fig. 16 and Appendix 5 showed that Mg content was relatively constant in the husk, pulp and seed of the mature fruit. It showed significant differences between the three fruit parts (P = 0.05).

5. Calcium (Ca)

In the bark (Fig.7 and Appendix 1) Ca content fluctuated between 1072-1158 mg/100 g and showed significant differences during the months. Similarly leaf Ca fluctuated between 550-620 mg/100 g with significant changes over the months (Fig.8 and Appendix 2) (P = 0.05).

In the young flower (Fig. 9 and Appendix 3) Ca content increased to the highest value (1205 mg/100 g) in March and then dropped until May (1168 mg/100 g). In the mature flower it increased until May (1246 mg/100 g), with a slight drop (1215 mg/00 g) in April. Ca level showed significant difference between the two floral stages (P = 0.05).

The data in Appendix 4 and Fig. 10 showed the content and seasonal variation of Ca in the young fruit. It increased in May and declined until July (1130 mg/100 g).

In the mature fruit (Fig. 11 and Appendix 5) Ca content increased in the husk until July (1243 mg/100 g). In both pulp and seed Ca dropped in June and increased again in July. Each mature fruit part showed significant changes between months in Ca content (P = 0.05).

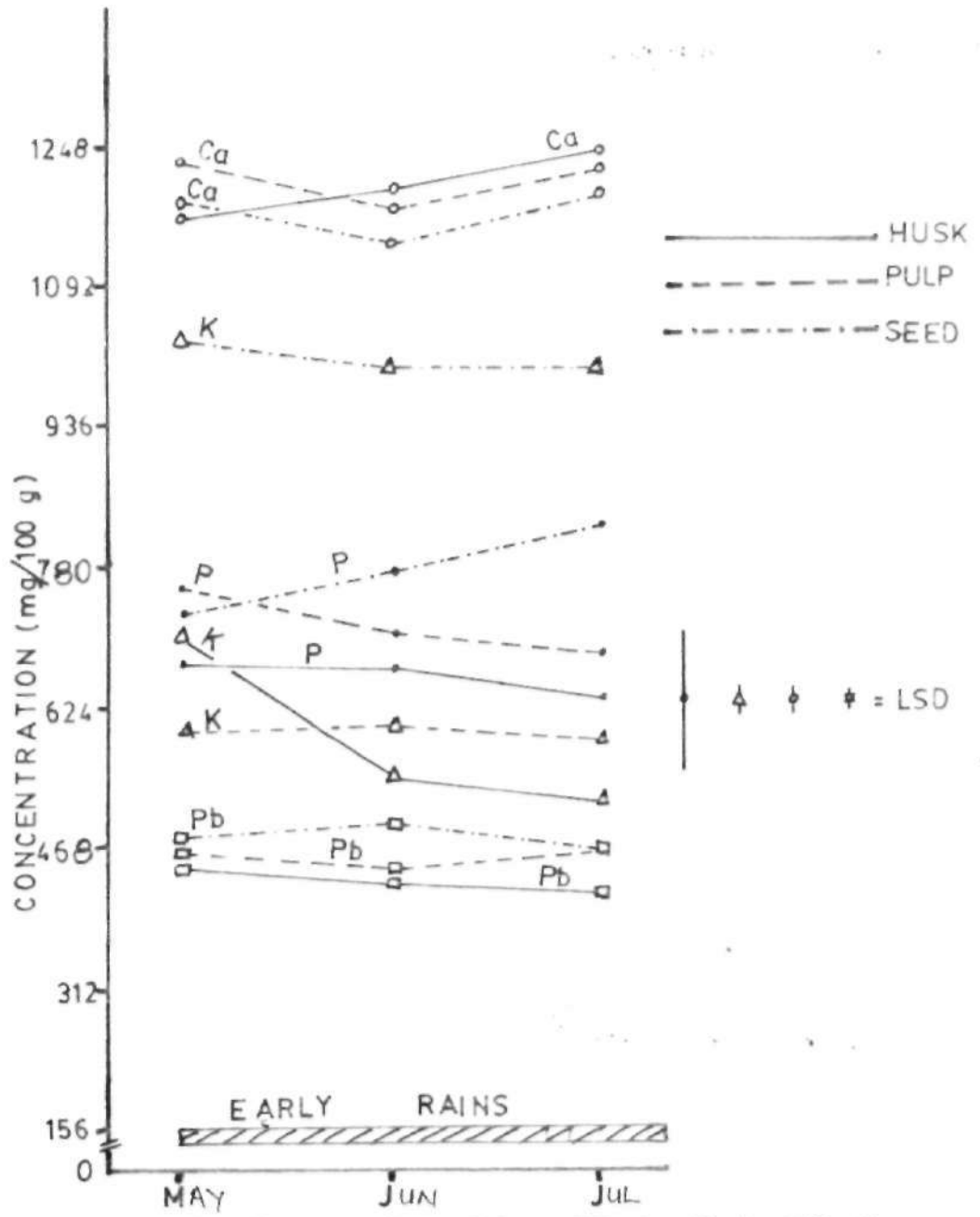


FIG.11 SEASONAL VARIATION OF Ca, K, P AND Pb IN THE HUSK, PULP AND SEED OF THE MATURE FRUIT. (LSD IS INDICATED, P = 0·05)

MICRONUTRIENTS

1. Iron (Fe)

In the bark (Fig. 12 and Appendix 1) Fe content declined rapidly to the lowest level (7 mg/100 g) in August. Thereafter it increased until October (21 mg/100 g). It showed significant changes between months (P = 0.05).

Leaf Fe declined sharply until the lowest level (24 mg/100 g) in February. It then increased rapidly until the first peak (97 mg/100 g) in April. It then decreased until October (68 mg/100 g) with slight increase during July (84 mg/100 g) and the second peak (88 mg/100 g) in August. It varied significantly between months (P = 0.05) (Fig. 13 and Appendix 2).

In the young flower (Fig. 14 and Appendix 3) Fe content increased to 19 mg/100 g in May. In the mature flower it increased in March (28 mg/100 g) and remained constant until April after which it dropped in May (24 mg/100 g). It varied significantly between the two floral stages (P = 0.05).

In the young fruit (Fig. 15 and Appendix 4) Fe content increased gradually between April (18 mg/100 g) and July (20 mg/100 g). In the mature fruit (Fig. 16 and Appendix 4) Fe content increased steadily in the husk until the highest level in July (35 mg/100 g). In both the pulp and seed it increased in June and decreased in July.

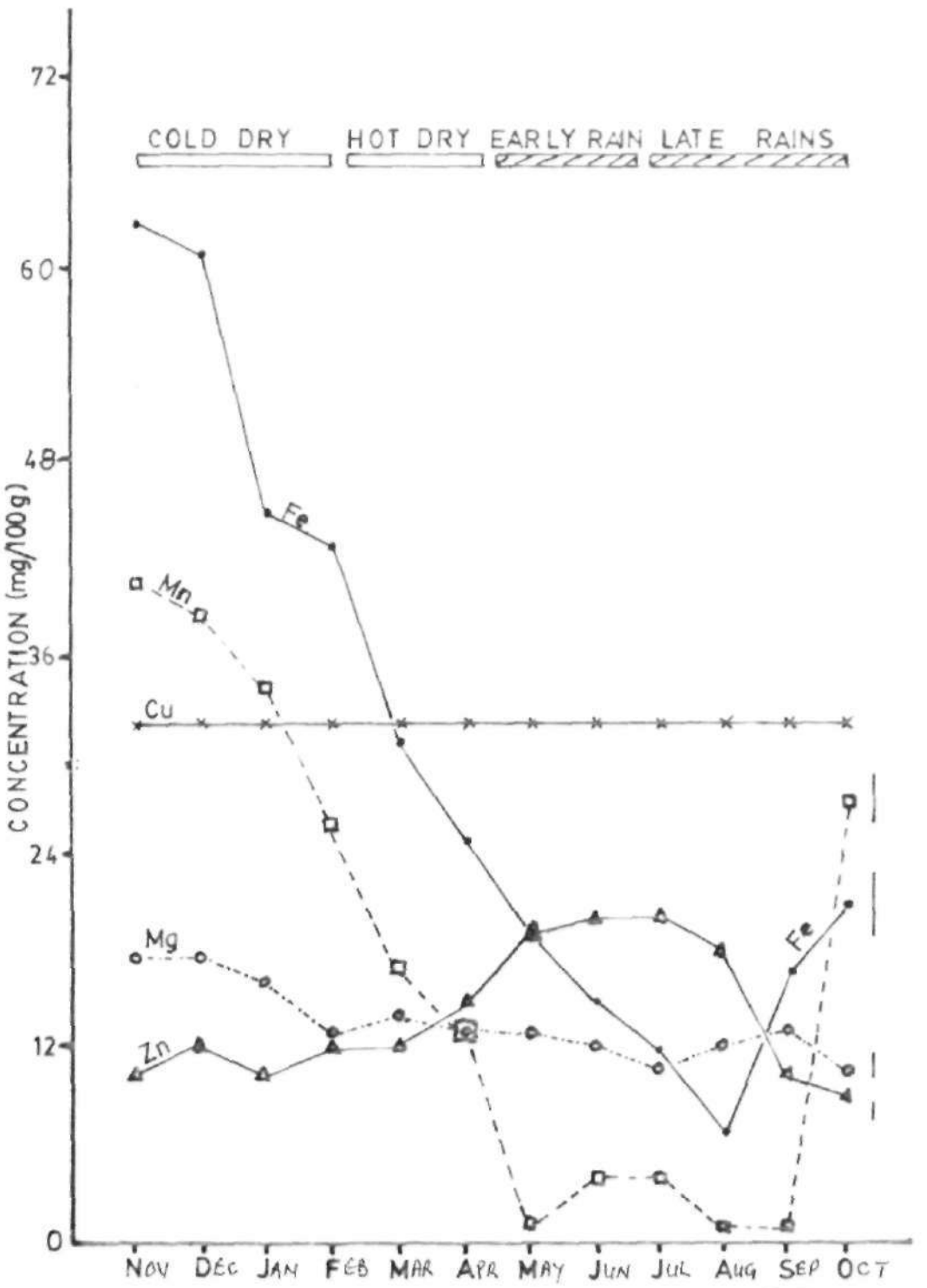


FIG. 12 SEASONAL VARIATION OF Fe, Mn, Cu, Mg AND Zn IN THE BARK. (LSD IS INDICATED, P = 0·05)

2. Zinc (Zn)

In the bark (Fig.12 and Appendix 1) Zn level fluctuated between 11-12 mg/100 g during November to March. Thereafter it increased to a constant level (10 mg/100 g) between June and July. It then dropped steadily until October (9 mg/100 g). It varied significantly with months (P = 0.05).

In the leaf (Fig.13 and Appendix 2) the level of Zn fluctuated (11-16 mg/100 g) during November through June. It then increased steadily to its peak (17 mg/100 g) in September and later dropped in October (16 mg/100 g). It also varied significantly between months (P = 0.05).

The content of Zn in the flower (Fig. 14 and Appendix 4) showed relatively constant values in both the young and mature flowers. The mature flower showed significant changes in Zn level with months (P = 0.05).

In the young fruit (Fig.15 and Appendix 4) Zn content was constant (11 mg/100 g) until May after which it dropped to 10 mg/100 g until July. The Zn content of the husk from the mature fruit (Fig. 16 and Appendix 5) was constant (16 mg/100 g) until June and increased in July (18 mg/100 g). In the pulp it increased throughout the months. But in the seed it dropped in June (16 mg/100 g) and increased in July (17 mg/100 g).

