THE EFFECT OF BURNING AND FERTILIZER APPLICATION ON CROP YIELDS AND SOIL CHEMICAL PROPERTIES UNDER SHIFTING CULTIVATION IN SOUTHERN NIGERIA

A Thesis

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by

Godwill Emelike Okoro

In Partial Fulfillment of the

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Department of Soil Science

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ABSTRACT

Laboratory and field studies were initiated on some Southern Nigerian soils to provide a better understanding of bush fallow system and to assess how the Alfisol and Ultisol soils may be profitably cropped for two or more years.

Dry matter yields of secondary bush and forest-type fallows were higher than those of the grass fallow. The length of the fallow influenced dry matter yields but the effect on amount produced was not dominant. Nutrient content per gram of dry residue varied among the fallows as a result of differences in vegetation, climate and age of the fallow. Nutrient storage was least in a grass fallow.

The quantity of ash after burning was generally small, ranging from 310 Kg/ha in the grass to 675 Kg/ha in the forest-type fallow. Recovery of nutrients as ash was less than 41 percent of the amount in the pre-burn residue. In greenhouse trials, only four times the estimated field amount of ash significantly improved maize dry matter yields and K uptake but not the uptake of other elements. The ash was inferior to KH_2PO_4 as a P source but it reduced P adsorption from KH_2PO_4 added to the Ultisol. Per cent Ca recovery by maize was similar for both ash and hydrated lime but the ash had a lower Ca content than the lime.

During burning, temperatures at the soil-litter interface and at the 5 cm soil depth ranged from 60 to 570 C and from 30 to 70 C, respectively. The duration of maximum

temperatures at these zones was less than 15 minutes. Surface samples of the Alfisol and Ultisol soils heated to 200 C in the laboratory were not markedly affected. However, at 400-600 C, their color changed to red hues, organic C was destroyed and the proportion of sand-size particles increased. Maize growth and nutrient uptake evaluated only on the Ultisol were reduced at 200 and 600 C and the reduction at 200 C was statistically significant.

Maize and cowpea yields in the first year on the Alfisol did not differ significantly between mulching and burning. Yield response by maize to any one of the added nutrients was not significant. Cowpea to which no fertilizer was added, did not respond significantly to residual fertilizer. In the second year, maize yields declined slightly and yield difference between residue methods was non-significant. The yield increase due to P was significant.

Maize yields on the Ultisol in the first year did not differ significantly between residue treatments but were one-half and one-third of yields on the Alfisol with and without fertilizer, respectively. Yield increase due to liming was not significant. Cowpea yields and nutrient response were comparable with those on the Alfisol. In the second year, maize yields declined by 32 and 60 per cent of the first year's yields with and without fertilizer, respectively. Yields under burning were significantly higher than those under mulching.

Fallow burning temporarily increased soil pH, organic C, available P and exchangeable bases of the two soils and decreased exchangeable Al estimated only on the Ultisol. As soil pH and base contents of the soils declined with time, exchangeable Al on the Ultisol increased. The decline in the soil properties was similar between mulching and burning and by the end of the second year, the levels of these properties were generally the same for mulching and burning. The nutrient decline was less pronounced on the Alfisol than on the Ultisol.

Fallowing on the short fallows studied had a beneficial effect on yields and this could not be attributed to burning. Mulching may be better than burning since it could minimize erosion, conserve nutrients and eliminate any detrimental effects of burning on soil properties and plant growth.

The Alfisol can support profitable and continuous grain production with modest fertilizer inputs and good crop management. The Ultisol appears capable of producing good maize and cowpea crops in the first year at least. Reasonable maize yields in a second year may be achieved with high nutrient inputs. Maintenance of adequate levels of N and P in both soils, and the reduction of exchangeable Al in the Ultisol may be major limitations to profitable and continuous crop cultivation.

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DEDICATION

To all members of my family for their patience, understanding and support.

To my wife Uchechi and to Ogechi our little "Cutie-pie".

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Chapter 1: General Introduction

1.1 Shifting Cultivation, Forest and Bush Fallow Management Systems in the Tropics.

Shifting cultivation or forest and bush fallow system is still the dominant form of land management in many areas of the low altitude tropics of Africa, Asia and South America. Ruthenberg (1971), described the system as one where a few years of cultivation alternates with several years of fallow. Sanchez (1976), defined it as one in which temporary clearings are cropped for fewer years than they are allowed to remain in fallow. The term "fallow" denotes the time allowed for the vegetation to regrow after cropping or describes the vegetation itself. The two connotations are used in this thesis as considered appropriate.

The practice of shifting cultivation is conducted on nearly 30 per cent of the World's exploitable soil resources. It provides subsistence for over 250 million people or about 8 per cent of the World's population (Hauck, 1974). The land under forest fallow is usually preferred for cultivation to any secondary forest or bush fallows. Thus, the system leads to a continual deforestation and a systematic elimination of the forest effect on climate. To this end, Faulkner and Mackie (1933) considered it a wasteful system.

The extensive literature on shifting cultivation covers a range of information from geographical and anthropological to cultural conditions (Conklin, 1963); economies and physical environment (Forde, 1934) to conservation and development of Africa's natural resources (Harroy, 1949; Worthington 1958). Nye and Greenland (1960), and Jurion and Henry (1969) reviewed the literature on shifting cultivation in South America. Grigg (1974) traced its evolution in relation to other world agricultural systems. The Ibadan seminar of FAO-SIDA on shifting cultivation and soil conservation in Africa (1974) and Sanchez (1976) have all attempted to bring together the diverse information of this aged-old agricultural system.

The classical shifting cultivation in the humid tropics in which the farmer moves from place to place as farms are changed from year to year has given way to a range of transitional systems. These systems depend on various cropping intensities and periods of bush fallow. Various factors such as population pressure and the development of more sedentary culture have resulted in the replacement of the classical practice by bush fallows and various cropping systems with high cropping intensity but shorter periods of fallows. Okigbo (1974) in a survey of the present agricultural system listed four transitional forms:

(a) long term bush fallows in the areas where the population density is low;

(b) short term bush fallows or planted fallows of shorter duration of two to five or slightly more years;

(c) rudimentary sedentary cultivation of often not more than two years of fallow and

(d) permanent or continuous cropping systems or compound gardening in which farm and household refuse, and simple crop rotations are the means of maintaining the fertility of the soil.

In the tropics in general, the transitional systems referred to above are remarkably similar from one area to the other. The farmers clear small plots of land with the aid of the machete and this is done during the dry season. The slashed fallow vegetation residues are then allowed to dry and are latter burned shortly before the onset of the rains. There may be minor variation in the practice adopted due to the differences in geographical environments and cultures. For instance, in some areas of Africa, incompletely burned residues can be reburned, but in the Pacific coasts of Colombia, heavy rainfalls prevent burning. In the latter situation, the residues are used as mulch. The geographical zone, food crops adapted to the area and habits of the people determine the specific crop or array of crops that may be planted. Generally, maize, rice, beans, yams and later cassava are the main crops. These crops are usually multiple or inter-cropped for one or two years before the land is abandoned to revegetate (fallow). The availability of primary forest lands, the population density and other land pressures determine the time allowed for revegetation which could last from four to twenty years. Most soil types are cropped with little regard for the fertility status. The foregoing review is evidence that the practice of shifting cultivation is fairly complex.

1.2 Forest and Bush Fallow System in Southern Nigeria.

In most of Southern Nigeria, farm lands are rotated on a yearly basis without a corresponding movement of homesteads. The slashed parcels of land are allowed to dry before the residues are burned late in February or in early March. Incompletely burned materials could be reburned as is done in the Sudan. In the tropical or derived savanna vegetation in Southwestern Nigeria, shifting cultivation consists of the removal of the grass and of the few shrubs and trees present by cutting and burning. The top soil is then piled up into mounds which vary in size depending on crop type and hoe size. Similar steps are taken in the rainforest areas where yams are planted on mounds and intercropped with maize, beans etc. In the second short cycle of cropping, the mounds give way to narrow ridges carrying maize, beans, peanuts and millets. After these crops are harvested, the land can then be abandoned to the regrowth of tall and coarse grasses in the savanna or to a thicket regrowth in the rainforest. The cycle is repeated after a number of years depending on the pressure on the land.

Generally, two methods of residue management are used where shifting cultivation is practised. In the Pacific coast of Colombia, the forest and bush fallow residues are used as mulch whereas, in most of the other tropical zones, including Southern Nigeria, the residues are burned.

There is a considerable controversy over the merits and demerits of shifting cultivation. The slashing of the fallow and the subsequent use of fire to exploit the tropical environment has been condemned by the FAO (1957) as wasteful in terms of land and human resources. The FAO study cited the system as a major cause of soil deterioration. Watters (1971) cited later FAO and FAO-SIDA (1974) studies which were less vehement in the condemnation of the system but maintained that the system considerably degrades the vegetation. This degradation causes a rapid decline in soil fertility and crop yields. Brinkmann and Nascimento (1973) did not consider residue burning a prudent practice but, believed that it is the cheapest means of bringing a climax forest vegetation to an immediate but temporary economic benefit.

1.3 The Problem

Shifting cultivation or bush fallow system is a stable agricultural system when land is abundant and population density is low. However, populations are increasing in most of the tropics and in Southern Nigeria in particular. This has resulted in the shortening of the time of fallowing or of re-vegetation. As a consequence of the reduction in fallow time, the quantity and quality of the fallow vegetation and residues have diminished. The recovery of leached nutrients from the lower soil depths - a process by which the top soil is enriched - is not being effectively achieved. Therefore, the total amount of nutrients held in the fallow vegetation and consequently contained in the ash where the residues are burned, has become insufficient for prolonged cropping. Thus, there is an urgent need to replace or improve the present agricultural system in order to meet the food needs of the areas concerned. A good understanding of the present system is germane to any replacement or improvement effort. Okigbo (1974), suggested that any alternative system must be viable, culturally acceptable, of less labor and permanently productive.

Within the framework of the above general problem, the present investigation has two main objectives:

1. To study the present agricultural system by

(a) evaluating quantitatively and qualitatively the primary production in typical fallows in representative areas of Southern Nigeria; nutrient storage in the biomass and nutrient recovery as ash.

(b) testing the effectiveness of ash as a source of nutrients and lime to improve crop dry matter yields and mineral nutrition in the greenhouse.

(c) assessing soil temperatures attained during burning in the field and how heating affects soil properties and crop performance in the greenhouse.

2. As intensive cultivation is becoming a common practice and the fertility of the soils is declining, government and other agencies are encouraging the use of fertilizers to boost food production. This study by using field trials on Alfisol and Ultisol soil types and by adopting a maize-cowpea-maize based cropping sequence will assess the productivity of the soils by

(a) comparing mulching with the traditional method of burning of fallow residues:

(b) evaluating fertilizer nutrient responses on the Alfisol and fertilizer and lime responses on the Ultisol soils;

(c) testing the effect of residue management methods and fertilizer application on the chemical properties of the two soils over a two-year period.

Information gathered from the component objectives will help the long term effort of developing a management system that will increase and sustain crop yields on a profitable and continuous basis.

Details of the foregoing objectives are given in the appropriate sections of the thesis.

1.4 The Physical Background and Soils of the Study Areas.

Southern Nigeria as referred to in this thesis embraces the former western and eastern regions of Nigeria. Western Nigeria lies between longitudes 2° 45' and 6° 45' east and latitudes 4° 43' and 9° 15' north. It covers approximately 11,700 square kilometres. It has an average annual rainfall of 1100 - 1500 mm. There are about 8 - 9 months of wetness which begins in mid-March and ends about mid November. The mean annual maximum and minimum temperatures range between 30 - 32 C and 18 - 24 C, respectively. The rainfall is regarded as the most important climatic factor affecting the vegetation which varies from a savanna woodland in the northern fringes to a tropical rainforest in the south (Keay, 1953).

The geology of the area is made up of three major components:

(i) undifferentiated crystalline basement complex of igneous and metamorphic rocks of precambrian age. Slightly more than 50 per cent of the area - mainly northern Savanna and central forest zone is underlain by such rocks.

(ii) largely unconsolidated sandstones - sedimentary deposits of mainly tertiary and to a lesser extent, quarternary ages. These are located in the south.

(iii) recent deltaic deposits also occurring in the coastal regions in the extreme south, Keay (1953).

Smyth and Montgomery (1962), Moormann, Lal and Juo (1975) summarized the major soils of the area as:

a) Alfisols which are moderately to strongly leached, well drained sandy loams to loamy sands derived from metamorphic and igneous basement complex rocks under savannah vegetation in the northern portions.

b) Ultisols - moderately to strongly leached and generally well drained upland soils, sandy loams to loamy sands derived as for (a) under forest vegetation in the central zone and also in the southern and southeastern areas.

Floyd (1969), Uzozie (1971) in Okigbo (1974), and Obi and Tuley (1973) extensively reviewed the physical background of the eastern region. It lies between longitudes 5^{o} 31' and 9^{o} 30' east and latitudes 4^{o} 15' and 7^{o} 05' north. It is rhomboidal in shape occupying approximately 76,334 sq. km. being bounded in the south by the Bight of Biafra, in the north by boundaries of the present states of Kwara, Benue and the northeastern states, in the east by the Cameroon Republic and in the west by the lordly River Niger and its tributaries.

It is a broad strip of country, most of which is less than 122 metres above sea-level. In the coastal areas, there are complex sandy lagoons, barrier beaches, creeks and swamps and north of these, the terrain rises gradually through open flat land broken in several places by ridges, valleys and isolated hills. The mean annual rainfall exceeds 4000 mm in the extreme south and northeast and declines in a central-northwesterly direction to below 1800 mm. The monthly average temperatures range from a minimum of 21 C to a maximum of 32 C. Annual temperature means are above 24 C everywhere but rarely above 29 C.

The vegetation, which is related to the climate, has been modified by human activities such as farming which involves burning, grazing etc. Starting from the coast inland, there are almost parallel vegetation zones of varying widths which consist of:

i) mangrove forest and coastal vegetation of salt water swamp,

ii) lowland tropical rain forest or moist forest,

iii) oil palm belt and derived savannah or woodland/savannah mosaic formed from moist forest vegetation as a result of human activities and

iv) isolated areas of montane vegetation around the Obudu Plateau.

Geomorphologically, there are two striking features:

1) a plateau of false bedded sandstone in the west varying in elevation from 160 to 300 metres. This runs southwards from the University town of Nsukka in the northeast and swings on a hogback to Awgu and Okigwe from where it narrows easterly to Arochuku.

2) a highland area in the extreme west, extending from the Oban Hills east of the lower Cross River basin northwards to the Obudu Plateau, which rises up to 1930 metres.

In describing the soils of the Southeastern part of Nigeria, Jungerius (1964) cited the description of African soils by D'Hoore. On this basis, Jungerius inferred that these soils are a reflection of the effects of the climate, vegetation and other organisms on the underlying parent rocks. These rocks have themselves weathered to varying degrees through time to produce:

(a) Oxisols, developed on the steep slopes of Nsukka-Okigwe and Arochuku escarpment;

(b) Inceptisols (young soils) derived from recently deposited alluvial materials on the banks of the main rivers and in the mangrove swamps of the coastal region;

(c) Alfisols derived from basalt in the upper Cross River region;

(d) Ultisols developed from coastal sediments and

(e) Hydromorphic soils developed on sites prone to periodic water-logging as in the Abakaliki area.

By and large, the Alfisols and Ultisols are, respectively, the major soils of the Southwestern and Southeastern areas of Nigeria where the field experiments were located. Detailed descriptions of these sites and of the soils can be found in the Appendix.

Chapter 2: The Role of Fallows in Shifting Cultivation Areas.

2.1 Review of Literature

2.1.1 *Fallow Biomass and Structural Components.*

The validity of shifting cultivation as an agricultural system derives from its dependence on forest and savannah fallows as the principal repository of nutrients for crop uptake. Such repository essentially involves nutrient accumulation in the vegetation or biomass during the fallow period and the cycling of these nutrients through the soil and back to the vegetation. The presence of such a closed nutrient cycle was recognized by Hardy (1936) in his studies in Trinidad.

Numerous studies have been directed towards quantifying the total biomass of tropical forest fallows and therefore, further elucidating the relations between the soil, fallow and crop yields. Bartholomew *et al.* (1953) in their Zairean studies, Greenland and Kowal (1960) in Ghana, Golley *et al.* (1969) in Panama, and Ovington and Olson (1970) in Puerto Rico as reported by Sanchez (1976) all indicated the constancy of the main forest parts. They reported that about 75 percent of the biomass consists of branches and trunks; 15-20 percent roots; 4-6 percent leaves; and 1-2 percent litter. Other studies by Bartholomew *et al.* (1953) in Yangambi, Jaiyebo and Moore (1964) in Nigeria, Snedaker (1970), and Teargas and Popenoe (1971) in Guatemala have all attempted a quantitative assessment of dry matter production of fallow plants, cultivated crops and the amounts of nutrients accumulated by the fallows. Sanchez (1976) estimated 200 - 400 tons/ha. of dry matter in one such South American forest fallow.

The characteristics, dynamic processes and equilibrium of the forest ecosystem of the humid tropics as well as those changes and processes occurring during fallow when land is uncultivated have been extensively reviewed by Nye and Greenland (1960), Hawkins and Brunt (1965), Moss (1969), Grigg (1974), Mouttapa (1974) and UNESCO (1975).

Okigbo (1977) suggested that the climax vegetation in a tropical rainforest or bush fallow of more than 5 years duration usually consists of a multistoried structure of evergreens or mixtures of evergreens and deciduous trees and shrubs, climbers and herbs. The intensity of growth, complexity and height that may be attained are determined by the number of years of development and extent to which man has used it. In describing the structure of the rainforest vegetation at Bamenda in West Cameroun, Hawkins and Brunt (1965) found 5 strata with the highest layer, mainly of scattered emergent trees 30 to 60m high; a second layer of trees 20-30m high with 60% open canopy; a lower stratum of shorter trees 10-20m high with a discontinuous canopy, below which there was a layer of shrubs and tall herbs 3-4m in height, and finally the lowest layer consisting of herbs and seedlings which were up to one metre in height. A forest of this kind is a biologically stable ecosystem in dynamic equilibrium in which growth is maintained in a closed cycle of nutrients. Nye and Greenland (1960) found that there was a rapid re-establishment of fallow after two to three years of traditional cropping and stated that depending on the dominant plant species, their rates of growth and development, the amount of wood which accumulates in 4-9 years of fallow may exceed 90-200 m^3/ha. The amount of dry wood added yearly may amount up to 12000 kg/ha. Moss (1969) found that up to 20 species of trees and shrubs and over 30 species of climbers and herbs with different depths and patterns of rooting may occur in such forests in humid tropical areas of West Africa. Holdridge *et al.* (1971) reported similar data for tropical America and Asia.

2.1.2 *Fallow and Soil Nutrient Storage.*

Nye and Greenland (1960) reviewed the literature on nutrient storage in typical tropical fallows as well as those stored in soils under such fallows. For the moist evergreen forest areas, a 40 year mature secondary forest in Kade, Ghana had a total N, P, K, Ca and Mg storage of 1831, 126, 819, 2526 and 346 kg/ha., respectively, for vegetational parts ranging from trash to litter. In the Yangambi area, an 18-year secondary forest contained a total of 359, 73, 405, and 501 kg/ha of N, P, K and Ca + Mg, respectively, while a 5 year secondary forest in the same area contained 391, 24, 344 and 293 kg/ha of N, P, K, Ca + Mg, respectively.

In moist semi-deciduous forest zones as in Kumasi Ghana, a 20 year secondary forest contained in leaves, stem and litter a total of 573, 39, 409, 523, and 213 kg/ha of N, P, K, Ca and Mg respectively while a 6 year fallow in Benin, southern Nigeria (predominantly Acioa barteri) tied up 311, 27, 174, 230 and 147 kg/ha of N, P, K, Ca and Mg, respectively. In the dry forest and savanna zones, nutrients stored in the fallow are considerably less as shown by data from southern Rhodesia where total N, P, K, Ca averaged 22, 2, 30 and 14 kg/ha, respectively. Sanchez (1973) also traced the range of N, P, K, Ca, Mg, S, Fe Zn, Mn and Cu in the total biomass of mature forests in Zaire, Ghana, Panama and Puerto Rico.

The foregoing data from various locations show the magnitude of nutrient storage in the fallow biomass of climax or near climax vegetation. It is the magnitude of this nutrient storage that gives the shifting cultivator the potential for developing a successful farming system.

Nye and Greenland (1960) were skeptical of data based on soil analysis designed to estimate the amount of nutrients added to the soil from the fallow vegetation because only a few of such investigations have taken cognizance of sampling errors. However, they recognized that nutrient addition to the soil could be related to the forest fallow age even though nutrient storage in an old forest takes place predominantly in the woody part. Much of this however, is not readily combustible and hence the magnitude of the addition to the soil may not be directly proportional to the age of the forest fallow. These authors as well as Sanchez (1976) have emphasized that the intensity of burning of fallow vegetation is a major variable in such estimations. For example, their study in Ghana of a 40-year old forest showed that burning of the fallow gave large increases of nutrient additions to the soil and these agreed well with the amounts contained in the combustible parts of the vegetation. Laudelout (1954) made similar observations in the former Belgian Congo, as reported by Nye and Greenland (1960), and found a fair agreement between estimates involving soil analyses and fallow plant composition. Greenland and Kowal (1960) working on West African Alfisols in equilibrium with mature forest estimated the magnitude of nutrient storage capacity and established that the top 30 cm layer of soil contained 2.6 times as much total N as the biomass but about the same levels of exchangeable Ca and Mg as the total plant calcium and magnesium. The top soil contained as much as 75 percent of the K in the fallow biomass as exchangeable K but only 9 percent of the biomass P as available P. Both the P and base status of this soil are higher than those of the Ultisols, Oxisols or some Inceptisols. Thus, the relationships in the latter could be different. In conclusion, Nye and

Greenland (1960) reviewing soil nutrient storage stated that the soils of the evergreen forests contain within the first 30 cm layer considerably less of all nutrients than are stored in the mature forest fallow vegetation. Phosphorous may be an exception to this generalization. In the moist deciduous forest type fallow vegetation, these authors noted that the soil type may determine the soil nutrient status. The levels of Ca and Mg in some soils of the moist deciduous forest areas exceeded the levels found in the secondary forest vegetation which was less than 20 years old. These nutrient levels are also comparable with the amounts stored in mature forest. The levels of K and P are comparable with levels in younger secondary forest vegetation. Soils of the rainforest areas which are considerably leached contain less nutrients in the surface horizon than those of the moist semi-deciduous forest. This is due in part to a lower level of organic matter in the former.

There is a dynamic flow of energy and materials in and out of the system under forest cover. These materials consist of some of the nutrients required by plants for growth and development. Two main processes are found in their movement in and out of the system: (a) uptake from the soil and atmosphere by vegetation and (b) removal from vegetation and return to the soil as litter, rain wash, burning and root excretion. Depending on the nature of the vegetation, the soil and climate, and the number of years of growth, the actual amounts of nutrients involved in each process may be considerable. Nye and Greenland in their studies at Kade in Ghana calculated the annual turn-over in nutrients on the basis of percentage total capital stored in vegetation in a 40-year old mixed secondary bush - N 11%; K 32%; C 12% and Mg 18%. The general conclusions from these observations were (i) that the subsoil contributes substantially to nutrients absorbed by plant roots (ii) rain wash from leaves makes a significant contribution of nutrients to the soil (ii) accumulation of nutrients is highest during the first five years following re-establishment of fallow and (iii) considerable amounts of nutrients are held in the wood and are released when the bush or forest trash is burnt. Okigbo (1974) believes that a rapid mineralization of organic matter occurs at the surface and at a temperature of 20-25 C under the forest, humus formation is in equilibrium with mineralization which releases nitrogen and other nutrients.

Gains in the nutrient cycle occur through rainfall, ashes from burning, dust, sea deposition as well as nitrogen fixation by micro-organisms. Losses occur through leaching and erosion, runoff and volatilization of nitrogen and organic sulfur through biological oxidation and burning (Nye and Greenland 1960, Moss 1969). Nye and Greenland (1960) postulated that during the fallow period, more nutrients are accumulated in the standing vegetation than in the soil. There is also evidence that in the forest fallow there is a net transfer of nutrients from subsoil as a result of deeper root penetration. Soils under forest contain more total phosphorus and calcium in the surface horizon than in the lower horizons and the amounts of exchangeable potassium, calcium and magnesium in the soil during fallow are smaller than the amounts in the aerial parts of the vegetation (Mouttapa, 1974). Nye and Greenland (1960) also quantified the nutrients stored in the aerial cover of fallow vegetation and in the soils from diverse locations.

In our prevailing traditional farming systems, fallows are used for the maintenance of soil fertility. Practices such as burning affect the amount of organic residues that are returned to the soil from the aerial parts of the fallow vegetation. Nutrients are carried in the aerial parts of the vegetation and in soil organic matter, sometimes to an extent greater than in the soil. The loss of nutrients as a result of burning could also affect the productivity of the soil.

Land clearing is done by slash and burn techniques in which forest cover may not be completely destroyed since only shrubs, climbers and herbaceous plants are slashed and burnt and large trees or economic trees are left standing. These may continue the nutrient cycling as in the original forest. Burning is said to destroy soil organic matter predisposing it to loss by erosion but at the same time makes nutrients more readily available to crops. However, the extent of destruction of soil organic matter will depend on the intensity and time of burning. The more intense the burn and the drier the material slashed, the more complete the destruction of soil organic matter and the greater the reduction of residual effects of organic residues. Burning may be carried out on residues left on the soil surface or buried in the ground (Hawkins and Brunt, 1965).

2.1.3 *Fallow Management - Burning.*

The rainforest climax vegetation normally has a well developed and intense growth of fallow. Physical management of the slashed material is difficult. Thus, the use of fire is the means by which the enormous amounts of forest material can be handled prior to cultivation. Nye and Greenland (1960) indicated that all the nutrients in the fallow vegetation except nitrogen and sulfur are preserved and returned to the soil in the form of ash. Hence, ash incorporation into the soil could be vital to the shifting cultivator. They summed up the effects of burning as follows:

1) Considerable amounts of nutrient ions from the aforementioned fallow vegetation as well as litter layer are spread in the ash on the surface of the soil in the form of carbonates, phosphates and silicates of the cations, although nearly all the nitrogen and sulfur are lost in gaseous forms.

2) The immediate soil surface is heated and this exerts some direct effect on the biological population, on the physical and chemical properties of the soil colloids, and on the

availability of nutrient ions.

3) The change in pH and nutrient availability may result in a very different microflora from that originally present.

There is little in tropical literature concerning the quantity and chemical composition of the ashes after a tropical forest is burned. Seubert's data (1977) from a burnt 17-year old secondary forest in an Ultisol of Yurimaguas showed an average of 4 tons/ha of ash on a dry weight basis. The true ash and partially burned or charred plant material added approximately 70-14-45 kg of N, P_2O_5, and K_2O/ha, 240 kg/ha of dolomitic lime and substantial amounts of micro-nutrients. Boyle (1973) indicated that burning a 32-year old jack pine forest on a sandy soil in Wisconsin gave ash that averaged about 16 tons/ha of dry matter with a variability among samples ranging from 5 to 54 tons/ha of ash. He calculated that the ash added to the soil about 46 to 595 kg K/ha, 37 to 1128 kg Ca/ha. Neither Boyle (1973), nor Seubert *et al.* (1977) gave an indication of how much dry biomass yielded the estimated quantities of ash. Their data underscore the tremendous variability encountered in studies of this nature.

Nye and Greenland's data (1960, 1964) from the Alfisols of Ghana were used by Sanchez, (1976) to produce calculations which showed that ashes added 1.5 to 3 tons/ha of Ca, about 180 kg/ha of Mg, and 600-800 kg/ha of K. Similar calculations were also made on Ultisols or Oxisols of Yangambi, Zaire and Liberian soils, presumed to be Ultisols,(Nye and Greenland 1960).

Sanchez, (1976) reported making similar calculations on six yellow latosols using the data of Brinkmann and Nascimento (1973) from Manaus in Brazil. Calcium added ranged from 275 to over 600 kg/ha, magnesium 30-80 kg/ha and potassium 90-240 kg/ha. From these data, Sanchez (1976), contended that the lower base status of the Oxisols and Ultisols results in a lower base status of the ash as compared with the Alfisols. However, he indicated that the intensity of the burn is also a significant variable. The determination and comparison of the intensity is not easy, hence the lack of information in literature on this topic. Furthermore, Sanchez (1976) contended that the burning process is less thorough in udic than ustic moisture regimes due to the higher moisture content in the cleared vegetation of the former regime during the period of the burn. There is also evidence that not all the nitrogen is lost during burning as was shown by Seubert *et al.* (1977) in Yurimaguas. The ash included charred materials that contained nitrogen.

b) *Mulching*:

The clearing and burning of fallow vegetation is equivalent to the removal of vegetation which may affect different components of the hydrologic cycle (Lal, 1975). In his extensive review of the role of mulching in tropical soil and water management, Lal (1975) indicated that mulching improves both the physical and chemical properties of the soil. He found that the organic matter content, (an important variable in the maintenance of the fertility status of tropical soils) and cation exchange capacity can be maintained at a high level by mulching. In terms of the physical advantages, he indicated that mulching can significantly control erosion by absorbing the direct impact of rain on the soil. This minimizes runoff losses since infiltration is maintained at its maximum level. Mulching improves the soil moisture regime by decreasing losses due to surface runoff and evaporation. By minimizing the direct impact of raindrops, mulching causes a minimum of crustation and helps to maintain the initial pore space (Lal, 1974). Observations in IITA field trials indicate that mulching influences earthworm activity by facilitating worm casting. Lal (1974), suggested that the high earthworm activity under mulch may account for the higher rate of infiltration in mulched plots. The belief is that worm channels are beneficial in enhancing root penetration and nutrient absorption from soils.

Studies by Lal (1973); Lal and Hahn (1973) suggested that in a tropical environment, mulch can keep soil temperatures more uniform and also decrease the amplitude of diurnal temperature variations.

2.2 Statements of Objectives

Under the prevailing traditional farming systems in several areas of tropical Africa and Asia, the shifting cultivator relies heavily on the nutrients stored in the vegetation to provide him with an alternative to fertilization and liming. Hence, the use of fire to hasten the release of these nutrients as plant ash. This has been described as a convenient and economic means of bringing the climax vegetation to a temporary higher economic value, Brinkmann and Nascimento (1973). A part of this study was therefore designed to assess the quantitative and qualitative roles of the fallows in selected areas of Southern Nigeria. The specific roles investigated included

1. (a) the amounts of plant dry matter from the above-ground parts of the fallow biomass.

   (b) the amounts of plant ashes that could result from the burning of the fallow residues.

   (c) the nutrient potential of the fallow vegetation and ashes, and in particular, the liming value of the ash samples especially on the Onne soil with a low pH.

2. Since burning in the field involves some element of soil heating, an attempt was also made to monitor the magnitude of the temperatures that are reached and so evaluate to what extent the soil surface or the root zone may be affected by heating.

2.3 Materials and Methods

2.3.1 The two field sites chosen were located at Ikenne and Onne in Southwestern and Southeastern areas of Nigeria, respectively.

Ikenne Site: This location lies in the Institute of Agricultural Research and Training Station about 80 kilometres south of Ibadan. The fallow vegetation in this area was dominated by *Eupatorium Odoratum* mixed with some shrubs and trees. The fallow itself was judged to be more than six (6) years old. It lies within the fringes of the savannah and has an annual rainfall of 1500 mm. Local accounts indicated that the site has been under bush but was slashed and uncropped in 1972. Detailed information on the site is given in Appendix I. The soil itself is a member of the Alagba series described as an Oxic Paleustalf and is derived from sedimentary materials in the rainforest zone of Southwestern Nigeria.

The physical and chemical characteristics of the soil are shown on Table 2.1.

Onne Site: This is located in the high rainfall substation of the International Institute of Tropical Agriculture (IITA), about 450 kilometres southeast of Ibadan with an annual rainfall of about 2600 mm. Of the very abundant fallow species, *Anthonata macrophylla* and *Alchornea cordifolia* are the most

TABLE SOME PHYSICAL AND CHEMICAL PROPERTIES OF IKENNE AND ONNE SOILS*

		Ikenne	Onne
Physical Properties:			
(i)	Sand) %	72	67
(ii)	Silt) %	15	15
(iii)	Clay) %	13	18
Chemical Properties:			
(i)	pH (1:1 soil/water)	6.10	4.30
(ii)	Organic carbon	1.56	1.04
(iii)	Total N	0.16	0.10
Extractable cations (me/100 g):			
(iv)	Ca	5.40	0.26
(v)	Mg	2.90	0.09
(vi)	K	0.25	0.07
(vii)	Na	0.16	0.14
(viii)	Mn	0.16	0.02
(ix)	Exchangeable Al	-	1.60
(x)	Bray I-P (ppm)	6.00	26
(xi)	CEC	9.04	2.86

*Data collected from IITA Soil Chemistry/Fertility Units dominant. The vegetation was judged to be over six years old and the detailed information of the site and the soil - described as a Typic Paleudult is shown in Appendix I and Table 2.1 respectively.

2.3.2 *Fallow Plant and Soil Sampling Before Slashing and Burning.*

Both sites described in the foregoing section were selected during late November of 1977. A third site was chosen on the IITA site at Ibadan to represent a primary forest situation although there was no common or dominant fallow or forest species. Hence this fallow is described as a primary mixed-type.

At Ikenne and Onne, metal squares [1x1 m^2] were used to demarcate random sampling sites at which all fallow vegetation was cut up, dried and weighed. At Ibadan, sample sites of 20 x 20 m^2 were subplotted into five units using 2x2 m^2 metal zones. All trash within these squares was cut and treated as for Ikenne and Onne. An estimation was then made of the fallow biomass production on a surface area basis. Subsamples were taken for nutrient analysis.

Soil Sampling: The first set of soil samples was taken two weeks before clearing and burning and another, one day after burning at four random locations within the plots and at depths of 0-7.5 cm, 7.5-15 and 15-30 cm. These locations were maintained throughout the project. Further samples were taken at other periods but spaced out to embrace the entire cropping period.

Procedure for the Ash Sampling:

When the sites at Ikenne and Onne were chosen, the labour for both slashing and burning was provided by the local people most of whom were farmers. Traverses were cut through the selected site in such a way as to demarcate four blocks representing the replicates of the latter established field trials. Four aluminium trays of 1x1 m^2 were placed in each of these blocks where burning was scheduled. This was done prior to the slashing so that samples of the litter could be taken without contamination by that from the floor of the fallow. The site was then slashed.

When the slashed vegetation had dried, 25 1x1 m^2 plots were selected at random, but within the four blocks (or replicates). These 25 units were marked out with the aid of a metal square. The specific field plots of 6 x 5 square metres were then burned on an individual basis by these farmers and in the same way they would have done on their own fields. When sufficient time had been allowed for the soil surface to cool, the powdery solid residue left after the combustible plant parts had been burned was carefully scooped off the soil surface with spatulas and from within the 1x1 m^2 plots described above. Care was taken to avoid mixing this residue - ash with soil. The unburned debris was also separated. Each 1x1 m^2 sample was bagged, later sieved with a 2 mm sieve and weighed. The samples from the four aluminium trays were bagged separately and reserved for analysis in order to compare with those collected from within the 1x1 m^2 units. Later, the 25 subsamples were bulked on a block basis to provide four main ash samples from which subsamples were taken for chemical analysis.

The sample procedure was used at the Ibadan sites except that the sampling area was increased to 4 sq. metres instead of the 1x1 m^2 at Ikenne and Onne.

2.3.2.1 *Soil, Plant and Ash Analysis.*

The soil samples were analyzed for:

(i) pH in water (1:1 soil:water) using a Beckmann Zeromatic pH metre.

(ii) Available P by the Bray No. I Method.

(iii) Exchangeable Al and Total Acidity by the Titration method after extraction with IN KCl.

(iv) Exchangeable cations extracted with IN NH_4OAc.

(v) Organic carbon by Walkley and Black method. Plant and ash samples were analyzed for

i) N by the Kjeldahl's steam distillation method.

ii) Ca, Mg, K, P, Fe, Mn and Zn after digestion with HNO_3 - $HCLO_4$ acid. Ca, Mg, Fe, Mn and Zn were determined on the Atomic Absorption Spectrophotometer [Perkin Elmer model 403]. P was estimated colorimetrically using Bausch and Lomb

Spectrophometer while K was determined by flame photometry. Details are shown in "Selected Methods for Soil and Plant Analysis. IITA Ser. I ed. A.S.R. Juo 1978.

2.3.2.2 *Soil Temperatures during Fallow Burning*

The temperatures reached in the field during the burning of the fallow vegetation were monitored at one selected location in Onne (one of the two field sites). The standing vegetation within an area of 20 x 20 sq. metres was slashed and allowed to dry. During this drying interval, five (5) trenches were dug on this site. These were connected by tunnels wide enough to facilitate movement from one trench to the other. Each trench served as a point of monitoring of temperatures of burning on a 5 x 5 sq. metre zone located within the large block (of 20 x 20 sq. metres). Thus, there were five sites staggered within this area and in such a way that the fire in one location could be prevented from spreading over the entire zone. The Omega portable pyrometer, model 8020, equipped with a general purpose and an extension handle was used to monitor the range of temperatures on the litter surface and top soil. Actual temperatures at 5 cm soil depth at each of the five sites were monitored with the aid of a temprobe temperature test kit having a range of 50-427 C. The means of the temperature reached in all locations and points were then plotted against the average time during which these were reached.

2.3.2.3 *Determination of the Lime Equivalence of Ash.*

After grinding the ash samples collected from Ikenne and Onne to pass through a 60 mesh sieve, triplicate 1.0 gm samples were boiled with HCl following the method of Jackson (1958). The neutralizing or lime equivalence was then calculated after back titrating with NaOH.

2.3.3 *Greenhouse Experiments on the Nutrient and Lime effects of Ash.*

Three greenhouse experiments were conducted to assess the effect of plant ash (collected from Ikenne and Onne) on the production of maize dry matter on the surface soil samples (0-15 cm) collected in these locations. Firstly, using the estimated field amounts, the effect of the ash on the dry matter production of maize was evaluated on the two soil types. On the Onne soil in particular, the effect of the ash as a source of lime was compared with that of hydrated lime.

The maize variety TZPB which was the test crop was planted at the rate of 10 seeds/pot and thinned to 5 plants/pot four days after germination. The pots were watered twice daily to field capacity. The nutrients were added at the rate of 100 ppm of N and P; 50 ppm of K; 15 ppm of Mg and 2-5 ppm of Zn. These were mixed in the appropriate combinations with the soil before adding the ash. The plants were grown for four weeks.

At harvest, the dry matter yields, nutrient concentration and total uptake were estimated.

Separate details of each experiment are given below:

Trial I: The soil used was the Ikenne sample. The main treatments were (a) No Ash; (b) Ash (based on the field quantity calculated on the field (≡ 430 kg/ha). The sub-treatments consisted of control, PK; NK; NP; NPK and NPK MgZn. Experimental design was a split-plot with four replications.

Trial II: The soil sample was the acid soil from Onne. The main treatments were (a) No Ash; (b) Ash (equivalent to 563 kg/ha - field quantity) and (c) lime ($Ca(OH)_2 \cdot 2H_2O$). The lime was added using the amount equivalent to the ash on the basis of its Lime equivalence value (101%, that is 563 kg/ha ash ≡ 568 kg/ha $CaCO_3$ ≡ 412 kg/ha hydrated lime). Sub-treatments of Control; PK; NK; NP; NPK; NPKMg; NPKZn and NPKMgZn were evaluated in a split-plot design of three replications.

Trial III: In this trial, the lime effects of several quantities of the Onne ash placed on the soil surface or mixed with the Onne soil were compared with various levels of hydrated lime ($Ca(OH)_2 \cdot 2H_2O$) which were mixed with the soil. The treatments consisted of:

(i) 563 kg/ha of ash broadcast on the soil surface

(ii) 563 kg/ha of ash mixed with the soil

(iii) 1126 kg/ha of ash broadcast on the soil surface

(iv) 1126 kg/ha of ash mixed with the soil

(v) 2252 kg/ha of ash mixed with the soil

(vi) 250 kg/ha of lime mixed with the soil

(vii) 500 kg/ha of lime mixed with the soil

(viii) 1000 kg/ha of lime mixed with the soil

(ix) 2000 kg/ha of lime mixed with the soil

The experimental design was a randomized complete block of four replications. A blanket application of nutrients was added at the rates stated earlier in order to maintain good growth.

2.3.4 *Effects of Ash on the P Contents of Equilibrium Solution.*

The soil solution is the immediate source of P for plants although there is very little P in this solution throughout the growth period. During the growing season, the soil solution P has to be frequently replenished. Dissolution or desorption from the inorganic solid-phase; mineralization of the organic solid phase and addition of fertilizers are some of the processes by which the soil solution P can be replenished (Robertson, 1980).