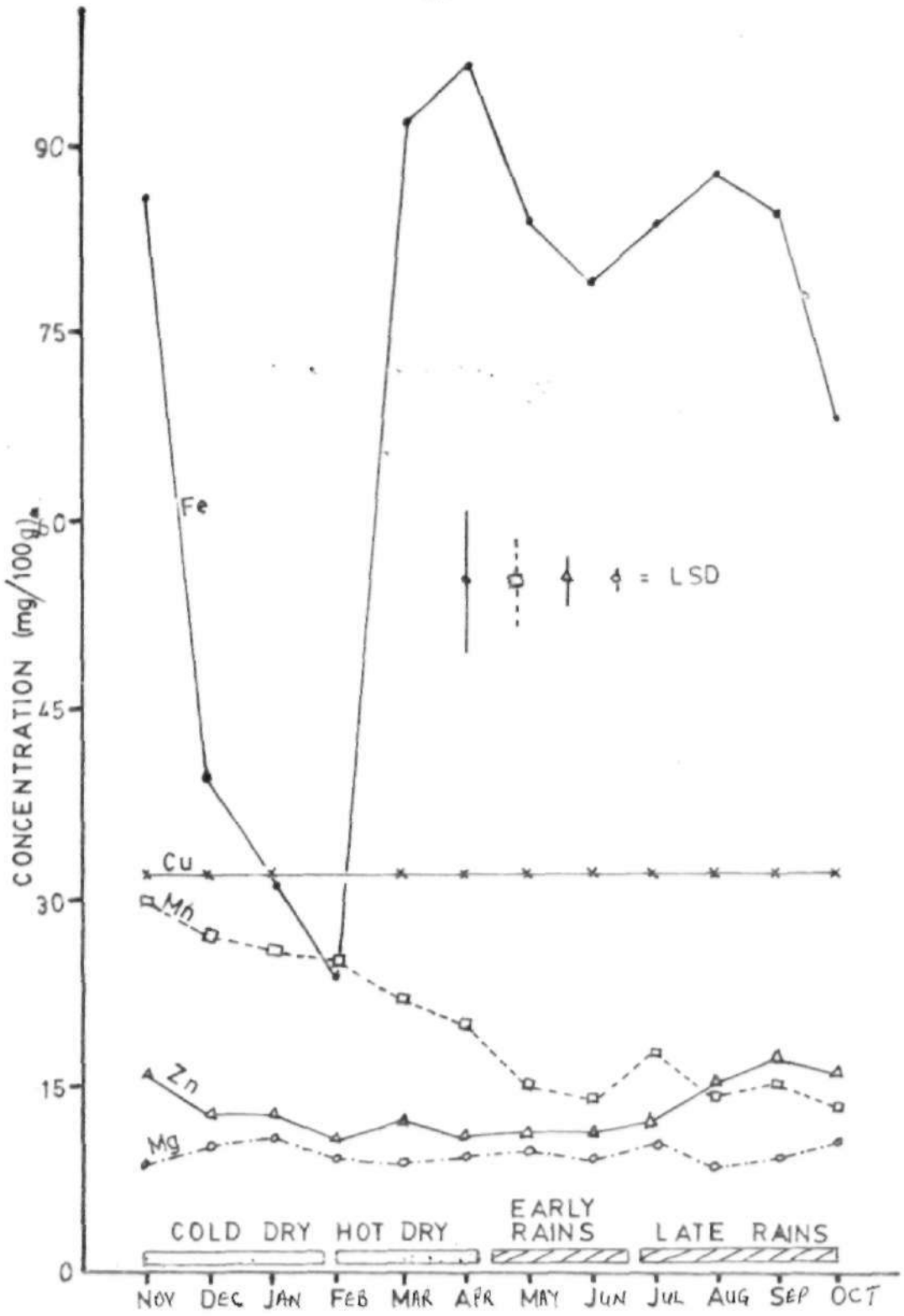


FIG.13 SEASONAL VARIATION OF Fe, Cu, Mn, Zn AND Mg IN THE LEAF. (LSD IS INDICATED, P = 0·05)

3. Lead (Pb)

The Pb content in the bark (Fig. 7 and Appendix 1) decreased between December (370 mg/100 g) and June (278 mg/100 g) with a slight increase in May (311 mg/100 g). It then increased to 338 mg/100 g in October after a slight drop (301 mg/100 g) in September. It showed significant differences between months ($P = 0.05$).

The level of Pb in the leaf dropped until the lowest level (255 mg/100 g) in February (Fig. 8 and Appendix 2). Thereafter it increased to 336 mg/100 g in August and October with a slight decrease in September (310 mg/100 g). There were significant changes in leaf Zn between months ($P = 0.05$).

In the young flower (Fig. 9 and Appendix 3) Pb content increased until March (351 mg/100 g) and then dropped rapidly in April (320 mg/100 g). It rose sharply in May (352 mg/100 g). In the mature flower the concentration of Pb increased until April (387 mg/100 g) and then dropped slightly (380 mg/100 g) in May. It varied significantly between the two floral stages ($P = 0.05$).

The young fruit (Fig. 10. and Appendix 4) showed steady decrease in Pb content until June (382 mg/100 g) after which it increased to 398 mg/100 g in July. In the mature fruit (Fig. 11 and Appendix 5) Pb content decreased steadily in the husk until July (418 mg/100 g). In the pulp, Pb decreased in June (446 mg/100 g) and then increased to 462 mg/100 g in July. It increased

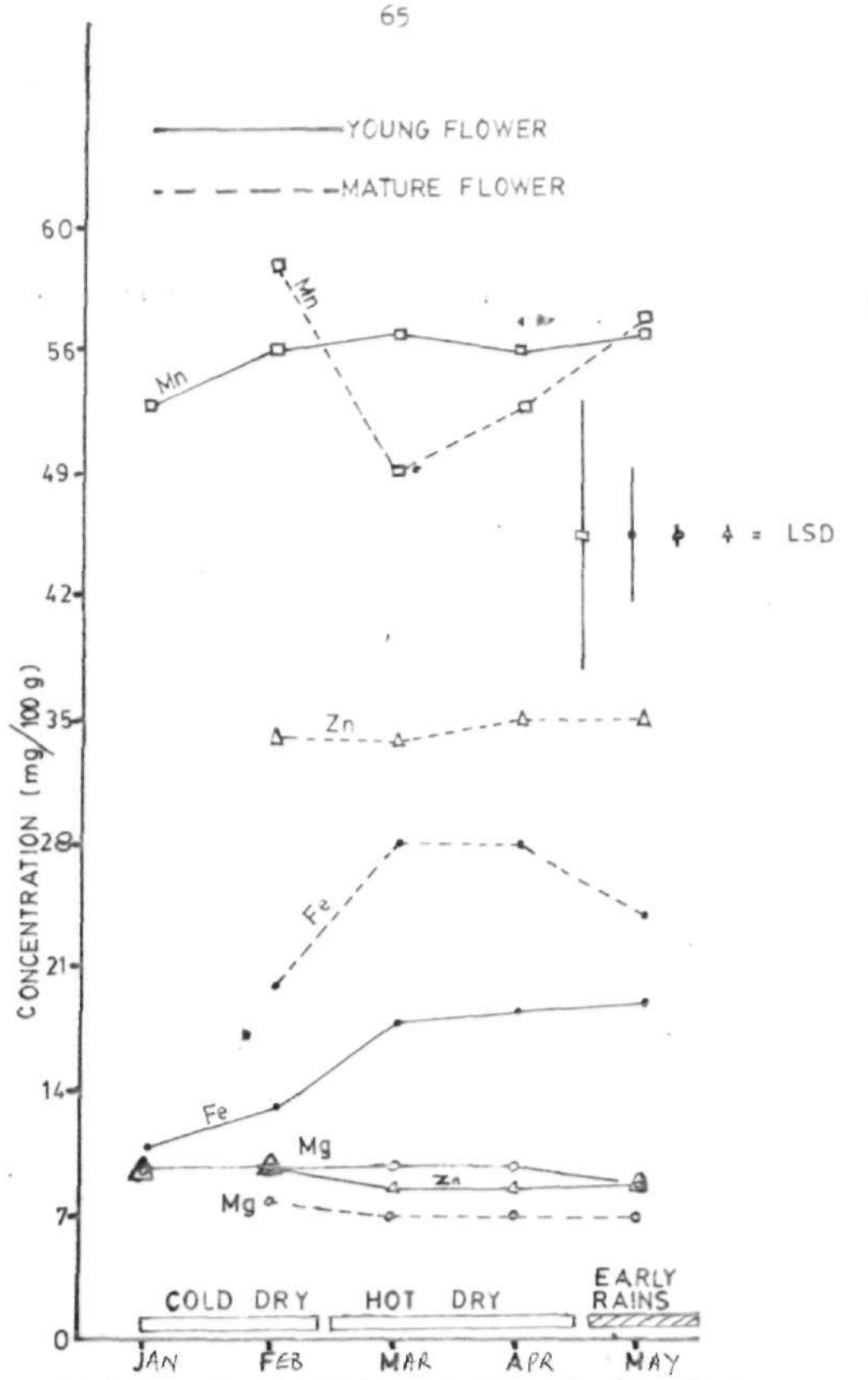


FIG. 14 SEASONAL VARIATION OF Mn, Zn, Fe AND Mg IN THE YOUNG AND MATURE FLOWERS. (LSD IS INDICATED, P = 0·05)

in the seed to 492 mg/100 in June and then decreased in July (465 mg/100 g). It varied significantly between the three fruit parts and with months within each part (P = 0.05).

4. Manganese (Mn)

In the bark (Fig. 12 and Appendix 1) Mn content dropped steadily to its first lowest level (0.5 mg/100 g) in May. It increased to a constant level (2 mg/100 g) between June and July. Thereafter it declined to its second lowest level (0.30 mg/100 g) in August and remained relatively constant until September. It then increased rapidly (13 mg/100 g) in October. It showed significant differences between months (P = 0.05)

Leaf Mn (Fig.13 and Appendix 2) decreased steadily until June (14 mg/100 g). Afterwards it increased to 10 mg/100 g in July and then declined until October (13 mg/100 g) with a slight increase (15 mg/100 g) in September. There were significant changes between months (P = 0.05).

In the young flower (Fig. 14 and Appendix 3) Mn level increased until May (57 mg/100 g) with a slight drop (56 mg/100 g) in April. In the mature flower it dropped rapidly (49 mg/100 g) in March. Thereafter it increased slightly in May.

The level of Mn increased gradually in the young fruit between April (57 mg/100 g) (Fig. 15 and Appendix 4). In the mature fruit (Fig. 16 and Appendix 5) Mn

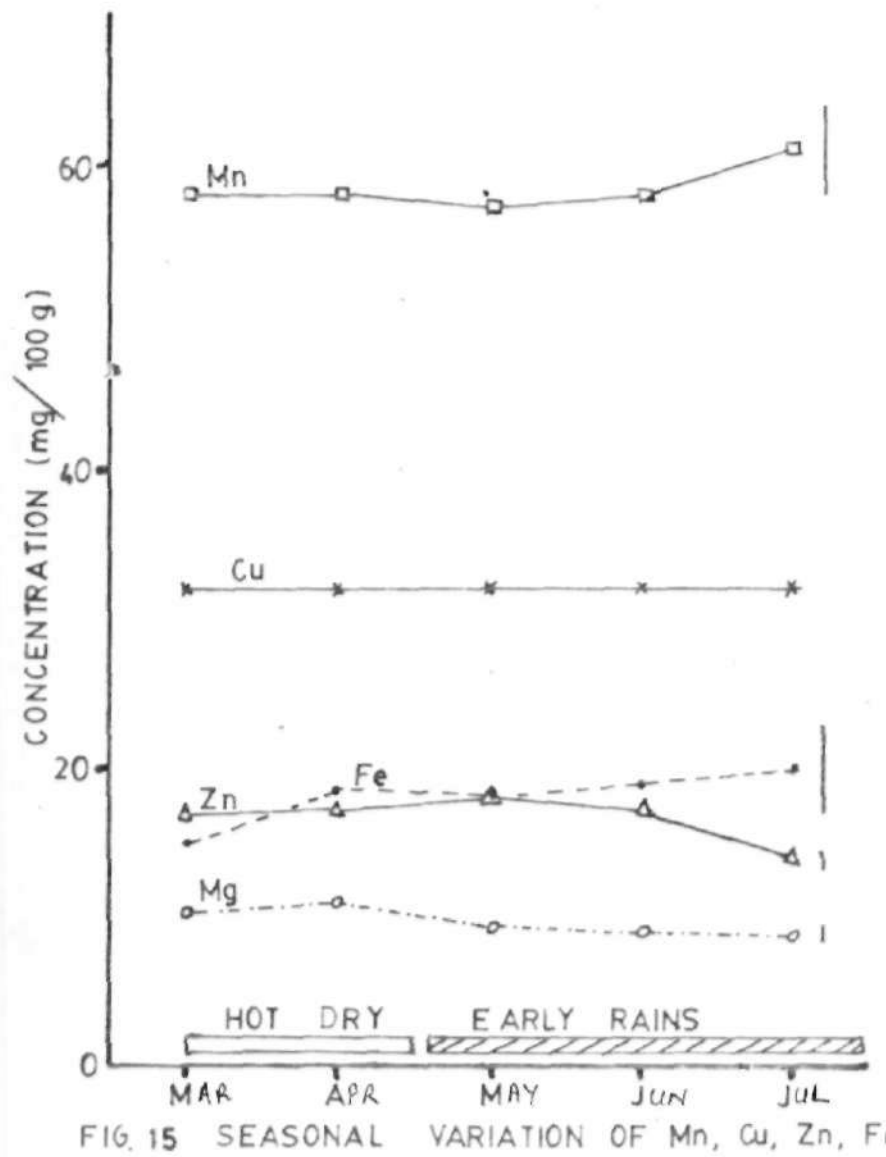


FIG. 15 SEASONAL VARIATION OF Mn, Cu, Zn, Fe AND Mg IN THE YOUNG FRUIT. (LSD IS INDICATED, P = 0·05)

content decreased in the husk in June (56 mg/100 g) and then increased slightly in July (57 mg/100 g). In the pulp Mn showed constant level between May and June (56 mg/100 g) and then declined in July (54 mg/100 g). In the seed it decreased steadily to 55 mg/100 g in July.