In the prevailing traditional farming system in Southern Nigeria, such replenishment can also occur through the process of burning and the resulting addition of plant ash to the soil. The P released into the soil solution reacts immediately with the inorganic fraction of the soil. Wild (1950) as cited by Soper and Racz (1980) suggested that the inorganic P portion may be crystalline compounds of P derived from the parent material or formed as fertilizer reaction products and varying amounts of P absorbed on discrete compounds of Al, Fe and hydrous oxides in acid soils.

The ash from burning contains inorganic P which may be soluble when added to soils. In low pH soils (as is the case in Southern Nigeria) precipitation of relatively insoluble salts, absorption on the particles of soil and occlusion can reduce the solubility of the ash-P. This will prevent P availability to plants and also reduce the solution P concentration. Hence, the study of the direct and indirect effects of addition of ash or the P in equilibrium solution could provide useful information regarding this element which appears to be one of the major limiting nutrients for crop production in the study areas.

To achieve the above objective, a laboratory study evaluated the effect of multiples of the field quantity of ash from Onne - 5X, 10X, 20X and 40X - on the amount of P in equilibrium solution. These amounts of ash were first equilibrated with 500 gm of Onne surface sample for six weeks in the laboratory at field capacity. At the end of this period, 3.0 gm duplicate samples of the mixture were again re-equilibrated for six days with 12.5, 25, 50, 100 and 200 ppm P at each level of the added ash. The P added was obtained from a solution of KH_2PO_4. The suspension electrolyte was 0.01M $CaCl_2$ in a total volume of 30 ml (1:10 soil : 0.01M $CaCl_2$).

Three drops of toluene were added to suppress microbial activity. The suspensions were shaken for one hour twice daily. At the end of the sixth day, the P in solution was determined following the method of Fox and Kamprath (1970). Thus, the direct effect of the addition of ash on solution P and the indirect effects of ash on P in phosphated soil were evaluated.

2.4 Results and Discussion

2.4.1 *The Biomass Primary Production of Selected Fallows.*

The two fallow sites at Ibadan and that at Ikenne in southwestern Nigeria were located within the same rainfall zone. The Onne fallow in southeastern Nigeria was located in the high rainfall forest belt. The forest fallow at Ibadan and the secondary bush at Ikenne were on Alfisol soil types; the grass fallow was on a sandy Inceptisol while the Onne was on a highly leached acid Ultisol. The Ibadan fallows had not been cultivated for nearly sixteen years and so were much older than the six year old bush regrowths at Ikenne and Onne. The selected fallows were representative of the vegetation types in the area and varied from secondary bush at Ikenne and Onne to grass and forest types at Ibadan.

The dry matter production at the Ibadan forest site was almost twice as much as that at the grass site (Table 2.2). The two Ibadan fallows were comparable in respect of time of vegetational growth but differed as a result of the type of vegetation and the fertility of the soil types. The higher dry matter yields at Ibadan forest were therefore associated with the effect of vegetation and soil which is relatively more fertile than that supporting the grass fallow.

The dry matter yields at the Ibadan sites were higher than that at the Ikenne bush fallow site although all three were in the same rainfall zone.. Since both fallows at Ibadan

BLE 2.2 FALLOW DRY MATTER YIELDS; AMOUNTS OF ASH AND THEIR MINERAL COMPOSITION.

.te	Material	Estimated Dry matter kg/ha	N	P	K	Ca	Mg	Zn	Mn	Fe
			Chemical Composition							
			%					ppm		
Ikenne (6 years fallow)	a) Preburn Fallow Vegetation (PFV)	5,610	1.90	0.11	0.89	0.87	0.52	25	143	128
	b) Ash (after burning)	430	0.69	0.29	1.78	3.53	1.93	456	1240	7800
Onne (6 years fallow)	a) PFV	10,088	2.14	0.30	2.18	1.40	0.69	35	859	209
	b) Ash	563	0.91	0.04	3.53	5.94	1.65	470	2500	6700
Ibadan Forest (over 15 years fallow)	a) PFV	45,511	1.27	0.07	0.75	1.46	0.37	78	525	*
	b) Ash	675	0.30	0.95	13.50	17.10	2.65	362	2391	5109
Ibadan Grass (over 15 years fallow)	a) PFV	19,888	0.49	0.04	0.56	0.45	0.20	24	150	*
	b) Ash	310	0.36	0.61	10.30	0.90	3.20	33	1875	4125

ɔt determined.

were older than the Ikenne fallow, time was the major factor that influenced the yields. The forest fallow produced nearly eight times more dry matter than the Ikenne bush on a similar soil type. In this regard, time and the nature of the vegetation at Ibadan forest were major influences which determined the yields. The grass fallow compared with the Ikenne bush produced four times more dry matter although the soil supporting the former fallow was less fertile. For these two fallows, time was more significant than either the soil or the type of vegetation in determining production.

The Onne fallow produced twice as much dry matter as the Ikenne fallow but both were comparable with respect to time. However, they were different in terms of the rainfall, soil and type of vegetation. The Onne site had a higher rainfall (2000 mm/year) compared with the Ikenne, but the Onne soil was less fertile than the Ikenne-Alfisol. Therefore, it seemed that the effect of rainfall and vegetation overshadowed that of the soil. Hence, where the time of vegetational growth was similar, other factors such as the rainfall and vegetation were more significant than the soil in determining dry matter production. These observations confirmed the suggestion by Nye and Greenland (1960) that the luxuriant vegetation in high rainfall areas of the tropics could be a reflection of the efficiency of nutrient recovery by the roots of fallow plants rather than of a rich supporting soil.

The forest and grass fallows at Ibadan produced nearly four and half times, and two times more dry matter respectively than the Onne bush. These differences were probably due to the effect of time, soils and vegetation. The three factors could have accounted for higher yields at Ibadan forest. Only the effect of time and soils would have caused higher yields at the grass site than at Onne, since the grass is usually regarded as a poor fallow species (Sanchez, 1976) compared with the dominant hardy *Anthonata macrophylla* at Onne. Although the effect of time seemed dominant in influencing the biomass primary production, this was not always true. Generally, the effects of the factors named in this discussion were confounded. No one single factor appeared to provide an over-riding influence on the dry matter production. However, when the fallows were grouped in terms of the length of growth of the vegetation, time favoured higher dry matter production for Ibadan sites versus Onne/Ikenne. The latter two fallows are the short, typical and more regularly cultivated types in Southern Nigeria. The primary production in these two cases was low.

2.4.2 *Nutrient Storage in the Fallow.*

The storage of nutrient elements in the preburn fallow vegetation followed the pattern of the biomass yields (Table 2.3). There was, however, no direct dependence of the storage on the yields. The factors which affected the biomass yields may to some extent, influence the nutrient storage. The differences in the amounts of nutrients stored among the fallows

ABLE 2.3 NUTRIENT CONTRIBUTION FROM PRE-BURN FALLOW VEGETATION (PFV) AND ASH FROM SELECTED SITES IN SOUTHERN NIGERIA.

ite	Material	$CaCO_3$ Equivalent (%)	Nutrient Contribution (And % Recovery in Ash)* N	P	K	Ca kg/ha	Mg	Zn	Mn	Fe
) Ikenne	i) PFV	-	107	6	50	49	29	0.14	0.08	0.72
	ii) Ash	76	3 (3)	1 (17)	8 (16)	15 (31)	8 (28)	0.19	0.53	3.40
) Onne	i) PFV	-	216	30	220	141	70	0.35	8.70	2.10
	ii) Ash	101	5 (2)	6 (20)	20 (9)	33 (23)	9 (13)	0.26	1.41	3.80
Ibadan Forest	i) PFV	-	458	26	270	526	134	3	19	**
	ii) Ash	**	2 (0.4)	6 (23)	91 (34)	115 (22)	18 (13)	0.24	1.60	3.50
Ibadan Grass	i) PFV	-	84	7	95	77	34	0.40	2.60	**
	ii) Ash	**	1 (1)	2 (29)	32 (34)	31 (40)	10 (29)	0.10	0.60	1.30

Figures enclosed in brackets represent per cent recovery of the specific elements in the ash.

not determined.

were due to the variability of the nutrient concentrations in these fallow vegetations.

The major elements N, P, K, Ca and Mg stored in the biomass ranged from 84-458; 6-30; 50-270; 49-526 and 29-134 kg/ha of each element, respectively. Phosphorus was the lowest. The forest fallow with the highest biomass yields also had the highest amount of each nutrient stored except P. In this case, there appeared to be some direct relationship between the biomass yields and nutrient storage. However, the grass fallow at the same site as the forest which had the second highest biomass was the third in terms of nutrient storage. Hence, no generalization can be made about the relationship between dry matter yields of the biomass and nutrient storage. It is probable that the quality of the plant species and the fertility status of the forest soil favoured a higher nutrient storage than was obtained at the grass site.

The Ikenne bush fallow had the least biomass yields and also the lowest levels of stored nutrients except for N where it ranked third. Since the rainfall here was the same as at the Ibadan sites, and the soil was similar to that of the forest, the nutrient storage at the Ikenne site may have been limited by the shortness of the fallowing time. Time also may have subsequently affected the biomass yields. Although the Ikenne soil was richer and more fertile than the grass fallow soil, and the plant species relatively better than the grass, yet the grass had a higher amount of stored nutrient probably also due to the effect of time.

The Onne bush fallow had the second highest levels of stored nutrients next to the forest. The P storage was higher than at the forest site. Since Onne was the third highest in biomass yields, again there was no relationship between yields and nutrient storage. The effect of the higher rainfall at Onne than at Ibadan grass or Ikenne bush could have favoured a higher nutrient storage at Onne. The type of fallow plant species and the efficiency of nutrient recovery by their roots as suggested earlier may be additional reasons for the higher storage of nutrients at Onne despite the poor fertility status of the supporting soil.

Since the Ikenne and Onne sites are the more typically cultivated fallows, the results indicate that the nutrient storage in the biomass is relatively low compared with the older and more developed forest site. Time is thus a major factor influencing nutrient storage when the typical fallows were compared with the forest fallow. In spite of the amounts of nutrients stored in the Onne fallow, high rainfall in the area has been shown to be a major contributory factor to nutrient leaching losses from decomposing residues. Therefore, the nutrient storage in the fallows while being reasonable as a source of nutrients can be predisposed to leaching loss which may limit its effectiveness.

It is concluded from the foregoing results that nutrient storage like the biomass yields may be influenced by factors such as vegetation, rainfall and time, but none of these factors was dominant. The extent of nutrient storage is dependent on any or a combination of these. The short fallows at Ikenne and Onne had low nutrient storage indicating that time was a strong factor influencing the magnitude of biomass yields and of nutrient storage.

2.4.3 *Amounts of Ash and Nutrient Recovery.*

The quantities of ash occurring after burning of the fallow vegetations were low and independent of the biomass yields except at the forest site in Ibadan (Table 2.2). Although the two fallows at Ibadan forest and Onne bush produced the higher amounts of ash as well as higher amounts of stored nutrients, there was no direct relationship between the amount of ash and the nutrient storage. These differences and variabilities may have been determined by the type of vegetation and the degree of burning at the sites. The small amounts of ash were partly a reflection of incomplete burning but this generalization was not always true. For example, for the two short fallows, the proportion of ash to the biomass yields (8 per cent) is in agreement with data reported by Nyle (1974) where complete burning had occurred. Therefore, for these short fallows, burning was as thorough as could be expected. The lower proportion (2 per cent) at the Ibadan sites may be an indication of incomplete burning or the nature of the material burned. Other factors such as rainfall, time etc. could also affect the resulting amounts of ash.

The nutrient recovery in the ash was generally small (Table 2.3). Burning caused the loss of virtually all of the N contained in the preburn fallow residues. The proportion of the nutrients in the biomass recovered in the ash was in all cases less than 50 per cent on the average. The nutrient recovery in the Ibadan forest ash was the highest except for N. The recovery in the grass was variable but higher than at the Ikenne site except for the N and P which were higher at Ikenne than at the Ibadan grass site. The Ikenne ash was the poorest in terms of the overall nutrient recovery. The Onne ash-nutrient recovery was higher than that of the Ibadan grass ash except for K and Mg which were higher in the ash at the latter site. The N recovery in the Onne ash was the highest but its P content was comparable to that contained in the forest ash. These variations are not easy to explain since the factors influencing the parameters are confounded.

Burning of the fallow residues is useful since it helps to reduce the amount of fallow litter and provide a clean seedbed. The nutrient potential of the ash resulting from the burning is small as indicated by the above results. The practice of burning may thus not be justified since the ash-nutrients could not be expected to significantly alter the fertility status of the fallow soils. However, the large amounts of unburned residues, undecomposed litter on the fallow floor and the intact roots of the fallow species are probably larger sources of nutrients to the soil. Over 70 per cent of the nutrient storage in the biomass is still unaccounted for. Therefore, these sources could considerably augment the effect of the ash and so enhance the soil fertility status.

2.4.4 *Temperatures of Litter and Soil during Fallow Burning.*

As indicated earlier, temperatures reached during bush fallow burning were monitored only at the Onne site. Measurements were made at the litter-soil interface and at the 5 cm soil depth. The observed trends (Fig. 2.1) showed that a mean temperature peak of 570 C was attained on the litter-soil interface within the first 10 minutes of burning. In practice, the temperatures were monitored at several spots and ranged from 180 to 840 C. In all cases when a peak temperature was reached, this was followed by a rapid decline. The fluctuations observed in the range of temperatures appeared to have been determined by the amount, type and spread of the fallow litter. Where there was a dense spread of litter, the temperature was high and prolonged. Where the material was thinly spread, the burning was brief.

The temperatures reached at the 5 cm soil depth were less variable in comparison with those on the litter-soil interface. They ranged from 28 to 82 C. The peak mean of 70 C was attained within the first 15 minutes of burning. As was the case with temperatures on the litter-soil interface,

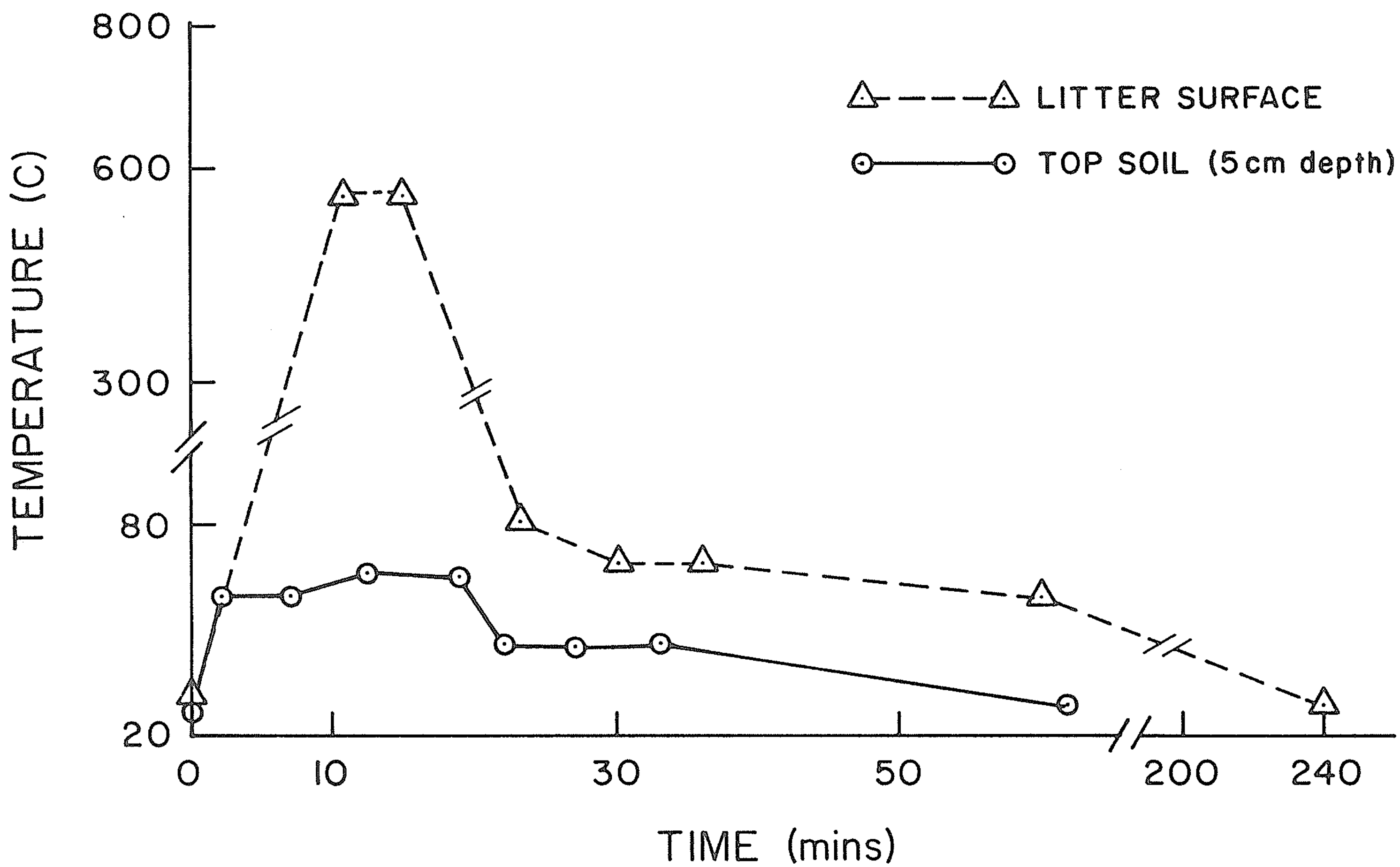

Fig. 2.1 The Magnitude and Duration of Temperatures during Bush Fallow Burning

the peak at each spot was followed by an immediate decline. It was also observed that where there was a considerable amount of litter or heaps of felled wood, soil temperatures at the 5 cm soil depth reached a peak of 90C. Again, the actual values varied according to the amount of litter on the soil and hence the duration during which this litter was completely consumed in the fire. In situations where logs of wood were left smouldering long after the burning, temperatures of over 90 C were attained at a depth of 5 cm of soil. In one situation, a temperature of 162C was monitored at a depth of 5cm nearly twenty-four hours after burning. In this spot, both soil color and texture were changed dramatically. This was probably an indication that very high temperatures could be reached in the zone of the plant roots if the effect of the burning is prolonged as a result of the presence of smouldering wood and the subsequent heat generated therefrom. This situation, however, occurred in very isolated spots. On the field site where a crop trial was later established, the intense heat associated with this kind of prolonged burning of logs of felled *Anthonata macrophylla* was confined to the few spots where actual burning of the logs had started. In the farmer's field, in general, the area covered by these spots would be less than one-tenth of the entire field. The redder hues and change in the texture suggested that only in those isolated spots could the prolonged effect of burning exert a significant impact on the soil.

In general, the temperatures reached at the litter-soil interface and at the 5 cm soil depth were not as high as has been widely thought. Even where the temperatures were high, the duration was short. One could then conclude that in most parts of Southern Nigeria where this system of bush fallow burning is practised, high temperatures may be reached on the surface of the soil in particular, but such temperatures appear to be of short duration. The effect of the heat on the root zone appears to be minimal except in very isolated spots where intense heat can alter the soil color and texture. Probably, this practice of burning does not influence the properties of the surface soil or the root zone to any great extent.

2.4.5 *Greenhouse Studies on the Nutrient and Lime Effects of Ash.*

Trial I: The addition of ash resulted in a slight but insignificant increase in the dry matter yields of maize on the Ikenne soil (Table 2.4). There were favourable responses to N, P, K and MgZn, but only those due to N and P were significant based on the means of the fertilizer treatments.

The ash significantly depressed the root dry matter (Table 2.5). Although all fertilizer elements improved the root weights, only the response to P was significant. The depressive effect of the ash on the root yields at all

TABLE 2.4 THE EFFECT OF FERTILIZER APPLICATION WITH AND WITHOUT PLANT ASH ON THE DRY MATTER YIELDS OF MAIZE GROWN ON THE IKENNE ALFISOL.

Fertilizer Treatments (Nutrient Combinations)	No Ash	Ash*	Fertilizer Treatment Means
	gm/pot **		
Control	4.6	4.8	4.7
PK	10.1	11.3	10.7
NK	5.0	5.4	5.2
NP	13.2	11.9	12.5
NPK	13.1	14.0	13.5
NPKMgZn	12.6	15.0	13.8
Main Treatment Means	9.8	10.4	10.1

Lsd (0.05)

(i) Between Main Treatment means (0.8)

(ii) Between Fertilizer means (1.6)

(iii) Between Fertilizer treatments under one Main treatment (2.2)

(iv) Between Main Treatment yields at the same Fertilizer treatment (2.1)

* Ash added ≡ 430 kg/ha

** Each Yield is a mean of four replicates.

TABLE 2.5 THE EFFECT OF FERTILIZER APPLICATION WITH AND WITHOUT PLANT ASH ON THE ROOT DRY MATTER OF MAIZE GROWN ON THE IKENNE ALFISOL.

Fertilizer Treatments	No Ash	Ash	Fertilizer Treatment Means
	gm/pot		
Control	6.6	4.0	5.3
PK	10.9	10.0	10.4
NK	6.0	5.2	5.6
NP	9.4	8.2	8.8
NPK	9.9	9.4	9.7
NPKMgZn	10.2	9.6	9.9
Main Treatment Means	8.8	7.7	8.3

Lsd (0.05) (i) Between Main treatment means (1.1)

(ii) Between Fertilizer means (1.9)

(iii) Between Fertilizer treatments under one Main treatment (2.6)

(iv) Between Main treatment yields at the same Fertilizer treatment (2.6)

fertilizer treatments cannot be explained.

Ratios of shoot:root increased significantly following the addition of ash (Table 2.6). This result might be expected because the root yields were significantly depressed by the ash resulting in an increase in the shoot/root ratios. Responses to N and P were significant as was the case with the dry matter yields of the plant tops. There was a negative response to K, but like the favourable response to MgZn, it was not significant.

The concentrations of N, P, K, Mg and Zn in the plant were not significantly affected by the addition of ash, but those of Ca and Mn were significantly decreased (Table 2.7). The ash alone (check) significantly increased K concentration, but, at the same time, Ca and Mg concentrations were significantly decreased. The ash probably contributed directly to K content in the plant but had no direct effect on Ca and Mg. Since the addition of ash slightly increased dry matter yields, dilution of Ca and Mg occurred.

A comparison of PK and NPK treatments indicated that N increased the concentrations of the other elements except N, P and K. Other comparisons showed that P decreased the concentrations of the other elements except Mg but had no effect on P concentration in the plant. The effect of added P in increasing dry matter yields may have caused the dilution of the other elements except Mg. There were only slight effects of the other added elements on each other's concentrations.

TABLE 2.6 THE EFFECT OF FERTILIZER APPLICATION WITH AND WITHOUT PLANT ASH ON THE SHOOT/ROOT RATIOS OF MAIZE GROWN ON THE IKENNE ALFISOL.

Fertilizer Treatments	No Ash	Ash	Fertilizer Treatment Means
Control	0.73	1.20	0.96
PK	0.94	1.13	1.03
NK	0.88	1.11	0.99
NP	1.44	1.48	1.46
NPK	1.36	1.50	1.43
NPKMgZn	1.27	1.63	1.45
Main Treatment Means	1.10	1.34	1.22

Lsd (0.05) (i) Between Main treatment means	0.13
(ii) Between Fertilizer means	0.25
(iii) Between Fertilizer treatments under one Main treatment	0.35
(iv) Between Main treatments at the same Fertilizer treatment	0.35

TABLE 2.7 THE EFFECT OF ASH AND FERTILIZER APPLICATION ON NUTRIENT CONTENT OF MAIZE.

Main Treatments	Fertilizer Treatments		N	P	K	Ca	Mg	Zn	Mn
					%				ppm
No Ash	Control		1.50	0.16	1.97	1.14	1.38	39	135
	PK		2.88	0.14	2.59	0.60	0.68	20	105
	NK		3.16	0.13	4.69	0.94	0.83	42	175
	NP		2.89	0.16	0.88	0.88	1.22	27	130
	NPK		2.75	0.13	2.16	0.68	0.84	27	135
	NPKMgZn		2.75	0.13	2.19	0.74	0.85	40	125
	Means		2.66	0.14	2.41	0.83	0.97	33	134
Plant Ash	Control		1.97	0.16	2.47	0.81	1.22	37	115
	PK		3.22	0.15	2.56	0.59	0.78	21	95
	NK		3.15	0.13	4.35	0.80	0.77	40	160
	NP		3.40	0.16	1.00	0.80	1.11	27	115
	NPK		3.06	0.14	2.13	0.71	0.89	26	105
	NPKMgZn		2.71	0.14	2.13	0.61	0.85	36	105
	Means		2.92	0.15	2.44	0.72	0.94	31	116
	Lsd (0.05)	(i)	.37	.02	.30	.05	.14	17	9
		(ii)	.30	.02	.31	.07	.05	3	16
		(iii)	.43	.02	.44	.10	.07	5	23
		(iv)	.53	.03	.50	.11	.15	5	23

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

The addition of ash had no significant effect on the total uptake of any of the nutrients evaluated (Table 2.8). The recovery of these nutrients in the ash has been shown earlier to be small, and this is a further evidence that the ash contributed very small amounts of the elements to the soil. The ash may, however, exert an indirect effect on the recovery of the elements by the plant. For example, in spite of 7 mg N/pot from the ash, there was an increase of 45 mg N/pot as a result of the addition of ash. This was an increase of about 17 per cent. Since N was not limiting, this increase was not significant but resulted indirectly from the increased dry matter yields with ash.

The P contribution by the ash was only 3 mg P/pot and the increase in P uptake due to the ash was very small. Therefore, even the small amount of P in the ash was not readily available during the four-week growth period of the plants in this study. There was an increase in the recovery of applied P-fertilizer when ash was added (18%) yet, there was no beneficial effect attributable to this increase.

The ash contributed 17 mg K/pot and the increase in total K uptake due to the addition of ash was slightly higher (20 mg K/pot). Therefore, more than the ash-K was recovered in the plant tops. The ash probably increased the uptake of K by directly increasing the supply of K to the soil or improved K uptake by indirectly influencing the yields of the dry matter. In the check treatment, there was an increase

TABLE 2.8 THE EFFECT OF ASH AND FERTILIZER APPLICATION ON TOTAL NUTRIENT UPTAKE IN MAIZE.

Main Treatments	Fertilizer Treatments	N	P	K mg/pot	Ca	Mg	Zn	Mn µg/pot
No Ash	Control	71	7	91	49	64	178	621
	PK	292	14	255	60	75	198	1047
	NK	158	6	235	47	42	211	877
	NP	378	21	114	116	161	355	1631
	NPK	359	17	281	88	109	345	1760
	NPKMgZn	344	16	273	93	107	497	1567
	Means	267	14	208	76	93	297	1251
Plant Ash	Control	93	8	117	39	58	174	552
	PK	363	17	286	65	87	237	1057
	NK	170	7	234	43	42	216	887
	NP	412	19	118	92	133	313	1343
	NPK	429	20	296	100	125	354	1460
	NPKMgZn	404	20	318	91	121	537	1574
	Means	312	15	228	72	94	305	1146
	Lsd (0.05) (i)	53	3	25	11	21	42	179
	(ii)	59	3	29	12	6	42	174
	(iii)	83	4	41	17	22	60	247
	(iv)	91	4	44	18	28	67	283

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

of 26 mg K/pot due to the ash. This was greater than the ash-K contribution. This increased K uptake in the plants was not followed by any dilution in K concentration (Table 2.7). Therefore, the addition of the ash had probably a direct effect on K uptake. The slight improvement in the recovery of applied K when ash was added indicates that there may also be an indirect effect but this cannot easily be separated from the direct effect discussed above.

The contributions of Ca and Mg from the ash were 34 and 19 mg/pot respectively. These were quite small and had no effect on the recovery of these elements. Similarly, the Zn and Mn contributions (441 and 1200 mg/pot respectively) were small. The addition of ash did not improve the uptake of the two elements. The addition of 12.5 mg Zn/pot did not improve Zn uptake probably because the plants already had a high Zn content.

Fertilizer N and P significantly increased the total uptake of all nutrients including N and P. The addition of K had no effect on the uptake of N and P, but significantly increased K recovery by the plant. Potassium also lowered the uptake of Ca and Mg. The depressive effect of K on Mg uptake was significant and not even the addition of Mg-fertilizer altered this trend. Barber (1968), had reported that excessive supply of K could depress the uptake of Ca and Mg.

The application of MgZn fertilizer had no effect on the uptake of the other elements.

Trial II: The dry matter yields of the maize were increased when ash and lime were added but only the increase due to the lime was significant as shown by the mean yields of the main treatments (Table 2.9). There were no significant yield differences between the ash and the lime. On the Onne soil used in this study, there were favourable responses to N, P, K and Mg, but only those due to P and K were significant based on the means of the fertilizer treatments. Although responses to Zn and MgZn were negative, they were not statistically significant.

In seven of the eight fertilizer treatments, dry matter yields were higher where ash was added than where it was not - but only the yield differences due to Zn and MgZn were significant. The lime yields were higher in all eight treatments than the check yields, but again, only the yields associated with Zn and MgZn were significantly higher. Therefore, the responses due to Zn and MgZn were associated with the effects of these elements on the yields. The lime yields were in seven out of eight treatments higher than the ash-yields although not significantly different. Therefore, since the lime was only slightly better than the ash, probably, the strong acid used in determining the lime equivalent might have dissolved materials which the soil could not in a few weeks of the study.

The significant yield response to P reported above was consistent for all three main treatments but that observed for

TABLE 2.9 THE EFFECT OF ASH, HYDRATED LIME (HL) AND FERTILIZER APPLICATION ON THE DRY MATTER YIELD OF MAIZE GROWN ON THE ONNE ULTISOL.

Nutrient Combinations (NC)	No Ash	Ash gm/pot**	Lime (HL)*	Nutrient Combination means
Control	3.4	4.3	4.9	4.2
PK	10.9	10.3	11.2	10.8
NK	4.5	5.4	6.2	5.4
NP	9.1	9.9	9.9	9.6
NPK	10.1	11.8	13.2	11.7
NPKMg	12.0	12.7	13.8	12.8
NPKZn	9.1	11.8	12.2	11.0
NPKMgZn	9.1	11.6	11.9	10.9
Main treatment means	8.5	9.7	10.4	9.6

Lsd (0.05)

(i)	Between Main treatment means	1.6
(ii)	Between Fertilizer means	1.5
(iii)	Between Fertilizer treatments under one Main treatment	2.6
(iv)	Between Main treatment yields at the same Fertilizer treatment	2.2

* Lime added ≡ 418 Kg/ha (equivalent to lime in ash)
** Each yield is a mean of three replicates

K occurred only when the soil was limed. Therefore, it is probable that liming by increasing the dry matter yields caused a response to K. Hence, K may become necessary for dry matter production when the Onne Ultisol is limed.

The uptake of N was significantly increased by the addition of either ash or lime as shown by the means of the main treatments (Table 2.10). The difference in the N uptake did not differ between the ash and the lime indicating that the lime effects of ash and hydrated lime were comparable but the N-supplying potential of the ash was not better than that of the lime which was not a N-source. The ash contributed only 12 mg N/pot but adding the ash increased the average uptake of N (main treatments) by 76 mg N/pot and also improved the recovery of fertilizer N. There was a close similarity between the N uptake trends and the yields suggesting that the yields determined the uptake patterns of N. This observation confirms that the effect of the ash on N uptake may be due to the indirect influence resulting from the increase in dry matter yields. Nitrogen may not have been limiting in this study because of the amount applied and the possibility of mineralized N from the soil organic matter. These reasons further confirm that the yields obtained were not limited by N.

The uptake of P was related to the yields in many respects. The addition of ash and lime increased P uptake but only the effect of lime was significant among the main treatments (Table 2.11). There was no difference between the

TABLE 2.10 THE EFFECT OF ASH, HYDRATED LIME AND FERTILIZER APPLICATION ON THE TOTAL UPTAKE OF N BY MAIZE GROWN ON THE ONNE ULTISOL.

Nutrient Combinations (NC)	No Ash	Ash	Lime (HL)	Nutrient Combination means
	mg N/pot			
Control	116	145	181	147
PK	214	246	231	230
NK	179	240	294	238
NP	334	376	421	377
NPK	336	469	532	446
NPKMg	409	459	534	467
NPKZn	342	459	470	424
NPKMgZn	325	475	445	415
Main treatment means	282	358	389	343

Lsd (0.05) (i) Between Main treatment means 48

(ii) Between Fertilizer means 38

(iii) Between Fertilizer treatments under one Main treatment 65

(iv) Between Main treatments at the same Fertilizer treatment 77

TABLE 2.11 THE EFFECT OF ASH, LIME AND FERTILIZER APPLICATION ON TOTAL P UPTAKE.

Nutrient Combinations	No Ash	Plant Ash mg P/pot	Hydrated Lime	Nutrient Combination Means
Control	7	11	11	10
PK	24	23	25	24
NK	8	10	11	10
NP	25	25	29	26
NPK	23	25	33	27
NPKMg	27	28	32	29
NPKZn	21	29	32	27
NPKMgZn	23	28	27	26
Means	20	22	25	22

Lsd (0.05) (i) Between Main treatment means 5

(ii) Between Fertilizer means 4

(iii) Between Fertilizer treatments under one Main treatment 6

(iv) Between Main treatments at the same Fertilizer treatment 7

ash and lime in respect of P uptake. The ash contributed 13 mg P/pot and this resulted in an increase of only 4 mg P/pot (check). The overall increase of P uptake in the trial (main treatments) associated with ash was even lower (2 mg P/pot). Therefore, the ash neither contributed a reasonable portion of its P content nor improved P uptake from fertilizer P. The recovery of P on this soil was as low as on the Ikenne soil. The superiority of the lime over the ash was associated with the effect of the former on the dry matter.

Nitrogen application increased P uptake and the increase was significant when the soil was limed. Phosphorus fertilizer significantly increased P uptake, but the other added nutrients had no effect on the uptake of P. In six of the eight fertilizer treatments, P uptake was higher when ash was added than when it was not, but the increase was significant only when Zn was applied with NPK fertilizer. The uptake of P due to the lime was also higher in six of the fertilizer treatments than with the ash but again, the uptake was significant when Zn was applied with NPK. When the soil was limed, MgZn fertilizer significantly depressed the uptake of P but there was no significant reduction of P uptake due to either Mg or Zn application alone. Therefore, the effect of the combination of MgZn fertilizer on P uptake may be associated with interaction between both elements or their combined effect on P recovery.

The uptake of K was significantly increased when ash or lime was applied but there was no significant difference between the ash and the lime as shown by the main treatment differences (Table 2.12). The ash-K contribution of 45 mg K/pot resulted in a recovery of 22 mg K/pot or 49% of the ash-K (check treatment). The uptake of K in the trial (main treatment means) was increased by 40 mg K/pot. These results suggest that the ash had some beneficial effect in respect of K uptake. This beneficial effect could be a direct contribution of K from the ash, justified by the 49 per cent ash-K recovery or indirectly related to the effect of ash on the yields. Although the addition of ash increased K uptake more than did liming, the utilization of fertilizer K was comparable between the ash and lime. Therefore, the beneficial effect of the ash was small since it was comparable with the lime which was not a K-source.

The addition of ash and lime caused an increase in the uptake of Ca but only the increase due to the lime was significantly higher than that due to either of the other main treatments (Table 2.13). The ash contributed 75 mg Ca/pot while the lime added 334 mg Ca/pot, respectively. The resulting increases in the uptake were 6 and 31 mg Ca/pot respectively. These results suggest that although the effect of ash on Ca nutrition was small, the percentage utilization of Ca was similar between the ash and the lime. The dry matter yields determined the trends of Ca uptake in the plants.

TABLE 2.12 THE EFFECT OF ASH, LIME AND FERTILIZER APPLICATION ON TOTAL K UPTAKE.

Nutrient Combinations	No Ash	Plant Ash mg K/pot	Hydrated Lime	Nutrient Combination Means
Control	113	135	124	124
PK	311	330	281	307
NK	191	217	265	224
NP	147	166	150	154
NPK	254	335	326	305
NPKMg	293	318	322	311
NPKZn	265	312	319	299
NPKMgZn	248	332	318	299
Means	228	268	263	253

Lsd (0.05)	(i) Between Main treatment means	20
	(ii) Between Fertilizer means	31
	(iii) Between Fertilizer treatments under one Main treatment	53
	(iv) Between Main treatments at the same Fertilizer treatment	53

TABLE 2.13 THE EFFECT OF ASH, LIME AND FERTILIZER APPLICATION ON TOTAL Ca UPTAKE

Nutrient Combination	No Ash	Plant Ash mg Ca/pot	Hydrated Lime	Nutrient Combination Means
Control	19	22	45	29
PK	72	78	108	86
NK	22	34	50	35
NP	80	82	110	91
NPK	73	79	112	88
NPKMg	79	78	107	88
NPKZn	73	99	112	95
NPKMgZn	74	74	102	83
Means	62	68	93	74

Lsd (0.05) (i) Between Main treatment means 11

(ii) Between Fertilizer means 12

(iii) Between Fertilizer treatments under one Main treatment 20

(iv) Between Main treatments at the same Fertilizer treatment 22

Magnesium uptake increased significantly as a result of the addition of ash and lime, but there was no significant difference between the means due to both treatments as indicated by the main treatment means (Table 2.14). The trends of Mg uptake followed closely those of Ca suggesting that the dry matter yields also influenced the Mg uptake. The contribution from the ash (21 mg Mg/pot) was small and although some of this may have been released for uptake, the uptake of Mg seemed mainly related to the indirect effect of ash on the yields. Phosphorous and Mg significantly increased the uptake of Mg and the recovery of the Mg from its fertilizer was not improved by addition of ash.

The uptake of Zn increased significantly following the addition of ash and lime, but the difference in the uptake between the ash and lime was not significant (Table 2.15). Despite the significant effect of ash on Zn uptake, the recovery of the Zn from the ash (595 mg Zn/pot) was small (only 12 mg Zn/pot). Although some of the Zn from the ash may have been used, the Zn uptake was significant only when Zn was applied as fertilizer. Only N and P fertilizers (in addition to Zn) significantly increased Zn uptake suggesting that the uptake of Zn may also be related to the yields of the dry matter.

From all of the foregoing results, one can conclude that the ash had no significant effect on the production of dry matter. The nutrient contributions of the ash were small

TABLE 2.14 THE EFFECT OF ASH, LIME AND FERTILIZER APPLICATION ON TOTAL Mg UPTAKE.

Nutrient Combinations	No Ash	Plant Ash mg/Mg/pot	Hydrated Lime	Nutrient Combination Means
Control	14	17	20	17
PK	22	28	28	26
NK	15	21	22	19
NP	28	34	36	33
NPK	25	30	36	30
NPKMg	37	42	52	44
NPKZn	20	36	37	31
NPKMgZn	32	42	45	40
Means	24	31	35	30

Lsd (0.05)	(i) Between Main treatment means	5
	(ii) Between Fertilizer means	6
	(iii) Between Fertilizer treatments under one Main treatment	10
	(iv) Between Main treatments at the same Fertilizer treatment	10

TABLE 2.15 THE EFFECT OF ASH, LIME AND FERTILIZER APPLICATION ON TOTAL Zn UPTAKE.

Nutrient Combinations	No Ash	Plant Ash μg Zn/pot	Hydrated Lime	Nutrient Combination Means
Control	204	216	284	235
PK	391	420	461	424
NK	256	410	450	372
NP	505	515	636	552
NPK	543	677	682	634
NPKMg	534	630	736	633
NPKZn	755	1113	941	936
NPKMgZn	792	1006	1101	966
Means	498	623	661	594

Lsd (0.05)

(i) Between Main treatment means 65

(ii) Between Fertilizer means 116

(iii) Between Fertilizer treatments under one Main treatment 201

(iv) Between Main treatments at the same Fertilizer treatment 198

and could not support an adequate mineral nutrition for the maize. The lime effect of the ash was confounded with the nutrient effects in respect of Ca. The ash was inferior to the lime in many of the compared parameters.

Phosphorous was the most limiting element on this soil and when the soil was limed, there was a response to K. This suggests that when the acid soil is limed, higher yields may result and cause a response not only to P but also to K.

Trial III: This study was used to test the effectiveness of ash to improve dry matter production and mineral nutrition of maize. Several levels of ash and two different methods of placement were evaluated as detailed in section 2.3.3. The ash treatments were also assessed against comparable levels of lime applied to the soil by mixing.

The ash significantly increased dry matter yields when either 1126 kg/ha of ash was broadcast or when 2252 kg/ha of the ash was mixed (Table 2.16). Broadcasting the ash was better than mixing and in the case of the lowest level of ash mixed, the difference was significant.