5. Copper (Cu)

All the organs showed constant levels of Cu (32 mg/100 g) throughout the season.

STANDARD CURVES

The standard curves obtained for the various substances are presented in figures 17-23.

FIELD TRIP

In all the places visited, the Parkia was observed as a common tree of the savanna parkland. It showed common occurrence in the farmlands especially in Zaria, Funtua, Kabomo, Katsina, Kano, Pambegua and Saminaka areas. It was less common towards the more humid south (between Auchi and Uromi) than in the drier north (Zaria - Abuja).

Interaction with the local people in Zaria, Funtua Kabomo, Katsina and Kano revealed that the tree has very high economic value. It is preserved and inherited by the successive generations along with the land. It is not cultivated in any of the areas. However it is tended, for example by mulching, when still young and it may be fenced to protect it from grazing animals. Harvesting the fruits without the consent of

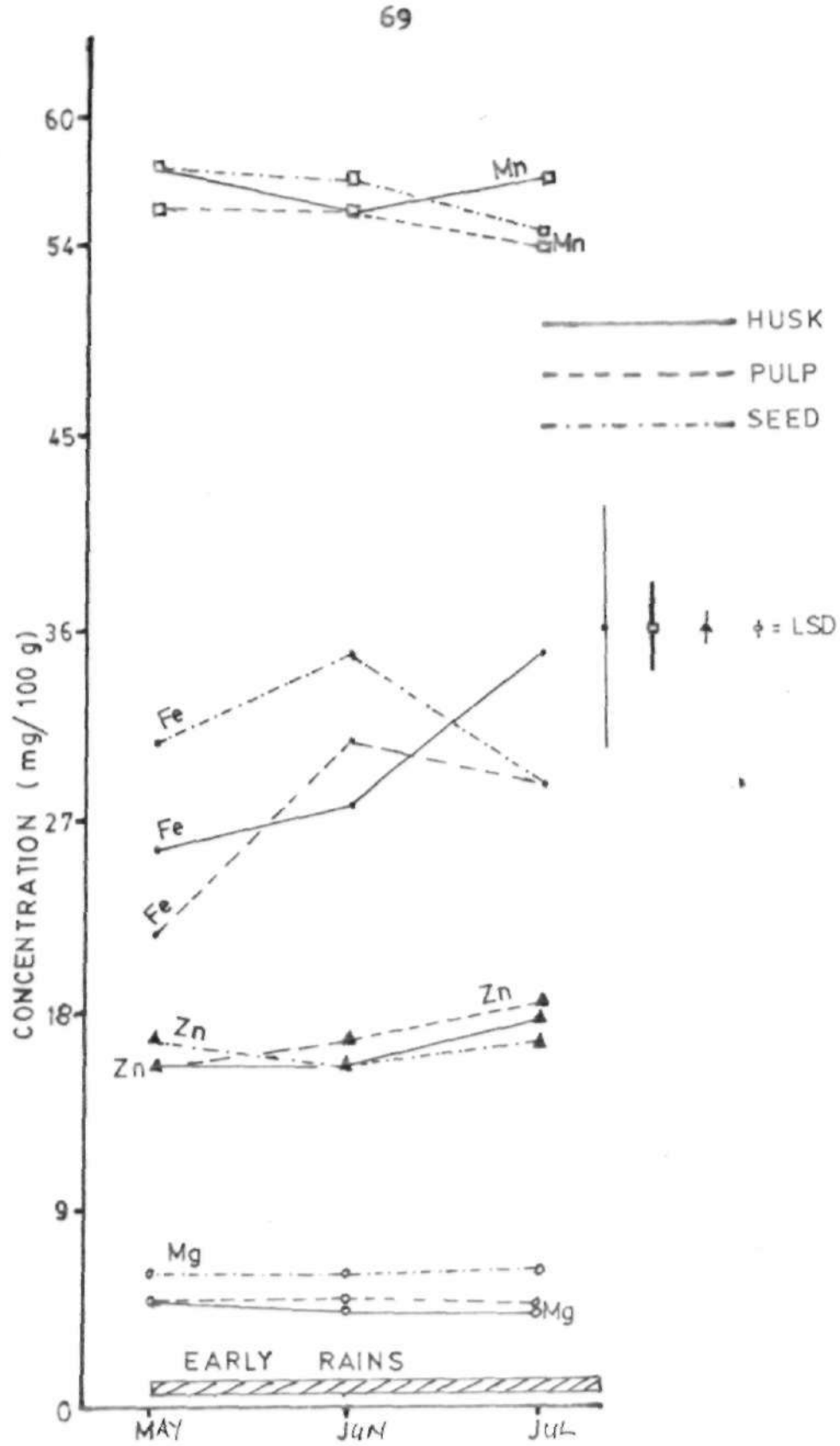


FIG.16 SEASONAL VARIATION OF Mn, Fe, Zn AND Mg IN THE HUSK, PULP AND SEED OF THE MATURE FRUIT.
(LSD IS INDICATED, P = 0·05)

of the owner is regarded as a theft in all the places but those that grow in the wild may be harvested by anybody. The tree which provides shade for farm workers, is reputed to have a long life but no evidence on this was recorded.

PHENOLOGY

P. clappertoniana is not usually a tall tree (Plate VI). It showed profuse and dichotomous branching. The tree, especially when old, showed greatly fissured bark. Young trees showed smooth bark.

DEFOLIATION

The trees used for this study shed their levels during March through May. In some other trees, defoliation started as early as February or ended as late as June. Some trees were totally or only partially defoliated while a few did not shed their leaves during the whole study period. They also did not flower nor bear fruits during the period.

The period of defoliation appeared to follow the time of reproductive growth. Where partial defoliation occurred, only the bearing branches appeared to be involved. Defoliation generally started when the leaves were aged and continued up to the fruiting period as was observed in majority of the trees.

The leaves were shed in fairly large quantities under the wind. The shed leaves formed a deep litter (1-1.5 cm) under the tree.