Dry matter yields increased as the amount of lime was increased up to the 1000 kg/ha rate. The yields obtained with the 1000 kg/ha of lime were significantly higher than

TABLE 2.16 THE EFFECT OF AMOUNTS AND METHODS OF PLACEMENT OF ASH AND HYDRATED LIME ON THE DRY MATTER YIELDS OF MAIZE GROWN ON THE ONNE ULTISOL.

Amount of Ash or Lime kg/ha	Placement Method	Matter Yields gm/pot*
Control	-	8.5
563 (Ash)	Broadcast	10.2
563 (Ash)	Mixed	7.8
1126 (Ash)	Broadcast	10.8
1126 (Ash)	Mixed	9.1
2252 (Ash)	Mixed	10.7
250 (Lime)	Mixed	9.0
500 (Lime)	Mixed	9.8
1000 (Lime)	Mixed	10.5
2000 (Lime)	Mixed	9.7

Lsd (0.05) Between two yield means 1.8

* Mean of four replicates

those of the check. At comparable levels and methods of placement, the yields due to the lime were higher than those due to the ash except at the 2000 kg/ha rate when yields due to the ash were slightly higher. The yields obtained with 500 kg/ha of lime were significantly higher than those obtained with 563 kg/ha of ash.

Nitrogen uptake followed the yield trends. Although the ash appeared to increase N uptake, there were no significant differences among the treatments (Table 2.17). Broadcasting resulted in a higher N uptake than mixing but the difference was not significant.

Liming at 500 kg/ha significantly increased the N uptake but the differences among lime treatments were not significant. At comparable levels and methods of placement, the N uptake was similar between the ash and lime treatments except at 500 kg/ha rate where the uptake of N was significantly higher with lime than with ash.

The addition of ash did not significantly increase P uptake except where 1126 kg/ha of ash was braodcast. However, the effect of the level of ash was related to the placement method. For example, broadcasting the smallest level of ash did not result in a significantly higher uptake of P by maize than broadcasting 1126 kg/ha. However, mixing the smallest level of ash (563 kg/ha) resulted in a significantly lower P uptake than mixing the 1126 kg/ha of ash. Mixing the smallest level of ash also resulted in a significantly lower P uptake

ABLE 2.17 THE EFFECT OF AMOUNTS AND METHODS OF PLACEMENT OF ASH AND HYDRATED LIME ON THE NUTRIENT UPTAKE BY MAIZE GROWN ON THE ONNE ULTISOL.

mount of Ash or Lime kg/ha	Placement Method	Nutrient Uptake N	P	K	Ca	Mg	Zn	Mn
		mg/pot					µg/pot	
Control	-	268	19	252	51	35	810	3980
563 (Ash)	Broadcast	282	21	322	46	45	700	4220
563 (Ash)	Mixed	254	15	311	48	37	740	4230
1126 (Ash	Broadcast	302	22	343	48	51	690	4350
1126 (Ash)	Mixed	284	18	343	53	45	790	4310
2252 (Ash)	Mixed	302	20	422	58	56	910	4880
250 (Lime)	Mixed	286	17	282	62	44	870	4420
500 (Lime)	Mixed	316	18	303	74	49	970	4190
1000 (Lime)	Mixed	306	20	300	86	58	950	3870
2000 (Lime)	Mixed	300	18	303	103	54	920	2390
Lsd (0.05) Between two uptake means under each nutrient		45	3	36	14	4	210	770

than with the check. Similarly, mixing 1126 kg/ha of ash caused a significantly lower P uptake than broadcasting the same level of ash. These results confirm that broadcasting the ash was significantly better than mixing with regard to P uptake.

Liming had no significant effect on the uptake of P although increasing the lime levels up to 1000 kg/ha slightly increased P uptake. However, among the lime treatments, the uptake of P was significantly higher when 1000 rather than 250 kg/ha of lime was applied. Phosphorus uptake when 500 kg/ha of lime was applied was significantly higher than at the comparable level of ash and method of placement. There were no significant differences between the ash and lime at the higher levels and comparable methods of placement.

The uptake of K increased significantly as the level of ash increased and the methods of placement had no effect. Part of this K may have been contributed by the ash. Since the uptake of K was more related to the level of ash added than to the dry matter yields, it seems probable that there was a sufficient K in the system without the ash.

Liming increased K uptake and levels of 500 to 2000 kg/ha were significantly better than the check. There were no significant differences in K uptake among the lime treatments. The effect of the lime on K uptake may be related to the yields. At comparable levels and methods of placement, the K uptake was higher with ash than with lime. Both 1000 and

2000 kg/ha levels of ash caused a significantly higher K uptake than did the lime. This result confirms that the ash may have contributed some of its K content towards the nutrition of the maize.

The ash had no significant effect on the uptake of Ca. As the level of lime increased, the uptake of Ca increased but only the lime levels of 500 to 2000 kg/ha were significantly better than the check. The utilization of Ca, however, decreased as the amount of lime added increased beyond 500 kg/ha (Fig. 2.2). It would seem that not more than 1000 kg/ha of lime may be required on this soil to maintain a desirable level of Ca utilization and still satisfy the need to lower Al saturation on the Onne acid soil.

The uptake of Mg increased significantly as the levels of ash increased indicating that the ash also contributed some of its Mg content. Broadcasting the ash was significantly better than mixing when either 563 or 1126 kg/ha of ash was added.

Liming also increased Mg uptake significantly. As the level of lime increased up to 1000 kg/ha, the uptake of Mg increased significantly. Liming with 2000 kg/ha significantly reduced Mg uptake in comparison with the uptake at 1000 kg/ha of lime. Liming was significantly better than the addition of ash in terms of Mg uptake when the levels used were 500 and 1000 kg/ha. However, at the 2000 kg/ha level, both the lime and ash were similar with respect to the uptake of Mg.

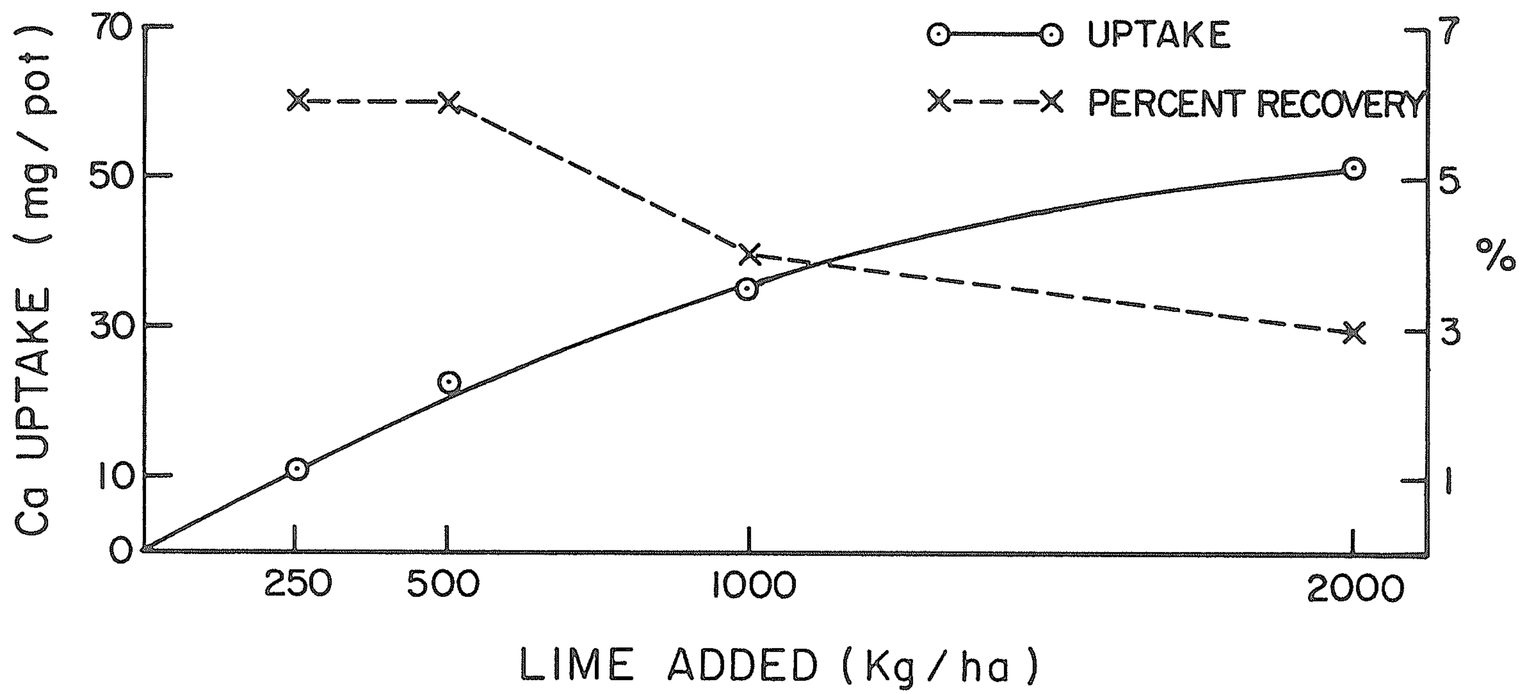

Fig. 2.2 Effect of Liming on Ca Uptake and Recovery by Maize

The uptake of Zn was not significantly affected either by ash or by lime. The uptake of Zn was comparable among all ten treatments. Adding ash increased Mn uptake but only with the 2252 kg/ha level was the increase significant. The method of placement had no effect on Mn uptake. Liming at the lower levels of 250 and 500 kg/ha increased Mn uptake slightly but as the level of lime was increased the uptake of Mn declined. The decline obtained when 2000 kg/ha of lime was applied, was significant. The slight increases of Mn uptake with ash and with lower rates of lime may be due to a better growth while the decline at higher levels of lime might be due to the effect of lime on soil pH. Increasing pH usually lowers the Mn solubility and so decreases its availability and plant uptake.

2.4.6 *The Effects of added Ash and P from KH_2PO_4 on the P Concentrations in Soil Solution.*

Varying levels of ash from the Onne site were incubated with surface soil samples from Onne which had been phosphated with KH_2PO_4. This was done in order to obtain information on the effect of ash on P concentration in the equilibrium solution. Another experiment assessed the P supplying potential of the ash in comparison with inorganic KH_2PO_4 following incubation with Onne surface soil samples. Details of these were described in section 2.3.4.

The addition of amounts of ash varying from 563 up to 22520 kg/ha resulted in an apparent decrease in the adsorption of P from KH_2PO_4 [Fig. 2.3]. Although the patterns of adsorption were variable probably due to the complex nature of the ash, yet all levels of ash decreased P adsorption. The ash could have contributed some P to the equilibrium solution but results in Fig. 2.4 showed that the levels of ash from 563 to 22520 kg/ha did not produce a marked change in the amount of P in solution. However, when comparable amounts of P from KH_2PO_4 were added to the soil, there was a near linear increase of P in solution as added P was increased. The magnitude of the increase of P in solution due to the KH_2PO_4-P ranged from four to ten times more than that due to the ash-P. Although both orthophosphate and pyrophosphate may have been present in the ash, only the free ortho-P was measured. The KH_2PO_4-P was more readily available in solution than the ash-P and so the reduction in P adsorption by ash in Fig. 2.3 was real. The reasons for this effect of ash are not known but, the ash could have blocked the soil's adsorptive surfaces and so reduced P adsorption from KH_2PO_4. Increasing the amount of ash increased the pH of the equilibrium solution (Fig. 2.5). An increase of soil pH has been reported by Juo in literature cited by Friesen (1978) to decrease P adsorption. The pH could have had some effect on the decrease of adsorbed P in this study but the pH effect was not consistent. For example, lower levels of ash decreased P adsorbed adsorbed but the pH change was small. High levels of ash increased pH but the decrease in P adsorption was not directly related to the pH effect or to the amount of ash.

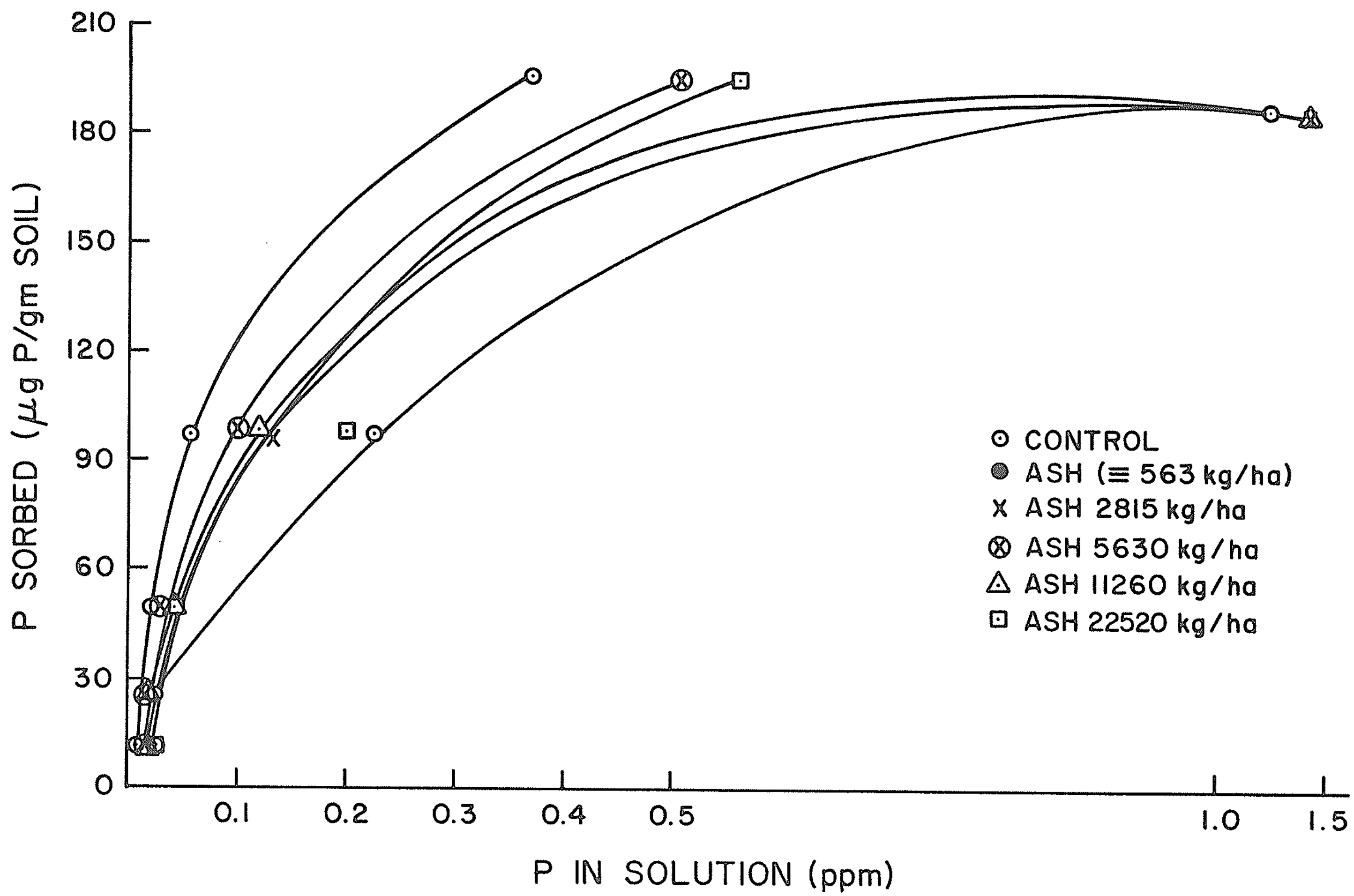

Fig. 2.3 Effect of Ash Levels on P Adsorption in Onne Ultisol

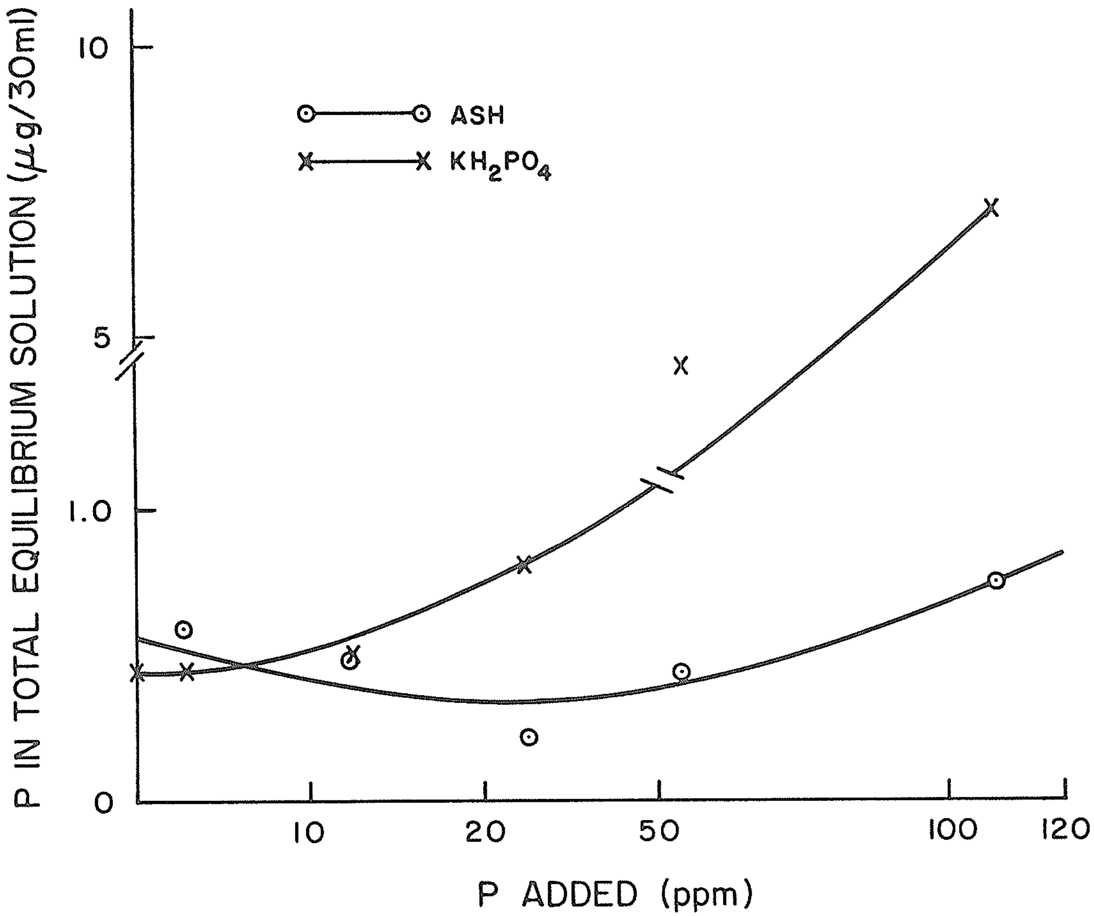

Fig. 2.4 Effect of Amounts of P added from Ash and KH_2PO_4 on P Concentrations in Soil Solution

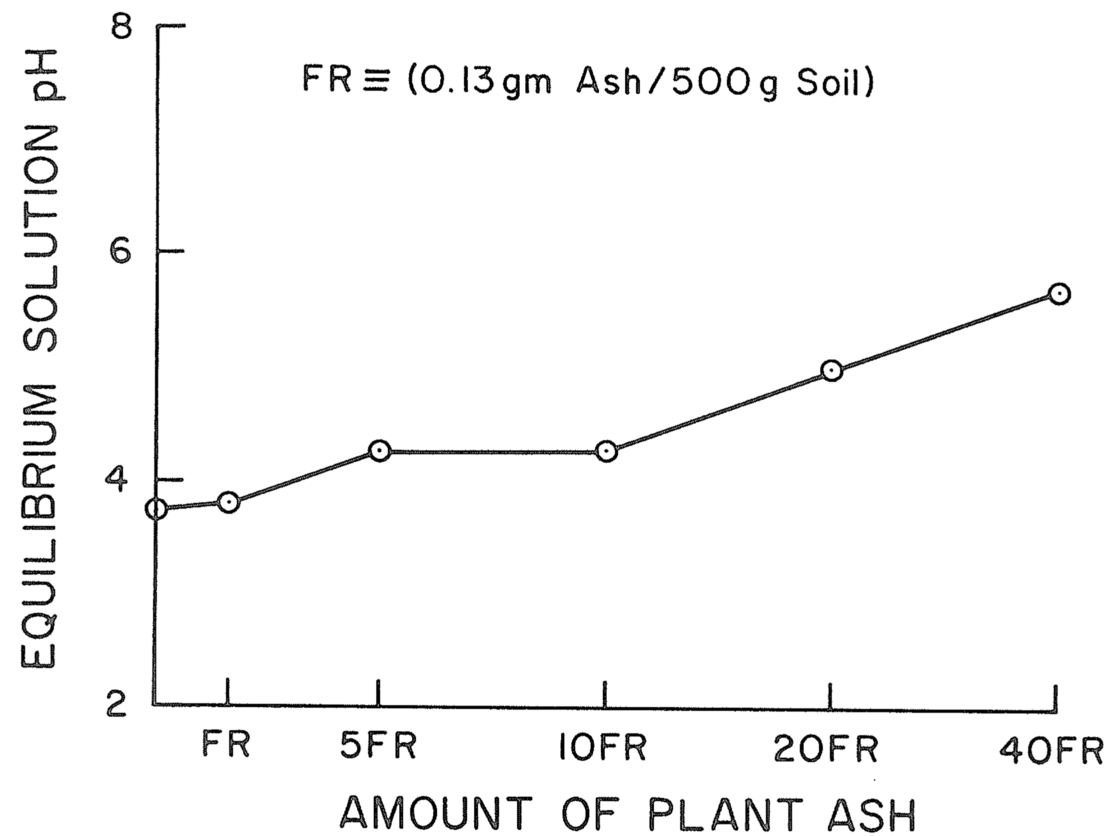

Fig. 2.5 Effect of Amounts of Ash on pH of Soil Solution

As a consequence of the variability in the adsorption patterns reported earlier, calculations of the conventional adsorption maxima and bonding energies for the different ash treatments were not meaningful. These results indicate that relative to a soluble P source, the ash-P was not a good source of P within the period of incubation used. The amount of P recovered in the ash had been shown elsewhere in this chapter to be small; even this small amount was not readily soluble. Although the solubility of the ash-P may have been affected by the short time of incubation, yet results of the greenhouse studies showed that the ash-P availability did not improve with time. Therefore, its solubility in the field may not be much different from that in the greenhouse.

Since the ash at all concentrations reduced the adsorption of P, such a reduction may help to decrease the fixation of fertilizer-P in the field especially on soils like the Onne Ultisol with known high P adsorption characteristics.

2.5 Summary and Conclusions.

Fallow primary production was evaluated at four different sites in Southern Nigeria. The dry matter yields were influenced by factors such as time of growth, type of vegetation, amount of rainfall and fertility of the soil. The effects of these factors were variable and not one factor had an overriding influence on the primary production. However, the dry matter yields were higher at the older fallow sites than at the short and more regularly cultivated ones.

Nutrient storage in the biomass compared well with that reported from similar agro-ecological areas in the tropics. There was a relationship between the fallow dry matter yields and the nutrient storage but the latter was not directly dependent on the former. The factors which influenced the dry matter yields may also affect the nutrient storage but again, there was no dominant effect of any one of the factors. Time appeared to have a strong influence over both dry matter yields and nutrient storage since the two short fallows studied contained small amounts of these compared with the older vegetations.

Burning of the fallow vegetations in preparation for cultivation reduced the amount of residues and thus provided a clean seedbed. Burning also added inorganic nutrients in the form of ash but the quantities of the ash that resulted were generally small and independent of the fallow dry matter yields. The small amounts of ash could be partly a reflection of incomplete burning or the type of vegetation burned. The effects of those factors enumerated above, which affected the biomass yields and nutrient storage could also influence the amounts of ash.

The recovery of each major element (as ash) in the preburn fallow material was small and in all cases below 50%. There was no close relationship between the nutrient storage in the fallow and the recovery in the ash. The loss of virtually all the N in the residues burned was particularly pronounced. In addition to the effect of the factors suggested above, the effects of the degree of burning and the type of plant species burned may account for the results obtained with regard to the recovery of nutrients. These results suggest that the small nutrient contribution from the ash could not be expected to markedly improve the fertility status of the soils irrespective of the type of fallow vegetation. Therefore, the nutrient potential of the ash is probably not the major benefit of burning. The large amounts of unburned residues in the field as well as undecomposed litter on the floor of the fallow and the intact roots of the fallow species may be large sources of nutrients which could considerably augment the effect of ash and so enhance the fertility of the soils.

Temperatures attained during burning were monitored at the litter-soil interface, and at the 5 cm soil depth. Results indicate that temperature increases were variable and of short duration but temperatures up to 570 and 70 C were monitored at the surface and the 5 cm depth, respectively. Actual temperatures attained and the duration for which they continued was found to depend on factors such as the amount and type of slashed vegetation.

The effect of heat per se during the type of burning practised in the area, on the mineralization of soil organic matter may not be as pronounced as is generally thought. The physical and chemical properties of the soil around the root zone may therefore not be altered to any considerable extent. However, where high temperatures are reached and are sustained for long periods, such change may be expected as was observed in isolated spots in the field where felled logs were left to burn for over 24 hours.

Greenhouse and laboratory studies assessed the effectiveness of ash samples, as sources of nutrients and lime, to improve maize dry matter production and mineral nutrition. Using the ash samples from the short typical fallow sites, it was established that the ash had no significant effect on the dry matter yields of maize. Similarly, the ash had no significant effect on the uptake of the major elements applied as fertilizer nutrients. These confirm that the nutrient contribution of the ash was small since its direct effect was not measurable. As a source of Ca, the ash was as good as hydrated lime but the amounts contributed by ash were smaller.

Increasing the levels of ash over the amount obtained at the Onne site improved the dry matter yield of maize when those levels were broadcast rather than mixed with the soil. The uptake of nutrients improved in a similar manner suggesting that the ash could directly contribute its mineral contents such as K and Mg in particular towards the nutrition of maize but the amounts of these elements were still small. Higher levels of ash can only be obtained by concentrated burning of the slashed residues but this is not the prevailing practice in most of Southern Nigeria.

The ash was not as good as $Ca(OH)_2 \cdot 2\,H_2O$, as a lime source. This suggests that the method used to determine the amount of lime to use overestimated the lime equivalent of the ash.

On both Ikenne and Onne soils used in these studies, there were responses to applied major elements especially N, P and K. The strongest response was to P and indicated that P was probably the most limiting element on both soils. The non-significant responses to the other elements suggest that their requirements were either marginal or dependent on the limiting effect of P. The ash was not a good source of this element partly because of the small amount in the ash and partly because of its relative insolubility compared with an inorganic PO_4 source such as KH_2PO_4. Extending the time of reaction of the ash in the soil as was done in the greenhouse did not improve the availability of P from the ash. However, the ash at all levels reduced the adsorption of P from the inorganic PO_4. Such a reduction may help to decrease the fixation of fertilizer-P in high P-fixing soils as the Onne Ultisol.

Liming the Onne soil up to 1000 kg/ha increased dry matter yields of maize and improved mineral uptake probably as a result of a favourable soil pH. Liming also resulted in a response to K suggesting that K may be required for dry matter production when the Onne soil is limed. It was also postulated that not more than 1000 kg/ha of the lime may be required on the Onne soil to maintain a desirable level of Ca and still satisfy the need to lower Al saturation to non-toxic levels.

Chapter 3: Effect of Soil Pre-heating on some Physical and Chemical Properties of Soils and Maize Performance

3.1 Introduction and Literature Review.

The use of fire in the management of natural ecosystems is a dominant land management method in many areas of the low altitude tropics. In Nigeria, it is the means by which the traditional farmer handles an enormous amount of precleared forest fallow in order to obtain a clean seedbed.

The magnitude and extent of soil heating during firing may be influenced among other things by the type and amount of cleared vegetation. Temperatures attained during field burning have been discussed in an earlier section of this study. Generally, burning or heating of soils affect the physical, chemical and biological components of soils (Nishita *et al.* 1970). These in turn, could influence the fertility of the soils.

The physical changes wrought by soil heating are those of texture, structure, water-holding capacity etc. Bouyoucos (1924), indicated that soils heated at high temperatures showed a reduction in clay content and an increase in larger size fractions. Similar observations have been made by Nishita *et al.* (1970), Sertsu and Sanchez (1978). Critical temperatures at which certain physical attributes may be altered have also been observed. Bouyoucos (1924) found that the heat of wetting, unfree water and plasticity began to change appreciably at about 230 C, reduced significantly at 485 C and were destroyed completely above 800 C. Rao and Wadahawan (1955) showed that the liquid and plastic limits as well as plasticity index decreased progressively up to 360 C while the soil becomes non-plastic above this temperature. Heyward (1938) reported that organic matter charring within the soil begins in the temperature range of 177 - 204 C. Nishita *et al.* (1970) observed various color gradations from brown to red for soils heated to 1000 C.

The chemical changes brought about by soil heating are associated with the solubility of a number of soil constituents. Kelly and McGeorge (1913), Johnson (1919) showed that heating up to 250 C generally increases soluble components which again decrease upon further heating. Johnson (1919) also found a slight increase around 350 C. Kelly (1914) and Gustafson (1922) observed that certain soluble constituents may not continue to increase up to 250 C and in fact found a gradual disappearance of nitrate between 200 - 250 C. Nishita *et al.* (1970) found that heat had variable effects on pH which decreased at 200 C but increased at higher temperatures. Organic matter content decreased with increasing temperatures above 200 C but was not completely oxidized until about 800 C. Total N content was related to the organic matter content since N is a component of soil organic matter. A lower temperature of soil heating increased inorganic N, Sertsu and Sanchez (1978).

Sreenivasan and Aurangabadkar (1940), Rotini *et al.* (1963) reported a progressive decrease of cation exchange capacity with increasing temperature.
These are associated with changes in organic matter, particle size distribution and dehydration of clay colloids and gels. Sertsu and Sanchez (1978) reported increases in available P, Fe and Mn at lower temperatures. Kang and Sajjapongse (in press) obtained similar results and reported marked increases in extractable P, Zn, Mn and Fe at 200 C and pronounced reductions in total N, organic carbon, organic P, extractable Mg and Ca. Nishita *et al.* (1970) found that the extractabilities of K and Ca remained fairly constant to about 300 or 400 C and then decreased with increasing temperatures. The extractability of Mg decreased when the soil was heated to 100 C, but increased at 600 C. In general therefore, heating a soil to very high temperatures may be detrimental to its fertility.

Nishita *et al.* (1970) reported reduction in bean growth in soils heated to high temperatures. Kang and Sajjapongse (in press) showed plant height and dry matter yield of rice to be higher when the soil was heated to 100 C but found no beneficial effect of heating with N, P and K addition. Furthermore, Nishita *et al.* (1970) found that Ca uptake decreased with increasing soil temperature as did Ca extractability. The uptake of Mg did not agree with the amount extractable suggesting the presence of other factors such as complementary ion relationships. The uptake of K was found to increase following heating of soils to temperatures up to 350 C and to decrease upon heating to higher temperatures. Its reduced uptake was suggested to be due to fixation and the fusion of soil particles at high temperatures. The uptake of P and Zn was little affected at lower temperatures but increased when the temperatures increased. Nishita *et al.*(1970), observed increased Mn uptake following heating of soils to about 300 C and a progressive decrease when the soil was heated to higher temperatures. These observations were attributed to probable changes in manganese solubility which in turn may have been related to its oxidation states. Kang and Sajjapongse (in press) also reported increased Mn uptake by rice following heating of soil to 200 C.

3.2 Study Objectives.

Since bush and forest fallow burning will probably remain the dominant system of land management in most of Southern Nigeria, an understanding of the direct affect of soil heating on soil properties is vital. In addition, the indirect influence of the heat on crop performance needs to be ascertained. This study was set up to achieve the above objectives and also to assess the effect of fertilizer application on crop performance on heated soils.

3.3 Materials and Methods

3.3.1 *Soil Heating and Analyses*

Two surface soil samples (0-15 cm) from Ikenne (Oxic Paleustalf) derived from metamorphic igneous basement complex rocks and Onne (Typic Paleudult) derived from tertiary and quarternary sediments were chosen for the heating experiment. These two soils were chosen because of the physical and chemical differences between them.

Experiment I. Effect of Heating on some properties of Ikenne and Onne Soils.

The collected samples were air dried and sieved through a 2mm sieve. Three hundred (300) gm triplicate samples were heated at temperatures of 60 and 100 C in the oven and at 200, 400 and 600 C in a muffle furnace. At each temperature, three times of heating, namely, 6, 12 and 24 hours were used. At the end of each time interval, samples were removed, allowed to cool and sub-samples were taken for the following determinations:

(i) Moist color using a Munsell color chart.

(ii) Particle size distribution by Bouyouco's hydrometer method.

(iii) Soil pH (1:1, soil:water) using a Beckmann Zeromatic pH meter.

(iv) Available P by the Bray I-P method.

(v) Organic Carbon (%) by Walkley and Black method.

(vi) NH_4-N by the regular Kjeldahl steam distillation method; NO_3-N by the brucine method of Greweling and Peech.

(vii) Exchangeable Al (in Onne soil) by extraction with IN KCl and titration of the leachate with NaOH.

(viii) Extractable cations (Ca, Mg, K and Mn). These were extracted with IN NH_4OAc at pH 7.0 and Ca, Mg and Mn determined by atomic absorption while K was estimated by a flame photometer.

(ix) Micronutrients (Zn, Fe and Mn). These were extracted with 0.1 NHCl and determined by atomic absorption.

Experiment II.

Batches of the Onne acid soil were passed through a 2mm sieve and then heated in porcelain dishes at temperatures of 100, 200 and 600C for six hours until sufficient quantities were obtained for a plant growth experiment. These temperature levels were the main treatments. Subtreatments consisted of fertilizer combinations of check, NPKCaMg Zn S; PK Ca Mg Zn S; NK Ca Mg Zn S; NP Ca Mg Zn S; NPK Mg Zn S: NPK Ca Zn S ; NPK Ca Mg S and NPK Ca Mg Zn. The experimental design was a split-plot of three replications. These elements were added from a mixture of their salts as considered appropriate for each treatment.

Nitrogen at 100 ppm was added as $NH_4H_2PO_4$ and NH_4NO_3; P at 100 ppm as $NH_4H_2PO_4$ and NaH_2PO_4; K at 50 ppm as KCl; Ca and Mg at 20 ppm each as $CaCl_2$ and $MgCl_2$, respectively;

Zn at 2.5 ppm as $ZnSO_4$ and ZnEDTA; and S at 10 ppm as $ZnSO_4$ and Na_2SO_4. The correct amounts of the salts were mixed with the soil (500gm/pot). The soil was watered to field capacity and then incubated for four days. Five seeds of maize, cultivar TZB, were planted in each pot. Seven days after germination, the plants were thinned to three per pot. The pots were watered twice daily to bring the soil to field capacity.

Plant heights were measured at 2, 3 and 4 weeks after planting (WAP). At the end of the fourth week, the plant tops were clipped at about 2cm from the soil surface, washed, dried and weighed for the dry matter vields. The oven-dried samples (65 C) were digested in HNO_3-$HClO_4$ acid mixture and assayed for nutrient concentration and total uptake by methods described elsewhere in this thesis.

3.4 Results and Discussion

3.4.1 *Effect of heating on the soil physical properties.*

(a) *Soil Color:* Heating the soils to 100 C did not cause any visible color change but heating to 200 C resulted in a substantial darkening of the two soils (Table 3.1). The change of color at 200 C was an indication that some organic matter charring had begun as suggested by Heyward (1938). Heating to 400 and 600 C for 12-24 hours resulted in a reddening of the soils. The intensity of the red hue decreased from the surface of the crucible to the bottom. These observations are in agreement with the results of Nishita *et al.* (1970). The color changes at high temperatures were attributed to the loss of organic carbon and to changes in the oxidation and hydration states of Fe and probably Mn compounds (Nishita *et al.* 1970; Sertsu and Sanchez, 1978).

(b) *Particle Size Distribution:* There were no appreciable changes in the particle size distribution when the two soils were heated up to 200 C for 6-24 hours (Tables 3.2 and 3.3). When the soils were heated to 400 and 600 C, the sand content increased in both soils; the silt content decreased only in the Ikenne soil but was unaffected in the Onne soil. At the high temperatures, the clay fraction in both soils declined. Similar results were obtained by Bouyoucos (1924); Sreenivasan and Aurangabadkar (1940); Rao and Wadhawan (1955); Rotini *et al.* (1963); Nishita *et al.* (1970) and Sertsu and Sanchez

TABLE 3.1 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE COLORS OF IKENNE AND ONNE SURFACE SOILS (0-15 cm).

Duration of Preheating (hrs)	Temperature Levels (C)					
	27	60	100	200	400	600
Ikenne Alfisol						
6	5YR 3/2	5YR 3/2	5YR 3/2	5YR 2/2	5YR 3/2	2.5YR 3/4
12	________	"	________	5YR 3/2	2.5YR 3/6	2.5YR 3/6
24	________	"	________	"	2.5YR 3/4	"
Onne Ultisol						
6	10YR 3/4	10YR 3/3	10YR 3/3	...3/2	2.5YR 4/6	2.5YR 4/8
12	________	________	________	10YR 2/1	2.5YR 3/4	2.5YR 4/6
24	________	________	________	10YR 3/2	2.5YR 4/8	2.5YR 4/8

TABLE 3.2 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE PARTICLE SIZE DISTRIBUTION OF IKENNE SURFACE SOIL (0-15 cm).

Temperature (C)	Duration of heating (hrs)	Particle Size % Sand	Silt	Clay
"0"*	-	82	19	6
	6	83	12	5
60	12	81	12	7
	24	83	12	5
	6	83	10	7
100	12	83	10	7
	24	81	10	9
	6	79	10	7
200	12	79	12	9
	24	79	12	9
	6	95	2	3
400	12	95	2	3
	24	95	2	3
	6	95	2	3
600	12	95	2	3
	24	95	2	3

* Room Temperature (27 C)

TABLE 3.3 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE PARTICLE SIZE DISTRIBUTION OF ONNE SURFACE SOIL (0-15 cm).

Temperature (C)	Duration of heating (hrs)	Particle Size %		
		Sand	Silt	Clay
"0"	-	76	6	18
60	6	79	4	17
	12	81	2	17
	24	79	4	17
100	6	77	6	17
	12	77	6	17
	24	75	6	19
200	6	79	4	17
	12	79	4	17
	24	81	2	17
400	6	95	4	1
	12	95	2	3
	24	93	6	1
600	6	93	6	1
	12	95	2	3
	24	93	6	1

(1978). The destruction of the soil organic matter at high temperatures caused an increase in the aggregation of fine particles into sand-size fractions. Nishita *et al.* (1970) referred to this effect as a calcination process in which oxides of iron and alumino-silicates play a very active part.

3.4.2 *Effect of heating on the soil chemical properties.*

(a) *Soil pH:* In both soils, heating at temperatures of up to 200 C did not result in any marked change on soil pH. However, when the soils were heated at 100 C for 12 hours, the pH of the Onne soil dropped by about 0.4 unit (Fig. 3.1). In general, increasing the temperature of heating appeared to progressively increase the soil pH of both samples. The maximum effect was reached by heating at 400 C for 6 hours. While increased duration of heating at 400 C caused a slight decline in the pH of the Ikenne soil, that of the Onne soil was not affected. At the highest temperature (600 C), heating for six hours resulted in an increase in pH for the Ikenne soil while that of Onne dropped. Prolonging the time of heating to 12 and 24 hours did not cause a further pH increase in the Ikenne or a further decline in the Onne soil.