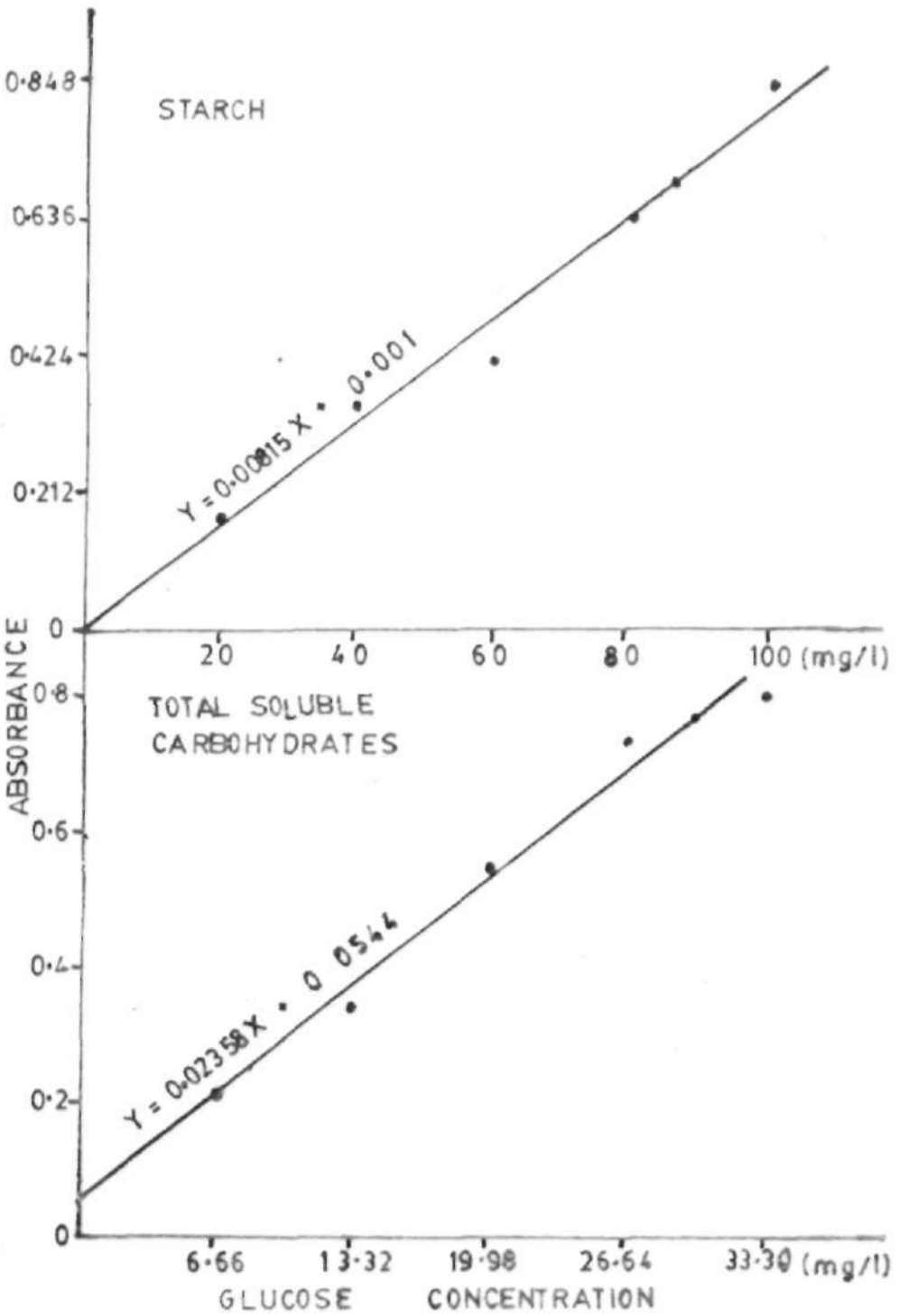


FIG. 17 STANDARD CURVES FOR STARCH AND TOTAL SOLUBLE CARBOHYDRATES

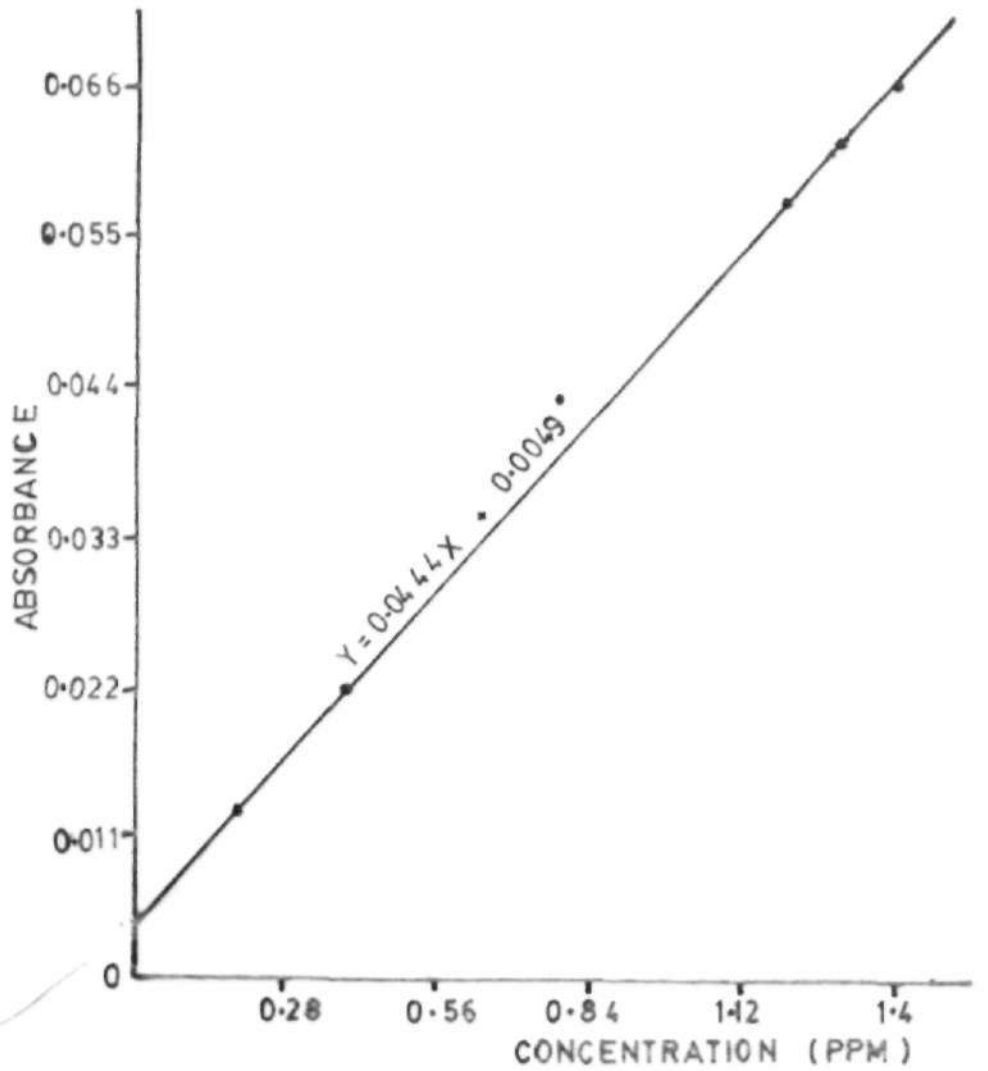


FIG. 18 STANDARD CURVE FOR COPPER

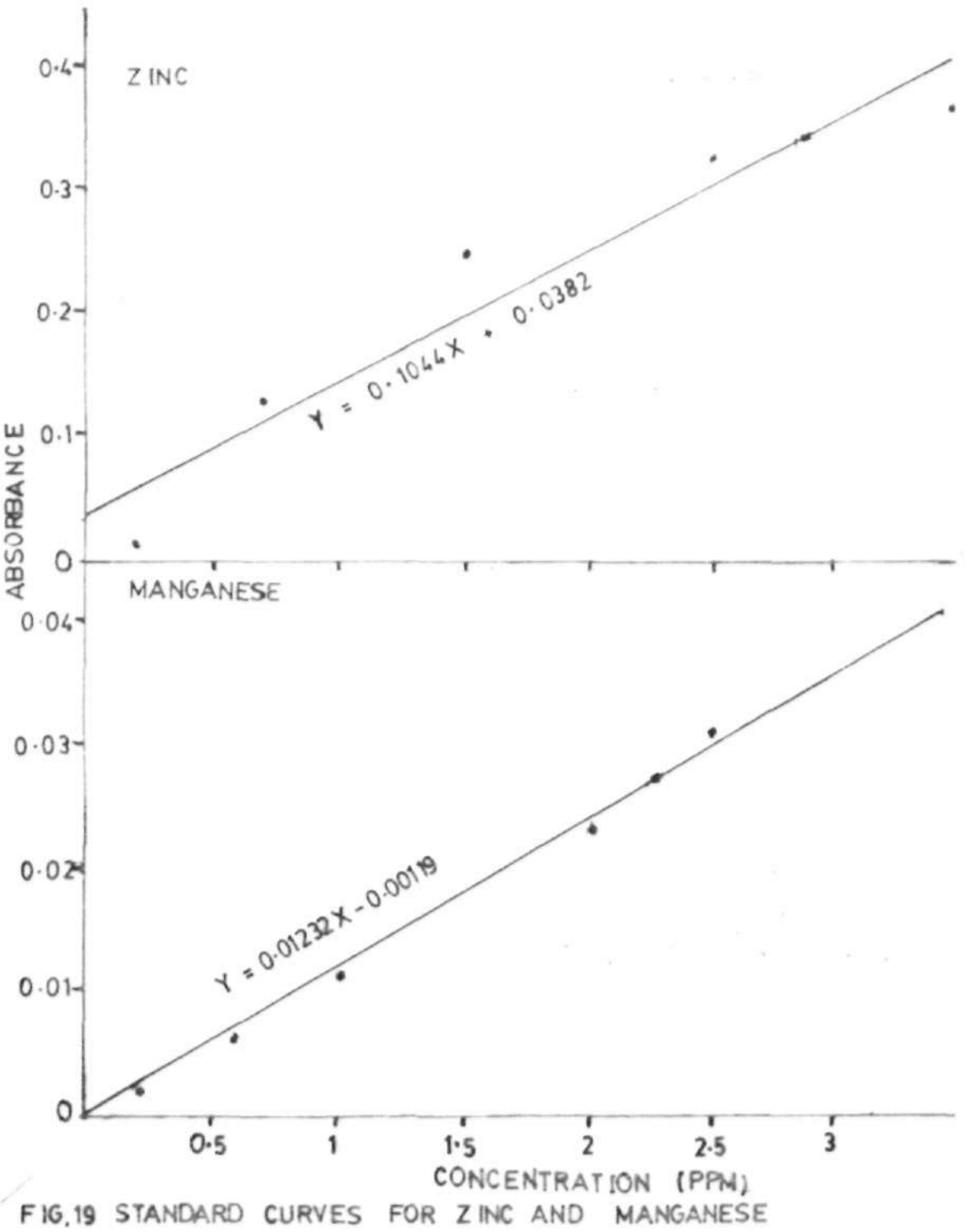


FIG. 19 STANDARD CURVES FOR ZINC AND MANGANESE

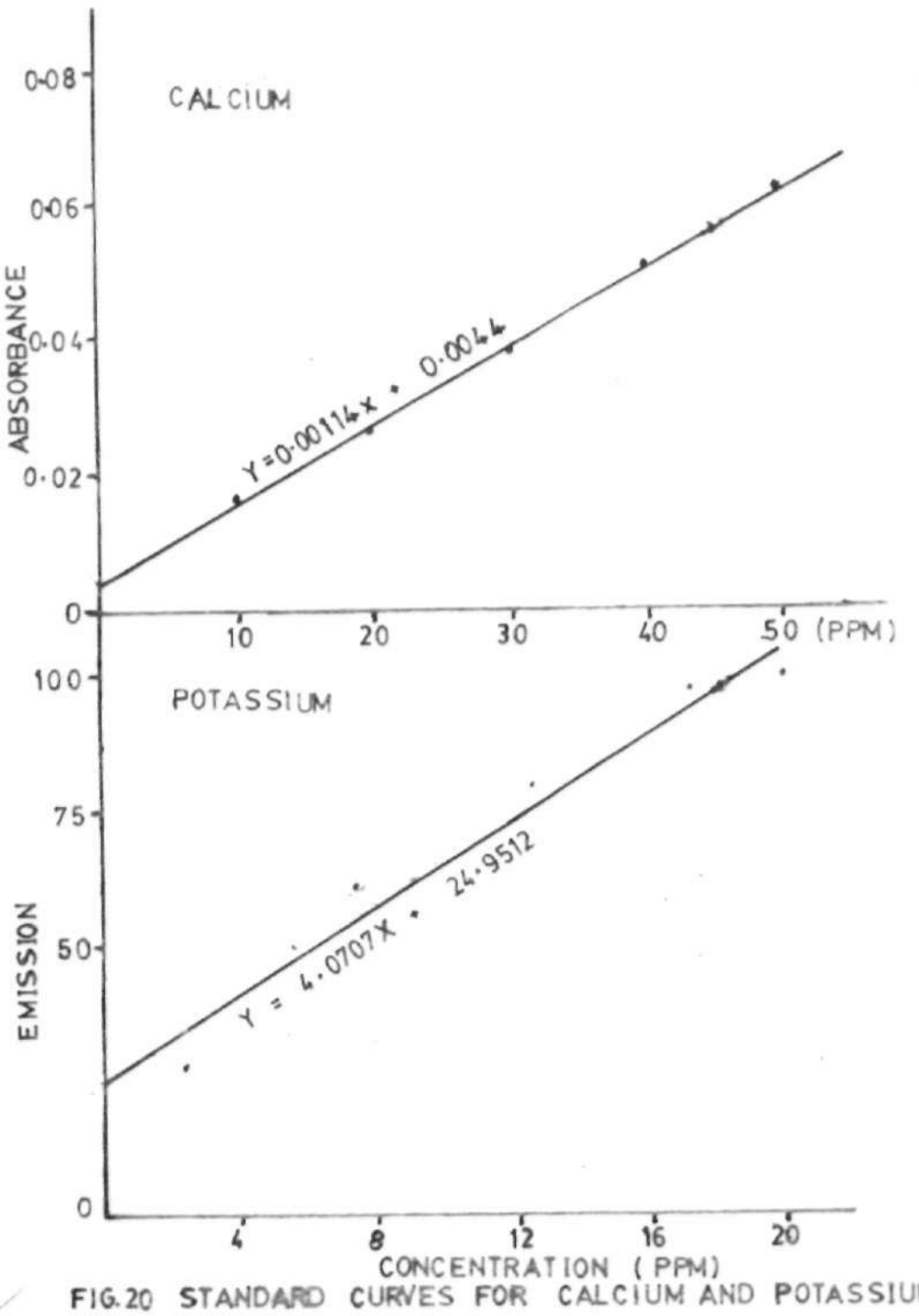


FIG.20 STANDARD CURVES FOR CALCIUM AND POTASSIUM

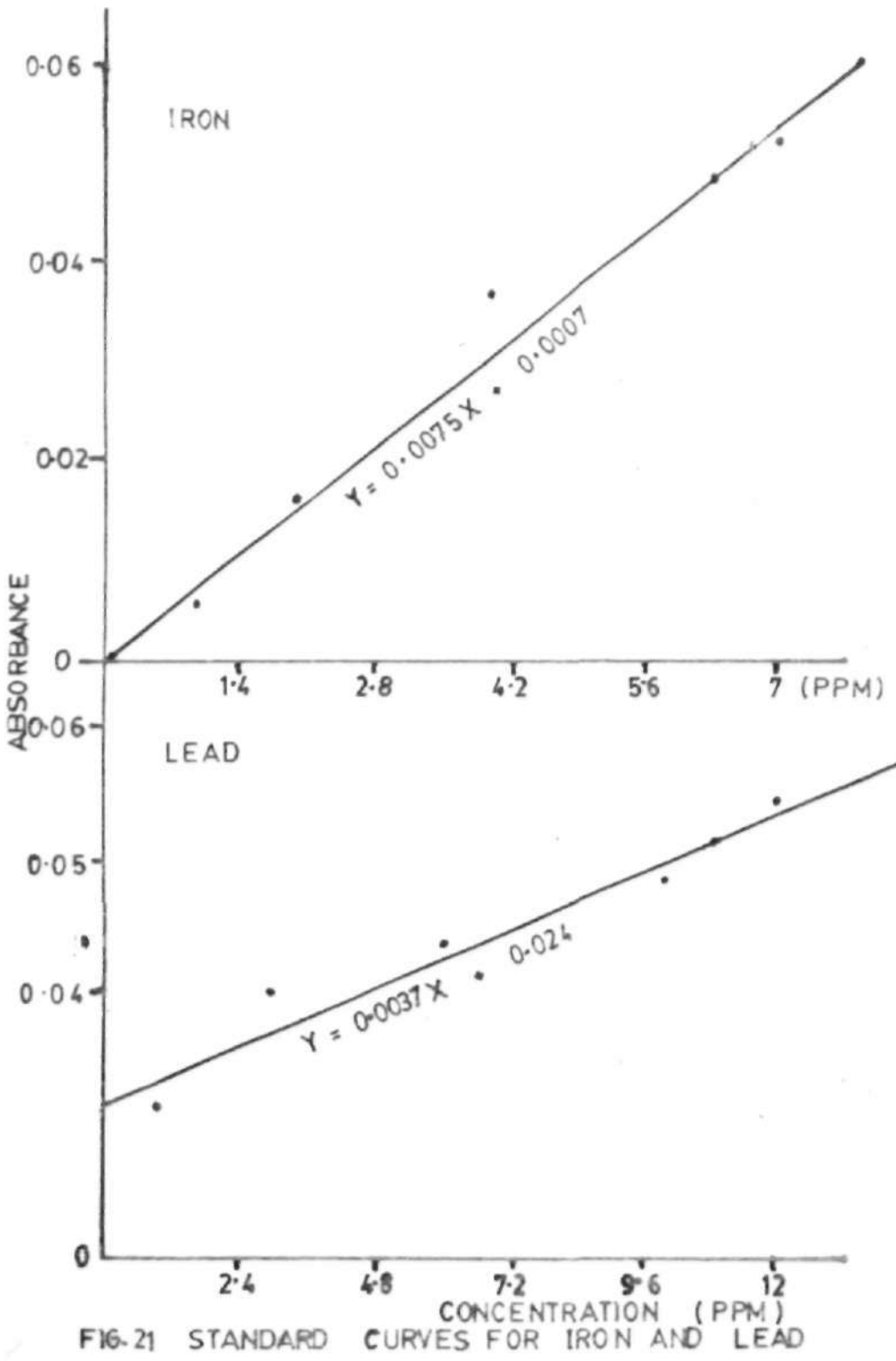


FIG-21 STANDARD CURVES FOR IRON AND LEAD

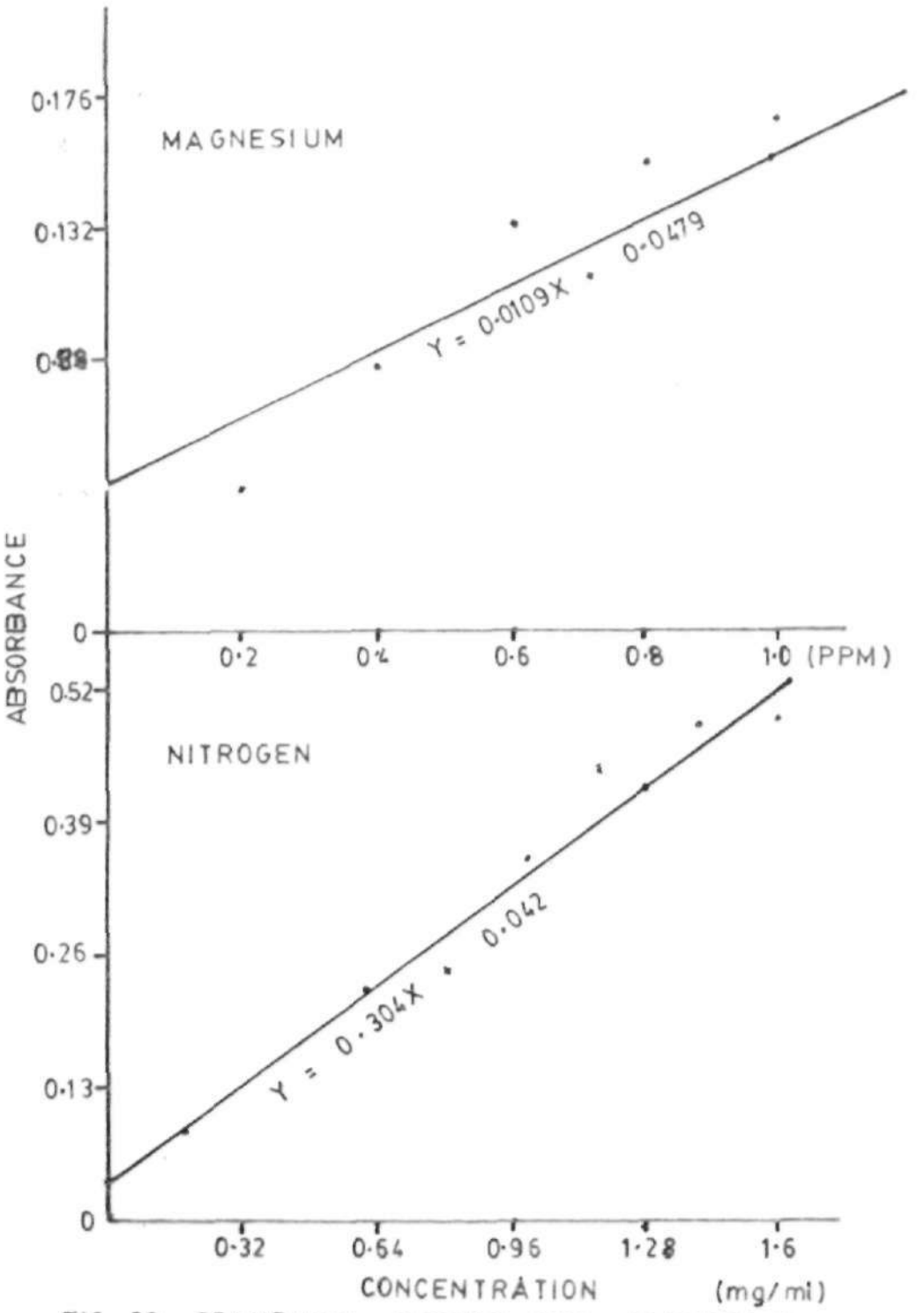


FIG. 22 STANDARD CURVES FOR MAGNESIUM AND NITROGEN

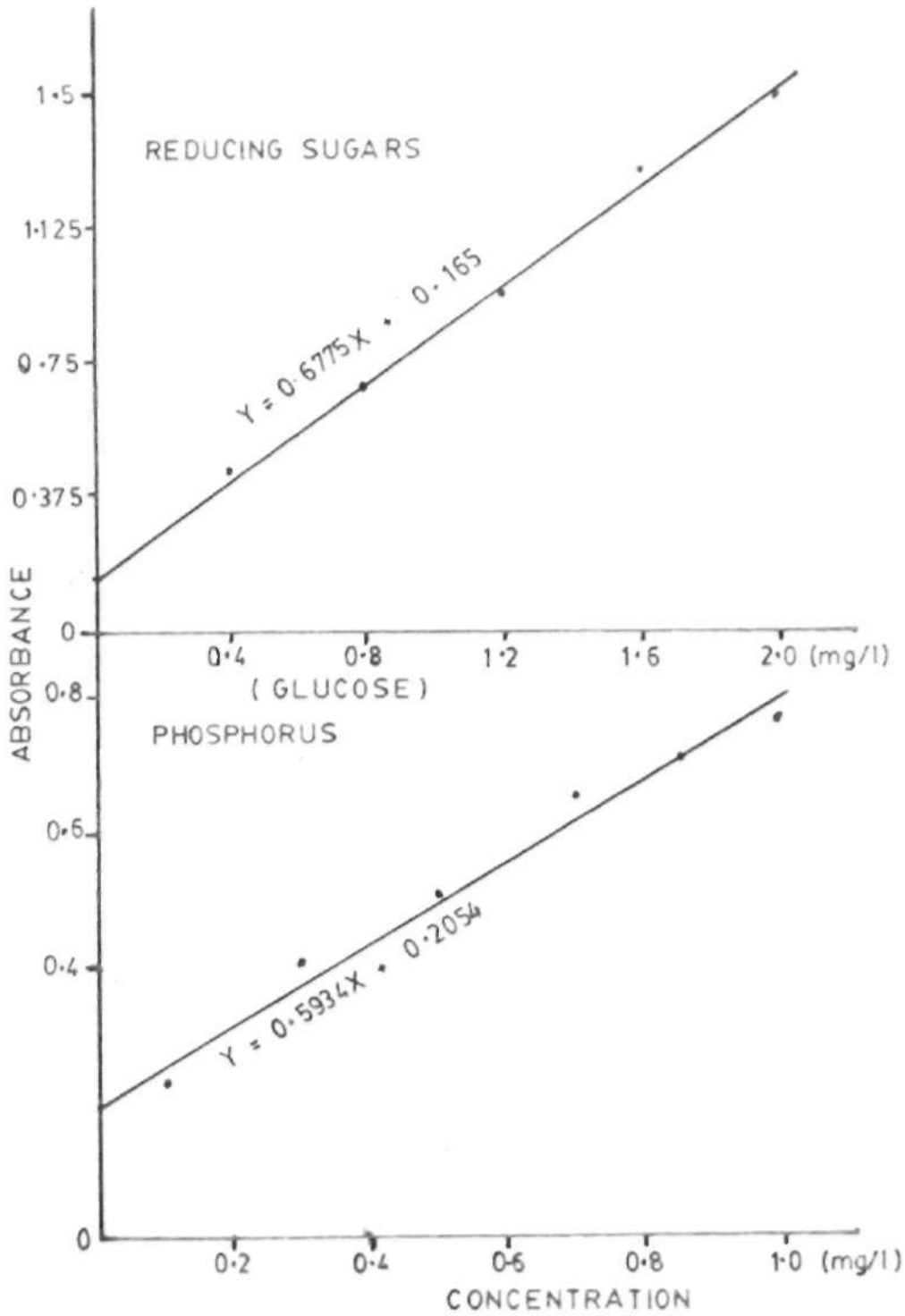


FIG. 23 STANDARD CURVES FOR PHOSPHORUS AND REDUCING SUGARS

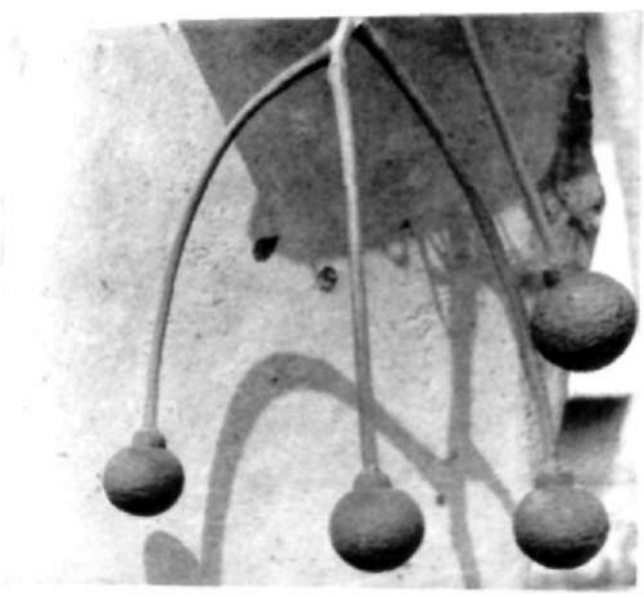


Plate I. Four Young Inflorescences of Parkia
(x ½)

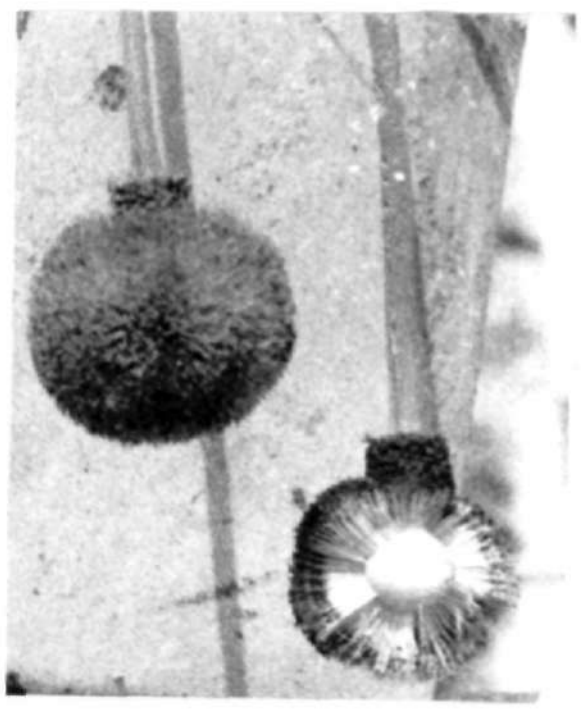


Plate II. Mature Inflorescences of Parkia
About half of the flowers of the
Specimen on the right hand side
were removed to show the receptacle.
Note the proximal sterile flowers
and the groove in which nectar accumulates.
(x ⅔)

The new leaves appeared two weeks after the end of defoliation (Plate V). The new leaflet was usually narrow and somewhat brownish in colour. In a couple of days it expanded rapidly and turned green. The new leaves showed softer texture than the older leaves. This soft texture was lost as growth progressed with season. New leaf production generally took place rapidly.