The pH changes which occurred at high temperatures could have been due to the oxidation of certain elements

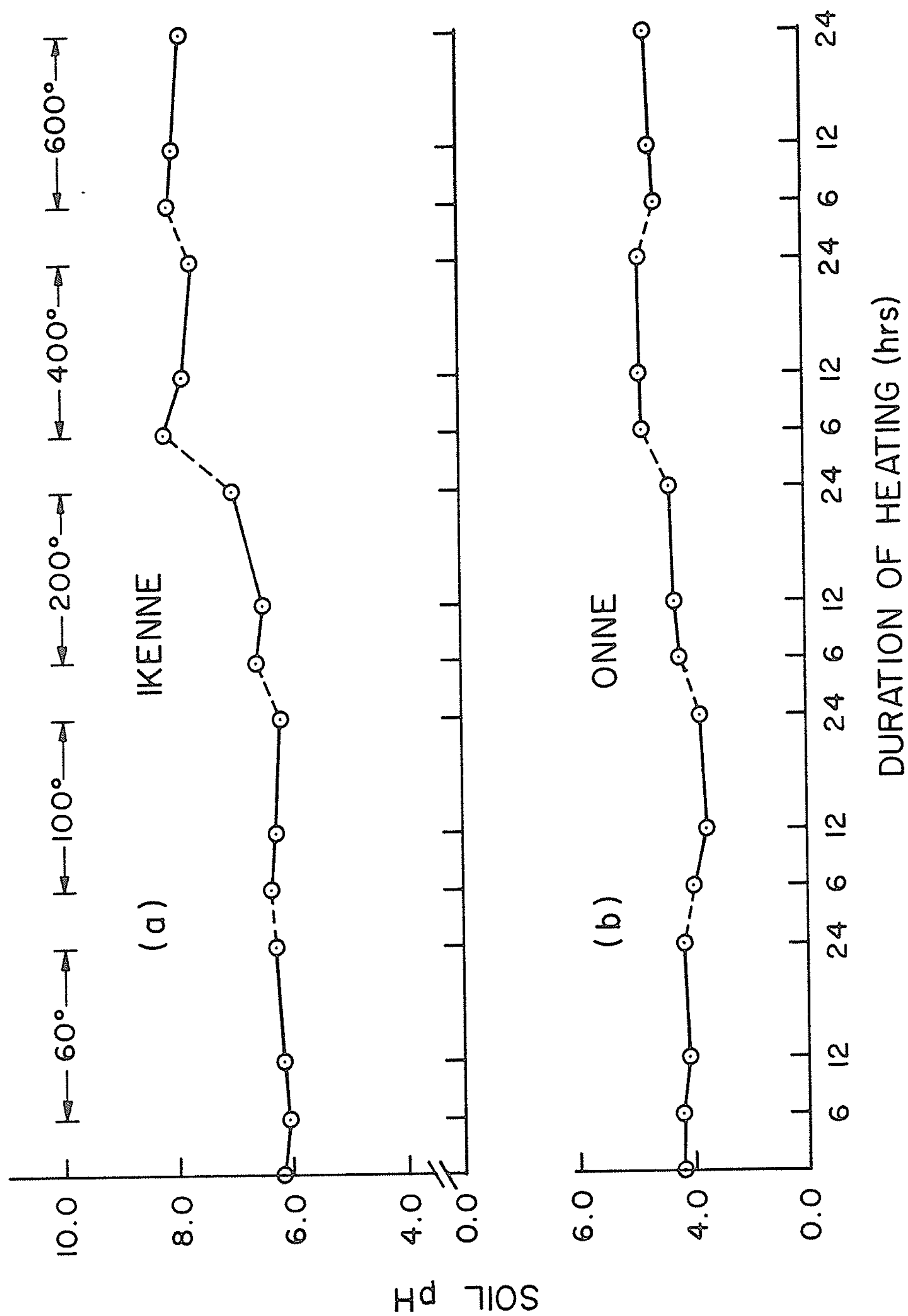

Fig. 3.1 Effect of Temperature and Time of Heating on Soil pH

coupled with the exposure of new surfaces and with colloidal dehydration. The formation of acid organic compounds due to a protolytic effect of heat on soils was postulated in literature cited by Laura (1974) to cause a decline in soil pH. In contrast, it is probable that the formation of oxides of certain cations, occlusion of Al in some complex compounds, formed at high temperatures may be responsible for any observed rise in pH of the Ikenne soil. The differences in the magnitude of the effect of heat on soil pH between the soils could be related to the presence or absence of these compounds.

(b) *Exchangeable Al and Total Acidity:* These parameters were measured only in the Onne soil which had appreciable levels of exchangeable Al. The exchangeable Al content was not influenced by soil heating at 200 C or less for 6 and 12 hours (Fig. 3.2a). Heating to 200 C for 24 hours markedly diminished the exchangeable Al content of the soil. However, the total acidity was found to increase substantially when the soil was heated at 60 and 100 C for 6 hours only (Fig. 3.2b). When the soil was heated at 100 C for 12 and 24 hours, respectively, the total acidity declined progressively, as compared to that of the soil heated at 60 C for 6 hours. There was, in general, a pronounced decline in both exchangeable Al and total acidity at temperatures of 400 and 600 C for all periods of heating. Heating the Onne acid soil at high temperatures would appear useful in terms of the

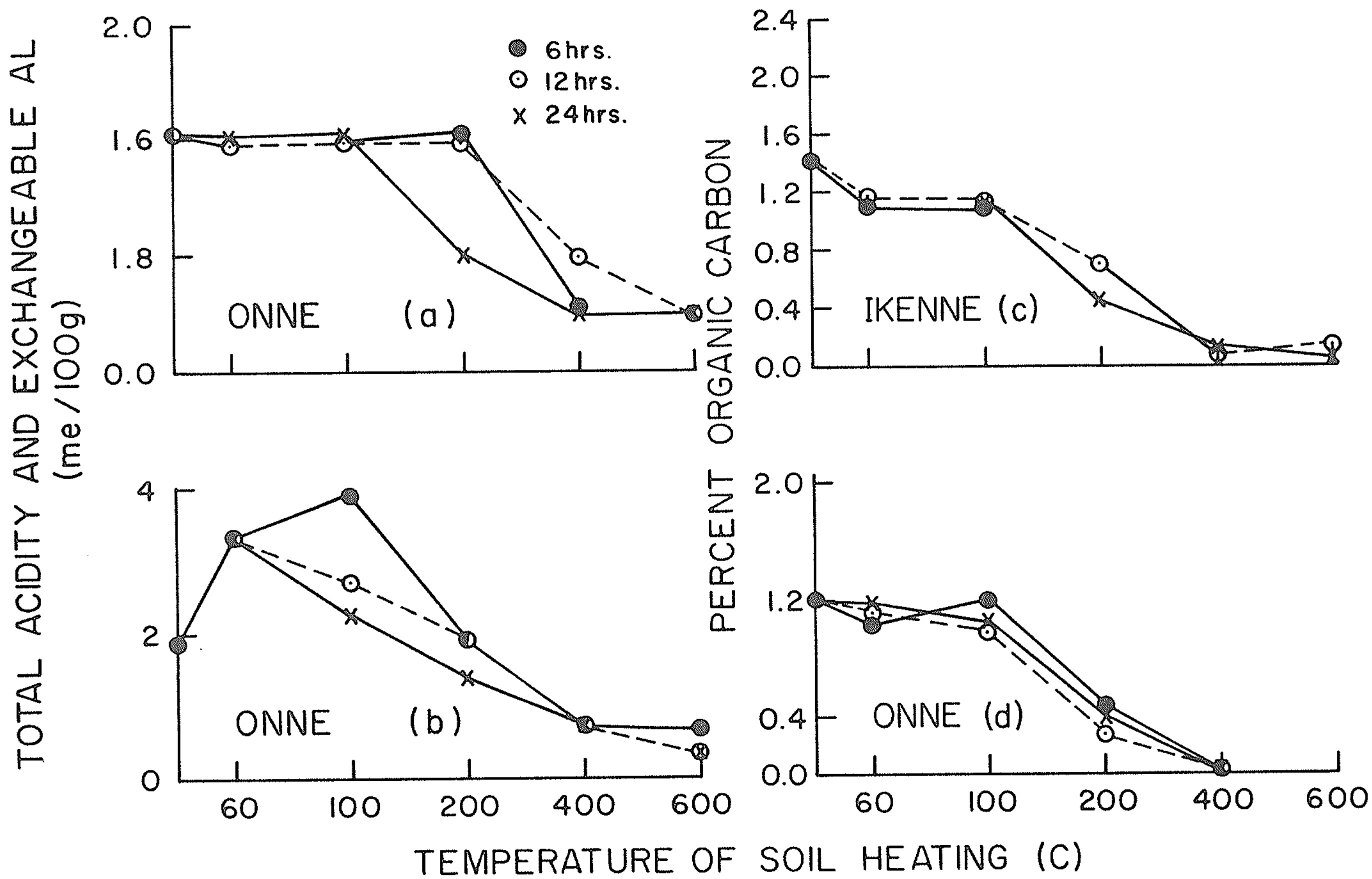

Fig. 3.2 Effect of Temperature and Time of Heating on Exchangeable Al, Total Acidity and Organic Carbon Contents

reduction of the total acidity of the soil. Probably, the formation of oxides of some cations and/or the occlusion of Al in some complex compounds was responsible for the reduction.

(c) *Organic Carbon (%):* There were no marked changes in the organic carbon contents of either sample when heated up to 100 C for 6, 12 and 24 hours. The minor changes observed in Figs. 3.2c and d, could be due to experimental error. When the soils were heated at 200 C, the decline in the organic carbon was very pronounced but there were no appreciable differences as a result of the duration of heating. The decline in Carbon content after heating at 200 C must be due to the destruction of soil organic matter (Heyward, 1938). At 400 and 600 C, there was very little carbon remaining in either soil. This was especially true of the Onne soil. A similar loss of organic matter due to heat was reported by Sertsu and Sanchez (1978). The increase in the sand-size fractions reported earlier, may have been facilitated by the destruction of organic matter and other colloidal materials in the soil at high temperatures.

(d) *Inorganic N (NH_4-N and NO_3-N):* Heating the two soils at 100 C and less for 6, 12 and 24 hours had no pronounced effect on NH_4-N (Fig. 3.3). However, heating at 200 C caused an increase in the extractability of NH_4-N which was slightly higher in the Onne soil than in the Ikenne soil. The duration of heating at 200 C had no effect on the NH_4-N content of the

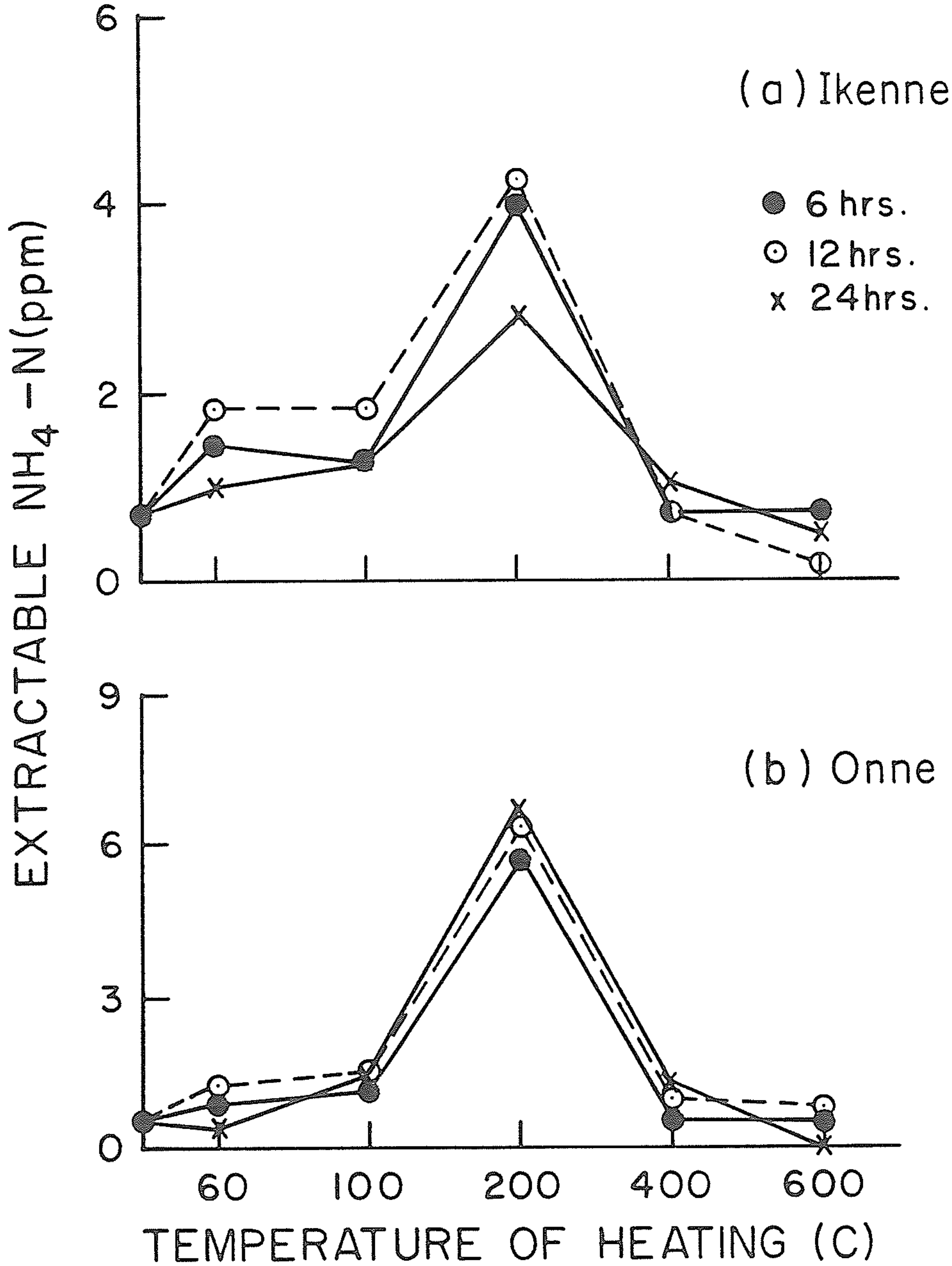

Fig. 3.3 Effect of Temperature and Time of Heating on NH_4-N Content

Onne soil but the extractability of NH_4-N decreased during 24 hours of heating in Ikenne soil. The increased extractability of NH_4-N in both soils was due to the breakdown of the organic matter at 200 C. Sertsu and Sanchez (1978) obtained a similar result and postulated that there was a release of NH_4-N which was retained at exchange sites. While such a retention could have occurred, the results of the study being discussed, appeared to indicate a very low NH_4-N retention. In consideration of the relationship between C and N in soils, high temperatures could cause a considerable loss of NH_4-N by volatilization. Debano *et al.* (1979), Biederbeck *et al.* (1980), reported an increase in NH_4-N due to soil heating. The increase was attributed by these authors to a protolytic effect as suggested in literature cited by Laura (1974) in which NH_4-N was postulated to be formed from organic nitrogenous compounds in soils through chemical reactions caused by heating.

Heating at 400 and 600 C resulted in a complete loss of extractable NH_4-N. This indicates that high temperatures caused a complete volatilization of the NH_4-N. Heating had no effect on the NO_3-N contents of either sample (Table 3.4).

(4) *Available P (Bray I-P)*: Heating up to 100 C had little effect on the available P of either soil (Table 3.5). Heating to 200 C resulted in increases in the available P. Sertsu and Sanchez (1978), Kang and Sajjapongse (in press) observed a similar increase in the available P content due to heating.

TABLE 3.4 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE NO_3-N CONTENT OF IKENNE AND ONNE SURFACE SOILS (0-15 cm).

Soil	Temperature of Heating (C)	Time of Heating (hrs) '0'	6	12 (me /100 g)	24
Ikenne	Control	0.35	-	-	-
	60	-	0.18	0.70	0.35
	100	-	0.53	0.18	0.53
	200	-	0.53	0.53	0.18
	400	-	-	0.18	0.35
	600	-	-	-	-
Onne	Control	0.35	-	-	-
	60	-	0.35	0.35	0.18
	100	-	0.18	0.35	0.53
	200	-	0.35	0.35	0.18
	400	-	0.18	0.18	0.35
	600	-	0.18	0.18	0.18

TABLE 3.5 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON AVAILABLE P IN IKENNE AND ONNE SURFACE SOILS (0-15 cm).

Soil	Temperature of Heating (C)	Time of Heating (hrs) '0'	6	12	24
			ppm		
Ikenne	Control	5	-	-	-
	60	-	5	5	6
	100	-	6	6	6
	200	-	53	59	51
	400	-	42	41	40
	600	-	39	37	41
Onne	Control	56	-	-	-
	60	-	53	45	47
	100	-	59	47	49
	200	-	89	94	91
	400	-	37	31	47
	600	-	25	42	46

The latter also found that organic P declined. The marked rise in available P at 200 C in both soils was due to organic matter decomposition at this temperature. The levels extracted at this temperature were probably related to the initial P content of the soils. The Onne soil which had a higher initial P also had a higher available P at 200 C than the Ikenne soil.

There was a slight decline of available P in both soils when they were heated at 400 and 600 C. Formation of complex compounds which could occlude P might decrease P extractability at high temperatures.

(f) *Exchangeable Cations: Ca.* Heating the Ikenne soil at 60 C for all times of heating decreased the exchangeable Ca contents (Fig. 3.4a). This was similar to the effect observed on the Onne soil except that there was an increase at 60 C for 24 hours of heating (Fig. 3.4b). While heating the Ikenne soil at 100 C for all periods markedly increased extractable Ca content, it decreased that of the Onne soil. There was no further effect of heating - at 200 and 400 C on the exchangeable Ca in Ikenne soil. The exchangeable Ca in the Onne soil increased substantially at 200 C as compared to exchangeable Ca present when the soil was heated at 100 C. Heating to 400 and 600 C resulted in a decrease of exchangeable Ca in the Onne soil. There was a similar decline of the exchangeable Ca in the Ikenne soil at 600 C and this decline was more rapid than in the Onne soil. These results show

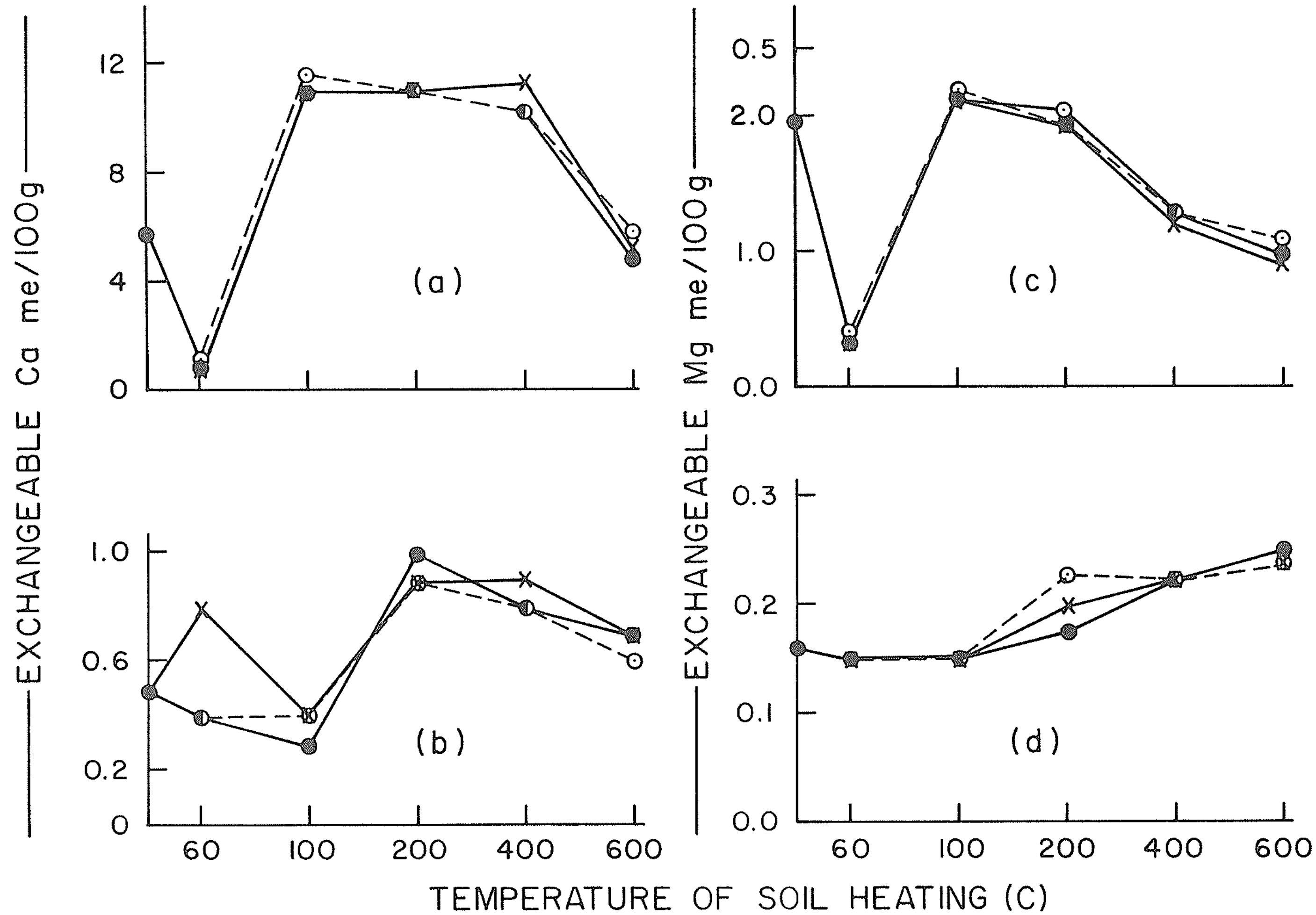

Fig. 3.4 Effect of Temperature and Time of Heating on Exchangeable Ca and Mg

no consistent trends. They differ from the results of Nishita *et al.* (1970), Kang and Sajjapongse (in press), who found pronounced reductions of Ca and Mg with heating at 200 C. The reason for this difference is not known but it could be related to the differences in the parent materials and the solubility states of the Ca-containing compounds formed as a result of heating. Probably, a clay mineralogical investigation, which was outside the scope of this study would be necessary to explain some of these observations.

Magnesium: The effect of heating on exchangeable Mg in the Ikenne soil was similar to that on exchangeable Ca. However, where heating caused a decline in the extractability of Mg, it was more rapid and more pronounced than that of exchangeable Ca. There was no effect of time of heating on the levels of exchangeable Mg (Fig. 3.4c). In the Onne soil, heating up to 100 C did not affect exchangeable Mg levels (Fig. 3.4d) but heating at 200 C increased the Mg extracted from this soil. The time of heating had no pronounced effect. Heating the Onne soil at 400 and 600 C resulted in a slight increase in exchangeable Mg. As was suggested earlier in respect of Ca, the reason for the behavior of Mg due to heating is not known but it could be related to the effects of dehydration and oxidation of soil constituents or to complex reactions which might influence the solubility and extractability of the cations.

Potassium: Heating the soils up to 200 C did not affect the exchangeable K, although it appeared that the initial K in the soils was high (Table 3.6). This high initial K content may have been an error of estimation. For the Ikenne soil, heating at 400 C had no effect but there was a slight decrease in exchangeable K content at 600 C. Heating the Onne soil at 400 C resulted in an increase in exchangeable K but at 600 C, the exchangeable K declined to the original levels. The destruction of the organic matter as well as the distortion of the layer silicate days could cause an increase in exchangeable K but the magnitude of the effects of the two processes on the K content of the samples is not known. It would appear that soil heating in general did not affect exchangeable K in any distinct manner.

(g) *Available Micronutrients: Zinc.* Heating the soils at 200 C had no effect on available Zn extracted by 0.1N HCl. Heating at 400 C increased the available Zn in Ikenne especially for 12 hours where a peak was reached (Table 3.7). A similar effect was observed in the Onne soil but the highest amount was extracted at 400 C for 6 hours of heating. While heating at 600 C caused a decline in available Zn in Ikenne soil, there was no effect in the Onne soil. Heating appeared to increase the solubility of Zn containing compounds and hence, increased the extractability of the Zn. This effect may vary with soils depending on the content of the Zn compounds as well as their solubilities. Sertsu and Sanchez (1978), reported that heating

TABLE 3.6 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON AVAILABLE K IN IKENNE AND ONNE SURFACE SOILS (0-15 cm).

Soil	Temperature of Heating (C)	Time of Heating (hrs) '0'	6	12	24
		me K/100 g			
Ikenne	Control	0.17	-	-	-
	60	-	0.09	0.09	0.09
	100	-	0.09	0.10	0.10
	200	-	0.09	0.09	0.10
	400	-	0.09	0.11	0.11
	600	-	0.04	0.05	0.05
Onne	Control	0.10	-	-	-
	60	-	0.08	0.09	0.08
	100	-	0.08	0.09	0.09
	200	-	0.09	0.09	0.10
	400	-	0.17	0.19	0.19
	600	-	0.08	0.07	0.08

TABLE 3.7 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE ACID (0.1N Hcl) EXTRACTABLE Zn IN IKENNE AND ONNE SURFACE (0-15 cm) SOILS.

Soil	Temperature of Heating (C)	Duration of Heating (hrs) '0'	6	12	24
		ppm Zn			
Ikenne	Control	1.24	-	-	-
	60	-	1.28	1.28	1.36
	100	-	1.32	1.68	1.24
	200	-	1.56	1.56	1.44
	400	-	1.88	2.16	1.72
	600	-	1.40	1.32	1.32
Onne	Control	0.76	-	-	-
	60	-	1.04	0.76	0.72
	100	-	0.80	0.72	0.80
	200	-	0.96	0.84	0.84
	400	-	1.92	1.64	1.72
	600	-	1.56	1.56	1.44

did not influence the extractability of Zn and Cu.

Manganese: The exchangeable Mn in Ikenne soil decreased when the soil was heated at 60 C (Table 3.8). Heating at 100 and 200 C caused pronounced increases in the exchangeable Mn in this soil. The increase was greater at 200 than at 100 C. Heating at 400 and 600 C resulted in a decrease in exchangeable Mn to levels comparable with the initial level. There was no effect of heating at 60 and 100 C on exchangeable Mn in Onne soil but heating 200 and 400 C doubled the extractable Mn in this soil. However, there was a noticeable decline in the Mn level after heating for 24 hours at 400 C. The Mn levels dropped to the initial level in the Onne soil when it was heated at 600 C. The peaks in exchangeable Mn in both soils at 200 C resembled the trend shown for NH_4-N indicating that the breakdown of organic matter at that temperature also affected the exchangeable Mn levels.

Iron: At 60 C and 6 hours of heating, the extractable Fe in the Ikenne soil increased two-fold but was not affected by heating for 12 and 24 hours (Table 3.9). Heating at 100 C increased the extractable Fe in the Ikenne soil and time of heating had no effect. Heating at 60 and 100 C increased the Fe extractable from the Onne soil and prolonging the heating time increased the extracted amounts of Fe. In both soils, heating to 200, 400 and 600 C markedly increased the extractable Fe. The red color hues described earlier must be related to

TABLE 3.8 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE EXTRACTABLE Mn IN IKENNE AND ONNE SURFACE SOILS (0-15 cm).

Soil	Temperature of Heating (C)	Duration of Heating (hrs) '0'	6	12	24
		me/100 g			
Ikenne	Control	0.08	-	-	-
	60	-	0.02	0.02	0.02
	100	-	0.40	0.44	0.46
	200	-	0.84	0.79	0.82
	400	-	0.06	0.05	0.05
	600	-	0.04	0.04	0.03
Onne	Control	0.02	-	-	-
	60	-	0.02	0.02	0.02
	100	-	0.02	0.02	0.02
	200	-	0.04	0.04	0.04
	400	-	0.04	0.03	0.02
	600	-	0.02	0.02	0.02

TABLE 3.9 THE EFFECT OF TIME AND TEMPERATURE OF HEATING ON THE ACID (0.1N Hcl) EXTRACTABLE Fe in IKENNE AND ONNE SURFACE (0-15 cm) SOILS.

Soil	Temperature of Heating (C)	Duration of Heating (hrs) '0'	6	12	24
		ppm Fe			
Ikenne	Control	4	-	-	-
	60	-	8	4	4
	100	-	6	7	7
	200	-	58	52	54
	400	-	91	135	112
	600	-	159	161	171
Onne	Control	51	-	-	-
	60	-	61	62	62
	100	-	64	70	77
	200	-	131	135	138
	400	-	158	162	143
	600	-	244	207	186

these elevated levels of extractable Fe and to the hydration and oxidation states of the ion. In some way, the dehydration process and increase in Fe contents due to heating must determine the onset of organic matter destruction and the aggregation of fine soil particles which follows the destruction. The redder hues of the Onne soil, probably, reflected either a greater dehydration or a greater increase in the Fe content of the soil at high temperatures.

3.4.3 *The effect of Soil heating on maize growth, dry matter production and mineral nutrition.*

(a) *Plant Heights:* Heating the soil at 100 C did not have any effect on the height of unfertilized plants at the 2nd, 3rd, and 4th weeks of growth, respectively (Fig. 3.5 a-c and App. 3.1-3.3). The height of unfertilized plants was depressed when the soil was heated at 200 C but only the depression at the 2nd week was significant (Appendix tables). Heating at 600 C also resulted in the depression of plant height. The reduction in plant height at 600 C was significant at the 4th week of growth as compared with plants growing on check soil and on soil heated at 100 C. There were no significant differences in height between plants growing on soil heated at 200 and at 600 C.

Fertilizer treatment containing all nutrients increased plant heights at each temperature level and at all stages of growth. As was the case with unfertilized plants, heating the

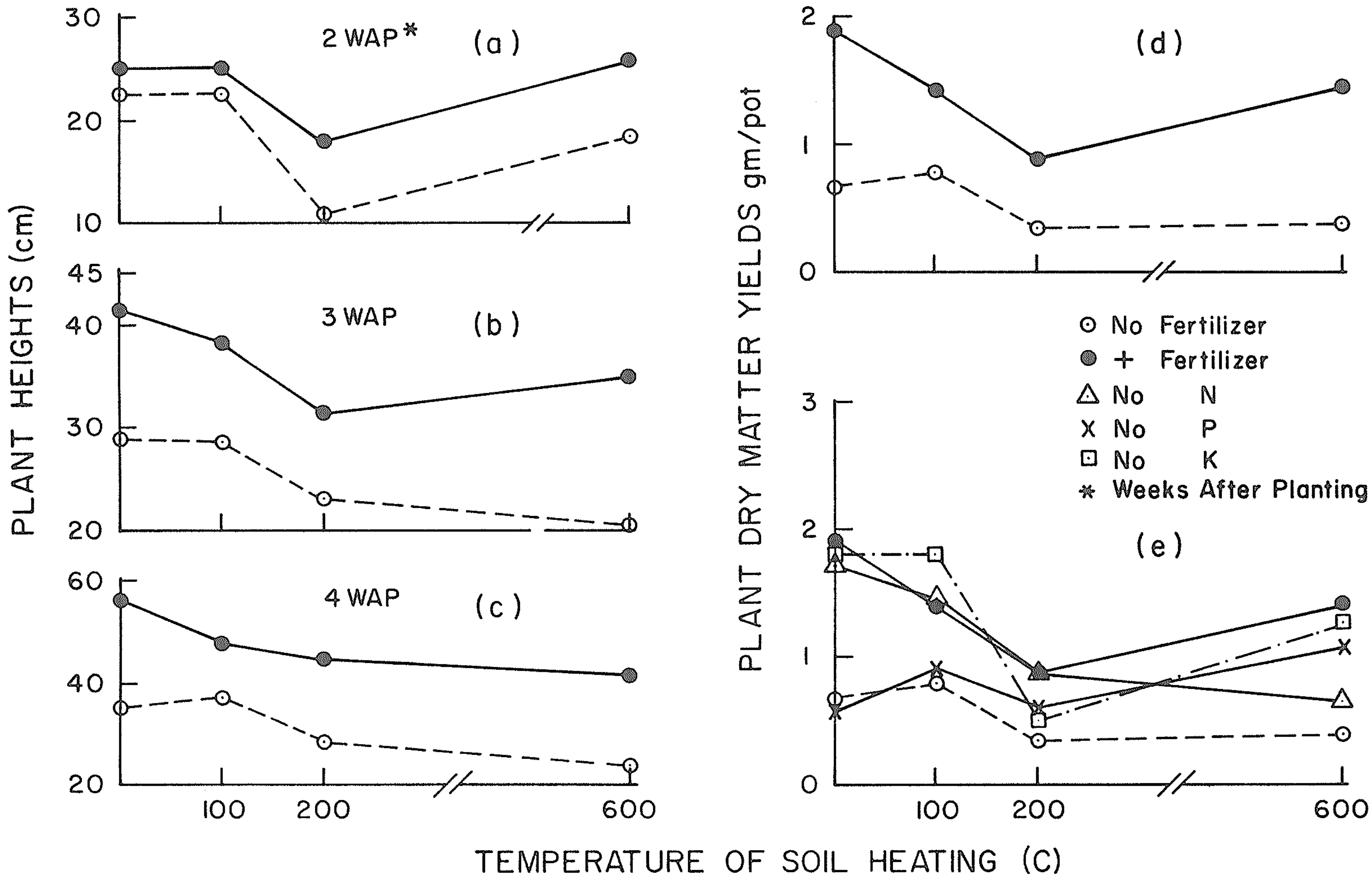

Fig. 3.5 Effect of Soil Heating and Fertilizer Application on Plant Heights and Dry Matter Yields

soil at 100 C did not cause any detrimental effect on the height of fertilized plants. Heating at 200 C depressed the height of fertilized plants and the depression was significant at the 3rd and 4th weeks of growth. The height of plants growing on soil heated at 200 C was depressed as compared with the plants growing on soil heated at 100 C and the height difference was significant at the 2nd week of growth. When the soil was heated at 600 C, height of fertilized plants was increased in the 2nd week, as compared with other temperature treatments. The difference in height was significant between plants growing on soil heated at 200 and at 600 C, in the 2nd week. In the 3rd week, plants growing on soil heated at 600 C were taller than those growing on soil heated at 200 C but the difference was not significant. In the 4th week, plants growing on soil heated at 600 C were shorter as compared with any of the other temperature levels. The difference in height at this time was significant between the plants growing on soil heated at 600 C and those on the unheated (check) soil.

In the first two weeks of growth, no element appeared to particularly limit plant heights but without N, K and Ca, plant heights were similar to the heights of those growing on unfertilized soil (App. 3.1). In contrast, without P, Mg, Zn and S, plant heights were similar to the heights of those growing on soil fertilized with all nutrients. In the third week, plants receiving all fertilizer treatments were significantly taller than those of the check or those without

N, P or Ca (App. 3.2). In the fourth week, a similar trend was obtained but the effect of Ca was intermediate. Plant heights were not affected when Mg, Zn or S was not applied.

(b) *Dry Matter Production:* Heating the soil tended to reduce the yield of dry matter (Fig. 3.5d). This reduction was statistically significant for the temperature means when the soil was heated at 200 C (App. 3.4). There were yield increases of dry matter due to N, P, K or Ca. Based on the nutrient combination means, only the response to P was significant. This result was a further confirmation of results discussed in Chapter 2 with respect to the significance of P application. The dry matter yield was depressed by Zn or S application but only the depression due to S was significant. The negative response to Zn may be due to its initial high content.

(c) *Mineral nutrition: Nitrogen.* The concentration of N in the plants differed significantly among the temperature treatment means (Fig. 3.6a and App. 3.5). The trends showed that N content at 200> 100> check> 600 C. The low N content at 600 C was due to the loss of virtually all of the N due to high temperature. Heating at 200 C resulted in a significantly higher N concentration than at any other temperature. This was probably related to the poor plant growth at that temperature. Therefore, N content in the plant at this temperature

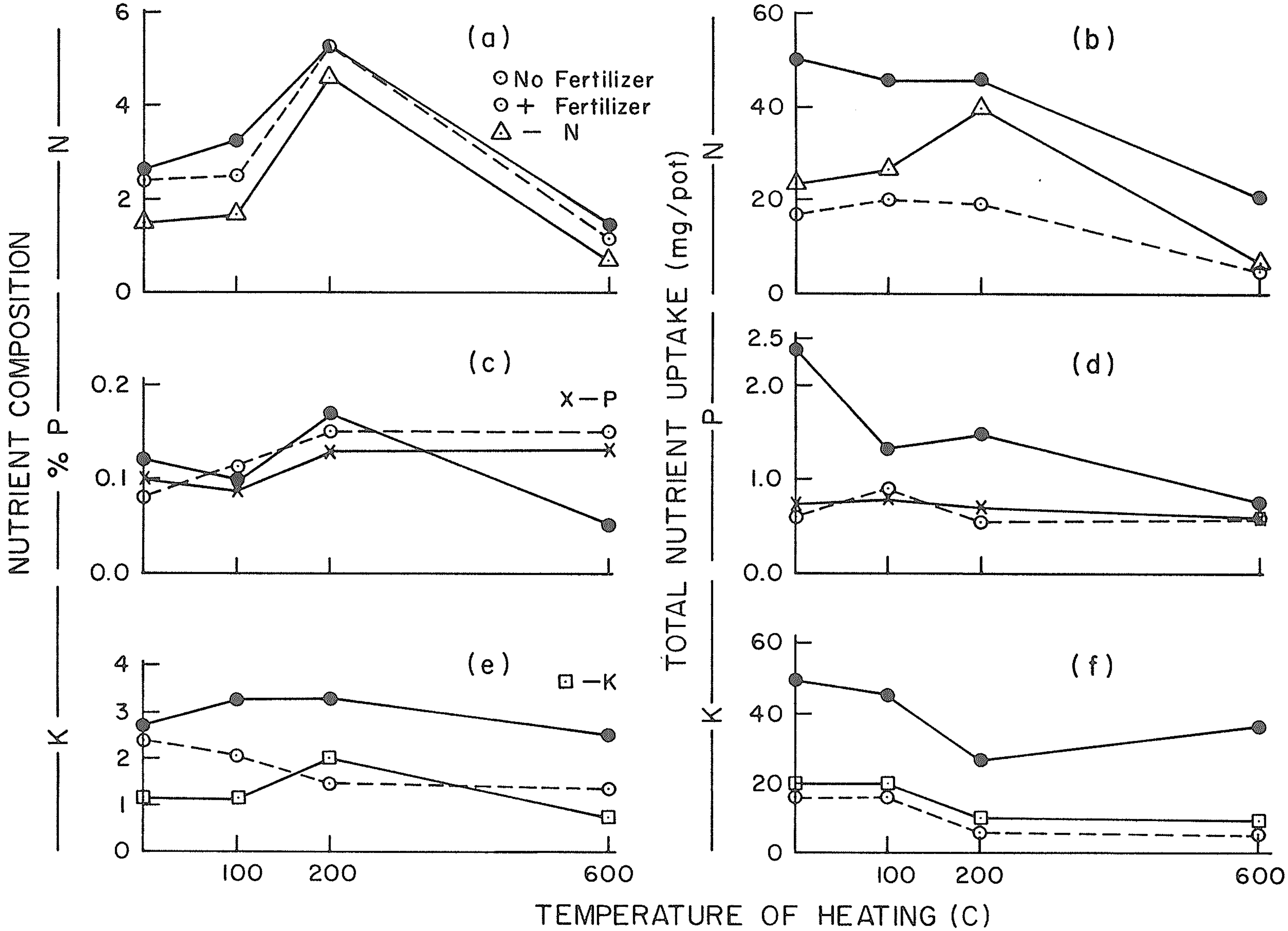

Fig. 3.6 Effect of Soil Heating and Fertilizer Application on Per cent Nutrient Content and Total N, P, and K Uptake

was not due to increased NH_4-N extractability or retention of the NH_4-N on the exchange complex as postulated by Sertsu and Sanchez (1978). There was no evidence of this type of retention in this investigation.

Nitrogen application significantly increased N content in the plant but the significant increase of N content due to Zn or S resulted from the depression of dry matter by either Zn or S.

The uptake of N did not differ significantly among the temperature treatment means except at 600 C where the uptake was significantly lower than at any other temperature (Fig. 3.6b and App. 3.6). Nitrogen and P application significantly increased N uptake.

Phosphorus: The concentration of P in the plant was not significantly affected by heating at 100 C. Heating at 200 C significantly increased P content in the plant (Fig. 3c and App. 3.7). Heating at 600 C significantly depressed the P content. Although the yield of dry matter was decreased by heating at 200 C, the extractability of P increased at this temperature. Unlike NH_4-N which could be volatilized, some of the P may have been retained and taken up by the plant at 200 C. This increased extractability could have resulted in increased P content in the plant at this temperature. However, total uptake of P at 200 C (Fig. 3.6d and App. 3.8) was lower than in the check. Therefore, the high P content in plant at 200 C was more probably due to decreased dry matter than to increased available soil P. The adsorption of P by this acid soil may account for the generally low recovery of P in this investigation.

Other nutrients depressed the uptake of P but only the depression due to N and K was significant. The application of P significantly increased P uptake.

Potassium: Neither the K content in the plant nor the total uptake differed significantly between plants growing on soil heated at 100 C and those on the check soil (Figs. 3.6 e and f; App. 3.9 and 3.10). Based on the temperature means, heating at 200 C significantly increased K concentration but also significantly depressed total K uptake. Where no K was added, heating at 200 C significantly increased K content in the plant but the reduction of the uptake was not significant.

Heating the soil at 600 C significantly decreased K content as compared with other temperature treatments. This was true also where no K was added. The uptake of K when the soil was heated at 600 C was significantly lower than the uptake at check soil and at 100 C but comparable to the uptake at 200 C.

Nitrogen and P application significantly depressed the K content and P also significantly increased total K uptake. The application of K significantly increased K content and uptake. There was a close similarity between the dry matter yield and K uptake indicating that the uptake of K was dependent on the dry matter yields.

Calcium: The Ca content and uptake in the plant were not significantly influenced by heating the soil to 100 C (App. 3.11 and Fig. 3.7a). When the soil was heated at 200 C, there was a significant depression in Ca content and uptake, based on the temperature treatment means. Therefore, Ca was the only element that was less with the low dry matter yield obtained when the soil was heated at 200 C. Calcium was thus a major factor influencing the production of dry matter when the soil was heated at 200 C. The Ca content in the plant was significantly increased when the soil was heated at 600 C as compared with other temperature levels. The uptake of Ca at 600 C was higher than at any other temperature level and the difference between 200 and 600 C was significant (App. 3.12).

The application of N significantly increased Ca content and uptake but P application had the opposite effect. The depression of Ca content due to P was significant. The uptake of Ca in check was similar to that without N or P. Probably, Ca influenced the response to N and P and was also related to the dry matter production. Response to Ca was not significant probably as a result of the low level (20 ppm) of Ca applied.

The extractability of Ca from heated soil was not related to the plant concentration of this element. For example, heating the soil at 100 C decreased Ca extractability but

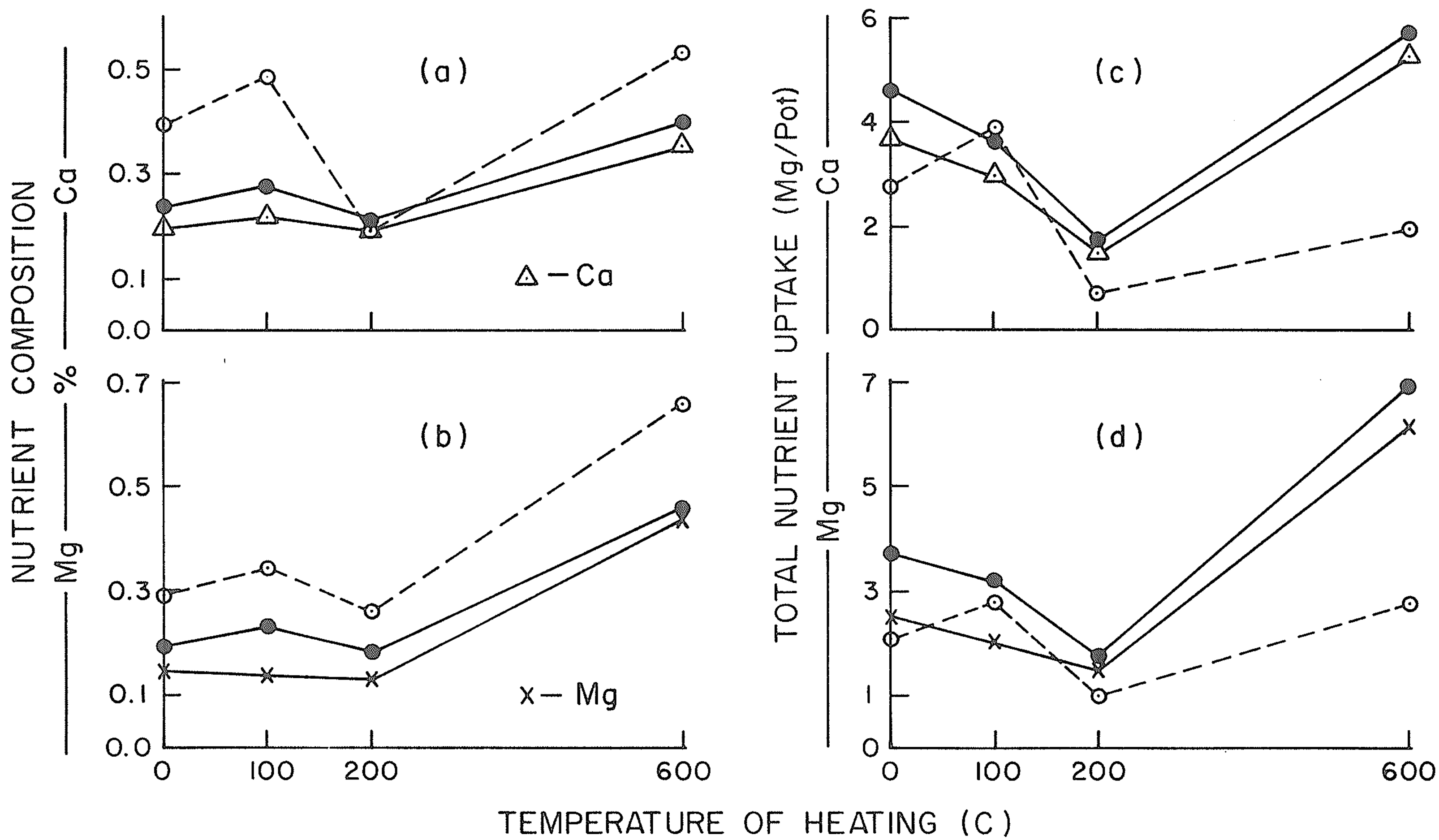

Fig. 3.7 Effect of Soil Heating and Fertilizer Application on Per cent Content and Total Ca and Mg Uptake

the Ca content in the plant was not affected. While Ca extractability increased when the soil was heated at 200 C, the plant Ca content declined significantly at 200 C. The exchangeable soil Ca was decreased by heating the soil at 600 C but the plant content increased significantly at this temperature as compared with the check.

Magnesium: The plant Mg content was not affected by heating the soil at 100 or 200 C but heating at 600 C significantly increased the Mg content in the plant (App. 3.13 and Fig. 3.7b). Heating the soil at 100 or 200 C lowered total Mg uptake and the decrease at 200 C was significant. When the soil was heated at 600 C, the uptake of Mg was significantly increased (App. 3.14 and Fig. 3.7c). The increase in Mg content and uptake at 600 C may probably be related to the increased extractability of Mg at this high temperature.

Zinc: Heating the soil at 100 or 200 C did not affect the plant Zn content. When the soil was heated at 600 C, the Zn content in the plant decreased significantly although the extractability was increased by heating at 600 C (App. 3.15). The application of P significantly decreased the plant Zn content which was generally higher where P was not applied. There may have been an interaction between P and Zn.

3.5 Summary and Conclusion.

The direct effects of heating on the properties of Ikenne and Onne soils as well as crop response to fertilizer application on heated soil were investigated in laboratory and greenhouse conditions, respectively.

Heating the soils at temperatures up to 200 C or less did not influence the physical properties of the soils. Heating the soils at 400 - 600 C changed the color and texture of the soils and resulted in changes in the chemical properties of the samples. However, high temperatures had variable effects on the extractability of soil nutrients.

The effect of heating of soil that accompanies bush fallow burning in the field depends on factors such as the magnitude of the temperature attained. The effects of high temperatures on soil properties obtained in the laboratory may not occur in the field because the heating may not be sufficiently prolonged and intense as to effect dramatic changes. The observations in the field where burning or heating was prolonged and intense confirm the changes in soil properties obtained at high laboratory temperatures. Such changes occurred in isolated field spots and therefore, do not prevail over a large cultivated area.

Heating the Onne soil at temperatures of 200 and 600 C resulted in a significant reduction in plant growth, dry matter production and mineral uptake. The increase in the extractability of some elements which occurred when the soil was heated at 200 C was not reflected in improved plant growth and nutrition. The increases usually reported as being due to burning may be partly due to the effect of heat but probably, it could be due more to biological mineralization in the field prior to the burning of the fallow residues. This contention is supported by the fact that the nutrient release due to soil heating was not effective in improving the production of dry matter.

Fertilizer application improved plant growth and nutrition but did not completely eliminate the detrimental effect of heating the soil at 200 or 600 C. The strongest nutrient response was due to P although Ca was the controlling factor when the soil was heated at 200 C,

It is concluded from this investigation that light burning in which soil temperatures are lower than 200 C and sustained for less than six hours is neither destructive of soil properties nor detrimental to plant growth, dry matter production and mineral nutrition. Higher soil temperatures than 200 C exert the opposite effects. Fertilizer application improves the plant growth and performance but may not completely eliminate the detrimental effect of heating at high temperatures.

Chapter 4: A Comparison of Mulching and Burning, With and Without Fertilizer Application on Crop Performance and Yields on the Ikenne Alfisol in Southwestern Nigeria.

4.1 Introduction and Literature Review

Alfisols and Ultisols are the most widely cultivated soils in many areas of Southern Nigeria. The Alfisols are more fertile than the Ultisols because of their higher cation exchange capacity. Aluminum toxicity which is a concern on the Ultisols is not regarded as a major problem on the Alfisols because of low exchangeable Al contents.

Prior to bush and forest fallow slashing, most of the plant nutrients are held in a closed cycle between the soil and the vegetation on it (Nye and Greenland, 1960). When the fallow vegetation is burned in preparation for cropping, volatile elements such as N and S are lost while the non-volatile ones such as Ca, Mg, P and K are deposited on the immediate soil surface in the form of ashes. These inorganic elements can be lost by leaching if the rainfall is high.

In most of Southern Nigeria, increase in population and other land use needs are decreasing the availability of arable lands. Cropping on the presently cultivated soils has become more regular and this is taxing their productivity. The amounts of fallow biomass, stored nutrients and those recovered as ash have decreased because the time of fallowing has shortened. As a result, the traditional method of slash and burn is no longer considered an efficient system. Retention of plant residues as mulch has been shown to improve crop yields (Jack *et al*, 1955; Jurion and Henry 1967; Ayanaba and Okigbo (1974). It was suggested by these investigators that the beneficial role of the mulch was due to its physical influence on the soil and to the release of nutrients during its decomposition. Other studies by Okigbo (1965; 1969); Kang (1972); and Lal (1973; 1974) confirm similar results. Many IITA studies favour the retention of fallow and crop residues on Alfisols because the removal of the residues have been shown to cause rapid decline of soil organic matter and crop yields (IITA Annual Reports, 1972-1974). Studies by Lal (1975, 1979) showed that the retention of residues as mulch (4-6 tons/ha) caused an effective absorption of the impact of raindrop and reduced surface run-off. The mulch helped to maintain a favourable rate of infiltration and improved crop growth and vigor. Akobundu (IITA Annual Report, 1976) indicated that the retention of maize stovers and Andropogon straw as mulches was helpful in suppressing weed growth and increasing the yields of selected crops.

Fertilizer responses have been widely reported on the Alfisols in Southwestern Nigeria. Increases in crop yields due to fertilizer application on this soil type were obtained by Agboola (1968); Ammon and Adètunji (1968, 1970 and 1973);

Fayemi (1966); Bredero (1962); Adetunji and Agboola (1973). Responses to N and P were more frequently observed than to K on the Alfisol at Ikenne. On the Egbeda Alfisol, where NPK alone did not produce any significant yield responses, Kang (personal communication) found marked responses to micronutrients, especially Zn, applied with NPK.

Increases in crop yields due to fertilizer and mulch application were obtained by Okigbo (1965 and 1969) but these were suggested to be confounded by the fertilizer and mulch treatments used. Some workers in Southern Nigeria have suggested that some fallowing might still be necessary even with an increase in fertilizer use in Southwestern Nigeria. Amon (1965); Ammon and Adetunji (1968, 1970 and 1973) reported that in a long term rotational trial involving maize, yam and cassava, high yields could not be sustained with inorganic fertilizer application without a fallow period. Piggot (1954) found that after a short fallow period in Sierra Leone, there was a large crop yield increase due to N and P. Probably, N and P may have been limiting as a result of shortened fallow time. Nye (1952), reported that after a fallow rest in Ghana, the application of only 135 kg/ha of Superphosphate resulted in a 27 percent increase in maize grain yield. Kang *et al.* (1977) suggested that the need to fallow may be eliminated on the Alfisols with fertilizer application and a proper crop husbandry and rotation. Such a system, as suggested by Kang, can sustain soil fertility and fairly high levels of crop yields on the more fertile Alfisols. The reason for the differences of opinions expressed above may be the level of management involved in the studies.

The burning of fallow residues may, for a long while, remain a part of the agricultural system in Southern Nigeria. As the decline in the fallow properties continues, there may be little justification for burning the residues. This will be particularly true since the nutrient effect of the ash is low. There is a scarcity of information on the effect of burning and fertilizer application on crop yields. The Nigerian government support for the use of fertilizers by the local farmers to increase production needs to be supported by appropriate studies, which will integrate fallow management and fertilizer application. The information obtained could be useful in advising the subsistence farmers on the efficient management of their fallows on a more profitable basis.

A field study was therefore established on the Ikenne Alfisol to (a) compare the effects of mulching and burning of fallow residues on crop yields and (b) evaluate crop responses to fertilizer treatments under either method of residue management.

4.2 Materials and Methods

The Ikenne site which was within the Experimental Station of the University of Ife, Nigeria was selected and described in late November, 1977. Details of the site were given in Chapter 2. The site was slashed of the standing vegetation in mid-February, 1978 using labour provided by the local people. The residues were allowed to dry through the remaining period in February, 1978. Then, in early March, the site was sub-plotted using a split-plot design in order to compare the effects of two main treatments of (a) Mulching and (b) Burning of the fallow residues. Following the field lay-out, the plots that were to be burned were fired as individual units using the same group of local farmers. The use of the local people was to ensure that as far as was possible, the traditional method of burning was achieved.

The subplot treatments consisted of fertilizer combinations of check (no fertilizer); PK; NK; NP; NPK and NPKMgZn applied to the first maize crop in 1978. Prior to fertilizer application in the mulched plots, the dry fallow residues were re-slashed and raked to a portion of the plot in order to facilitate fertilizer application. The appropriate fertilizer combinations were thoroughly mixed, broadcast and worked into the top soil using a rake. This was done for both main treatment after which, the residues of the mulched plots were uniformly raked back within the plots.

Nitrogen was applied in two applications; 150 kgN/ha broad-cast at planting using Calcium ammonium nitrate [$Ca(NH_4NO_3)2$]

and 50 KgN/ha was side-dressed four weeks after planting using Urea. Phosphorus, K, and Mg were applied at the rate of 30 kg/ha of each element using Single superphosphate, Muriate of potash and hydrated Magnesium sulphate, respectively. The zinc applied was at the rate of 5 kgZn/ha using Zinc sequestrene.

Three seeds of maize (Cv TZPB) treated with Aldrex T were planted on March 13, 1978 a week after fertilizer application in each hill using a spacing of 1m x 30cm in plots of 30 sq. metres. Two weeks later, the plants were thinned to one per hill giving a population of 33300 plants per hectare.

Weed Control: Preplanting weed control was achieved by spraying with paraquat a day before planting. During the growing season, weeds (predominantly *Eupatorium odoratum*) were either slashed or hoed as was required to maintain a clean seedbed.

The maize was harvested on June 27, 1978 and the stover residues were left on the soil as mulch materials. During the period before the next crop (cowpea) was planted, the fast growing weeds were slashed within the plots and later sprayed with paraquat. On August 29, 1978, cowpea seeds innoculated and treated with furadan were planted at a spacing of 1m x 25cm within the same plot areas used for the maize. After establishment, the plants were thinned to one per hill. At six weeks after planting, all N-receiving plots were side-dressed with 60 kgN/ha using Calcium ammonium nitrate. Nitrogen was added mainly to ensure that N was not limiting. No other nutrient was applied to the cowpea and weeding was carried on as previously described for the maize (P and K were not added to the cowpea in order to assess the residual effects of the nutrients applied earlier in 1978).

Harvesting of the cowpea was done as frequently as possible since the pods were ready at different times. However, two major harvests were carried out on November 20, and December 8, 1978. The pods were air-dried and then shelled for seed yields (14% moisture content). The stover was left on the soil as mulch as was the case with the 1978 maize.

In early March, 1979 the weeds that had grown after the cowpea, were slashed and the field was again prepared for maize. The same fertilizer treatments as in 1978 were applied using the same sources. On March 25, 1979 maize (Cv TZB) was planted using the same spacing as in 1978. Harvesting was on July 16, 1979. Other management practices were similar to those used in 1978.

Crop Assessments and Analyses: For the two maize crops in 1978 and 1979, plant samples were taken at the time of thinning, for tissue dry matter and mineral contents. At silking, earleaf samples were similarly assessed. Stover and grain yields (12% moisture content) were evaluated at harvest and subsamples were taken for nutrient analyses. For the cowpea, the index leaf at flowering, seed yields and seed weights were the evaluated parameters.

4.3 Results and Discussion

4.3.1 *Dry Matter Yields of Maize and Mineral Nutrition at Two weeks after Planting (2WAP)*

The plants in burned plots established faster than those in mulched plots based on field observations. The dry matter yield of the plants at 2WAP did not differ significantly between mulching and burning as shown by the means of the two residue treatments (Table 4.1). However, the dry matter yields due to mulching were consistently higher than those due to burning at all fertilizer treatments.

The addition of NPK significantly increased the dry matter yields of the plants as compared with the check. The responses due to N and P were significant indicating that the response to NPK was essentially due to N and P. There were no significant responses to K or to the addition of MgZn at this stage of growth.

The plant contents of N, K, Ca, Mg and Zn did not differ significantly between the main treatments (Table 4.2). However, the plant P content was significantly higher under mulching than under burning while the Mn content was significantly higher under burning than under mulching. The application of N significantly increased the plant content of N and also significantly decreased the concentration of Ca, based on the nutrient means (Table 4.3a). The increase in N content due to N application was significant only under mulching as in Table 4.2. The application of P based on nutrient means,

TABLE 4.1 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE DRY MATTER YIELDS AT TWO WEEKS AFTER PLANTING (2WAP).

Fertilizer Treatments	Residue Management gm/plant Mulching	Burning	Fertilizer Means
Control	7.9	5.3	6.6
PK	9.2	8.7	9.0
NK	8.5	6.3	7.4
NP	14.7	9.4	12.1
NPK	13.9	10.8	12.4
NPKMgZn	16.4	9.8	13.1
Residue Management (Main Treatment) Means	11.8	8.4	10.1

Lsd (0.05)	(i)	Between Main treatment means	(3.6)
	(ii)	Between Fertilizer means	(1.9)
	(iii)	Between Fertilizer treatments under one Main treatment	(2.7)
	(iv)	Between Main treatment yields at the same fertilizer treatment	(4.3)

TABLE 4.2 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE NUTRIENT CONTENTS IN MAIZE AT TWO WEEKS AFTER PLANTING (2WAP).

Treatments: Residue Management	Treatments: Fertilizer Application		N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)
Mulch	Control		3.62	0.30	3.88	0.57	0.75	47	120
	PK		3.65	0.44	4.73	0.55	0.70	42	113
	NK		4.15	0.29	5.14	0.47	0.61	49	139
	NP		4.68	0.44	3.80	0.53	0.74	41	120
	NPK		4.76	0.44	5.46	0.42	0.61	42	120
	NPKMgZn		4.45	0.43	4.87	0.48	0.64	51	124
	Means		4.22	0.39	4.65	0.50	0.68	45	123
Burn	Control		3.54	0.23	3.16	0.70	0.75	42	154
	PK		3.92	0.37	4.31	0.58	0.70	39	143
	NK		3.47	0.24	4.66	0.56	0.57	40	191
	NP		4.06	0.34	3.86	0.57	0.70	40	154
	NPK		4.01	0.33	4.19	0.53	0.64	43	158
	NPKMgZn		4.47	0.32	5.05	0.47	0.61	45	161
	Means		3.91	0.31	4.21	0.57	0.66	42	160
	LSD (0.05)	(i)	0.38	0.02	1.74	0.12	0.16	7	13
		(ii)	0.65	0.04	1.40	0.10	0.12	7	32
		(iii)	0.69	0.04	2.10	0.15	0.19	9	31

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

TABLE 4.3 THE EFFECT OF FERTILIZER APPLICATION ON NUTRIENT CONTENTS AND TOTAL UPTAKE IN MAIZE AT TWO WEEKS AFTER PLANTING (2WAP).

a) Fertilizer Treatment	Nutrient Contents						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	3.58	0.27	3.52	0.64	0.75	45	137
PK	3.79	0.41	4.52	0.57	0.70	41	128
NK	3.81	0.27	4.90	0.52	0.59	45	165
NP	4.37	0.39	3.83	0.55	0.72	41	137
NPK	4.39	0.39	4.83	0.48	0.63	43	139
NPKMgZn	4.46	0.38	4.96	0.48	0.63	48	143
Lsd (0.05)	0.46	0.03	0.98	0.07	0.09	5	22

b) Fertilizer Treatment	Nutrient Uptake						
	N	P	K	Ca	Mg	Zn	Mn
			mg/plant			μg/plant	
Control	235	18	255	41	48	299	843
PK	335	37	415	46	63	354	1132
NK	287	20	377	38	44	337	1177
NP	532	49	473	65	87	494	1585
NPK	543	49	601	58	77	520	1682
NPKMgZn	588	51	610	62	83	640	1818
Lsd (0.05)	93	9	189	11	13	101	296

significantly increased N and P contents in the plant. The plant content of K was significantly increased following K application which significantly reduced Ca and Mg contents probably due to the inter-relationships among these elements. An excessive supply of K has been postulated by Barber (1968) to reduce Ca and Mg uptake. Such a reduction could occur if the K level in this soil was more than required for optimum growth. The lack of significant response to K may be partly indicative of the adequacy of K. There was no significant effect of the addition of MgZn on the plant content of Mg but it significantly increased the concentration of Zn in the plant.

The total uptake of nutrients at 2WAP showed that mulching was better than burning. The uptake of N, P, Ca, Mg and Zn was significantly higher under mulching than under burning (Table 4.4). The higher uptake of these elements due to mulching resulted from the higher dry matter yields obtained as a result of the mulch treatment. The mulch effect on P uptake at this stage of growth is real, since the higher yields due to mulching are not reflected in a dilution of plant P content.

The application of NPK resulted in a significant increase in the uptake of the elements but only the effects of N and P components of the fertilizer were significant, based on the means of the fertilizer treatments (Table 4.3b). There was no significant reduction in the uptake of Ca and Mg due to K. Therefore, the reported effect of K on plant contents of Ca

TABLE 4.4 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE TOTAL NUTRIENT UPTAKE IN MAIZE TOPS 2WAP.*

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn	Mn
			mg/plant					µg/plant	
Mulch	Control		283	24	337	44	56	372	890
	PK		330	41	452	41	64	383	1013
	NK		353	25	435	40	51	416	1160
	NP		687	65	553	77	109	604	1770
	NPK		652	61	756	59	85	579	1670
	NPKMgZn		739	71	730	77	104	838	2060
	Means		507	48	544	56	78	532	1427
Burn	Control		186	12	173	37	39	226	795
	PK		340	32	377	51	61	324	1250
	NK		221	15	319	35	36	257	1193
	NP		376	33	392	52	64	383	1399
	NPK		434	36	446	57	69	460	1693
	NPKMgZn		436	31	490	46	61	441	1575
	Means		332	27	366	46	55	349	1318
	Lsd (0.05)	(i)	112	14	349	9	13	182	418
		(ii)	132	13	268	15	19	143	418
		(iii)	121	18	416	16	21	219	553

*Weeks after planting.

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

and Mg was not due to excessive K level. The depression of Ca and Mg contents in the plant following K application was probably a result of dilution.

From these results, N and P would appear to be the two most essential elements required on this Alfisol to ensure a satisfactory early maize growth and mineral nutrition.

4.3.2 *Dry matter yields of Earleaf Samples, Nutrient Contents and Uptake.*

The dry matter yields of the earleaves of maize at silking were not significantly different between mulching and burning as indicated by the main treatment means (Table 4.5). The addition of NPK significantly increased the earleaf dry matter yields as compared to the check but only the responses due to N and P were significant. The addition of MgZn did not result in any significant effect on the earleaf dry matter yields.

The plant contents of the elements did not differ significantly between mulching and burning (Table 4.6) although the mean concentrations of N, P and K were lower than the levels considered adequate in the earleaf tissue (Barber and Olson, 1968). The low contents of these elements were particularly true where they were not applied. The levels of Ca, Mg, Zn and Mn seemed adequate by the same standard.

Based on the nutrient means (Table 4.7), the plant N content was not significantly affected by N application which signi-

TABLE 4.5 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE DRY MATTER YIELD OF MAIZE EARLEAF SAMPLES.

Nutrient Combinations	Residue Management Mulching	Burning	Nutrient Combination Means
	gm/leaf		
Control	3.8	3.2	3.5
PK	4.1	4.0	4.1
NK	4.1	3.8	4.0
NP	4.5	4.0	4.3
NPK	4.6	4.5	4.6
NPKMgZn	4.6	4.7	4.7
Residue Management Means	4.3	4.0	4.2

Lsd (0.05)

(i) Between Main treatment means (0.6)

(ii) Between Fertilizer means (0.4)

(iii) Between Fertilizer treatments under one Main treatment (0.5)

(iv) Between Main treatment yields at the same fertilizer treatment (0.7)

TABLE 4.6 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT CONTENTS IN THE EARLEAF SAMPLES.

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn	Mn
					%				ppm
Mulch	Control		2.48	0.22	1.69	0.48	0.55	26	53
	PK		2.38	0.36	1.90	0.48	0.52	19	53
	NK		2.37	0.19	1.76	0.48	0.53	27	64
	NP		2.61	0.35	1.39	0.68	0.79	24	83
	NPK		2.55	0.35	1.88	0.61	0.68	21	75
	NPKMgZn		2.70	0.33	1.64	0.63	0.68	24	79
	Means		2.52	0.30	1.71	0.56	0.63	24	68
Burn	Control		2.36	0.28	1.88	0.56	0.57	24	56
	PK		2.33	0.33	2.02	0.52	0.54	20	53
	NK		2.62	0.28	1.95	0.55	0.57	24	75
	NP		2.55	0.33	1.38	0.65	0.76	22	86
	NPK		2.61	0.34	1.71	0.68	0.72	21	75
	NPKMgZn		2.73	0.33	1.81	0.59	0.65	22	64
	Means		2.53	0.32	1.79	0.59	0.64	22	68
	Lsd (0.05)	(i)	0.34	0.04	0.35	0.07	0.12	1	14
		(ii)	0.32	0.03	0.37	0.10	0.11	8	17
		(iii)	0.43	0.05	0.47	0.11	0.15	4	17

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

TABLE 4.7 THE EFFECT OF FERTILIZER APPLICATION ON EARLEAF NUTRIENT COMPOSITION.

Fertilizer Treatment	Nutrient Contents						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	2.42	0.25	1.79	0.52	0.56	25	55
PK	2.36	0.35	1.96	0.50	0.53	20	53
NK	2.50	0.24	1.86	0.52	0.55	26	70
NP	2.58	0.34	1.39	0.67	0.78	23	85
NPK	2.58	0.35	1.80	0.65	0.70	21	75
NPKMgZn	2.72	0.33	1.73	0.61	0.67	23	72
Lsd (0.05)	0.23	0.02	0.26	0.07	0.08	3	12

ficantly increased Ca and Mg contents. The contents of P, Ca and Mg increased significantly as a result of P addition but the Zn content was significantly reduced. The addition of K significantly increased plant K content and also resulted in a significant depression in the plant content of Mg probably due to dilution. There was no significant effect of the addition of MgZn on the plant concentration of the two elements. However, P content in the plant was significantly reduced by MgZn application.

4.3.3 *Grain yields; the nutrient concentration and the total nutrient uptake in the grain.*

The average grain yields of maize (4981 kg/ha) obtained at the Ikenne site in the first year of bush fallow cultivation were comparable with those reported by other IITA workers. These yields indicate that with good management, high maize yields can be obtained on this Alfisol. There were no significant yield differences between mulching and burning of the fallow residues (Table 4.8). However, yields of maize due to mulching were higher than those due to burning at each fertilizer treatment.

The addition of NPK significantly increased the grain yields of maize as compared to the check. Responses to the individual elements were not significant. The addition of MgZn in the first year resulted in a significant increase in the yields of maize. The yields obtained without fertilizer

TABLE 4.8 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE GRAIN YIELD AT IKENNE.

Nutrient Combinations	Residue Management Mulching kg/ha	Residue Management Burning kg/ha	Nutrient Combination Means
Control	4228	3706	3967
PK	5069	4830	4950
NK	4939	4812	4876
NP	5205	4720	4963
NPK	5327	5275	5301
NPKMgZn	5838	5824	5831
Residue Management Means	5101	4861	4981

Lsd (0.05)	(i)	Between Main treatment means	(835)
	(ii)	Between Fertilizer means	(522)
	(iii)	Between Fertilizer treatments under one Main treatment	(738)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(1045)

application (3967 kg/ha) were as high as could be expected as compared with farmers yields on similar bush fallow sites (Moormann and Forbes-personal communication). Such yields may induce the subsistence farmer not to use fertilizer but the yield advantage due to fertilizer application is important. The increase in yields as a result of fertilizer application also indicates that the yield potential of the maize was probably not attained.

Nutrient contents in the grain did not differ significantly between mulching and burning as indicated by the means of the main treatments (Table 4.9). The contents of N and P in the grain were particularly low as compared with the adequate range reported by Barber and Olson (1968). The concentrations of K, Ca, Mg and Zn were adequate by the same criterion. It seems probable that N and P were limiting yields even where the two elements were added. Only the application of P significantly increased the grain contents of N and P based on the nutrient means (Table 4.10a).

Total nutrient uptake in the grain was not significantly different between mulching and burning (Table 4.11). The addition of NPK significantly increased the uptake of the elements except Ca, as compared with the check (Table 4.10b). The effects of the single elements on the uptake of nutrients in the grain were not significant except in the case of P where P application significantly increased N uptake only. The uptake of nutrients in the stovers was not different between mulching

TABLE 4.9 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF MAIZE GRAIN AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn
			%					ppm
Mulch	Control		1.58	0.27	0.45	0.20	0.09	29
	PK		1.64	0.37	0.56	0.14	0.12	31
	NK		1.54	0.17	0.33	0.11	0.06	22
	NP		1.72	0.33	0.48	0.13	0.10	26
	NPK		1.69	0.35	0.50	0.15	0.12	29
	NPKMgZn		1.58	0.34	0.51	0.22	0.11	29
	Means		1.63	0.31	0.47	0.16	0.10	28
Burn	Control		1.44	0.27	0.44	0.14	0.08	26
	PK		1.55	0.35	0.52	0.18	0.11	28
	NK		1.45	0.28	0.47	0.14	0.10	26
	NP		1.65	0.35	0.53	0.20	0.12	27
	NPK		1.61	0.30	0.45	0.10	0.10	23
	NPKMgZn		1.63	0.34	0.50	0.15	0.11	27
	Means		1.56	0.32	0.49	0.15	0.10	26
	Lsd (0.05)	(i)	0.09	0.05	-	-	-	-
		(ii)	0.18	0.10	-	-	-	-

(i) Between Main Treatment means

(ii) Between Fertilizer concentrations under one Main treatment

TABLE 4.10 THE EFFECT OF FERTILIZER APPLICATION ON NUTRIENT CONTENT AND UPTAKE IN MAIZE GRAIN.

a) Fertilizer Treatment

Fertilizer Treatment	N	P	K	Ca	Mg	Zn
	Nutrient Content					
			%			ppm
Control	1.51	0.27	0.45	0.17	0.09	28
PK	1.60	0.36	0.54	0.16	0.12	30
NK	1.50	0.23	0.40	0.13	0.08	24
NP	1.69	0.34	0.51	0.17	0.11	27
NPK	1.65	0.33	0.48	0.13	0.11	26
N°KMgZn	1.61	0.34	0.51	0.19	0.11	28
Lsd (0.05)	0.12	0.07	——	nd	——	——

b) Fertilizer Treatment

Fertilizer Treatment	N	P	K	Ca	Mg	Zn
			kg/ha			gm/ha
Control	60	11	18	7	4	110
PK	79	18	27	8	6	145
NK	74	16	20	6	4	120
NP	83	17	25	8	5	135
NPK	88	18	26	7	6	140
NPKMgZn	94	20	30	11	6	165
Lsd (0.05)	11	4	6	nd	2	30

TABLE 4.11 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON TOTAL NUTRIENT UPTAKE OF MAIZE GRAIN AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn
					kg/ha			gm/ha
Mulch	Control		66	12	19	9	4	130
	PK		83	19	29	7	6	160
	NK		76	18	16	5	3	110
	NP		89	17	25	7	5	140
	NPK		90	19	27	8	6	160
	NPKMgZn		92	20	30	13	6	170
	Means		83	18	24	9	5	145
Burn	Control		53	10	16	5	3	90
	PK		75	17	25	8	5	130
	NK		71	14	23	7	5	130
	NP		77	16	25	9	5	130
	NPK		85	16	24	5	5	120
	NPKMgZn		95	20	29	9	6	160
	Means		75	16	24	7	5	127
	Lsd (0.05)	(i)	15	4	6	-	1	30
		(ii)	11	4	6	-	2	30
		(iii)	15	5	8	-	2	40
		(iv)	20	6	9	-	2	40

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatment yields at the same Fertilizer treatment.

and burning (App. 4.3). Based on the summation of the uptake values of nutrients in the grain and stover, the recovery of added nutrients can be calculated. The recovery of N and P was low. This was particularly true of P.

The uptake of nutrients in the grain and stover under check treatment was higher with mulching than with burning. This advantage suggests that mineral nutrition of the maize was better although not significantly higher where the fallow residues were used as mulch than where they were burned.

4.3.4 *Dry matter yields of Cowpea index leaves and the nutrient contents in the leaf.*

The means of the dry matter yields of cowpea index leaves were the same under both the mulching and burning management systems (Table 4.12). There was a significant effect of the residual NPK application as compared with the check and based on the nutrient treatment means. However, only the response to P was statistically significant. There was no significant response to the residual effect of MgZn.

Nutrient contents in the leaves did not differ between the main treatments (Table 4.13) and N content was high even when no N had been applied. The low P content in the index leaves was an evidence that P could have been deficient. Leaf contents of the other elements seemed adequate although Mn level was high.

Residual effect of NPK resulted in a significant increase

TABLE 4.12 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE DRY MATTER YIELD OF COWPEA INDEX LEAVES.

Nutrient Comibations	Residue Management Mulching gm/leaf	Burning	Nutrient Combination Means
Control	0.47	0.55	0.51
PK	0.57	0.56	0.57
NK	0.49	0.53	0.51
NP	0.63	0.57	0.60
NPK	0.61	0.56	0.59
NPKMgZn	0.60	0.61	0.61
Residue Management Means	0.56	0.56	0.56

Lsd (0.05	(i)	Between Main treatment means	(0.01)
	(ii)	Between Fertilizer means	(0.07)
	(iii)	Between Fertilizer treatments under one Main treatment	(0.09)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(0.14)

TABLE 4.13 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE NUTRIENT CONTENTS IN COWPEA INDEX LEAVES.

Treatment: Residue Management	Treatment: Nutrient Combinations		N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)
Mulch	Control		5.08	0.23	2.18	1.78	0.61	243	360
	PK		5.19	0.34	1.78	2.02	0.73	230	432
	NK		5.01	0.26	2.02	1.74	0.62	290	350
	NP		4.96	0.28	1.41	2.02	0.83	306	377
	NPK		4.99	0.29	1.71	1.88	0.74	270	388
	NPKMgZn		4.95	0.31	1.59	2.18	0.81	203	484
	Means		5.03	0.29	1.78	1.94	0.72	257	399
Burn	Control		4.74	0.26	1.76	1.87	0.68	238	359
	PK		5.03	0.35	1.74	1.81	0.73	263	381
	NK		4.92	0.28	1.78	1.75	0.63	174	331
	NP		5.11	0.35	1.45	1.94	0.85	291	344
	NPK		5.18	0.34	1.52	2.04	0.85	210	388
	NPKMgZn		5.04	0.35	1.74	2.03	0.82	219	394
	Means		5.00	0.32	1.67	1.91	0.76	233	366
	Lsd (0.05)	(i)	0.64	0.04	0.15	0.31	0.11	49	62
		(ii)	0.46	0.05	0.29	0.29	0.13	114	63
		(iii)	0.75	0.06	0.29	0.40	0.16	113	82

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

in leaf contents of P and Mg but K was significantly reduced. Neither residual N nor the supplemental N significantly affected concentrations of any element in the leaf (Table 4.14a) but, residual P significantly increased the leaf contents of P, K, Ca, Mg and Mn but had no significant effect on N and Zn. Phosphorus therefore played a dominant role in the nutrition of cowpea at this stage of growth. There were no significant responses due to residual K or MgZn.

4.3.5 *Cowpea grain yields and nutrient contents in the grain.*

The yields of the cowpea were good compared with yields obtained at the IITA, Ibadan, Nigeria using the same variety on a similar Alfisol. There was no significant yield difference between the main treatments (Table 4.15), but there was evidence that yields were slightly higher under mulching than under burning. Residual NPK did not significantly affect cowpea yields as compared with the check. There were also no significant responses to residual N, P or K or to supplemental N. Residual effect of MgZn on yields of cowpea was not significant. Despite the lack of significant response to nutrients, there was evidence that yields were higher as a result of nutrient addition to the previous crop. The highest cowpea yields were obtained under mulching and with residual NPK MgZn. This result was an indication that the cowpea yield potential may not have been reached. Probably, greater residual fertilizer effect could result in higher

TABLE 4.14 THE EFFECT OF FERTILIZER APPLICATION ON NUTRIENT CONTENT IN COWPEA INDEX LEAVES AND GRAIN.

a)

Fertilizer Treatment	Nutrient Contents (Induex Leaves)						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	4.91	0.25	1.97	1.83	0.65	241	360
PK	5.11	0.35	1.76	1.92	0.73	247	407
NK	4.97	0.27	1.90	1.75	0.63	232	341
NP	5.04	0.32	1.43	1.98	0.84	299	361
NPK	5.09	0.32	1.62	1.96	0.80	240	388
NPKMgZn	5.00	0.33	1.67	2.11	0.82	211	439
Lsd (0.05)	0.33	0.04	0.19	0.21	0.09	80	45

b)

Fertilizer Treatment	Nutrient Content (Grain)						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	3.87	0.32	1.16	0.02	0.22	47	26
PK	3.86	0.41	1.18	0.02	0.23	44	23
NK	3.91	0.32	1.19	0.03	0.22	46	25
NP	3.75	0.40	1.13	0.02	0.22	45	27
NPK	3.95	0.41	1.16	0.02	0.23	44	27
NPKMgZn	3.91	0.38	1.16	0.02	0.22	46	23
Lsd (0.05)	0.25	0.02	0.05	———	nd	———	

TABLE 4.15 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON COWPEA GRAIN YIELD AT IKENNE.

Nutrient Combinations	Residue Management kg/ha Mulching	Residue Management kg/ha Burning	Nutrient Combination Means
Control	972	910	941
PK	1111	950	1031
NK	966	1018	992
NP	1112	980	1046
NPK	1067	1029	1048
NPKMgZn	1276	1022	1149
Residue Management Means	1084	985	1035

Lsd (0.05)	(i)	Between Main treatment means	(128)
	(ii)	Between Fertilizer means	(165)
	(iii)	Between Fertilizer treatments under one Main treatment	(233)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(244)

yields. Such yields would be dependent on higher initial fertilizer application which may not be economically rewarding to the subsistence farmer, even if the fertilizer nutrients were readily available.

Nutrient contents in the grain did not vary significantly between the residue management systems. From the responses to residual fertilizer, it was certain that without P application in 1978, P concentration in cowpea grain was significantly decreased (Table 4.14b and App. 4.4).

4.3.6 *Dry matter yields of maize and mineral nutrition at four weeks after planting (4WAP) in 1979.*

The dry matter yields of maize at this stage of growth did not differ significantly between mulching and burning treatments (Table 4.16). The application of NPK significantly increased the dry matter yields as compared to the check. However, only responses to N and P were significant. The addition of MgZn had no significant effect on the dry matter yields.

Nutrient contents in the plant were not significantly different between the two main treatments except in the case of Mn which was significantly higher under mulching than under burning (Table 4.17). The plant contents of N and P were low as compared to the levels considered adequate at this stage of growth. The contents of K, Ca, Mg, Zn and Mn, seemed adequate. The level of P. in particular, was critically

TABLE 4.16 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE DRY MATTER YIELD OF MAIZE TOPS 4WAP AT IKENNE.

Nutrient Combinations	Residue Management Mulching	Burning	Nutrient Combination Means
	gm/plant		
Control	5.4	5.3	5.4
PK	8.2	6.3	7.3
NK	6.1	6.3	6.2
NP	8.8	9.0	8.9
NPK	9.7	8.3	9.0
NPKMgZn	8.8	10.1	9,4
Residue Management Means	7.9	7.6	7.7

Lsd (0.05)	(i)	Between Main treatment means	(1.8)
	(ii)	Between Fertilizer means	(1.6)
	(iii)	Between Fertilizer treatments under one Main treatment	(2.2)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(2.6)

TABLE 4.17 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE NUTRIENT CONTENTS IN MAIZE AT 4WAP.