FRUITING

The fruits on initial production were spindle-shaped with a tendency to coil back towards the peduncle. They developed with very rapid increase in size and weight, In some of the trees, the developing fruit reached 25 cm - 36 cm within two weeks (Plate III).

The initially amber coloured young fruit later turned green. Following the increase in weight, the fruits hung down in bunches. The rapid increase in weight of the developing fruit led to apparent increase in weight of the load on the crown of the tree. The heavy fruits tended to make the branches sag by pulling them down (Plate VI). Fruits were as few as one or as many as 33 in a bunch.

The seeds reached appreciable size within three weeks of fruiting. In the young fruit, the positions of the seeds were observed as swellings on the fruit. The swellings disappeared when the fruit reached maturity (Plate IV).

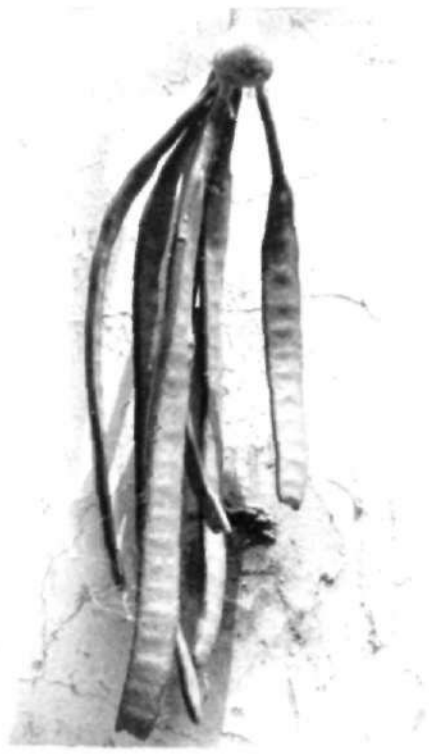


Plate III. Young Fruits of Parkia.
(x ⅓)

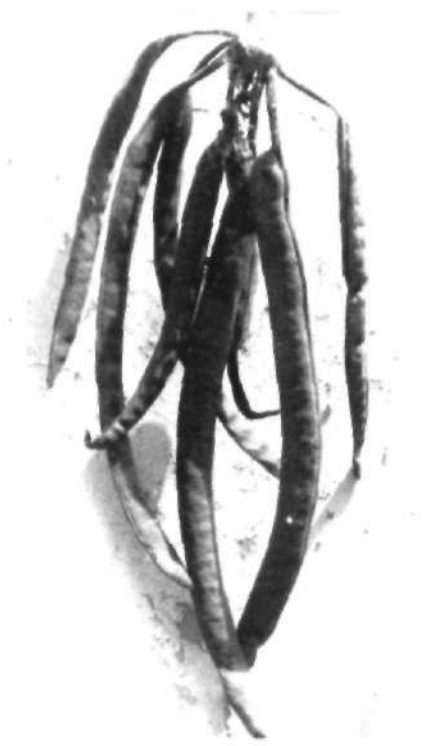


Plate IV. Mature Fruits of Parkia.
(x ⅓)

In the developing fruit, the mesocarp remained as a white solid mass. At maturity it became powdery and yellowish. Fruiting occurred in the experimental trees between March and May.

The fruit reached maturity within six to eight weeks of its formation. At maturity it became dry (Plate IV) and lost up to 50% of its fresh weight. During this period the branches sprang back up. Fruits were not lost by premature dropping as had been observed in flowers. Fruits turned brown at maturity during May to July.

HARVEST

The ripe fruits were harvested except the diseased pods in all the trees observed. The harvest was rapid as the fruits ripened in large quantities at a time. In most of the places visited, women and children were seen returning from the farms or woodland with container-loads of the fruits. Long hooks were used to pluck the fruit. The children climbed to reach the fruits high up on the tree.

PARASITE OF THE PLANT

The parasitic plant Tapinanthus dodoneifolius (Family: Loranthaceae) was often found growing on many of the trees observed.

LOCAL USES OF PARKIA PRODUCTS

Various interviews with the local people revealed that many Parkia products are used for food and non-food purposes. In Zaria, Funtua, Kabomo and Katsina, the



Plate V. Parkia tree at time of new growth flush. Note the developing fruits.



Plate VI. Parkia tree at the end of vegetative growth. Ripe fruits hand down in bunches.

bark is used to make preparations for the treatment of infective hepatitis (locally referred to as yellow fever). The bark is ground, mixed with water and lime juice and administered orally. The bark may also be boiled over-night. After cooling, the water is drained and used to bathe the patient. Similarly the leaves are used for the treatment of diarrhoea. They are collected and boiled for 1-2 hours and allowed to cool a bit. The patient then sits over the steam from the pot.

The bark is rich in tannin and used by local tanners (Leather Research Institute, Zaria; personal communication). The fruit husk or the entire fruit is used as fish poison in Gashua and Lake Chad areas (Borno State). They are pounded, mixed with water and added to the stream or pond. The fish which rush to the water surface to feed on them later become stupefied. They are then easily collected with baskets.

Parts of the fruits are used as food, e.g. the seeds are used to prepare a local food seasoner called "dawadawa". The seeds are decoated after boiling for some time, after which they are then boiled again over-night and fermented. They are then pounded into a paste and moulded into cakes which are usually flat. Dawadawa has a very pungent smell. When roasted, before use, this smell is lost and replaced by a rather pleasant aroma.

The dry pulp may be collected and mixed with "fura" (a food drink made from Sorghum) to increase its flavour. The dry powdery pulp may also be mixed in water and allowed to sediment and set. When it sets, the water is discarded and the hard cake stored. It is later cut into bits and eaten especially when other foods are scarce. The pulp cake is locally known as "garin-dorowa".

In Zaria, Funtua, Katsina and Kano, it was found that the fermented seeds are washed and used as a condiment in the same manner as "egusi" (melon seeds).

Children, in particular, eat the mealy pulp fresh from the mature fruit. They also collect the mature flowers to suck the nectar. In Funtua and Katsina areas, the mature red flowers are removed and mixed with "Kwuli-kwuli" (groundnut cake) as a source of flavour, but this practice was not wide spread.

CHAPTER FIVE

DISCUSSION

Analysis of plant tissues has become a valuable tool in diagnosing the nutritional status of plants. The technique was employed here to study the nutritional status of P. clappertoniana which is a very important tree crop particularly in the savanna region of Nigeria. Zimmermann and Brown (1974) have noted the importance of knowledge of utilisation of assimilates in primary and secondary growth and in flower and fruit production of forest trees.

The data presented in the results showed important differences in seasonal changes of the various constituents determined in different organs of P. clappertoniana. All substances, except Cu, showed significant changes with time in the shoot organs (the bark and leaves). The trend of changes also varied with the different organs analysed.

Generally, the mineral nutrients showed considerable changes in different organs with time during the period. Lanning and Garabedian (1963) made similar observations in various parts of the strawberry plant; the range of concentration of a particular element varied with plants and was also affected by the condition under which plants grew (Sutcliffe and Baker, 1974). In strawberry it was also noted that during the development of storage organs such as fruits and seeds; materials including organic and inorganic ions are diverted from various

parts of the plant towards the region of active growth. Similar observations were recorded for P, Mg, Ca, Fe, Pb, Zn and Mn in the shoot organs during the present investigation.

SEASONAL CHANGES IN CARBOHYDRATE CONCENTRATIONS

1. Starch

Starch concentration showed significant changes with time in the various organs except the mature flower, and the husk of the mature fruit. Starch in the bark dropped to a relatively constant level from November to January (Fig. 3). It then accumulated until it peaked for the dry season in April. Dowler and King (1966) reported similar observations for starch in peach twigs during winter. They reported that starch content of peach twigs decreased from November until January. Since energy is required for maintenance of the tree during the dry, cold months (November - February) an overall decrease in food reserve would be expected. Siminovitch et al. (1953) attributed fall in sucrose level in the bark of black locust tree (Robinia sp) during winter, to respiration.

The highest level of starch in the bark occurred in September. Smith et al. (1968) reported a similar level of starch in the stem of Rhamnus frangula in May.

Starch accumulated in the leaves between April and July but declined in the bark during the same period. Similarly levels of TSC and RS increased in the bark. The drop in starch in the bark and the accumulation

of TSC and RS during the same period indicated mobilisation of reserve carbohydrates during flushing. Leaf starch accumulated while TSC declined also during the period. This showed conversion of the imported carbohydrates for storage and utilisation during growth. Wardlaw (1968) reported that during early growth, a leaf requires carbohydrate for its development and will show a net import of assimilates.

Starch in flowers and fruits accumulated during development. Kramer and Kozlowski (1979), noted that in mature deciduous woody plants, when fruits and seeds begin to develop they become strong sinks and food is transported into them at the expense of vegetative growth. Tandon and Kalra (1983) reported similar accumulation of starch in Mango fruit and Fekete and Wieweg (1974) observed that leguminous seeds synthesize starch from sucrose imported from the photosynthesizing leaves.

During flowering (January - May) starch generally accumulated in the bark. Hocking and Steer (1983) observed that the stem was more important for carbohydrate storage in Helianthus annuus L. during flowering.

Depletion of starch and other carbohydrates in the shoot and their concomitant accumulation in the reproductive parts may be largely due to their predominant movement into these areas which form strong sinks during their development. Siminovitch et al. (1953) reported that in the black locust tree

(Robinia sp), reproductive growth (flowering and fruiting often draws heavily on reserve materials especially where large quantities of fruits are produced. The profuse production of young and rapidly expanding leaves between May and June should have resulted in large production of the soluble carbohydrates and the excess converted to starch in the leaf.

Starch content also varied significantly between the floral stages and between the mature fruit parts. The seed showed the highest level of starch (43 g/100 g) This was close to FAO (1949) report that Parkia seed contained 50 g/100 g (dry matter) of starch.

2. Total Soluble Carbohydrates (TSC) and Reducing Sugars (RS)

Generally TSC in the bark showed an opposite trend to that of starch (Fig. 3). The tendency for TSC to increase in the shoot organs during the cold, dry months may be for utilisation in respiration to provide energy for maintenance of the plant during the period.

In the bark the lowest level of starch was obtained in July while the highest levels of TSC and RS occurred in the same month. This may indicate continuous translocation of carbohydrates in their soluble forms to the developing fruits. The stem did not appear to be a major storage organ for carbohydrates during the period.

In both the bark and leaf, RS generally showed similar pattern of variation as the TSC (Fig. 3). In both organs carbohydrates were retained more in their soluble forms.

During floral development it appeared that RS accumulated as the flower developed but dropped later, at maturity. The mature flower yielded nectar which is a sweet sugary liquid. It is obvious that some of the soluble carbohydrates (TSC and RS) were lost through the nectar.

Like TSC, RS decreased in the developing fruit as starch accumulated. Probably both TSC and RS were converted into starch for storage in the developing fruit.

In the mature fruit RS generally decreased in both the husk and pulp but accumulated progressively in the seed. This agreed with Tandon and Kalra (1983). They observed that RS increased in Mango seed after fruit set.

The apparent increase in RS levels in the bark during the cold months may be due to the conversion of starch, during the cold weather, whose concentration dropped at the same time. Similiar observation was reported for RS in the living bark of black locust tree (Robinia sp.) (Siminovitch et al., 1953).

The TSC content varied significantly with the tree in the bark, leaf, flower and mature fruit parts, while only RS in mature fruit parts showed

similar variation with trees. The TSC varied significantly with time in the different organs except the leaves, mature flower and seed. The RS showed similar variation in the organs except the mature flower, seed and between mature fruit parts.

SEASONAL CHANGES IN PROTEIN CONTENTS

In the bark, protein declined rapidly between November and January after which no significant changes were observed until June. Although leaf protein showed a similar, but less rapid trend until April it was significantly higher than protein in the bark. This indicated movement of nitrates (NO_3^-) and amides (NH_4^+) the basic sources of nitrogen for protein synthesis, from the soil to the shoot. Gilliam and Wright (1977) reported a highly significant correlation between dry matter accumulation and both leaf nitrogen and soil nitrates in three Ilex cultivars.

The drop in leaf protein between November and April (Fig.6) was probably due to movement of the substances out of the ageing leaves before defoliation. Koontz and Biddulph (1957) observed that in the bean plant older leaves exported N and protein as they age. Protein from the leaves and bark may move into the developing reproductive organs which showed relatively high protein levels at the same time.

Protein content dropped in the young fruit with time but increased in the seed (Table 1). Mckee (1962) observed that the ripening seeds characteristically

synthesize and accumulate protein especially in peas, beans and pulses. The drop in seed protein at fruit maturity indicated that protein level declined after fruit set. In developing mango fruit (Tandon and Kalra, 1983), similar observations were reported for protein. The initial accumulation of seed protein was similar to Sun et al. (1978). They reported that protein accumulated in the growing seeds of Phaseolus vulgaris L.

The depletion of leaf protein in September and October was consistent, with the observations of Morrison and Pirie (1961) that leaf protein diminished as the leaves of forages mature. Leaf protein also dropped in January - April during the flowering period and increased thereafter. This observation was at variance with Hocking and Steer (1983). They observed that the amount of protein in the vegetative parts of Helianthus annuus, especially the leaves, declined after flowering.

The seed showed an average protein level of 31.64 g/100 g. This was in close agreement with Fetuga et al. (1974) who recorded a protein level of 303 g/kg (i.e. 30.3 g/100 g) in the seed of the same species. Platt (1945) similarly recorded 15 g/100 g of protein while Leung et al. (1968) recorded 32.3 g/100 g, in seed of the same species. Protein level was generally low in both the husk and pulp but high in the seed. During fruit development protein probably moved from these fruit parts and accumulated in the seed.

Both protein and N in the flowers and mature fruit varied significantly with trees. Both constituents also showed significant changes with the month in all the plant parts analysed except the flowers and the young fruit. They varied significantly between the floral stages and between the mature fruit parts.

SEASONAL CHANGES IN MACRONUTRIENT CONTENTS

The data presented in the results showed differences in the patterns of seasonal variation of the nutrients in different organs analysed. There were significant changes in levels of some of the nutrients over the season. High nutrient demand occurred during certain stages of the plant's growth and development.

1. Nitrogen

Nitrogen generally showed a similar trend of changes as protein. Leaf N was higher than the stem (Appendix 6). Steer and Hocking (1983) made similar observations in Helianthus annuus.

During the period between mature flower and mature fruit, N generally accumulated in the vegetative organs. Hay et al. (1953) found in Zea Mays that N decreased from pollination to maturity. Leaf N was highest in "Souri" olive during the cold months (Fahmy, 1958). In this study leaf N was highest in August during the late rains. The drop in leaf N between November and February (Fig.6) was in agreement with Good and Tukey (1967). They observed that N was exported from mature tissues to young growing ones in Chrysanthemum morifolium.

The shoot organs generally showed higher levels of N during the wet season (May - October) than during the dry season (November - April). Slowik et al. (1979) reported that avocado plants grown in low soil mositure showed significantly low N irrespective of the content of the nutrient in leaves, stems and roots.

Nitrogen level was generally low in both the husk and pulp but relatively high in the seed. Draper (1976) observed that during development in the bean plant the most important change was a movement of N into the seeds.