Treatment: Residue Management	Treatment: Nutrient Combinations		N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)
Mulch	Control		3.07	0.21	3.00	1.10	0.95	47	140
	PK		3.17	0.29	4.48	1.19	0.79	38	90
	NK		3.44	0.23	4.10	1.16	0.76	42	158
	NP		3.23	0.27	4.38	0.78	0.56	41	128
	NPK		3.51	0.29	4.53	1.18	0.75	43	135
	NPKMgZn		3.34	0.27	4.57	1.09	0.70	47	116
	Means		3.29	0.26	4.18	1.08	0.75	43	128
Burn	Control		3.17	0.24	2.56	0.93	0.85	41	101
	PK		3.05	0.28	4.15	0.89	0.74	45	105
	NK		3.41	0.27	3.66	0.83	0.70	41	105
	NP		3.13	0.31	4.41	1.11	0.75	49	105
	NPK		2.82	0.28	4.74	1.07	0.71	40	113
	NPKMgZn		3.26	0.34	4.46	0.83	0.66	63	113
	Means		3.14	0.29	4.00	0.94	0.74	47	107
	Lsd (0.05)	(i)	0.35	0.03	1.00	0.23	0.16	12	4
		(ii)	0.43	0.04	0.98	0.26	0.15	12	34
		(iii)	0.51	0.04	1.32	0.32	0.20	16	31

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

low suggesting that P may have been more limiting than N.

The plant contents of the elements were not significantly affected by the addition of the specific elements of the fertilizer treatments (Table 4.18a). Nutrient uptake in the plant was not significantly different between the residue management methods (Table 4.19). The addition of NPK resulted in a significant increase in the uptake of the major elements as compared with the check. However, only the effect of P on the uptake of these elements was significant (Table 4.18b). This was a confirmation that P was limiting at this stage of plant growth in 1979.

4.3.7 *Dry matter yields of earleaves and the nutrient contents in the leaf in 1979.*

The dry matter yields of maize earleaf samples at silking, like the yields of the plant dry matter at 4WAP, were not significantly different between the main treatments (Table 4.20). Based on the nutrient treatment means, the addition of NPK significantly increased the dry matter yields of the leaves. However, this response was significant only as a result of mulching. The responses to N and P were similarly significant only as a result of mulching. The application of MgZn had no significant effect on the dry matter of the leaves.

Nutrient contents in the leaf did not vary significantly between the main treatments (Table 4.21). The leaf N and P contents were low although N was within the adequate range

TABLE 4.18 THE EFFECT OF FERTILIZER APPLICATION ON NUTRIENT CONTENT AND UPTAKE IN MAIZE AT FOUR WEEKS AFTER PLANTING.

a) Fertilizer Treatment

Fertilizer Treatment	Nutrient Content						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	3.12	0.23	2.78	1.02	0.90	44	121
PK	3.11	0.29	4.32	1.04	0.77	42	98
NK	3.43	0.25	3.88	1.00	0.73	42	132
NP	3.18	0.29	4.40	0.95	0.66	45	117
NPK	3.17	0.29	4.64	1.13	0.73	42	124
NPKMgZn	3.30	0.31	4.52	0.96	0.68	55	115
Lsd (0.05)	0.30	0.03	0.70	0.18	0.11	8	24

b) Fertilizer Treatment

Fertilizer Treatment	Nutrient Uptake						
	N	P	K	Ca	Mg	Zn	Mn
			mg/plant			µg/plant	
Control	169	12	169	56	48	247	527
PK	229	22	315	78	56	319	696
NK	206	16	247	59	43	270	468
NP	284	26	394	85	59	357	1053
NPK	286	26	416	103	59	377	1210
NPKMgZn	310	29	424	90	59	567	1088
Lsd (0.05)	58	6	79	20	12	65	213

TABLE 4.19 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON TOTAL NUTRIENT UPTAKE IN MAIZE TOPS AT 4WAP.

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn	Mn
			mg/plant					μg/plant	
Mulch	Control		165	11	180	64	51	274	528
	PK		264	25	366	98	65	320	728
	NK		195	14	260	65	42	270	274
	NP		283	23	383	69	49	362	1145
	NPK		338	28	432	116	58	416	1481
	NPKMgZn		293	24	411	97	62	422	1030
	Means		256	21	339	85	55	344	943
Burn	Control		172	13	157	48	45	219	526
	PK		194	18	263	57	47	317	664
	NK		217	17	234	52	44	270	662
	NP		285	28	404	100	68	352	960
	NPK		234	24	399	90	59	337	939
	NPKMgZn		327	34	437	83	56	716	1145
	Means		238	22	316	72	53	369	816
	Lsd (0.05)	(i)	45	8	125	33	nd	85	261
		(ii)	82	8	112	28	-	92	310
		(iii)	86	11	158	41	-	117	371

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

TABLE 4.20 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE DRY MATTER YIELD OF MAIZE EARLEAVES.

Nutrient Combinations	Residue Management Mulching gm/leaf	Burning	Nutrient Combination Means
Control	4.1	4.1	4.1
PK	4.2	4.6	4.4
NK	4.2	4.4	4.3
NP	4.6	4.7	4.6
NPK	5.2	4.7	4.9
NPKMgZn	4.7	4.8	4.8
Means	4.5	4.5	4.5

Lsd (0.05) (i) Between Main treatment means (0.4)

(ii) Between Fertilizer means (0.5)

(iii) Between Fertilizer treatments under one Main treatment (0.6)

(iv) Between Main treatment yields at the same Fertilizer treatment (0.7)

TABLE 4.21 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE NUTRIENT CONTENTS IN MAIZE EARLEAVES.

Treatment Residue Management	Treatment Nutrient Combinations		N	P	K	Ca	Mg	Zn	Mn
					%			ppm	
Mulch	Control		2.73	0.15	1.45	1.21	0.34	54	245
	PK		2.92	0.20	1.90	1.14	0.29	45	255
	NK		2.52	0.14	1.68	1.20	0.30	48	245
	NP		2.93	0.19	1.91	1.16	0.29	46	265
	NPK		3.05	0.20	2.23	1.20	0.34	46	265
	NPKMgZn		2.73	0.17	1.98	1.11	0.25	48	255
	Means		2.81	0.17	1.86	1.17	0.30	48	255
Burn	Control		2.65	0.16	1.41	1.21	0.36	49	245
	PK		2.69	0.22	2.18	1.23	0.31	45	275
	NK		2.89	0.16	1.63	1.20	0.29	45	255
	NP		2.80	0.20	2.03	1.16	0.26	48	275
	NPK		3.02	0.19	2.16	1.20	0.28	54	245
	NPKMgZn		2.98	0.22	2.28	1.21	0.31	46	265
	Means		2.83	0.19	1.95	1.20	0.30	48	260
	Lsd (0.05)	(i)	0.19	0.03	0.14	0.12	0.07	nd	nd
		(ii)	0.37	0.03	0.30	0.10	0.06		
		(iii)	0.39	0.04	0.30	0.15	0.08		

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations at the same Fertilizer treatment

(2.75 - 3.25) cited in literature. The leaf P content was well below the adequate range (0.25 - 0.35) and this may be a further evidence, that P was limiting in 1979 and could have probably limited the uptake of N. The leaf contents of the other elements evaluated seemed adequate but Mn content was high.

The leaf contents of N, P and K increased significantly following the addition of NPK as compared with the check (Table 4.22). The leaf Ca content was not affected but the Mg content was significantly depressed by NPK application. However, only the effect of P on the leaf contents of N, P and K was significant. The concentration of K in the leaf increased significantly as a result of the added K.

The foregoing results provide a supporting evidence that P level was low or improperly applied, either of which, resulted in the limiting effect of the element. Previous data on the cowpea support this contention.

4.3.8 *Grain yields of maize and the nutrient content in the grain in 1979.*

The grain yields of maize in 1979 declined by 21 percent as compared with yields obtained in 1978. In spite of this yield decline, the average yield was reasonable and, as in 1978, mean yield difference between mulching and burning was not significant (Table 4.23). However, the yields due to burning were higher than those due to mulching in four of the six fertilizer treatments. The trend in 1978 was a reverse

TABLE 4.22 THE EFFECT OF FERTILIZER APPLICATION ON NUTRIENT CONTENT AND UPTAKE IN EARLEAF SAMPLES.

Fertilizer Treatment	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	2.69	0.16	1.43	1.21	0.35	52	245
PK	2.81	0.21	2.04	1.17	0.30	45	265
NK	2.71	0.15	1.66	1.20	0.30	47	250
NP	2.87	0.20	1.97	1.16	0.28	47	270
NPK	3.04	0.20	2.20	1.20	0.31	50	255
NPKMgZn	2.86	0.20	2.13	1.16	0.28	47	260
Lsd (0.05)	0.26	0.03	0.21	0.07	0.04	—— nd ——	

TABLE 4.23 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE GRAIN YIELDS ON IKENNE ALFISOL.

Nutrient Combinations	Residue Management Mulching kg/ha	Residue Management Burning kg/ha	Nutrient Combination Means
Control	2864	2675	2770
PK	4098	4386	4242
NK	3016	3385	3201
NP	4366	4526	4446
NPK	4454	4448	4451
NPKMgZn	4316	4509	4413
Residue Management Means	3852	3988	3920

Lsd (0.05)	(i)	Between Main treatment means	(612)
	(ii)	Between Fertilizer means	(379)
	(iii)	Between Fertilizer treatments under one Main treatment	(536)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(764)

of this. In that year, yields due to mulching were higher than yields due to burning in all of the fertilizer treatments. The yields at each fertilizer treatment did not differ significantly between both residue treatments in 1978 and 1979. It can be postulated that there was only a small difference in physical and chemical properties between the two residue management systems.

The addition of NPK resulted in a significant grain yield increase as compared with the check but only the yield increase due to P was significant. Unlike in 1978, there was no significant yield increase due to the addition of MgZn in 1979. Since the yields due to NK were comparable with yields of the check, and these were significantly lower than the yields due to other subtreatments, which contained P, P was therefore the most limiting nutrient in 1979. A similar deduction was made in respect of the yield data in 1978. In addition, it can be postulated from the yield results above, that the N level was probably adequate for the yields obtained, even where no N was added. This contention is confirmed by the relatively high yield due to PK. Thus, the N supplying power of the Alfisol may have been improved by the cowpea which probably fixed some N in the soil.

Nutrient contents in the grain were not significantly different between the main treatments (Table 4.24). Nitrogen and P contents in the grain were much lower than the levels considered to be adequate. The grain P content was particularly

TABLE 4.24 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE NUTRIENT COMPOSITION OF MAIZE GRAIN AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combination	N	P	K %	Ca	Mg	Zn ppm
Mulch	Control	1.65	0.23	0.51	0.010	0.15	27
	PK	1.50	0.25	0.54	0.011	0.15	24
	NK	1.90	0.23	0.59	0.012	0.17	30
	NP	1.70	0.23	0.57	0.012	0.16	28
	NPK	1.64	0.26	0.63	0.011	0.16	28
	NPKMgZn	1.67	0.23	0.55	0.012	0.16	29
	Means	1.68	0.24	0.57	0.011	0.16	28
Burn	Control	1.77	0.26	0.52	0.017	0.15	29
	PK	1.58	0.25	0.57	0.012	0.16	24
	NK	1.71	0.24	0.59	0.013	0.17	29
	NP	1.74	0.33	0.70	0.011	0.19	31
	NPK	1.47	0.26	0.54	0.013	0.16	26
	NPKMgZn	1.67	0.26	0.59	0.013	0.17	29
	Means	1.66	0.27	0.59	0.013	0.17	28
	Lsd (0.05) (i)	0.08	0.04	0.11	0.002	0.04	nd
	(ii)	0.28	0.05	0.11	0.003	0.03	
	(iii)	0.27	0.06	0.15	0.003	0.05	

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment concentrations as the same Fertilizer treatment low. This is consistent with greenhouse studies in the earlier sections of this thesis, which had also shown that P was one of the most limiting elements on the two soil types investigated. The result of the effect of P leads one to postulate that P could also have limited the uptake of N on the Alfisol. The concentrations of K, Ca, Mg and Zn by similar comparative standards, were considered to be adequate.

The effects of specific elements on the grain nutrient contents were not significant except in the case of P and K. The addition of P significantly reduced N content in the grain while K also depressed K content in the grain (Table 4.25). The effect of K on grain K content was not expected but this was mainly due to the reduction observed under burning.

TABLE 4.25 THE EFFECT OF FERTILIZER APPLICATION ON NUTRIENT CONTENT AND UPTAKE IN MAIZE GRAIN.

Fertilizer Treatment	Nutrient Content					
	N	P	K %	Ca	Mg	Zn ppm
Control	1.71	0.25	0.52	0.014	0.15	28
PK	1.54	0.25	0.56	0.012	0.16	24
NK	1.81	0.24	0.59	0.013	0.17	30
NP	1.72	0.28	0.64	0.012	0.17	30
NPK	1.56	0.26	0.59	0.012	0.16	27
NPKMgZn	1.67	0.25	0.57	0.013	0.17	29
Lsd (0.05)	0.20	0.03	0.07	0.002	0.02	nd

4.4 Summary and Conclusion

The effects of mulching versus burning of fallow residues and fertilizer application on crop yields and mineral nutrition were investigated on a Southwestern Nigerian Alfisol. During the two years in which the trial was conducted, two crops of maize and one of cowpea were grown.

For the two years (1978 and 1979), crop yields and mineral nutrition were comparable between the mulch and the burn management systems. However, mulching had a slight edge over burning especially in 1978. Mulching was judged a better method of residue management because it provided a physical cover to the soil and probably slowly released the organically bound nutrients in the residues. Burning provided a clean seedbed and facilitated planting but as the decomposition of the mulch residue set in, mulching was less laborious to manage than burning.

The similarity between mulching and burning in most of the estimated parameters indicates that there may actually be small physical and chemical differences between the two management methods. This may be particularly true when typical short fallows such as the Ikenne are cultivated.

The crop yields obtained in both years without fertilizers were satisfactory as compared with the farmer's yields. This was an indication that in two years of cultivation, reasonable crop yields were possible at the Ikenne fallow site with good crop husbandry alone. The yields at this site were more influenced by the soil fertility level than by the nutrient storage in the fallow biomass.

Fertilizer application markedly improved crop yields on this soil confirming that these amendments are required to boost crop production and yields. Although responses due to the major elements in the first year were not great, these nutrients were still necessary for good yields. Results in 1978 also indicate that when the three major elements are applied, Mg and Zn will be required if yields are to be substantially increased.

Cowpea yields in the first year were satisfactory as compared with yields obtained by other investigators at the same site. Although there were no responses to residual effect of fertilizers applied to the previous maize, there was evidence that P deficiency limited the attainment of the yield potentials of not only the cowpea and preceeding maize, but also of the succeeding maize in 1979. The deficiency effect of P was more pronounced in 1979 than in 1978 and P may also have limited N uptake. This partially explains the lack of significant response to added N. In addition, the cowpea augmented the N supplying power of the soil and also supplemented the effect of applied N. Therefore, the use of cowpea or other N-fixing legumes is recommended not only as a means of reducing the amount of N to be applied but also as a means of increasing the number of crops that the subsistence farmer can grow in the first year of bush fallow cultivation.

It would seem that less than 200 kgN/ha would be required over a two-year period of cultivation on the Alfisol when a good N-fixing crop is used in the rotation. There is a strong evidence that P is the key factor in obtaining and sustaining high yields given a good crop rotation and a level of management similar to the case in the present investigation. It appears that more than 60 kgP/ha would be needed over a two-year period as was the case in this trial. However, further research is needed to ascertain the requisite level of P and appropriate method of its placement on the Alfisol. Only minimal amounts of K may be required to maintain a balance between N and P and ensure a good growth but, the K level will increase with cropping.

It may be necessary to increase the levels of Mg and Zn used in the present study if the P level is increased although there was no evidence of the deficiency of either nutrient. Higher levels of Mg and Zn may not be required in the second and subsequent years of cultivation except as may be necessary, based on soil and tissue analysis.

In conclusion, the retention of fallow residues as mulch is encouraged except where the amounts of fallow litter are likely to hinder cultural practices such as planting. In this situation, light burning, enough to provide a cleaner seedbed may be appropriate since this is not destructive of soil properties or detrimental to plant growth and performance.

Chapter 5: A Comparison of Mulching and Burning With and Without Fertilizer and Lime, on Crop Yields and Mineral Nutrition on the Onne Ultisol in Southeastern Nigeria.

5.1 Introduction and Literature Review

As a consequence of high rainfall in Southeastern Nigeria, most of the soils which are of the Ultisol order are strongly leached. The soils have low cation exchange capacities and high exchangeable Al contents which contribute to their low pH. Nutrient deficiencies coupled with Al toxicity caused by the leaching and by the high Al saturation of the soil complex are the most immediate problems in managing these soils.

The increase in population has resulted in the land that is available for cultivation being more regularly exploited. Since fertilizer and lime are not usually used, and the nutrient and lime effects of the ash after the traditional slash and burn practice are not sustained beyond the first one or two years of cultivation (IITA Annual Report, 1974), soil nutrient deficiencies and soil acidity are increasing. Unpublished results of experiments in the area indicate that neither fertilizers nor lime application may effectively correct either the nutrient deficiencies or the Al toxicity once these problems have developed in these Ultisols. Results from the Yurimaguas Experimental Station in Peru on similar soil type confirmed that macro and micronutrient deficiencies developed after the first two years of slash and burn management in spite of the application of NPK and lime (NCSU 1973-1977).

Investigations on Southern Nigeria Ultisols have generally indicated that responses to fertilizer and lime application were related to the fertilizer sources used. For example, fertilizer sources such as urea and ammonium sulfate were shown in IITA studies (Annual Report, 1974) to reduce soil pH. High lime levels were then needed. It was suggested in the above studies that the decline in crop yields when such fertilizer sources were used, was due to the resulting soil acidification. In contrast, Kang (1978) suggested that the low yields on the Ultisols result from the low fertilizer use efficiency, especially of N which is lost in large amounts by leaching. When the N level was increased, the losses of Ca and Mg were enhanced. These losses, as suggested by Juo (personal communication) induced the deficiencies of Ca and Mg and increased soil acidity on the Ultisol.

Increasing the amount of lime applied in order to decrease the soil acidity decreased the available soil P determined by Bray-I method (IITA Annual Report, 1976). Greenhouse studies by Juo (Soil Chemistry Subprogram Report, 1976) using an Ultisol soil similar to the Onne soil showed that low lime rates ($<$ 1000 kg/ha $CaCO_3$), increased plant dry matter yields but high lime rates ($\gtrsim$ 2000 kg/ha) significantly depressed the dry matter yields of maize. Subsequent IITA studies (Annual

Report, 1976), confirmed that lime levels of 1000 - 2000 kg/ha induced Mg deficiency on the Onne Ultisol and also depressed the dry matter yields of maize in the greenhouse.

In a field study at the Amakama area of Southeastern Nigeria, it was found that small lime ($CaCO_3$) dosages of about 200 - 500 kg/ha increased maize yields on a soil similar to the Onne Ultisol (Uzu, personal communication). Uzu's results led him to suggest that higher lime rates may be uneconomic if used on a continuous basis. Friesen (1978) did not obtain a significant response by maize to lime levels up to 2000 kg/ha in the first year at Onne but exchangeable Al in the soil was reduced substantially. However, in the second year, Friesen reported a yield increase of 50 percent as a result of liming. In literature cited by Friesen (1978), liming with over 1000 kg/ha reduced crop yields by reducing P availability. Although Pulver and Horst (unpublished data) reported no response by cowpea to liming, Friesen obtained a response by cowpea to 500 kg/ha of lime after the first year of cultivation at Onne. The results of Pulver and Horst were also not substantiated by the data of Kang (1978) in which it was shown that greenhouse grown cowpea on unlimed Onne Ultisol was chlorotic and Ca deficient. The chlorotic plants were N-deficient and N application corrected the chlorosis and partially corrected the Ca-deficiency. Liming using 250 - 1000 kg/ha ($CaCO_3$) was shown in Kang's studies to improve nodulation and increase dry matter yields. The higher lime level slightly lowered plant Ca content.

It would appear from all of these studies reviewed, that fertilizer and lime responses on the Ultisol may depend on the sources and amounts of these amendments as well as on the specific test crop. In order to obtain good yields and sustain them on a regular basis, there will be the need to strike a balance between adequate fertilizer nutrients, soil acidity parameters such as Al, and specific crop requirements.

5.2 Materials and Methods

Details of the procedures are given in Section 4.2. The main treatments compared, were mulching and burning of the fallow residues. The subplot treatments at the Onne site were different from those at the Ikenne site, and consisted of nutrient combinations of check; NPK; NPK Mg Zn and NPK Mg Zn + Lime.

The levels and sources of fertilizer were the same as at Ikenne except that P and K were applied at the rate of 40 kg/ha of each element. The lime was applied only in 1978 at the rate of 1000 kg/ha using hydrated lime ($Ca(OH)_2 \cdot 2H_2O$). All other practices were similar to those used at the Ikenne site.

5.3 Results and Discussion

5.3.1 *Dry matter yields, nutrient content and nutrient uptake of maize three weeks after planting (3WAP).*

The dry matter yields of maize at 3WAP did not differ significantly between mulching and burning as shown by the main treatment means (Table 5.1). However, dry matter yields following burning were higher than the yields following mulching. The addition of NPK (nutrient combination means) significantly increased the plant dry matter yields. The response to Mg Zn was not significant. Lime application resulted in a significant increase in the dry matter yields.

The plant contents of N, P, K and Mn were significantly increased following mulching than following burning as indicated by the main treatment means (Table 5.2). The higher concentrations of these elements due to mulching were proabably a result of the lower dry matter yields obtained under the mulch treatment. The addition of NPK significantly increased the contents of N, P and Ca but had no significant effect on the other elements (Table 5.3a). Phosphorus content was significantly depressed by the addition of MgZn which also significantly increased the contents of Mg and Zn. Liming significantly increased K and Ca contents but also significantly reduced the plant contents of Mg and Mn.

The total uptake of nutrients did not differ significantly between the two methods of residue management (Table 5.4). The addition of NPK resulted in a significant increase in plant

TABLE 5.1 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON DRY MATTER YIELDS OF MAIZE AT THREE WEEKS AFTER PLANTING (3WAP).

Nutrient Combinations	Residue Management gm/plant Mulching	Burning	Nutrient Combination Means
Control	4.4	5.5	5.0
NPK	6.8	9.3	8.0
NPKMgZn	5.8	7.0	6.4
NPKMgZn + Lime	8.5	8.9	8.7
Means (R.M.)	6.4	7.7	7.0

Lsd (0.05)	(i)	Between Main treatment means	(2.3)
	(ii)	Between Fertilizer means	(1.9)
	(iii)	Between Fertilizer treatments under one Main treatment	(2.7)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(3.2)

TABLE 5.2 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF MAIZE TOPS AT 3WAP.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		%					ppm	
Mulch	Control	0.90	0.35	3.73	0.33	0.42	41	584
	NPK	3.70	0.57	3.68	0.39	0.37	43	556
	NPKMgZn	4.10	0.50	3.48	0.37	0.53	76	499
	NPKMgZn + Lime	3.70	0.43	4.27	0.61	0.47	69	291
	Means	3.60	0.47	3.80	0.42	0.45	57	482
Burn	Control	2.80	0.31	3.52	0.26	0.42	36	419
	NPK	3.40	0.43	3.23	0.41	0.41	36	386
	NPKMgZn	3.20	0.35	3.09	0.33	0.50	59	337
	NPKMgZn + Lime	3.10	0.34	3.42	0.44	0.45	63	258
	Means	3.13	0.36	3.30	0.36	0.44	48	321
	Lsd (0.05) (i)	0.40	0.08	0.28	0.08	0.04	10	63
	(ii)	0.76	0.09	0.76	0.09	0.07	10	125
	(iii)	0.76	0.09	0.71	0.11	0.07	13	124

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatments at the same Fertilizer treatment

TABLE 5.3 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON NUTRIENT CONTENT AND UPTAKE IN MAIZE AT 3WAP.

a) Fertilizer Application

	Nutrient Content						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	2.85	0.33	3.63	0.30	0.42	39	502
NPK	3.55	0.50	3.46	0.40	0.39	40	471
NPKMgZn	3.65	0.43	3.29	0.35	0.52	68	418
NPKMgZn + Lime	3.40	0.39	3.85	0.53	0.46	66	275
Lsd (0.05)	0.54	0.06	0.54	0.06	0.05	7	89

b) Fertilizer Application

	Nutrient Uptake						
	N	P	K	Ca	Mg	Zn	Mn
			mg/plant			μg/plant	
Control	142	17	180	15	21	190	2405
NPK	280	40	273	32	31	267	3630
NPKMgZn	231	27	210	24	34	431	2655
NPKMgZn + Lime	295	34	325	46	40	567	2345
Lsd (0.05)	79	10	77	9	8	97	500

TABLE 5.4 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON TOTAL ELEMENT UPTAKE IN MAIZE TOPS AT 3WAP.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		mg/plant						
Mulch	Control	130	16	168	14	19	180	2500
	NPK	250	40	251	26	25	296	3810
	NPKMgZn	241	29	202	21	31	439	2950
	NPKMgZn + Lime	313	37	339	52	40	587	2460
	Means	233	30	240	28	29	376	2927
Burn	Control	154	17	191	15	23	200	2310
	NPK	310	39	294	38	37	237	3450
	NPKMgZn	221	25	217	27	36	422	2360
	NPKMgZn + Lime	277	30	311	39	39	547	2230
	Means	240	28	253	30	34	374	2588
	Lsd (0.05) (i)	95	9	78	13	8	115	730
	(ii)	120	14	108	12	12	137	
	(iii)	133	15	129	16	13	162	

(i) Between Main treatment means

(ii) Between Fertilizer treatment under one Main treatment

(iii) Between Main treatment at the same Fertilizer treatment uptake of N, P, K, Ca, Mg and Mn (Table 5.3b). The uptake of P, Zn and Mn increased significantly following the addition of MgZn. Liming significantly increased K, Ca and Zn uptake in the plant.

5.3.2 *Ear-leaf dry matter yields and nutrient content.*

Mean dry matter yields of the ear-leaf samples were not significantly influenced by mulching as compared to burning of residues (Table 5.5). The addition of NPK (nutrient means) significantly increased the ear-leaf dry matter yields but, neither the application of MgZn nor liming significantly influenced the dry matter yields of the ear-leaf samples.

The contents of P, K, Zn and Mn in the ear-leaf were significantly higher under mulching than under burning (Table 5.6). Manganese concentrations appeared to be generally high. Nitrogen level was low as compared to what is considered to be adequate in the ear-leaf tissue (2.75 - 3.25) indicating that N could have been limiting growth. Although the leaf P content was high, evidence from greenhouse studies had indicated that P was the major limiting element not only on this Ultisol but also on the Alfisol soil at Ikenne. Therefore, the high P content in the ear-leaf is not conclusive proof that P was adequate since low ear-leaf dry matter yields could have resulted in a high nutrient content. The leaf contents of K, Ca, Mg and Zn

TABLE 5.5 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE EARLEAF DRY MATTER YIELDS OF MAIZE.

Nutrient Combinations	Residue Management Mulching gm/leaf	Burning	Nutrient Combination Means
Control	2.8	2.9	2.9
NPK	4.3	4.4	4.4
NPKMgZn	3.6	4.9	4.3
NPKMgZn + Lime	4.8	4.8	4.8
Residues Management Mean	3.9	4.3	4.1

Lsd (0.05)	(i)	Between Main treatment means	(0.9)
	(ii)	Between Fertilizer means	(0.9)
	(iii)	Between Fertilizer treatments under one Main treatment	(1.3)
	(iv)	Between Main treatment yields at the same Fertilizer treatment	(2.3)

TABLE 5.6 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE EARLEAF NUTRIENT COMPOSITION.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
				%				ppm
Mulch	Control	2.26	0.55	2.53	0.17	0.34	18	150
	NPK	2.48	0.52	2.42	0.27	0.24	21	225
	NPKMgZn	2.73	0.55	2.39	0.27	0.33	28	184
	NPKMgZn + Lime	2.68	0.44	2.13	0.44	0.34	29	113
	Means	2.54	0.52	2.37	0.29	0.31	24	168
Burns	Control	2.07	0.34	1.95	0.16	0.16	14	101
	NPK	2.36	0.44	1.66	0.36	0.32	17	131
	NPKMgZn	2.29	0.36	1.50	0.32	0.33	23	113
	NPKMgZn + Lime	2.69	0.42	2.11	0.50	0.39	23	94
	Means	2.35	0.39	1.80	0.33	0.33	19	110
	Lsd (0.05) (i)	0.20	0.04	0.55	0.06	0.03	3	41
	(ii)	0.31	0.08	0.48	0.08	0.07	5	46
	(iii)	0.32	0.08	0.67	0.09	0.06	5	56

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatment at the same Fertilizer treatment seemed to be adequate.

There was a significant increase in the leaf contents of N, Ca and Mn as a result of the addition of NPK (Table 5.7). The addition of MgZn also significantly increased Mg and Zn contents of the leaf. There was a significant increase in the leaf Ca content only due to burning. The specific effects of the elements in the fertilizer treatments were confounded as a result of the combination of the elements applied.

5.3.3 *Grain yields, nutrient content and nutrient uptake in the grain.*

The average grain yields of maize at the Onne site in the first year of cultivation were considerably lower than those obtained at the Ikenne site. The mean yields did not differ significantly between mulching and burning, as shown by the main treatment means (Table 5.8). In this first year of cultivation at Onne, the addition of NPK resulted in a significant increase in grain yield (nutrient means). The yield response to each of the elements added is not known as a result of the confounding effect of the nutrient combinations used. There was no yield response to MgZn application. Liming increased the grain yields by about 15 per cent but the increase was not statistically significant.

At each nutrient combination treatment, grain yields under mulching were higher than those obtained where residues

TABLE 5.7 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON THE EARLEAF NUTRIENT CONTENT.

Fertilizer Application	Nutrient Contents						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	2.17	0.45	2.24	0.17	0.25	16	126
NPK	2.42	0.48	2.04	0.32	0.28	19	178
NPKMgZn	2.51	0.46	1.95	0.30	0.33	26	149
NPKMgZn + Lime	2.69	0.43	2.12	0.47	0.37	26	104
Lsd (0.05)	0.21	0.05	0.32	0.06	0.05	3	30

TABLE 5.8 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE GRAIN YIELD.

Nutrient Combinations	Residue Management Mulching	Residue Management Burning	Nutrient Combination Means
	ka/ha		
Control	1740	1190	1465
NPK	3412	2727	3070
MPKMgZn	2878	2802	2840
NPKMgZn + Lime	3495	3008	3252
Residues Management Means	2881	2432	2657

Lsd (0.05)	(i)	Between Main Treatment means	(671)
	(ii)	Between Fertilizer means	(480)
	(iii)	Between Fertilizer treatments under one Main treatment	(679)
	(iv)	Between Main treatments at the same Fertilizer treatment	(873)

of the bush fallow were burned. This was an indication that mulching was slightly better than burning of the residues in the first year. Although the yield advantage of 449 kg/ha due to mulching may seem numerically small, it is important from the subsistence farmers' standpoint.

The addition of NPK increased grain yields by about 110 per cent (nutrient combination means) in the first year indicating that the nutrient content of the Onne soil was low. Liming did not result in a significant yield increase in the first year, as was also reported by Friesen (1978) on the same Ultisol. This may have been related to a lack of soil disturbance during clearing and cultivation, which would have increased the level of exchangeable Al.

The concentrations of the elements in the grain did not differ significantly between the mulching and burning treatments except in the case of N and Ca (Table 5.9). Nitrogen content in the grain was significantly higher under mulching than under burning while the reverse was true for Ca. In addition, the N content in the grain was low as compared to the optimum levels cited earlier in Chapter 4. The level of P in the grain may be described as intermediate whereas, the concentrations of K, Ca, Mg and Zn seemed to be adequate.

Total uptake of nutrients by the grain (main treatment means) indicated that N, P, K and Zn were significantly higher under mulching than under burning (Table 5.10). The uptake of Ca and Mg was similar between the two methods of residue

TABLE 5.9 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE GRAIN NUTRIENT COMPOSITION.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn
		%					ppm
Mulch	Control	1.76	0.39	0.54	0.14	0.15	35
	NPK	1.77	0.35	0.45	0.13	0.12	28
	NPKMgZn	1.68	0.45	0.58	0.15	0.17	37
	NPKMgZn + Lime	1.63	0.41	0.55	0.16	0.15	36
	Means	1.71	0.40	0.53	0.15	0.15	34
Burn	Control	1.62	0.47	0.64	0.22	0.18	39
	NPK	1.60	0.37	0.45	0.19	0.13	28
	NPKMgZn	1.55	0.32	0.41	0.15	0.12	27
	NPKMgZn + Lime	1.62	0.47	0.63	0.15	0.18	39
	Means	1.60	0.41	0.53	0.18	0.15	33

TABLE 5.10 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE GRAIN TOTAL NUTRIENT UPTAKE.

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn
					kg/ha			gm/ha
Mulch	Control		31	7	9	3	3	59
	NPK		60	12	15	4	4	96
	NPKMgZn		48	13	17	4	5	108
	NPKMgZn + Lime		57	15	19	6	5	124
	Means		49	12	15	4	4	97
Burn	Control		19	6	8	3	2	46
	NPK		44	10	13	5	4	77
	NPKMgZn		44	9	11	4	3	74
	NPKMgZn + Lime		48	14	19	4	5	117
	Means		39	10	13	4	4	79
	Lsd(0.05)	(i)	9	1	2	nd	1	6
		(ii)	12	2	9	-	3	46
		(iii)	14	2	8	-	2	40

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatments at the same Fertilizer treatment

management. The higher uptake of the major elements by the grain due to mulching is probably a confirmation that mulching was a better method of handling the fallow residues than burning. Specifically, the uptake of N in check treatments was significantly higher under mulching than under burning. This observation suggests that either N loss due to burning of the residues significantly lowered the N supplying potential under the burning treatment or that the N contribution from the decomposing mulch residues was significant.

The addition of NPK significantly increased the uptake of N, P and Zn but had no significant effect on K, Ca and Mg based on the nutrient combination means (Table 5.11). While it is possible that a deficiency of N and P may have limited the grain yields, there was no evidence that Zn was deficient. Probably, Zn uptake by the grain was dependent on the yields. There was no significant increase in the uptake of Mg and Zn by the grain as a result of MgZn application. The uptake of P was significantly increased by liming.

5.3.4 *Maize stover yields and nutrient content.*

The stover yields did not differ significantly between mulching and burning (Table 5.12). The yield trends as well as the nutrient content were similar to those obtained in respect of the grains in Section 5.3.3. Both nutrient contents and uptake in the stovers were higher under mulching than under burning. This is further evidence that mulching

TABLE 5.11 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON UPTAKE OF NUTRIENTS IN MAIZE GRAIN.

Fertilizer Application	Nutrient Contents					
	N	P	K	Ca	Mg	Zn
			kg/ha			gm/ha
Control	25	7	9	3	3	53
NPK	52	11	14	5	4	87
NPKMgZn	46	11	14	4	4	91
NPKMgZn + Lime	53	15	19	5	5	121
Lsd (0.05)	9	1	6	nd	2	32

TABLE 5.12 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE STOVER YIELDS.

Nutrient Combinations	Residue Management Mulching kg/ha	Residue Management Burning kg/ha	Nutrient Combination Means
Control	1514	1145	1330
NPK	2724	2407	2566
NPKMgZn	2670	2460	2565
NPKMgZn + Lime	3001	2753	2817
Residues Management Means	2497	2191	2344

Lsd (0.05)	(i)	Between Main treatment means	(1039)
	(ii)	Between Fertilizer means	(482)
	(iii)	Between Fertilizer treatments under one Main treatment	(682)
	(iv)	Between Main treatments at the same Fertilizer treatment	(1172)

was a better method of managing the fallow residues than burning (App. 5.3 and 5.4). It is also an evidence that liming did not result in any significant improvement in crop performance in the first year of cultivation of the bush fallow.

5.3.5 *Cowpea index leaf dry matter yields and nutrient content.*

The dry matter yields of the index leaf samples of cowpea were not significantly different between mulching and burning as indicated by the means of the two treatments (Table 5.13). Yield responses to the residual effects of NPK; Mg Zn or lime application were not significant (nutrient combination means).

The nutrient concentrations in the index leaves were not significantly affected by mulching as compared to where the residues were burned except in the case of Mn (Table 5.14). The Mn level was significantly higher under mulching than under burning. However, the leaf Mn levels seemed to be generally high and suspect. Neither the residual effect of fertilizer nor of lime application on the leaf nutrient concentrations was significant (App. 5.5).

5.3.6 *Cowpea seed yields and nutrient content.*

The average cowpea seed yield of 1149 kg/ha obtained at the Onne site was good compared with the yields reported in the area (Wien, personal communication and IITA Annual Reports 1974-1976). Although cowpea yields did not differ significantly

TABLE 5.13 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON INDEX LEAF DRY MATTER YIELDS OF COWPEA.

Nutrient Combinations	Residue Management Mulching	Burning	Nutrient Combination Means
Control	0.14	0.12	0.13
NPK	0.12	0.11	0.12
NPKMgZn	0.12	0.10	0.11
NPKMgZn + Lime	0.12	0.09	0.11
Residue Management Means	0.12	0.10	0.11

Lsd (0.05)	(i)	Between Main treatment means	(0.05)
	(ii)	Between Fertilizer means	(0.03)
	(iii)	Between Fertilizer treatments under one Main treatment	(0.04)
	(iv)	Between Main treatments at the same Fertilizer treatment	(0.06)

TABLE 5.14 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF COWPEA INDEX LEAF.

Treatment: Residue Management	Treatment: Nutrient Combinations	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)
Mulch	Control	5.40	0.42	1.99	1.49	0.48	48	810
	NPK	5.40	0.44	2.13	1.86	0.42	43	754
	NPKMgZn	5.30	0.42	1.78	1.50	0.41	55	788
	NPKMgZn + Lime	5.30	0.42	1.87	2.33	0.37	53	398
	Means	5.33	0.42	1.94	1.79	0.42	50	687
Burn	Control	4.70	0.43	2.04	0.98	0.41	41	525
	NPK	5.20	0.45	1.88	1.57	0.37	43	559
	NPKMgZn	5.30	0.42	1.89	1.89	0.40	55	484
	NPKMgZn + Lime	5.20	0.44	2.01	2.14	0.42	49	405
	Means	5.07	0.43	1.95	1.64	0.40	47	493
	Lsd (0.05) (i)	0.35	0.07	0.64	0.14	0.19	9	55
	(ii)	0.47	0.04	0.36	0.64	0.06	8	152
	(iii)	0.67	0.06	0.51	0.90	0.08	11	215
	(iv)	0.67	0.09	0.76	0.16	0.20	13	193

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

between mulching and burning, yields due to mulching were higher at each fertilizer combination treatment (Table 5.15).

There were no significant yield responses due to the residual effects of fertilizer or lime treatments. However, the yield increase due to NPK Mg Zn + Lime as compared to the check indicates that nutrient and lime may have been beneficial. There are conflicting reports regarding cowpea response to fertilizer and lime application on the Onne soil. While Friesen (1978) found no significant yield response to the addition of 1000 kg/ha of Lime ($CaCO_3$) in the first year, yields of cowpea increased significantly in the second year as a result of 500 kg/ha of the lime. Kang (1978), also reported that liming significantly increased cowpea dry matter yields on the Onne soil used in a greenhouse study. However, Pulver and Horst in unpublished data, cited by Friesen (1978) found no significant response by cowpea to liming or to fertilizer application even after two years of bush fallow cultivation at the Onne site. The differences between these results and those of the present study are not easy to explain. They may be related to cultivar differences, varying fertility levels and lime sources used for the studies. From the present study being discussed, there was an indication that yields of the cowpea could have been better if NPK Mg Zn + Lime had been applied to the cowpea.

Some leaf chlorosis was observed in the field and this could be a nutrient deficiency or disease symptom. In green-

TABLE 5.15 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON COWPEA GRAIN YIELDS.

Nutrient Combinations	Residue Management Mulching kg/ha	Burning	Nutrient Combination Means
Control	1138	1010	1074
NPK	1128	1045	1087
NPKMgZn	1203	1156	1180
NPKMgZn + Lime	1282	1223	1253
Residues Management Mean	1188	1109	1149

Lsd (0.05)
(i) Between Main treatment means (160)
(ii) Between Fertilizer means (191)
(iii) Between Fertilizer treatments under one Main treatment (271)
(iv) Between Main treatments at the same Fertilizer treatment (279)

house studies, Kang (1978) found that chlorotic cowpea was N deficient. The low N content in the ear-leaf samples of the previous maize crop indicated that N could have been deficient, thus confirming Kang's findings. However, the N content of the cowpea index leaf appeared to be adequate. Therefore, the observed chlorosis could be due to a multiple nutrient deficiency or due to Al toxicity.

The nutrient contents in the grain were not significantly affected either by mulching or by burning of residues except in the case of Mn. The Mn level was significantly higher due to mulching than due to burning (Table 5.16). The Mn content in the grain was generally high but since the grain does not need to be washed for Mn determination, it seemed that the previously reported high Mn results in the leaf are true and showed the right trends. The residual effects of fertilizer and lime treatments on grain nutrient contents were not statistically significant (App. 5.6).

5.3.7 *Dry matter yields of maize, nutrient content and uptake two weeks after planting (2WAP) in 1979.*

The dry matter yields of maize at 2WAP were lower than those obtained at about the same stage of growth in 1978. This decline in dry matter yields was an indication that early plant growth and establishment was poorer in 1979 than in 1978. The difference in the mean plant dry matter yields between mulching and burning was nearly significant (Table 5.17).

TABLE 5.16 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF COWPEA GRAIN.

Residue Management	Treatment Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		%					ppm	
Mulch	Control	3.85	0.49	2.31	0.02	0.24	44	75
	NPK	4.02	0.47	2.58	0.02	0.23	39	83
	NPKMgZn	3.64	0.46	2.26	0.02	0.23	49	75
	NPKMgZn + Lime	3.64	0.47	2.31	0.02	0.22	46	64
	Means	3.79	0.47	2.36	0.02	0.23	44	74
Burn	Control	3.57	0.50	2.40	0.02	0.23	44	79
	NPK	3.65	0.49	2.35	0.02	0.25	43	64
	NPKMgZn	3.74	0.47	2.33	0.02	0.22	49	64
	NPKMgZn + Lime	3.84	0.46	2.30	0.02	0.22	42	53
	Means	3.70	0.48	2.34	0.02	0.23	44	65
	Lsd (0.05) (i)	0.19	0.02	0.27	nd	0.01	4	8
	(ii)	0.30	0.02	0.11		0.02	3	11
	(iii)	0.42	0.03	0.15		0.03	5	15
	(iv)	0.41	0.03	0.30		0.63	5	15

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

TABLE 5.17 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE DRY MATTER YIELDS ON MAIZE TOPS AT TWO WEEKS AFTER PLANTING (2WAP) IN 1979.

Nutrient Combinations	Residue Management Mulching	Residue Management Burning	Nutrient Combination Means
	gm/plant		
Control	0.55	0.46	0.51
NPK	0.60	0.64	0.62
NPKMgZn	0.76	0.63	0.70
NPKMgZn + Lime	0.73	0.48	0.61
Residue Management Means	0.66	0.55	0.61

Lsd (0.05)

(i) Between Main treatment means (0.12)

(ii) Between Fertilizer means (0.15)

(iii) Between Fertilizer treatments under one Main treatment (0.21)

(iv) Between Main treatments at the same Fertilizer treatment (0.21)

Based on the nutrient combination means, responses to the addition of NPK, MgZn or to the residual effect of liming were not significant. However, the response to NPK + MgZn was significant as compared to the check. This response was probably an indication that some or all of these nutrients may be limiting growth of maize at this stage. This observed effect of NPK + Mg Zn was significant under the mulch treatment as compared with the check of that residue method.

The plant content of nutrients was generally higher than in 1978 mainly due to a poorer growth in 1979. Only the plant contents of N and Mn were significantly affected by residue treatments (Table 5.18). Both elements were significantly higher under mulching than under burning. The addition of NPK caused a significant increase in N and P contents and also significantly decreased Mg and Mn contents probably as a result of dilution (Table 5.19a). The contents of Mg and Zn increased significantly following Mg Zn application. The effect of residual lime on nutrient contents was not significant except in the case of Mn where residual lime significantly depressed the plant Mn content.

The uptake of nutrients showed that N, Ca, Zn and Mn were significantly higher as a result of mulching than as a result of burning (Table 5.20). The uptake of N and P was significantly enhanced following the addition of NPK as shown by the nutrient combination effects (Table 5.19b). Phosphorus, Mg and Zn uptake was also significantly enhanced by the addition

TABLE 5.18 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF MAIZE TOPS AT 2WAP.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K (%)	Ca	Mg	Zn	Mn (ppm)
Mulch	Control	4.68	0.48	4.06	0.84	0.57	44	349
	NPK	5.65	0.73	4.67	0.83	0.43	47	281
	NPKMgZn	5.19	0.66	4.34	0.85	0.51	76	255
	NPKMgZn + Lime	5.36	0.71	4.85	1.00	0.49	81	124
	Means	5.22	0.65	4.48	0.88	0.5	62	252
Burn	Control	4.02	0.45	4.48	0.97	0.58	45	206
	NPK	4.93	0.65	4.55	0.78	0.37	42	184
	NPKMgZn	5.18	0.66	4.85	0.84	0.50	85	180
	NPKMgZn + Lime	5.38	0.69	5.28	1.01	0.49	82	105
	Means	4.88	0.61	4.79	0.90	0.49	64	169
	Lsd (0.05) (i)	0.15	0.07	0.71	0.37	0.14	4	71
	(ii)	0.46	0.07	0.59	0.32	0.15	12	58
	(iii)	0.42	0.09	0.86	0.47	0.19	11	85

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatments at the same Fertilizer treatment

TABLE 5.19 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON NUTRIENT CONTENT AND UPTAKE IN MAIZE AT 2WAP IN 1979.

a) Fertilizer Application

	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	4.35	0.47	4.27	0.91	0.58	45	278
NPK	5.29	0.69	4.61	0.81	0.40	45	233
NPKMgZn	5.19	0.66	4.60	0.85	0.51	81	218
NPKMgZn + Lime	5.37	0.70	5.07	1.01	0.49	82	115
Lsd (0.05)	0.32	0.05	0.42	0.26	0.11	8	41

b) Fertilizer Application

	N	P	K	Ca	Mg	Zn	Mn
			mg/plant			μg/plant	
Control	21	3	22	5	3	22	139
NPK	32	4	29	5	3	27	137
NPKMgZn	36	5	33	6	4	56	153
NPKMgZn + Lime	30	4	30	7	3	49	71
Lsd (0.05)	7	1	8	2	1	10	343

TABLE 5.20 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON TOTAL NUTRIENT UPTAKE IN MAIZE AT 2WAP (1979).

Treatment: Residue Management	Treatment: Nutrient Application	N (mg/plant)	P (mg/plant)	K (mg/plant)	Ca (mg/plant)	Mg (mg/plant)	Zn (µg/plant)	Mn (µg/plant)
Mulching	Control	26	3	23	5	3	24	187
	NPK	34	4	28	5	3	28	164
	NPKMgZn	39	5	34	6	4	58	193
	NPKMgZn + Lime	39	5	35	8	4	59	94
	Means	35	4	30	6	4	42	160
Burning	Control	18	2	21	4	3	20	91
	NPK	30	4	29	5	2	26	110
	NPKMgZn	32	4	31	5	3	53	113
	NPKMgZn + Lime	25	3	25	5	2	39	48
	Means	26	4	27	5	3	35	91
	Lsd (0.05) (i)	6	1	8	1	1	7	43
	(ii)	7	1	8	2	1	10	34
	(iii)	10	1	11	3	1	14	48
	(iv)	10	2	13	3	1	13	58

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

of Mg Zn. Liming in 1978 resulted in a significant decrease in P and Mg uptake under burning.

5.3.8 *Ear-leaf dry matter yields and nutrient content in 1979.*

In 1979, the dry matter yields of maize ear-leaf samples did not differ significantly between mulching and burning (Table 5.21). A similar result was obtained in 1978. There was a significant increase in dry matter yields of the ear-leaf samples as a result of NPK addition. The responses to Mg Zn or to residual effect of lime were not significant.

The nutrient contents in the ear-leaf were not significantly affected by mulching as compared to where the residues were burned except in the case of Mg which was significantly higher under mulching (Table 5.22). The mean N content of the ear-leaf was lower than the lower level of the range (2.75 - 3.25) considered to be adequate in the literature cited elsewhere in this thesis. The concentrations of P, K, Ca, Mg, Zn and Mn appeared to be adequate on the same basis of evaluation. It would appear that N may have been limiting maize performance as was confirmed in the field by the yellowing of maize even where N had been applied. There was evidence from greenhouse studies that P was the most limiting element on this soil. Therefore, P could also be as limiting as was N despite the "adequate" concentration of the P in the ear-leaf tissue. Probably, a poor maize growth in 1979 resulted in a high content of P in the leaf. The nutrient problem on the

TABLE 5.21 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE DRY MATTER YIELDS OF MAIZE EARLEAF.

Nutrient Combinations	Residue Management Mulching gm/leaf	Burning	Nutrient Combination Mean
Control	3.1	2.7	2.9
NPK	4.1	3.7	3.9
NPKMgZn	4.1	4.2	4.1
NPKMgZn + Lime	4.2	4.2	4.2
Residue Management Means	3.9	3.7	3.8

Lsd (0.05)	(i)	Between Main treatment means	(0.5)
	(ii)	Between Fertilizer means	(0.5)
	(iii)	Between Fertilizer treatments under one Main treatment	(0.7)
	(iv)	Between Main treatments at the same Fertilizer treatment	(1.1)

TABLE 5.22 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE NUTRIENT COMPOSITION OF MAIZE EARLEAF.

Treatment: Residue Management	Treatment: Nutrient Addition		N	P	K	Ca	Mg	Zn	Mn
					%			ppm	
Mulch	Control		1.94	0.49	2.15	1.16	0.26	43	350
	NPK		2.86	0.53	2.40	1.25	0.18	45	345
	NPKMgZn		2.86	0.48	2.28	1.23	0.23	55	355
	NPKMgZn + Lime		2.91	0.49	2.42	1.31	0.20	51	310
	Means		2.64	0.50	2.31	1.24	0.22	49	340
Burn	Control		2.11	0.45	2.71	1.07	0.19	39	290
	NPK		2.77	0.49	2.54	1.20	0.15	39	320
	NPKMgZn		2.84	0.46	2.29	1.32	0.19	60	330
	NPKMgZn + Lime		2.93	0.42	2.60	1.30	0.19	54	275
	Means		2.66	0.46	2.54	1.22	0.18	48	304
	Lsd (0.05)	(i)	0.21	0.05	0.56	0.15	0.04	7	48
		(ii)	0.33	0.09	0.47	0.10	0.04	9	38
		(iii)	0.35	0.09	0.68	0.17	0.05	10	57

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatments at the same Fertilizer treatment

Onne soil at this time may not be confined to N and P although it seemed that N deficiency could be more pronounced than that of P or any other element.

The addition of NPK resulted in a significant increase of the leaf contents of N and Ca but at the same time, the Mg content was significantly decreased (Table 5.23). The application of Mg Zn significantly increased Mg and Zn contents. There was a significant decrease in leaf Mn content due to the residual effect of liming which had no significant effect on the contents of the other elements.

5.3.9 *Maize grain yields, nutrient content and nutrient uptake by grain in 1979.*

The average maize grain yield in 1979 was 37 percent lower than in 1978. The yields due to burning were significantly higher than those due to mulching as shown by the mean yields of the methods of residue management (Table 5.24). In three out of four fertilizer treatments, yields due to burning were higher than but not significantly different from those due to mulching. The total grain yields in 1978 and 1979 still indicated that mulching was better than burning by 181 kg/ha.

There was a significant grain yield increase resulting from the addition of NPK. This increase was attributed to the effect of all three elements. The yield increase in 1979 due to NPK application represented nearly 267 per cent compared with 110 per cent increase in 1978 due to the same fertilizer

TABLE 5.23 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON THE NUTRIENT CONTENT IN MAIZE EARLEAF IN 1979.

Fertilizer Application	Nutrient Contents						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	2.03	0.47	2.43	1.12	0.23	41	320
NPK	2.82	0.51	2.47	1.23	0.17	42	333
NPKMgZn	2.85	0.47	2.29	1.28	0.21	58	343
NPKMgZn + Lime	2.92	0.45	2.51	1.31	1.20	53	293
Lsd (0.05)	0.23	0.06	0.34	0.07	0.03	6	27

TABLE 5.24 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE GRAIN YIELDS.

Nutrient Combinations	Residue Management Mulching kg/ha	Burning	Nutrient Combination Means
Control	556	595	576
NPK	2190	2036	2113
NPKMgZn	1682	2233	1958
NPKMgZn + Lime	1799	2355	2077
Residue Management Means	1537	1805	1681

Lsd (0.05) (i) Between Main treatment means (249)

(ii) Between Fertilizer means (527)

(iii) Between Fertilizer treatments under one Main treatment (746)

(iv) Between Main treatments at the same Fertilizer treatment (687)

treatment. However, the absolute yield increases were 1605 and 1537 kg/ha in 1978 and 1979, respectively. Therefore, the soil nutrient content in the first year of the fallow cultivation was higher than in the second year. The lower soil nutrient base in 1979 resulted in a higher per cent yield response to NPK application. When the yields under check treatments (no fertilizer treatment) were compared in both years, the reduction in 1979 was 61% as compared to the yields in 1978. This result was a confirmation of the assertion that the soil nutrient content in 1979 may have been considerably depleted. The yield results at this site in 1979 are a clear indication that the decline in fertility is one of the major reasons why the subsistence farmer "shifts" or rotates the fallow sites. However, in the present study, the low maize yields in 1979 were preceded by a good yield of cowpea. This result suggests that with good management, at least two crops can be grown on the Ultisol in the first year following the clearing of the bush fallow. Without a higher nutrient addition in the second year, it may not be economical to grow crops such as maize, which have a high nutrient requirement. Cassava, which is the major staple food crop in most of the rainforest areas of Southern Nigeria, or other crops with a lower nutrient requirement and management demands may be a better alternative.

Nutrient concentrations in the grain did not differ significantly between mulching and burning (Table 5.25).

TABLE 5.25 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF MAIZE GRAIN.

Treatment: Residue Management	Treatment: Nutrient Addition	N	P	K	Ca	Mg	Zn
				%			ppm
Mulch	Control	1.76	0.31	0.63	0.014	0.17	32
	NPK	1.95	0.34	0.64	0.013	0.18	28
	NPKMgZn	1.67	0.36	0.68	0.014	0.20	38
	NPKMgZn + Lime	1.88	0.38	0.73	0.013	0.20	38
	Means	1.82	0.35	0.67	0.014	0.19	34
Burn	Control	1.72	0.38	0.73	0.011	0.20	36
	NPK	1.87	0.33	0.64	0.016	0.17	28
	NPKMgZn	1.85	0.43	0.82	0.015	0.23	41
	NPKMgZn + Lime	1.75	0.40	0.78	0.014	0.21	38
	Means	1.80	0.39	0.74	0.014	0.20	36
	Lsd (0.05) (i)	0.29	0.12	0.19	0.002	0.06	nd
	(ii)	0.14	0.07	0.13	0.004	0.04	nd
	(iii)	0.33	0.13	0.22	0.004	0.07	nd

(i) Between Main treatment means

(ii) Between Fertilizer treatments under one Main treatment

(iii) Between Main treatments at the same Fertilizer treatment

The N content in the grain was below the level considered adequate. The grain contents of P, K, Mg and Zn were intermediate to adequate but the Ca content was quite low.

The grain N content increased significantly following NPK application but this treatment had no significant effect on the other nutrients (Table 5.26a). The addition of Mg Zn resulted in a significant depression of grain N content but also caused a significant increase in P, Mg, K and Zn contents. Lime applied in 1978 had no significant effect on the concentration of any of the elements evaluated.

Nutrient uptake by the grain did not vary significantly between mulching and burning (Table 5.27). The average grain - N uptake was 6 per cent lower in 1979 than in 1978 although N recovery from applied N was the same in both years. The uptake of P by the grain was 10 per cent lower in 1979 than in 1978 and P recovery from applied P fertilizer was also 10 per cent lower in 1979 than in 1978. These results are an indication that both N and P could have been deficient in 1979 or inefficiently utilized. However, related to the yields obtained in 1979, the reductions are less suggesting that yield reductions may also be due to other elements. The grain uptake of K and Mg in both years was similar but Ca recovery in the grain was 94 per cent lower in 1979 as compared to 1978. The low grain content and uptake of Ca suggests that Ca was lost from the soil system by leaching and this may have reduced the plant uptake of this element. This result partially con-

TABLE 5.26 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON THE NUTRIENT CONCENTRATION AND UPTAKE IN THE GRAIN IN 1979.

a) Fertilizer Application	Nutrient Content N	P	K	Ca	Mg	Zn
			%			ppm
Control	1.74	0.35	0.68	0.013	0.19	34
NPK	1.91	0.34	0.64	0.015	0.18	28
NPKMgZn	1.76	0.40	0.75	0.015	0.22	40
NPKMgZn + Lime	1.82	0.39	0.76	0.014	0.21	38
Lsd (0.05)	0.14	0.05	0.09	0.003	0.03	12

b) Fertilizer Application	N	P	K	Ca	Mg	Zn
			kg/ha			gm/ha
Control	10	2	5	0.08	1	20
NPK	40	7	14	0.30	4	59
NPKMgZn	35	8	15	0.28	4	78
NPKMgZn + Lime	44	8	16	0.28	5	79
Lsd (0.05)	9	2	4	0.03	1	20

TABLE 5.27 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE TOTAL NUTRIENT UPTAKE BY MAIZE GRAIN.

Treatment: Residue Management	Treatment: Nutrient Addition	N	P	K	Ca	Mg	Zn
				kg/ha			mg/ha
Mulch	Control	10	2	6	0.08	1	18
	NPK	41	7	14	0.28	4	61
	NPKMgZn	28	6	11	0.24	3	64
	NPKMgZn + Lime	46	7	13	0.23	4	68
	Means	31	6	11	0.21	3	53
Burn	Control	10	2	4	0.07	1	21
	NPK	38	7	13	0.33	4	57
	NPKMgZn	41	10	18	0.33	5	92
	NPKMgZn + Lime	42	9	18	0.33	5	89
	Means	33	7	13	0.27	4	65
	Lsd (0.05) (i)	8	3	4	0.04	1	20
	(ii)	9	2	4	0.03	1	20
	(iii)	12	3	6	0.02	2	28
	(iv)	13	4	6	0.02	2	31

(i) Betweem Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

firms the suggestion by Friesen (1978) that the Ca concentration in the Onne soil system could become critically low in the second year of cultivation without liming. Based on leaching studies on the Onne soil, Friesen (1978) further suggested that the soil Ca level could be depreciated when the soil is fertilized with NPK without the addition of lime. Both Ca and Mg could be lost as nitrates and the loss may induce their deficiencies.

It is difficult to attribute the yield reduction in maize yields in 1979 to the deficiency of any specific nutrient but the results indicate that a lower nutrient content in 1979 was the most important factor. The increasing exchangeable Al content in the soil as well as the declining soil pH with time (Chapter 6) provided a further indication that crop yield decline on this Ultisol in 1979 was related mainly to a low soil nutrient level.

5.4 Summary and Conclusion

A comparison of the effects of Mulching and Burning with and without fertilizer and lime application on crop yields and nutrition was investigated on an Ultisol in Southeastern Nigeria. In two years of the investigation, two crops of maize and one of cowpea were grown.

There were no pronounced differences in crop yields between mulching and burning in the first year indicating that the physical and chemical differences between the two residue management methods may be small. In the second year, yields due to burning were markedly higher than the yields due to mulching but, the total yields for the two years were higher as a result of mulching.

Nutrient retrieval from the residues is likely to be higher when the residues are used as mulch than when they are burned. This advantage may account for the higher total nutrient uptake under mulching and also for the higher overall yields due to mulching than due to burning. In addition, by providing a protective cover over the soil, mulch reduced the effect of leaching and subsequent nutrient loss. The results do not support the continued practice of fallow burning which may be more labour demanding than mulching. However, the major advantage of burning in this investigation seems to be the provision of a cleaner seedbed which facilitates cultural practices in the field.

Fertilizer application increased crop yields in both years. The yield response to fertilizer was similar in both years but the actual grain yield increase of maize was smaller in the second year. The difference was due to a lower soil nutrient level in the second year. Therefore, higher crop yields in the second and subsequent years of cultivation would require higher fertilizer application than was used in this study.

Liming the Onne Ultisol is required to reduce possible Al toxicity but liming did not prove to be very beneficial in the first year for two main reasons. Firstly, the exchangeable Al content was low compared with the level expected to result in lime response. Secondly, the cultivation technique used in this investigation involved a minimal disturbance of the sub-soil which contains a high exchangeable Al content. Hence, the danger of increasing exchangeable Al in the root zone by soil disturbance was reduced. However, there was strong evidence from cowpea grown in the first year and also from the second maize crop, that liming would have been necessary after the first maize crop and in the subsequent year of cultivation. The lime would be required at this time to supply adequate soil Ca and prevent yield reduction due to Al toxicity.

The yields at the Onne site, especially of the maize, were lower than at the Ikenne site at comparable treatments although the fallow biomass production and nutrient storage were higher at the former site. Therefore, crop yields on the typical fallows in Southern Nigeria may not be related to either the fallow biomass production or the nutrient storage. Yields obtained at the two representative sites seem to have been dependent on the level of soil fertility. Thus, the yields were higher on the Ikenne Alfisol soil which had a higher cation exchange capacity than the Ultisol at Onne. The rainfall was lower at the Alfisol site and this may have reduced the incidence of nutrient loss by leaching.

From results at the Onne site in particular, one can conclude that on similar Ultisols in Southern Nigeria, two crops of maize and cowpea can be successively grown with NPK following the slashing of the bush fallow vegetation. Burning of the slashed residue does not provide any major nutrient advantage over mulching. Mulching is considered more beneficial in terms of its effect on nutrient supply, soil protection and subsequent yields. However, where slashed residues are large and are likely to hinder field operations, light burning is recommended to help provide a cleaner seedbed. Light burning as is usually practised by most subsistence farmers is neither destructive of soil properties nor detrimental to plant performance.

Nitrogen may be applied at 200 kg/ha over a two-year period but the level of P may have to be increased beyond 40 kg/ha in the second and subsequent years of cultivation. Further investigations need to be carried out to establish the most suitable levels of N and P. The methods of N placement that will reduce leaching losses will need to be ascertained. Based on other results reported elsewhere in this thesis, the major factor affecting P availability on the Ultisol is fixation. Perhaps, not more than 40 kg/ha of P may be needed for optimum yields if a more efficient method of application can be developed to reduce P adsorption. Since there was no response to K, the level used in this study seemed adequate but it may be increased above 40 kg/ha as cropping, is extended and liming becomes necessary. Other nutrients such as Mg are needed at minimal amounts to help maintain nutrient balance in the soil. The Mg requirement may be satisfied by the use of dolomitic limestone as a lime source.

Minimal soil disturbance will reduce the level of lime required in the first year of cultivation to lower the danger of Al toxicity. Probably, in the second and subsequent years, about 1000 kg/ha of lime would be needed to maintain a desirable soil Ca level and an optimum soil pH. A lime plan will need to be developed based on soil tests.

From the yield results in the second year, it is postulated that it may be uneconomical to grow high nutrient demanding crops such as maize at this time. Therefore, it is suggested that other crops such as cassava, with a much lower soil nutrient requirement and less management demand be grown after a legume. The legume itself may help to reduce the amount of N required in the second and later years of cultivation. The cassava is particularly suited for the rotation since it is the major staple in Southern Nigeria and also has a high tolerance for soil acidity. Such a management system may be a good approach to a profitable crop production as cultivation is intensified on the Ultisol.

Chapter 6: A Comparison of Mulching and Burning with and without Fertilizer and Lime Application on the Chemical Properties of Representative Alfisol and Ultisol Soils in Southern Nigeria.

6.1 Introduction and Literature Review

It has been suggested by Nye and Greenland (1960) that the efficiency of nutrient recovery by the roots of fallow species rather than the fertility of the soils is responsible for the luxuriance of tropical vegetation. These authors also considered the decline in the fertility of the soils after only a short period of cultivation and attributed it to the low amounts of available nutrients initially present. The crop yield declines in the second year of cultivation on these soils, as reported in Chapters 4 and 5 were in part, a confirmation of the drop in the fertility level of the soil especially on the Ultisol.

Generally, it is believed that bush fallow burning is an effective means used by the shifting cultivator to recover the nutrients in the above ground parts of the biomass. While this may be true, evidence from the present study has shown that there could be substantial N loss from the residues as a result of burning. Furthermore, burning of the fallow residues did not cause a yield increase in relation to the retention of the residues as mulch. These observations suggest that burning was not essential as a means of retrieving the nutrients in the fallow biomass.

The retention of the residues as mulch will provide soil cover against the impact of rainfall and so decrease nutrient losses by erosion and leaching (Lal, 1974). The slow decomposition of mulch residues may minimize the loss of volatile elements and increase the availability of inorganic soil nutrients. This is important especially in areas of Southern Nigeria where fertilizer use is rare. The advantages due to mulching, as suggested above, may account for the higher yields obtained on the two soils where the residues were retained as mulch. Mulching may be particularly advantageous on steep slopes and in high rainfall sites as in some areas of Southern Nigeria.

The effect of burning on some specific chemical properties of soils in the tropics has been extensively reviewed in literature. Some of these properties include:

(a) *Soil pH:* Nye and Greenland (1964) reported that burning of fallow residues on a Ghanaian Alfisol resulted in an increase of pH in the top 0-5 cm soil depth from 5.8 to 8.1. Castro de Suarez (1957) found that after fallow residue burning, there was an increase in soil pH from 4.6 to 5.4. He also reported that the burning of crop residues after harvest resulted in smaller pH increases as compared with fallow residue burning. Popenoe (1957) reported an increase in pH of the top soil from

5.8 to 6.4. The increase was followed by a decline to the original soil pH in the second year in plots that were burned but not cropped. Watters and Bascones (1971) obtained a small increase of 4.1 to 4.4 in the 0-8 cm in the Venezuelan Andes. Data compiled by North Carolina State University (1973,1974), Boyle (1973), Lal *et al.* (1974) confirmed similar increases in soil pH after burning. However, there is a consensus that these increases are short-lived.

(b) *Organic matter (per cent C)*: A decrease in soil organic matter due to burning is suggested in literature as being minimal. This is probably because the temperature reached during burning is not high enough to effect a significant combustion of soil organic matter. In fact, small increases after burning have been reported by Nye and Greenland (1964); Popenoe (unpublished data). This was attributed to the presence of charcoal particles in the soil. Generally, organic matter in the top soil depths declines as a result of increasing soil temperatures caused by exposure and also as a result of dilution by tillage implements. Brams (1971), found that the soil organic matter decline on a Sierra Leonian Oxisol was high within the first five years after burning and cultivation. The sharpest drop occurred in the first year. Nye and Greenland (1964), did not obtain any pronounced decline in relation to the preburn level in Ghana. However, they reported organic matter declines in subsequent years of cultivation. The magnitude of organic matter dimunition after burning may be related to the initial or preburn level. This may explain the difference between the results from Sierra Leone and Ghana since the organic matter level was lower in the Sierra Leonian Oxisol.

Most workers in the tropics suggest that changes in the soil organic matter status in the traditional shifting cultivation system are small. When marked declines occur as a result of cultivation, they do so in the first few months after burning and exposure of the soil with cultivation (NCSU 1973).

(c) *Available P:* In Guatemala, Popenoe (unpublished data) found that available P in the 0-5 cm depth quadrupled after burning of the bush fallow residues. This increase was followed by a decline six months later but the available P determined by Bray I method, was still twice the pre-burn level twelve months afterwards. Similar trends were obtained in Colombia and Venezuela by Castro de Suarez (1957) and by Watters and Bascones (1971), respectively. Urrutia (1967) suggested that P was less mobile than the exchangeable bases and this immobility enhanced P conservation in the soil. Recent studies by Boyle (1973) and Seubert *et al.* (1977) have confirmed the increase in available P after burning but the effect was not as long lasting as was suggested by Urrutia (1967).

Despite the suggestion by Nye and Bertheux (1957) that P deficiencies may not be observed in the forest zones as a result of the efficiency of nutrient recovery by fallow species, greenhouse and field investigations in earlier sections of this thesis confirmed that P was the most deficient element on the Alfisol and Ultisol soils. Such P deficiencies are likely to be pronounced if the P in the fallow cycling system is as small as was reported in Chapter 2.

(d) *Exchangeable bases:* The amounts of the exchangeable bases reported to be added to the soil after burning have been variable. Nye and Greenland (1964) showed that large amounts of Ca, Mg and K were added by the ash. Data from North Carolina (1973, 1974) and results obtained by Boyle (1973) and Seubert *et al.* (1977) confirmed nutrient increases after burning but the increase was less than was reported by Nye and Greenland (1964). The North Carolina studies reported large leaching losses of Mg and K in the first year of cultivation following burning but loss of Ca was less. Popenoe (unpublished data) found that the exchangeable K in the 0-5 cm depth tripled after burning but decreased by one-third of the new value within only three months. Potassium returned to its initial level before the end of the first year of cultivation. Popenoe also found that Ca and Mg increased by 50 and 75 per cent, respectively, in the 0-5 cm depth but returned to original levels within twelve months after burning. Later studies by Popenoe (1957) confirmed that Ca and Mg moved beyond the 40 cm depth in the first year after burning. Seubert *et al.* (1977) obtained similar results. These results indicate that burning may have similar effects on most soils in the tropics but the magnitude and duration of the effects will vary from one fallow or soil site to another. The length of the fallow, nature of burned vegetation, the soil order, the amounts of nutrients accreted as ash and the moisture regimes are some factors which determine how long the nutrient effects of the ash may last.

Crop removal, erosion, leaching and run-off are processes which increase nutrient losses. These losses can be serious in high rainfall areas such as at Onne (Ultisol). At Ikenne (Alfisol), where the rainfall is less, the losses due to leaching may be less but they are still serious especially in respect of those elements already in short supply. Fertilizer application is one major step taken to replenish these losses. In the high rainfall areas of Southern Nigeria, leaching of cations accelerates the development of soil acidity. The addition of acid forming N-fertilizer to the already low pH soils in the area of this study further increases the problem of soil acidity. The method of fertilizer management has been shown by Dunton *et al.* (1954) as cited by Obi (unpublished paper) to affect soil reaction. For example, there is a marked increase in soil acidity in the vicinity of banded fertilizer as a result of hydrolysis of Aluminum. While broadcasting may reduce the level of acidification, leaching loss of N may be facilitated and so N utilization will be limited. The leaching of bases such as Ca, Mg and K will lead to increased contents of Al in the soil and cause Al toxicity.

An adequate knowledge of the changes in the chemical properties of the representative soils in Southern Nigeria as influenced by time, land management and fertilizer use is vital. This information is required to help in (a) selecting appropriate crops and cropping sequences, (b) maintaining reasonable crop yields and adequate soil fertility level as cropping is intensified. This section of the thesis has two main objectives: (a) to ascertain the effects of the traditional method of fallow burning on certain soil chemical properties and (b) to monitor systematically the chemical properties of the Alfisol and Ultisol soils under burning as compared to mulching, with and without fertilizer and lime (Ultisol) application.

6.2 Materials and Methods

The sites on which the cropping trials (Chapters 4 and 5) were established were used for this portion of the investigation. The sites were selected and described in late November, 1977 (Details are given in Section 2.3.1 and in the Appendix). The first set of soil samples was taken from three depths of 0-7.5; 7.5-15; and 15-30 cm, respectively and from the one m^2 plots which were randomly selected for the biomass studies in Chapter 2. A total of thirty-two samples was taken for each of the three depths at both Ikenne and Onne. These samples were analyzed as described elsewhere in this thesis and they represent the preburn fertility level of the soils.

When the cut fallow vegetation was sufficiently dry, the 30 sq. metre experimental plots were laid out as described in Chapter 4. The dry litter was burned within the plots. Based on treatment and replication numbers, there were a total of 48 and 32 plots at Ikenne and Onne, respectively, and half of these was burned at either location. Within each of the experimental plots, four zones were randomly selected and marked with numbered bamboo stakes. These zones were permanently used to demarcate the soil sampling sites through the entire period of the investigation (1978/1979). This was done for all plots whether the residue was burned or used as mulch.

The second set of soil samples was taken a day after burning and only from the burned plots and from around the zones referred to above. These samples were taken from the three soil depths being studied and at each of the four zones within the plot. Soil samples from similar depths were then bulked on a replicate basis. This procedure was used for all subsequent sampling in the field following the application of fertilizer and lime treatments. The permanent sampling site procedure was used in order to minimize soil variability. This second set of soil samples was analyzed and used as an estimate of the effect of burning on soil chemical properties.

The batches of soil samples taken systematically at various dates were air-dried, sieved with a 2 mm sieve and analyzed as described in Section 2.3.2.1.

6.3 Results and Discussion

6.3.1 *The Effect of Burning of Bush Fallow Residues on the Chemical Properties of the Ikenne Alfisol.*

(a) *Soil pH:* There was an increase in soil pH of the Alfisol following the burning of the fallow residues. The increase was most pronounced at the 0-7.5 cm depth [Table 6.1]. There was little effect of burning on soil pH at the 15-30 cm soil depth. The rise in pH of the top soil compared favourably with results obtained by Castro de Suarez (1957) and Popenoe (1957) but the increase was smaller as compared with the data of Nye and Greenland (1964) on a Ghanaian Alfisol. These differences may be a reflection of the type of fallow, the amount of residues burned and the intensity of the burning. For short fallows such as the Ikenne, the increase in soil pH after burning may not be very remarkable.

(b) *Organic matter (per cent C):* The percent organic carbon increased at all the three depths after burning. The greatest increase occurred at the 0-7.5 cm depth. The observed increase in organic carbon was most likely due to the presence of charcoal particles after burning rather than a reflection of an increase in soil organic matter per se. Similar results were obtained by Nye and Greenland (1964) and the same conclusion was drawn by these authors. The observed increases of carbon at the lower soil depths may be due to soil contamination

TABLE 6.1 THE EFFECT OF FALLOW RESIDUE BURNING ON SOME SOIL CHEMICAL PROPERTIES OF THE IKENNE ALFISOL.

Time	Soil pH	Organic C (%)	Bray I-P (PPM)	NH_4OAc Extractable Cations			
				Ca	Mg me/100 g	K	Mn
			0 - 7.5 CM				
BBI*	6.10	1.45	3.30	7.68	2.60	0.13	0.06
ABI**	7.20	2.11	13.00	11.00	3.90	0.30	0.22
			7.5 - 15 CM				
BBI	6.00	0.72	1.00	3.99	1.70	0.03	0.08
ABI	6.00	0.91	3.00	4.48	2.20	0.04	0.37
			15 - 30 CM				
BBI	6.10	0.49	0.80	2.91	0.92	0.02	0.08
ABI	6.20	0.63	1.60	3.57	1.07	0.02	0.36

* Before Burning at Ikenne.

** After Burning at Ikenne.

at sampling or to soil variability.

(c) *Available P:* The available P determined by the Bray I - method was quadrupled at the 0-7.5 cm depth after the burning of residues. This was probably an indication that the burning increased the available P content of the soil. However, the recovery of P in the ash as was shown in Chapter 2, was small. Therefore, the increase in available P in the top soil was only partially due to the ash. Seubert *et al.* (1977) had also reported that the increase in available P after burning in Yurimaguas exceeded the P content of the ash. They attributed the increase to a rapid mineralization of organic P from the roots as well as from the leaves of fallow vegetation prior to burning. While this may be true, there was no proof of such mineralization in this study because the soil in the unburned plots was not sampled at the same time after burning was completed. The effect of heat on the soil during burning could also increase available P. There was evidence that available P in the lower soil depths was affected by these processes although the effect was less than was obtained in the top soil.

(d) *Exchangeable bases (Ca, Mg and K):* Burning resulted in a considerable increase in the soil contents of these bases. The increases were highest in the top 0-7.5 cm. The K content at the lower soil depths was not affected by burning. Although there were increases of Ca and Mg at the lower soil depths there appeared to be no corresponding increase in soil pH at the 15-30 cm depth in particular. This may be an indication that sampling variation was small or the Alfisol was buffered against sharp changes of pH at that depth. Nye and Greenland (1964) had reported exceptionally high amounts of bases after burning and these resulted in the increase in soil pH they observed.

As was observed in the case of available P, the increases in the Ca, Mg and K contents of the surface layer after burning were higher than were contained in the ash (Table 6.2). Besides the possibility of mineralization prior to burning, these increases are difficult to account for.

(e) *Available Mn:* This increased after burning and at all three soil depths. The increase was more pronounced at the two lower soil depths than in the top soil. Again, the increase is difficult to explain only on the basis of burning.

The status of exchangeable Al was not evaluated on this soil because of the trace amounts of exchangeable Al before burning and because Al toxicity has not been reported to be a problem.

TABLE 6.2 THE EFFECT OF BUSH FALLOW CLEARING AND BURNING ON THE P, K, Ca AND Mg CONTENTS IN IKENNE SURFACE (0 - 7.5 cm) SOIL.

Samples	Location	P	K	Ca	Mg
				kg/ha	
	IKENNE				
(1) Soil (Before slashing and burning)		4	57	1721	349
(2) Vegetation		6	50	49	29
(3) Plant Ash		1	8	15	8
(4) Soil (After clearing and burning)		15	132	2465	525
Increases		11	75	744	176

6.3.2 *The Effect of Burning of Bush Fallow Residues on the Chemical Properties of the Onne Ultisol.*

(a) *Soil pH:* The soil pH in the top 0-7.5 cm depth increased after burning but there was hardly any change at the lower soil depths (Table 6.3). The increase of pH in the surface layer was lower than was obtained at Ikenne site. The difference was probably due to the higher initial soil pH of the Ikenne Alfisol as compared to the Onne Ultisol. The observed soil pH increase in the surface 0-7.5 cm layer was comparable with values obtained by Suarez de Castro (1957); Popenoe (1957) and Watters and Bascones (1971) on similar Ultisols.

(b) *Organic matter (per cent C):* The results obtained at Onne differed from those at Ikenne in that the increase in percent C at the top 0-7.5 cm depth was lower at Onne and there was no noticeable change at the lower soil depths.

(c) *Available P:* There was an increase in available P as determined by Bray I-method, at the 0-7.5 cm depth but it was proportionally lower than the increase obtained at Ikenne. Although there was no pronounced change in the available P contents at the 7.5-15 cm depth, yet there was a noticeable decrease at the 15-30 cm depth after burning. This result was probably due to sampling or analytical error. Generally, the high available P levels in the Ultisol could be misleading because the acid extractant used in the Bray I-

TABLE 6.3 THE EFFECT OF FALLOW RESIDUE BURNING ON SOME SOIL CHEMICAL PROPERTIES OF THE ONNE ULTISOL.

Time	Soil pH	Organic C. %	Bray I-P PPM	NH_4OAc Extractable Cations (me/100 g) Ca	Mg	K	Mn	Exchangeable AL Al^{3+}	Total Acidity $(Al^{3+} + H)$
				0 - 7.5 CM					
BBO*	4.30	1.73	108	1.32	0.39	0.16	0.04	1.44	1.92
ABO**	5.00	1.82	123	2.96	0.85	0.33	0.14	0.08	0.53
				7.5 - 15 CM					
BBO	4.30	1.19	100	0.76	0.23	0.10	-	1.50	2.01
ABO	4.40	1.09	101	0.58	0.22	0.12	0.01	0.75	1.74
				15 - 30 CM					
BBO	4.40	0.76	89	0.33	0.13	0.06	-	1.68	2.06
ABO	4.30	0.69	71	0.32	0.12	0.06	-	0.93	1.94

* Before Burning at Onne.

** After Burning at Onne.

procedure may (Juo, personal communication) extract significant proportions of Al-bound P which is the dominant fraction in acid Ultisols. This over-estimates available P in this soil. Besides, several IITA scientists have reported P deficiencies at Onne in spite of the high available P content. Results of greenhouse studies discussed elsewhere have also confirmed this observation.

(d) *Exchangeable bases (Ca, Mg and K)*: Contents of all three elements doubled in the top 0-7.5 cm depth following burning. There was no pronounced change in their levels at the lower soil depths. Such an increase in the base status of the Ultisol is important in view of the low supply of bases prior to burning. However, the nutrient contents of the ash were much lower than the resulting increase recorded after burning (Table 6.4). A similar result was obtained at Ikenne. Seubert *et al.* (1977) made similar observations in Yurimaguas, Peru. The nutrient contribution due to ash was smaller than they calculated as being due to burning. On both soils studied, P, K, Ca and Mg contents after burning (as shown in the appropriate Tables) were more than could be attributed to the effects of burning. The calculated increases in these elements were in general higher than were reportedly recovered as ash after burning. These results are different from those reported by Nye and Greenland (1964) in which the total amounts of nutrients in the biomass were accounted for by

TABLE 6.4 THE EFFECT OF BUSH FALLOW CLEARING AND BURNING ON THE P, K, Ca AND Mg CONTENTS IN ONNE SURFACE (0 - 7.5 cm) SOIL.