2. Phosphorus (P)

The data (Fig. 7) showed that P was readily mobile and was redistributed among the shoot organs. Leaf P declined during the fruiting period and probably moved into the developing fruit where it accumulated especially in the seed. These observations were in close agreement with Sparks (1977), who reported that fruiting suppressed accumulation of P in leaves of the pecan tree (Carya illinoensis). Both periods of flowering and fruiting did not affect P levels in the bark.

The apparent depletion in leaf P during vegetative growth (May - July) was similar to the observation in Pistachia leaflets where Uriu and Crane (1977) reported rapid drop in P level during leaf expansion.

During fruit development, P generally declined in the young fruit. In the mature fruit P showed a

steady decline in the bark and pulp and progressive accumulation in the seed (Fig.11). Probably P was retranslocated into the seed through the husk and pulp as the fruit attained maturity. Painter and Raese (1965) recorded similar P accumulation in the kernel of walnuts (Juglans regia L.). Average P level in the seed of P. clappertoniana was 1109 mg/100 g. Fetuga et al. (1974) reported an average level of 2463 mg/kg (i.e. 246.3 mg/100 g) in the seed of the same species. Leung et al. (1968) recorded a P level of 384 mg/100 g also in the seed of the same species.

Phosphorus content showed significant changes with time in the bark and leaves. It showed similar differences between the floral stages.

3. Potassium (K)

Potassium showed a similar pattern of changes in both the stem and leaves during the period. Both organs achieved their highest levels of K in July (for leaves) and September (for the bark). There was gradual increase in leaf K as the season progressed until July. McClung and Lott (1956) reported an opposite trend in peach leaves.

During defoliation, K dropped slightly in the bark and rapidly in the leaves. Probably the nutrient was translocated into the floral organs before the aged leaves were shed.

After an initial high level, K eventually dropped in the developing fruit. It increased from the husk

to the seed among the mature fruit parts. The accumulation of leaf K during fruit development (May - July) was in close agreement with Jensen (1978) in wheat and Bengtsson and Jensen (1983) in Cucumis sativa. They reported that K increased in young leaves with the development of flowers and fruits.

Potassium level varied significantly with time in the shoot organs, the young fruit and husk. It was significantly different in the floral stages and mature fruit parts. It only varied significantly between plants in the bark.

4. Magnesium (Mg)

In the bark Mg dropped between November and January after which there was no significant change again until May (Fig.12). Leaf Mg increased until January and then dropped until March. Thereafter no significant change occurred until July (Fig.13). The lowest leaf Mg occurred in August, during harvest. Spiers (1982) reported that lowest leaf Mg in Tipflue Rabbiteye blueberry occurred during harvest.

In the young fruit, Mg showed an initial increase but declined gradually between May and July. It accumulated in the seed of the mature fruit. It was probably transported into the seed from the husk and pulp both of which showed lower levels of Mg than the seed. Magnesium also declined in both husk and pulp during fruit maturity. The average

Mg content of the seed was 6.32 mg/100 g. Fetuga et al. (1974) recorded an average of 3628 mg/kg (i.e. 362.8 mg/100 g) in the seed of the same species.

Magnesium level varied significantly between the trees only in the mature fruit. It showed significant monthly changes in the shoot organs and the young fruit. It was similarly different in the floral stages and the mature fruit parts.

5. Calcium (Ca)

All the organs sampled showed high levels of Ca. High leaf Ca was in agreement with Cannon et al. (1960) in leaves of Quercus palustris.

Calcium accumulated highest in both the bark and leaves towards the end of the late rains (July - October). Bingham (1961) reported a similar trend in Ca accumulation in Avocado leaves. The generally low variation in Ca levels in the organs analysed was in agreement with reports that the element was not readily mobile in plant tissues of Phaseolus vulgaris (Bukovac and Wittwer, 1957, and Ahmad, 1963), in Chrysanthemum morifolium (Good and Tukey, 1967), in peanut fruit (Hallock et al., 1971), in avocado plants (Slowik et al., 1979) and in apple fruits (Jones et al. 1983).

The order of decreasing Ca levels in the organs was observed as Pulp > mature flower > husk > young flower > bark > young fruit > seed > leaf (Appendix 6). Generally higher levels of Ca in the

reproductive organs (flowers and fruits) than in the shoot organs(the bark and leaves) indicated possible export of the nutrient from the shoot into the reproductive organs. The lower leaf Ca was probably due to greater Ca distribution from the foliar organ than from the stem. Ehrler et al. (1958) and Greene and Bukovac (1968) reported that Ca movement in Phaseolus vulgaris involved distribution and redistribution.

Jones et al. (1983) recorded that Ca uptake in developing apple fruits continued from flowering to harvest with a tendency to drop later after fruit growth. In this study it was observed that during reproductive growth Ca generally accumulated in the floral and fruit organs until fruit maturity.

The Ca content of the flowers varied signifcantly with trees and between young and mature flowers. Calcium levels also showed significant changes with time in the shoot organs and the mature fruit parts.

SEASONAL CHANGES IN MICRONUTRIENT CONTENTS

1. Iron (Fe)

The rapid trend of increase and decrease in Fe levels in the shoot organs (Figs. 12 and 13) indicated that the nutrient was readily mobile in the organs. There was a tendency for leaf Fe to accumulate towards the end of the growth season (July - August). Bingham (1961) reported that leaf Fe accumulated in Avocado as the leaves became older. Kelly and Shier (1965) reported a similar observation in leaves of

Taxus media. The leaves also showed upward trends in Fe level between February and April and during July to August. A similar observation was recorded in leaf Fe of Washington Navel orange (Citrus sp.), (Labanauskas et al., 1959).

The decrease in Fe in the shoot organs during the period of reproductive growth may indicate retranslocation of the nutrient into these organs. Similarly the drop in leaf Fe between November and February was probably due to mobilisation and export of the nutrient out of the senescing leaves prior to leaf fall.

The seed average Fe content of 32 mg/100 g was close to Leung et al. (1968) who recorded 33.2 mg/100 g, and Fetuga et al. (1974) who obtained 380 mg/kg (i.e. 38 mg/100 g) both in the seed of the same species.

Iron content showed significant differences between trees, in the flowers and in young fruit. It also showed significant changes with time in the shoot organs. It was significantly different in the young and mature flowers.

2. Zinc (Zn)

In the bark, Zn increased until July. During the same period it declined in the leaf. The definite change in the Zn contents of the shoot organs indicated that the nutrient was readily mobile in them. The drop in leaf Zn and its subsequent accumulation in the bark and the floral organs also indicated that

the element was retranslocated from the leaf into the stem and the developing floral organs. The latter were stronger sinks and generally accumulate higher Zn than the former. Leaf Zn dropped to a constant level during the period of new growth flush (May - June). Uriu and Crane (1977) reported that leaf Zn dropped rapidly during leaf expansion in Pistachia.

High average Zn content in the seed (17 mg/100 g) than Fetuga et al. (1974) was observed. They recorded average Zn level of 62 mg/kg (i.e. 6.2 mg/100 g) in the seed of the same species.

There was significant variation with tree in Zn content of the young fruit. It showed significant changes with time in the shoot organs and in the pulp. The floral stages were significantly different in their Zn contents.

3. Manganese (Mn)

The sustained drop in levels of Mn in both the bark and leaves (Figs.12 and 13) indicated that the element was readily mobile in the shoot organs. The bark generally showed very low levels of Mn. In fact, some of the trees showed zero Mn levels in some months during the period.

Manganese accumulated in both young and mature flowers (Fig.14). During floral development there was a steady decrease in Mn level of the bark and leaves. This probably showed that the shoot organs

supplied Mn to the floral organs during their development.

Some of the Mn from the shoot may have also moved into the developing fruit, especially during defoliation. The nutrient accumulated in the young fruit. In the mature fruit, it accumulated in the husk and dropped in the pulp and seed.

The reproductive organs (Appendix 6) contained about double the level of Mn in the leaves and about six times that of the bark. The floral organs showed similar high levels of Mn. These observations showed that the bulk of the plants' Mn was accumulated in the reproductive organs.

The average level of Mn (58 mg/100 g) in the seed was much higher than Fetuga et al. (1974). They recorded an average level of 70 mg/kg (i.e. 7 mg/100 g) in the seed of the same species. There were significant monthly changes of Mn only in the shoot organs.

4. Lead (Pb)

The apparent accumulation of Pb in the bark (Fig. 7) and its general decrease in the leaves (Fig. 8) during November through January probably indicated that the nutrient was mobilised and exported to the stem before the ageing leaves were shed later.

Lead content increased in the two floral stages but accumulated higher in the mature flowers. The

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drop in leaf Pb during flowering and its increase in the flowers showed that the developing floral organs were strong sinks for the nutrient.

All the mature fruit parts showed higher Pb contents than other organs on a monthly basis. This indicated that Pb was exported more into the fruit. The highest level of Pb was found in the pulp, followed by the seed.

Lead content of the mature fruit varied significantly between trees. Similarly changes in Pb content with time were significant in the shoot organs and within each of the three mature fruit parts. The floral stages and the mature fruit parts showed significant differences in their Pb contents.

5. Copper (Cu)

Copper maintained a constant level in all the organs during the period. These observations were at variance with Labanauskas et al. (1961) in Fuerte Avocado leaves. They reported significant changes in Cu over the season. However, Davidson (1961) reported that Cu did not show significant changes with time in leaves of selected species of ornamental plants.

Further investigation is necessary to clarify this point.

CONCLUSION

The study showed the trends in the monthly variation of the different constituents in different organs of the plant. The constituents varied with the vegetative and reproductive phases of the plant. There was a general depletion of most of the constituents in the shoot during the period of new growth flush and during reproductive growth.

During floral and fruit development starch, protein, [illegible] nitrogen, Mg, Ca, Fe, Pb, Zn and Mn declined in the shoot organs, especially in the leaf. They subsequently accumulated in the reproductive organs. Starch, TSC and protein were particularly high in the pulp and seed of the mature fruit. The reducing sugars, K, Mg, Mn and Pb declined in all the mature fruit parts during fruit set. Iron, Zn and total soluble carbohydrates accumulated in the husk and pulp but declined in the seed. On the other hand starch, protein, [illegible] nitrogen, P and Ca concentrations increased in the seed but dropped in both the husk and pulp.

Total soluble carbohydrate, reducing sugars, K, Fe, Pb and Mn levels increased in both the young and mature flowers during the reproductive phase of the plant. The contents of total soluble carbohydrates, reducing sugars, protein, [illegible] nitrogen, P, Zn and Pb which declined in the young fruit later accumulated

in the mature fruit parts, particularly in the pulp and seed.

During vegetative growth, starch and Pb which declined in the bark, accumulated in the leaves. During the same period total soluble carbohydrates, reducing sugars, protein, nitrogen, K, Ca, Zn and Mn showed upward trends in both the bark and leaves. At the end of the growth season when leaves became older (August - October) leaf starch, total soluble carbohydrates, reducing sugars, protein, nitrogen, P, K and Ca showed declining trends. Some nutrients such as Mg, Fe, Zn, and Pb, however accumulated during the same period.

During senescence (November - February) leaf starch, total soluble carbohydrates reducing sugars, K Mg, and Ca showed high concentrations. However leaf protein, nitrogen, P, Fe, Zn, Pb and Mn decreased during the same period.

During leaf fall (March - May) the leaves showed high levels of starch, reducing sugars, protein, nitrogen, K, Mg and Pb. They also showed declining levels of total soluble carbohydrates, P, Ca, Fe, Zn and Mn. The reproductive organs showed increasing levels of starch, total soluble carbohydrates, reducing sugars, Ca, Fe, Zn and Mn, most of which dropped in the foliar organ during defoliation.

P. clappertoniana has been noted as an important tree crop in the economy of the people, especially in the drier northern part of Nigeria. The seed is used to prepare "dawa-dawa" (a food seasoner) which is distributed to other areas of the country as an important article of trade. When used for food, the seed and the pulp may form important sources of the mineral elements which they store in large amounts. The pulp cake ("garin-dorowa") may be a ready source of energy due to its high content of total soluble carbohydrates.

The mature flower showed high concentrations of most of the minerals, especially Ca, Fe, Zn and Mn. Through its nectar, or when used directly to prepare "kwuli-kwuli" (groundnut cake) it may be an important source of minerals for human nutrition.

The leaves similarly showed relatively high levels of nitrogen, P, K, Mg, Fe and Pb. This makes the litter a useful source of these nutrients to the soil, when used as manure.

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Constituent	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	SE	LSD
1.Starch (g)	2.80	2.61a	2.63a	2.70a	3.31c	3.34c	3.03b	2.30	1.94	3.70	3.90	3.10b	0.16	0.13
2.Total soluble carbohydrates (g)	1.02b	1.03b	1.15b	1.45c	1.40c	1.70c	1.42c	1.58	1.79	0.74a	0.85a	0.85a	0.09	0.12
3.% Reducing sugar	0.41a	0.45a	0.40a	0.50a	0.54b	0.61b	0.75	1.61d	1.69d	1.56c	1.46c	1.30c	0.15	0.09
4.Protein (g)	6.65c	3.73b	2.79a	3.04a	2.31a	3.04a	2.80a	3.97b	4.74	6.05c	6.20c	4.33b	0.41	0.89
5.Nitrogen (mg)	1.06d	0.60b	0.45a	0.49a	0.37a	0.49a	0.45a	0.64b	0.76c	0.97d	0.99d	0.69c	0.07	0.12
6. Phosphorus (mg)	222.00a	222.00a	189.00a	238.00b	284.00b	301.00b	232.00a	354.00c	354.00c	430.00d	525.00	423.00d	28.45	65.32
7. Potassium (mg)	506.00a	506.00a	514.00a	526.00b	529.00b	519.00a	533.00b	551.00	648.00	745.00	835.00	726.00	31.56	14.84
8.Magnesium (mg)	18.00c	18.00c	16.00	13.00b	14.00b	13.00b	13.00b	12.00a	11.00a	12.00a	13.00b	11.00a	0.67	1.64
9.Calcium (mg)	1095.00a	1085.00a	1120.00a	1074.00a	1072.00a	1102.00a	1092.00a	1151.00a	1100.00a	1150.00	1141.00a	1148.00a	8.51	79.20
10.Iron (mg)	63.00d	61.00d	45.00c	43.00c	31.00	25.00	19.00b	15.00a	12.00a	7.00	17.00b	21.00	5.22	3.68
11.Zinc (mg)	11.00a	12.00b	11.00a	12.00b	12.00b	15.00	19.00	20.00c	20.00c	15.00	10.00	9.00	1.13	0.38
12.Lead (mg)	354.00c	370.00	358.00c	310.00b	308.00b	295.00b	311.00b	278.00a	287.00a	314.00	301.00b	335.00	6.11	15.01
13.Manganese(mg)	19.00	16.00	16.00	12.00c	8.00b	6.00b	0.50a	2.00a	2.00a	0.30a	0.50a	13.00c	2.00	2.95
14.Copper (mg)	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	0.00	0.00

Appendix 1 MONTHLY MEANS OF CARBOHYDRATE , PROTEIN AND NUTRIENT CONTENTS (PER 100 g DRY WEIGHT) OF THE BARK (MEANS BEARING THE SAME LETTER ALONG EACH ROW ARE NOT SIGNIFICANTLY DIFFERENT P = 0.05.

Constitutent	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	SE	LSD
1.Starch (g)	2.50a	2.90a	2.20a	3.20a	2.53a	2.70a	3.20a	3.00a	3.30a	3.73	3.30a	3.20a	0.10	1.00
2.Total soluble carbohydrate (g)	3.60b	3.60b	3.95c	4.55d	4.75e	4.73e	4.55d	4.10	3.90c	3.77	3.40a	3.45a	0.14	0.11
3.% Reducing sugar	0.35a	0.26a	0.37a	0.32	0.69	1.13b	1.29	1.62	1.82	2.03	1.03b	1.12b	0.17	0.11
4.Protein (g)	8.00b	8.56b	7.20b	7.71b	6.24a	6.21a	8.43b	9.17c	8.71b	9.09c	7.71b	6.00a	0.31	1.37
5.Nitrogen (g)	1.37b	1.37b	1.27b	1.24b	0.99a	0.99a	1.47b	1.56c	1.54c	1.47b	1.23b	0.96a	0.05	0.25
6.Phosphorus (mg)	653.00b	558.00b	509.00a	600.00b	845.00c	986.00d	1038.00d	954.00d	875.00c	753.00c	617.00b	409.00a	56.46	130.60
7.Potassium (mg)	636.00a	664.00a	682.00b	772.00c	799.00	700.00b	739.00c	869.00d	902.00d	873.00d	705.00c	657.00a	25.27	32.71
8.Magnesium (mg)	9.40a	10.80b	11.00b	9.40a	9.00a	10.00b	10.60b	9.80b	10.00b	8.60a	9.40a	10.40b	0.22	1.31
9.Calcium (mg)	550.00a	620.00b	571.00a	502.00a	597.00b	592.00b	371.00a	589.00b	620.00b	610.00b	611.00b	575.00a	6.12	30.13
10.Iron (mg)	86.00c	40.00	31.00a	24.00a	92.00c	97.00	84.00c	79.00b	84.00c	88.00c	83.00c	68.00b	6.37	11.49
11.Zinc (mg)	16.00b	13.00a	13.00a	11.00a	12.00a	11.00a	11.00a	11.00a	12.00a	15.00b	17.00b	16.00b	0.62	3.09
12.Lead (mg)	340.00d	318.00c	274.00a	259.00	271.00a	270.00a	276.00a	302.00b	320.00c	336.00d	310.00b	336.00d	8.35	14.30
13.Manganese (mg)	30.00	27.00b	26.00b	25.00b	22.00b	20.00a	15.00a	14.00a	18.00a	14.00a	15.00a	13.00a	1.64	7.82
14.Copper (mg)	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	32.00a	0.00	0.00

Appendix 2 MONTHLY MEANS OF CARBOHYDRATE, PROTEIN AND NUTRIENT CONTENTS (PER 100 g DRY WEIGHT) OF THE LEAF.(MEANS BEARING THE SAME LETTER ALONG EACH ROW ARE NOT SIGNIFICANTLY DIFFERENT, P= 0.05).

Constituent	YOUNG FLOWER							MATURE FLOWER					
	Jan	Feb	Mar	Apr	May	SE	LSD	Feb	Mar	Apr	May	SE	LSD
1.Starch (g)	4.90a	5.10b	5.00a	5.20b	5.20b	0.05	0.19	2.00a	2.10a	2.00a	2.00a	0.02	0.19
2.Total soluble carbohydrate (g)	0.98	1.02a	1.06a	1.08	1.12	0.02	0.03	0.87a	0.86a	0.87a	0.89a	0.004	0.03
3.% Reducing sugar	2.34a	2.52a	2.90a	2.79a	3.45	0.17	0.78	1.96a	2.30a	2.27a	2.15a	0.07	0.78
4.Protein (g)	10.42a	9.64a	9.46a	8.73a	8.20a	0.31	2.31	8.15a	6.51a	6.77a	9.00	0.51	2.31
5.Nitrogen (g)	1.70a	1.54a	1.51a	1.40a	1.31a	0.06	0.40	1.31a	1.04a	1.08a	1.44	0.08	0.40
6.Phosphorus (mg)	622.00a	664.00a	620.00a	670.00a	631.00a	9.93	113.76	540.00a	428.00a	480.00a	510.00a	11.30	110.76
7.Potassium (mg)	607.00e	640.00e	685.00c	677.00e	682.00e	13.07	115.28	483.00a	532.00a	560.00a	535.00a	15.53	115.20
8.Magnesium (mg)	10.00c	10.00c	14.00c	10.00c	9.00c	0.10	1.05	8.00a	7.00a	7.00a	7.00a	0.22	1.05
9.Calcium (mg)	1165.00a	1184.00a	1205.00a	1190.00a	1168.00a	8.70	42.24	1215.00a	1230.00a	1215.00a	1200.00a	6.10	42.24
10.Iron (mg)	11.00a	13.00a	15.00a	15.5a	19.00a	1.40	3.36	20.00a	27.00a	25.00a	24.00a	1.66	8.36
11.Zinc (mg)	14.00a	14.00a	5.00a	5.00a	9.00a	0.22	.78	34.00a	34.00a	35.00a	35.00a	0.25	0.78
12.Lead (mg)	319.00a	327.00a	351.00a	330.00a	352.00a	8.30	42.62	346.00a	357.00a	357.00a	370.00a	8.33	45.62
13.Manganese (mg)	53.00c	50.00c	57.00c	56.00c	57.00c	0.06	1.50	61.00a	52.00a	53.00a	54.00a	2.30	15.00
14.Copper (mg)	33.00a	32.00a	34.00a	34.00a	33.00a	0.00	0.00	32.00a	33.00a	33.00a	33.00a	0.00	0.00

Appendix 3 [illegible] OF DIFFERENT [illegible] OF [illegible] (P = 1% & 5%) [illegible] OF [illegible] YOUNG AND MATURE FLOWERS.

([illegible] DUNCAN MULTIPLE RANGE TEST AND NOT APPLICABLE [illegible] P = .05)

	MATURE FRUIT PART														
	HUSK					PULP					SEED				
Constituent	May	Jun	Jul	SE	LSD	May	Jun	Jul	SE	LSD	May	Jun	Jul	SE	LSD
1.Phosphorus (mg)	673.00b	670.00b	631.00b	11.05	166.81	763.00a	794.00a	681.00a	15.94	166.81	726.00c	774.00c	825.00c	23.34	166.81
2.Potassium (mg)	709.00	552.00c	524.00c	47.01	30.64	601.00b	505.00b	586.00b	4.91	30.64	1035.00a	1006.00a	1006.00a	7.89	30.64
3.Magnesium (mg)	5.00a	4.65a	4.45a	0.13	0.63	5.12c	4.85c	4.55c	0.13	0.63	6.40b	5.20b	6.35b	0.05	0.63
4.Calcium (mg)	1174.00a	1200.00a	1243.00	16.43	42.64	1240.00	1150.00a	1225.00a	15.06	42.64	1192.00c	1140.00	1194.00c	14.43	43.64
5.Iron (mg)	26.00a	23.00a	35.00a	2.23	11.24	22.00d	31.00d	29.00d	2.23	11.24	31.00a	35.00a	29.00a	1.44	11.24
6.Zinc (mg)	16.00a	16.00a	18.00a	0.54	2.16	16.00c	17.00c	15.00	0.72	2.16	17.00d	16.00d	17.00d	0.27	1.12
7.Lead (mg)	446.00	432.00a	410.00a	7.08	23.03	470.00	446.00e	462.00e	5.76	23.03	476.00a	492.00	465.00a	6.40	23.03
8.Manganese (mg)	58.00c	56.00c	57.00c	0.47	3.97	56.00a	56.00a	54.00a	0.54	3.97	58.00b	57.00b	55.00b	0.72	3.97
9.Copper (mg)	32.00a	32.00a	32.00a	0.00	0.00	32.00a	32.00a	32.00a	0.00	0.00	32.00a	32.00a	32.00a	0.00	0.00

Appendix 5 MONTHLY MEANS OF NUTRIENT CONTENTS (PER 100 g DRY WEIGHT) OF THE HUSK, PULP AND SEED OF THE MATURE FRUIT (MEANS BEARING THE SAME LETTER ALONG EACH ROW ARE NOT SIGNIFICANTLY DIFFERENT FOR EACH MATURE FRUIT PART) P = 0.05.

CONSTITUENT	ORGAN							
	BARK (125)	LEAF (125)	YOUNG FLOWER (32)	MATURE FLOWER (21)	YOUNG FRUIT (20)	MATURE FRUIT (15)		
						HUSK	PULP	SEED
1. Starch (g)	2.95	3.03	5.08	2.03	16.86	7.07	22.6	43.00
2. Total soluble carbohydrate (g)	1.22	4.03	1.05	0.88	6.91	1.78	9.69	4.63
3. % Reducing sugars	0.96	1.02	2.80	2.17	2.33	1.99	1.12	0.38
4. Protein (g)	4.14	7.86	9.29	7.62	6.46	3.12	3.18	31.64
5. Nitrogen (g)	0.66	1.26	1.49	1.22	1.03	0.50	0.52	5.01
6. Phosphorus (mg)	322.00	742.00	641.00	506.00	754.00	658.00	716.00	775.00
7. Potassium (mg)	595.00	759.00	659.00	546.00	667.00	595.00	598.00	1016.00
8. Magnesium (mg)	14.00	10.00	10.00	7.25	9.96	4.70	4.84	6.32
9. Calcium (mg)	1112.00	591.00	1183.00	1227.00	1180.00	1206.00	1216.00	1175.00
10. Iron (mg)	30.00	72.00	16.00	25.00	18.00	30.00	27.00	32.00
11. Zinc (mg)	14.00	13.00	9.40	34.50	11.00	17.00	17.00	17.00
12. Lead (mg)	319.00	301.00	334.00	368.00	394.00	433.00	477.00	474.00
13. Manganese (mg)	8.11	20.00	56.00	55.25	58.40	57.00	55.00	57.00
14. Copper (mg)	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00

Appendix 6 MEAN CARBOHYDRATE, PROTEIN AND NUTRIENT CONTENTS (PER 100g DRY WEIGHT) ORGANS OF THE WEST AFRICAN LOCUST BEAN (PARKIA CLAPPERTONIANA KEAY (MEANS BASED ON NUMBER OF SAMPLES SHOWN IN PARENTHESIS AND OBTAINED FROM FIVE TREES).