Samples	Location	Nutrient Contents			
		P	K	Ca kg/ha	Mg
	ONNE				
(1) Soil (Before slashing and burning)		121	70	296	53
(2) Vegetation		30	220	141	70
(3) Plant Ash		6	20	33	9
(4) Soil (After clearing and burning)		138	145	663	115
Increases		17	75	367	62

nutrient contribution from the ash. Seubert *et al.* (1977) postulated that a rapid mineralization of the organically bound nutrients within the fallow system during the interval after slashing and before burning was a major reason for the increase. While such a mineralization process is plausible, it cannot be substantiated in this present study for reasons suggested elsewhere in this chapter. It is probable that the present study under-estimated the nutrients present in the biomass or those accreted as ash, or the effect of heat on soil mineralizable nutrients. However, results of green-house studies (Chapter 2) where the nutrient supply potential of high levels of ash was investigated, did not show a marked increase in nutrient recovery in the plant as a result of extremely high levels of ash. Similarly, laboratory investigation of the effect of heating on soil nutrient release did not provide evidence of increased nutrient availability due to soil heating at temperatures comparable to those that are commonly attained in the field.

6.3.3 *A Comparison of Mulching and Burning with and without Fertilizer Application on the Chemical Properties of the Alfisol.*

Changes in chemical properties of the representative Alfisol and Ultisol soils during the period of the present investigation are an assessment of the fertility status of the soils as a result of both residue management and fertilizer treatments. They may help to explain the decline in crop yields obtained on the two soils in the second year of the study.

(a) *Soil pH*

(i) *Effect of Residue Treatment:*

The mean values of soil pH taken at different dates showed that pH in the top 0-7.5 cm soil depth was higher under burning than under mulching treatment (Fig. 6.1). Although the soil pH under burning was higher throughout the period of the investigation, the effect was more pronounced during the first month than at the latter stage of the study.

Where the fallow residues were retained as mulch, the pH values at the 0-7.5 and 7.5-15 cm depths were about the same but they were higher than at the 15-30 cm depth during the first six months of cultivation (Fig. 6.2). Differences in soil pH among the depths were small after the first six months.

Where the residues were burned, the pH was higher in the 0-7.5 cm soil depth than in either of the lower depths during the first six months after burning (Fig. 6.3). The soil pH in the 0-7.5 cm depth was higher than in the other depths,

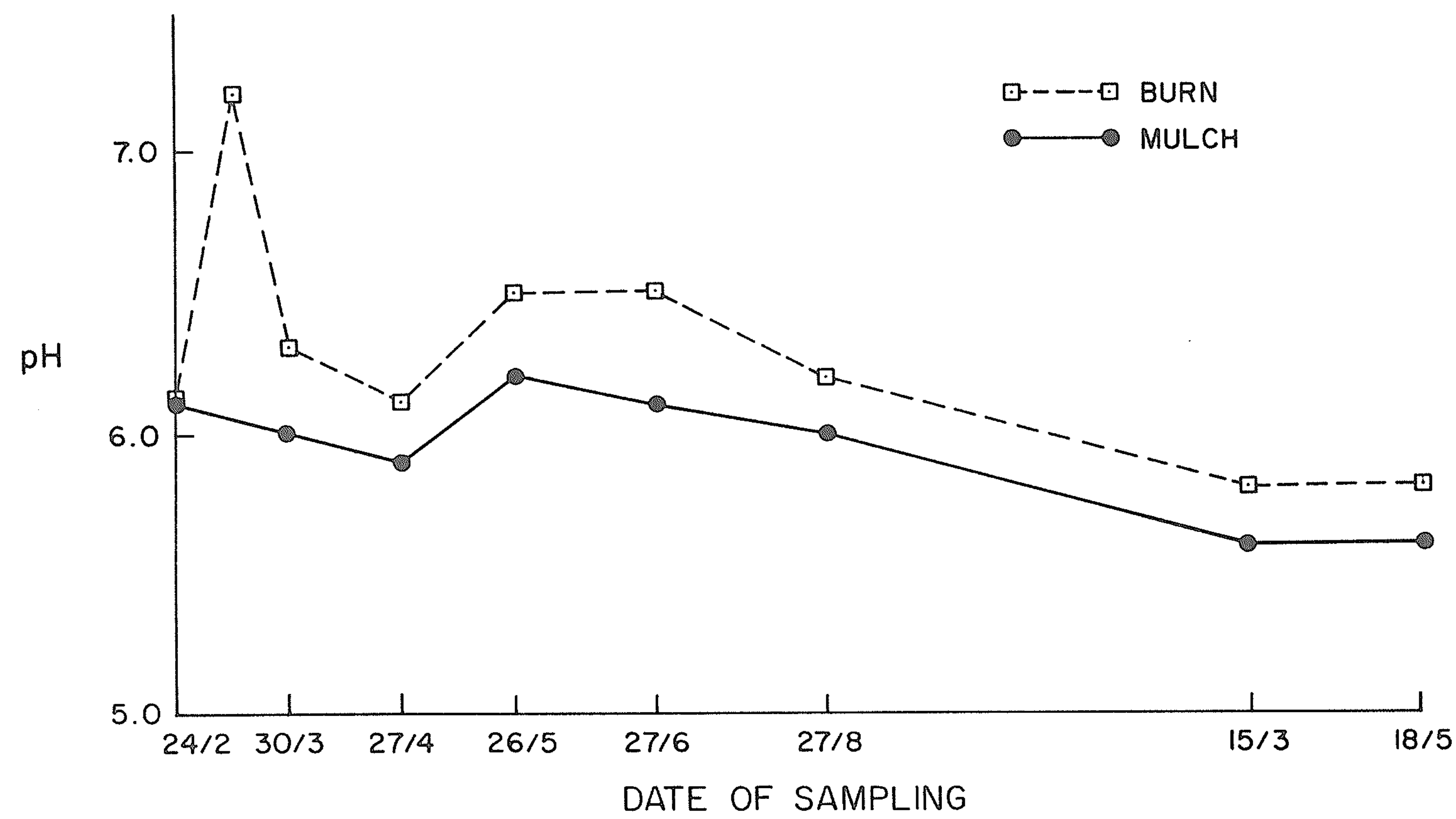

Fig. 6.1 Effect of Residue Management on Soil pH in 0 – 7.5 cm depth

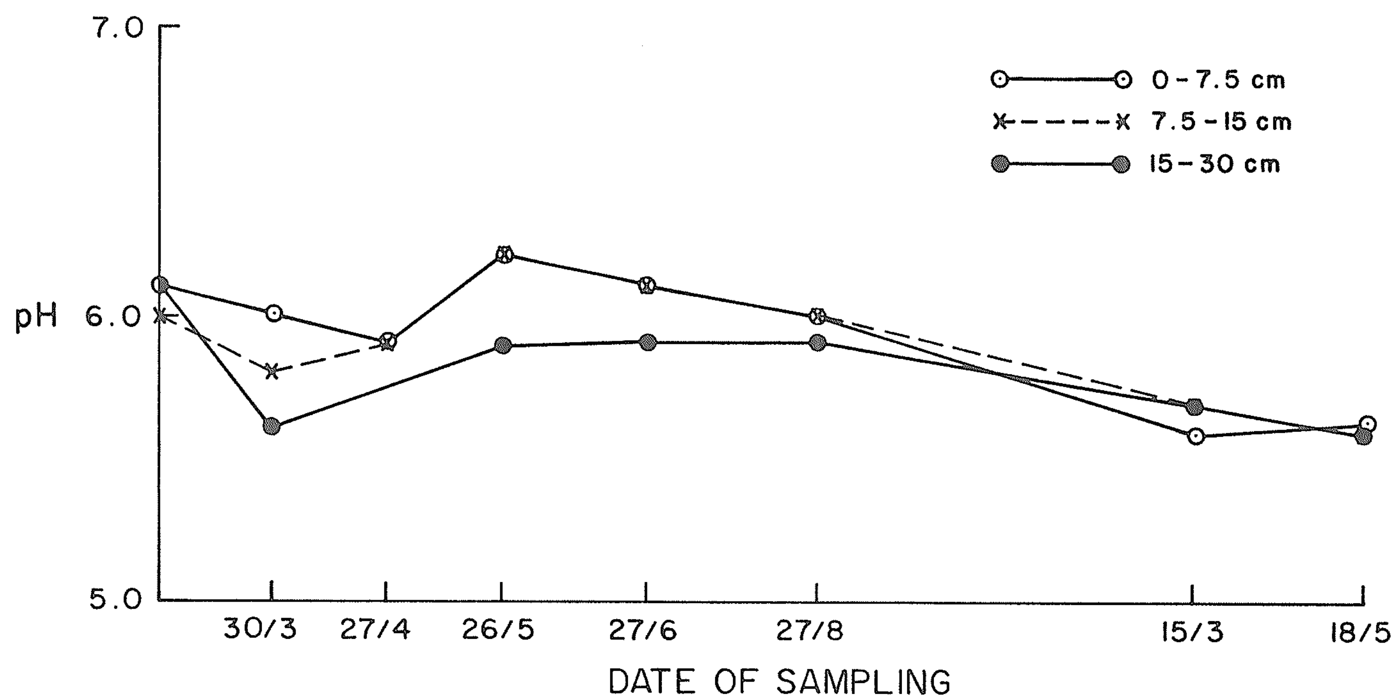

Fig. 6.2 Effect of Mulching on Soil pH in different soil depths

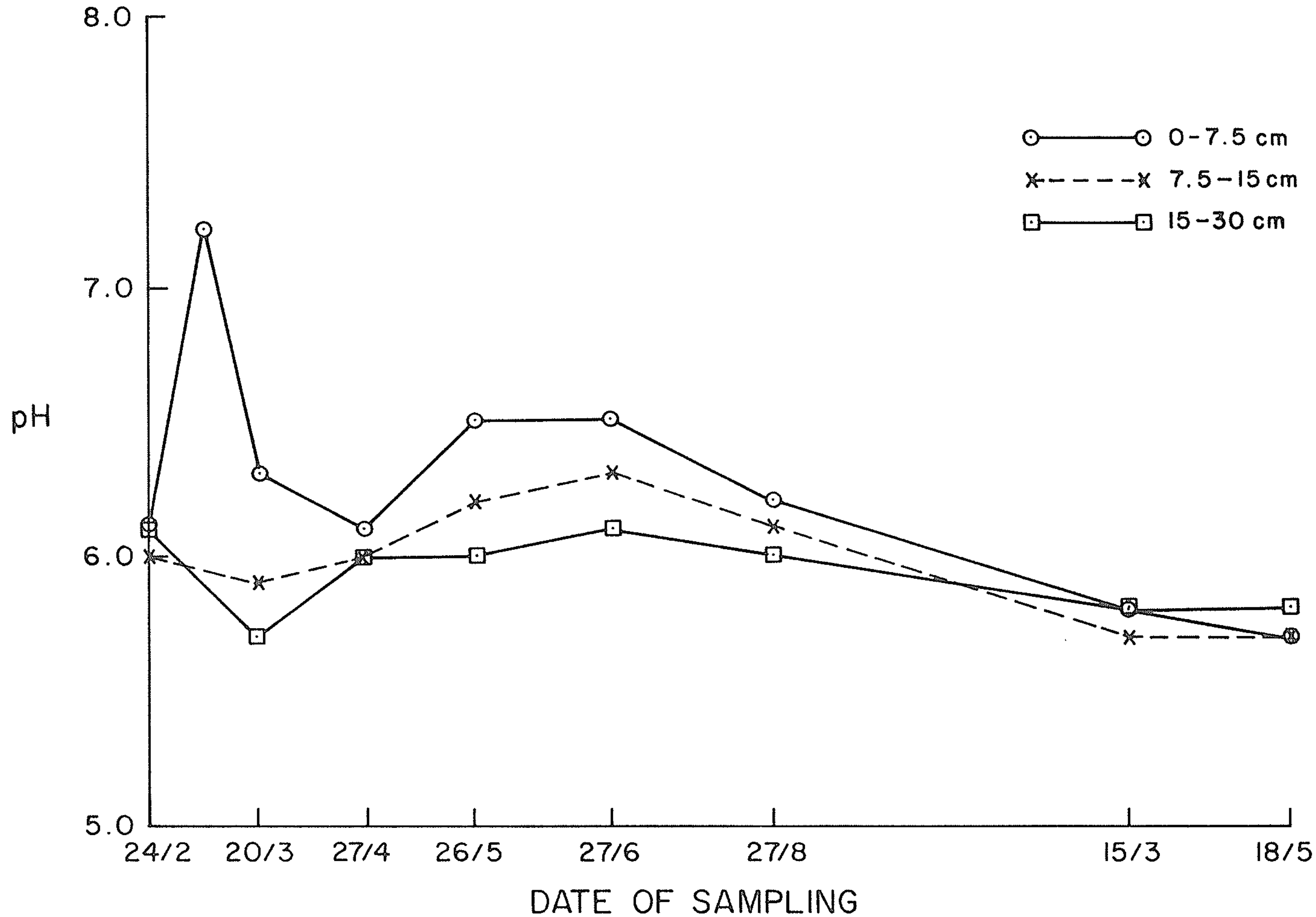

Fig. 6.3 Effect of Burning on Soil pH in different Soil depths

particularly during the first month. In the 7.5-15 and 15-30 cm depths, the pH of the soil was the same during the first two months but became higher at the 7.5-15 cm depth in the subsequent months preceding August, 1978. After this date, the pH of the soil at all three depths was practically the same, and showed a definite declining trend.

(ii) Effect of Fertilizer Treatments:

When the residues were retained as mulch, the pH values in the top 0-7.5 cm depth of check treatment were the same as when P and K were applied without N (Fig. 6.4). Nitrogen had a pronounced depressing effect on soil pH of the Alfisol where the residues were retained as mulch. The presence of Ca^{2+} in the N-source used did not nullify the effect of N application on soil pH.

When the residues were burned, N did not depress the soil pH of the top 0-7.5 cm depth as it did under mulching (Fig. 6.5). During the first five months after fertilizer application, the pH in the top soil did not differ appreciably among the fertilizer treatments. However, after August, 1978 the changes in pH at the 0-7.5 cm depth were similar to those obtained under mulching. In the second year of the study, the pH values for check and PK treatments were the same and higher than for the other fertilizer treatments.

(b) *Organic matter*

(i) Effect of Residue Treatment:

There were no marked differences in the soil organic

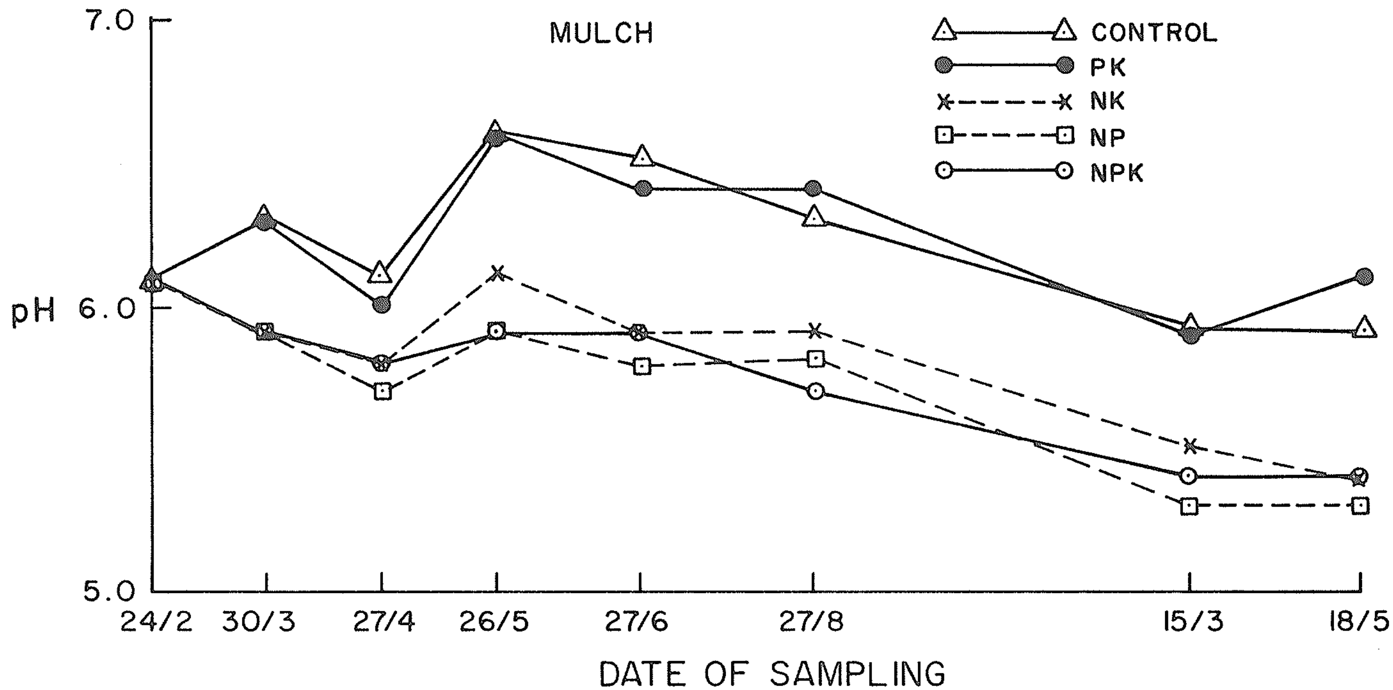

Fig. 6.4 Effect of Fertilizer Application and Mulching on Soil pH in 0 - 7.5 cm depth

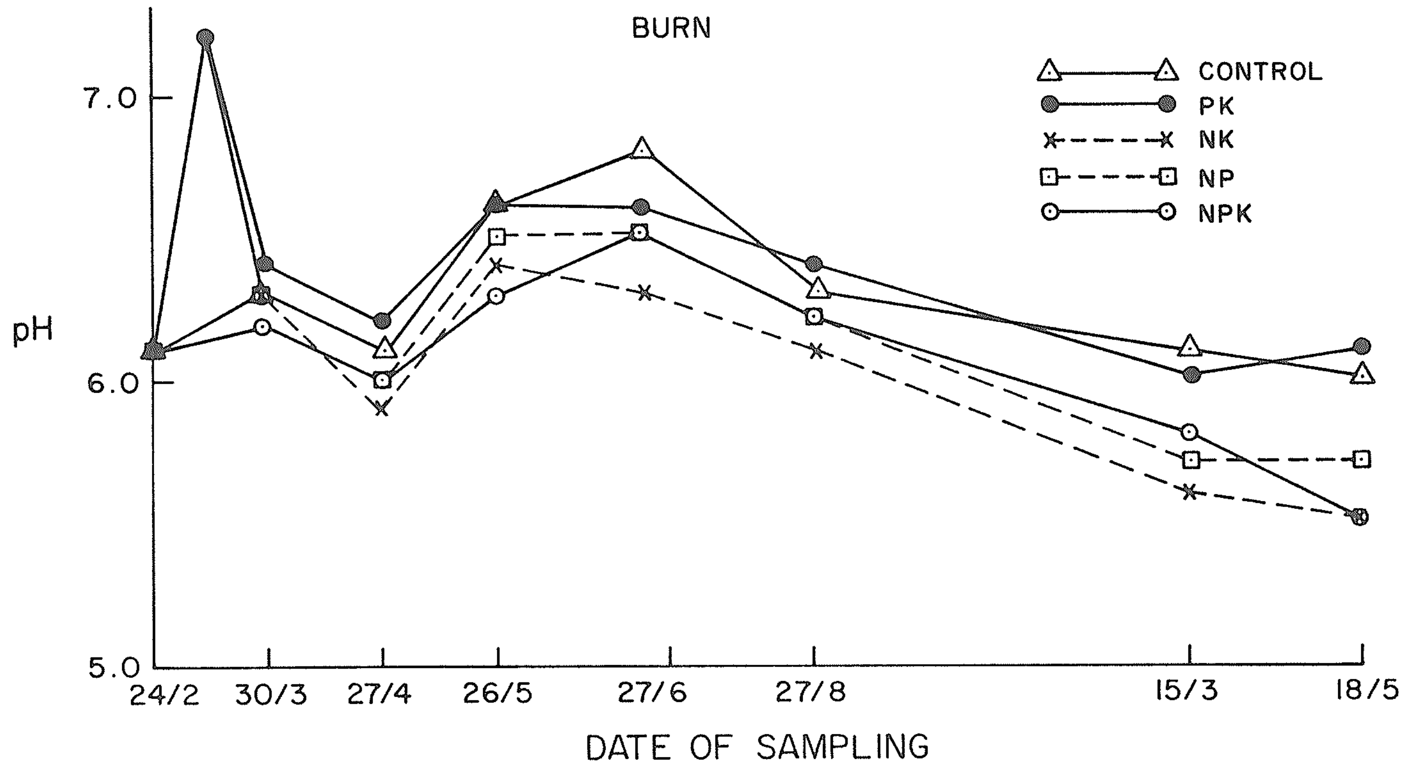

Fig. 6.5 Effect of Fertilizer Application and Burning on Soil pH in 0 - 7.5 cm depth

matter content in the top 0-7.5 cm depth on mulched as compared to burned plots (Fig. 6.6). Although there were fluctuations in organic matter levels at different dates, the differences observed were probably due to sampling variation rather than a reflection of real differences.

Where the fallows were retained as mulch, there were considerable differences in the organic matter values among the soil depths (Fig. 6.7). The organic matter content in the 0-7.5 cm depth was higher than in either the 7.5-15 or 15-30 cm depth throughout the period of the study. The differences between the organic matter contents of the two lower depths were pronounced only during the first 3-4 months and diminished markedly after June, 1978.

Similar results as reported for the organic matter changes with mulching were obtained where the residues were burned (Fig. 6.8). Under the two methods of residue management, there was no dimunition of soil organic matter in the top 0-7.5 cm depth at the end of the investigation as compared with the initial precultivation level.

(ii) Effect of Fertilizer Treatment:

There were also no marked changes in the level of soil organic matter in the 0-7.5 cm depth as a result of fertilizer application whether the fallow residues were used as mulch (Fig. 6.9) or burned (Fig. 6.10). The effects of nutrient combinations on soil organic matter content in the top soil did

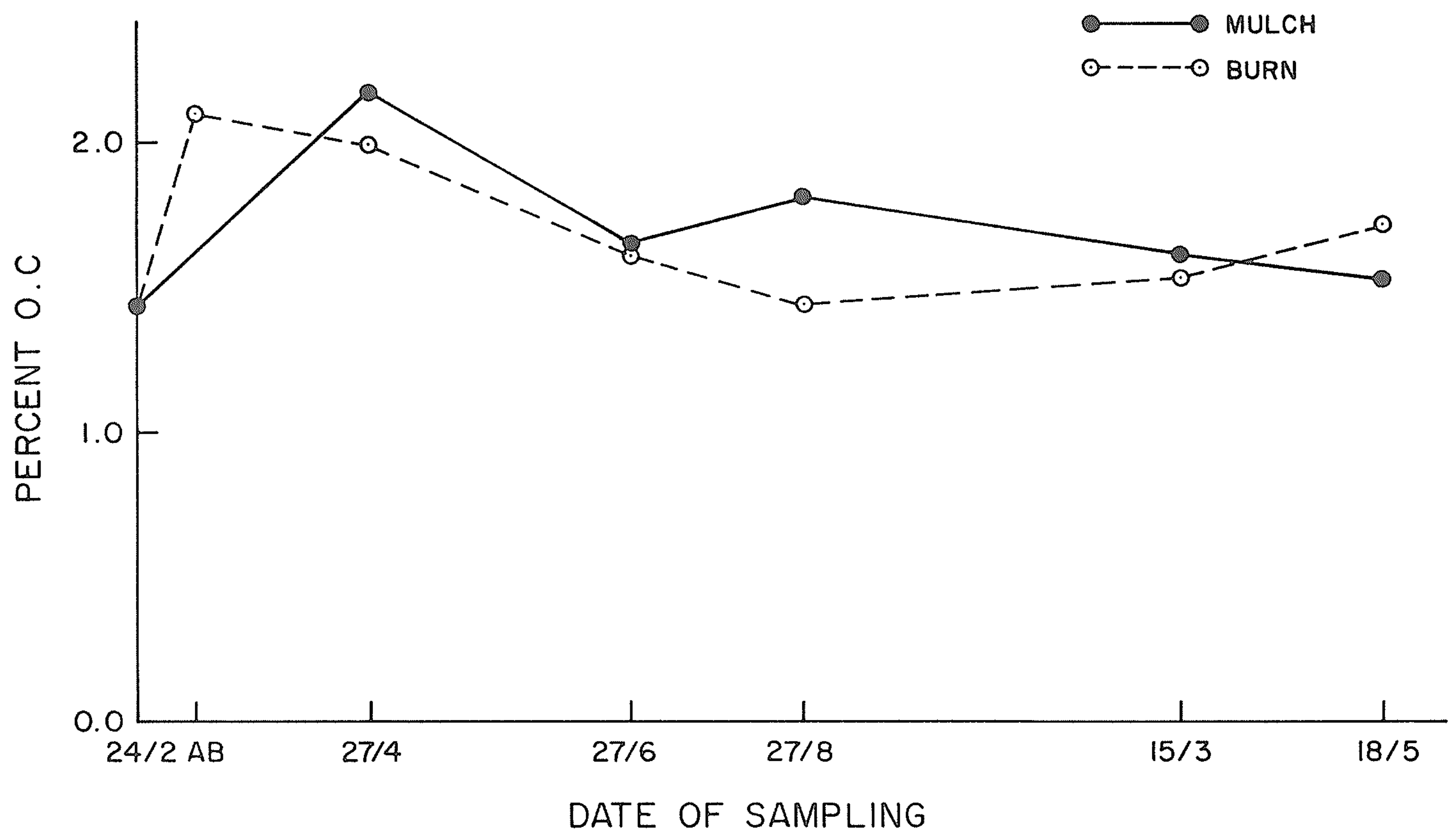

Fig. 6.6 Effect of Residue Management on Soil Organic Matter Status in 0 - 7.5 cm depth

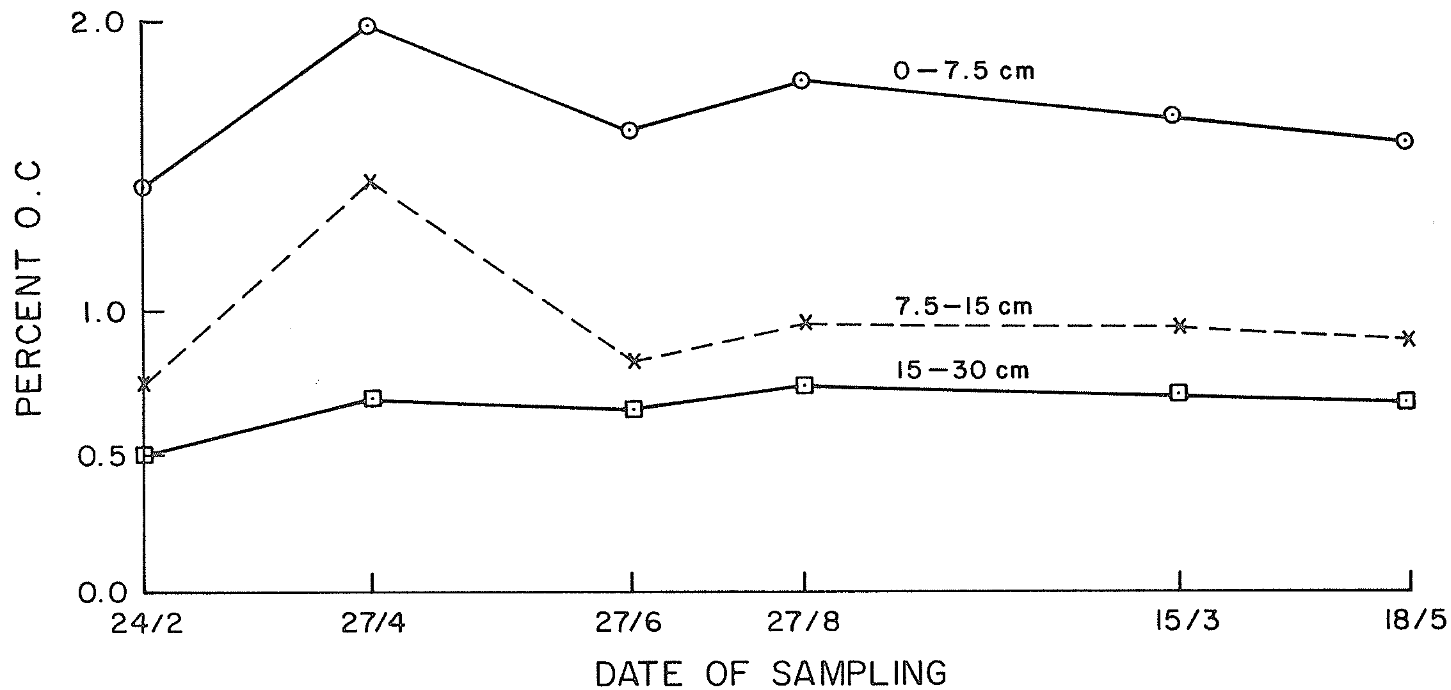

Fig. 6.7 Effect of Soil Depths and Mulching on Organic Matter Status

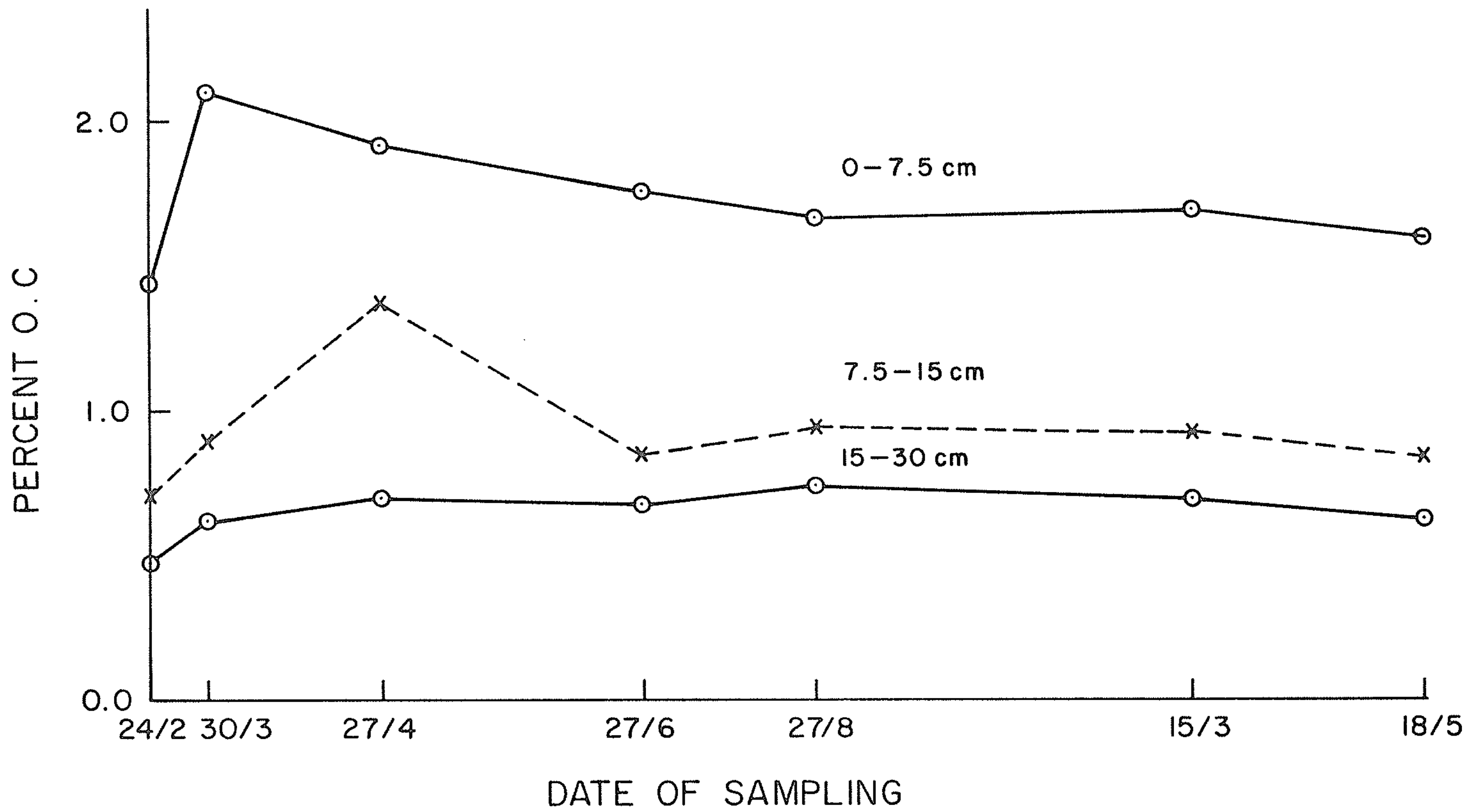

Fig. 6.8 Effect of Soil Depths and Burning on Organic Matter Status

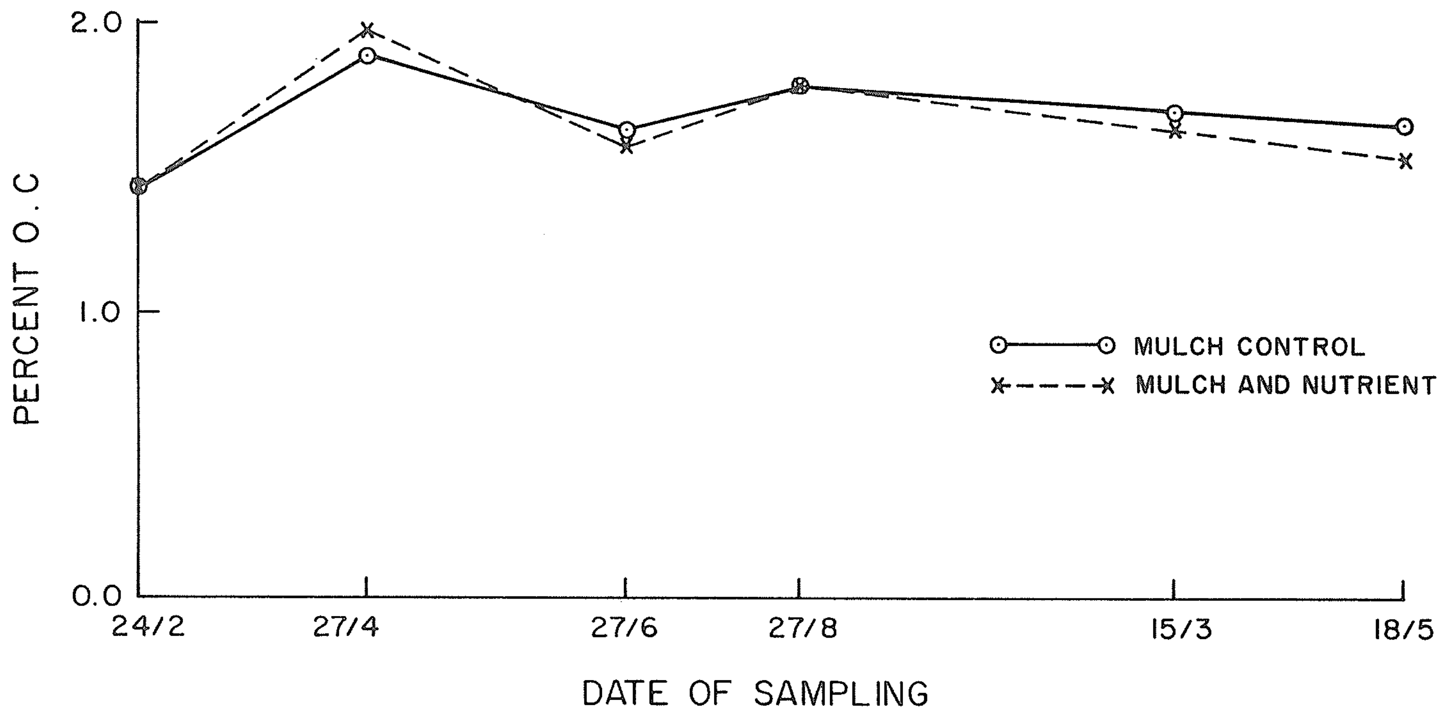

Fig. 6.9 Effect of Fertilizer Application and Mulching on Soil Organic Matter in 0 - 7.5 cm depth

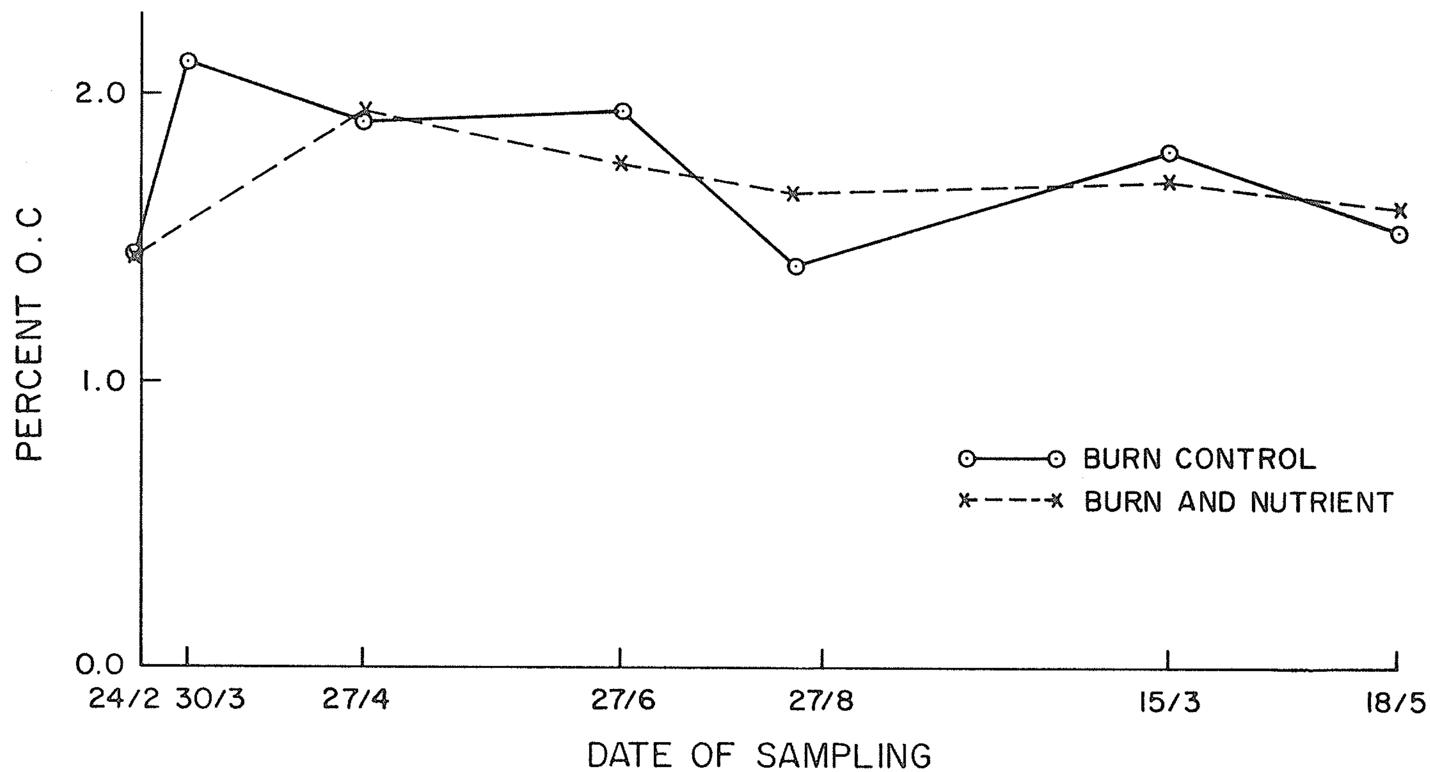

Fig. 6.10 Effect of Fertilizer Application and Burning on Soil Organic Matter in 0 - 7.5 cm depth

not differ from the general trends shown in the above illustrations.

Long term studies conducted in Ibadan, Nigeria (IITA Annual Report 1973) indicated that yield declines on the Alfisol could be due to a reduction in soil organic matter content. While this may be true, the present study did not provide evidence for significant organic matter decline which could have decreased yields.

(c) *Available P*

(i) Effect of Residue Treatment:

The mean available P values determined by Bray I-procedure at different dates showed that there were no differences between mulching and burning in respect of this estimate (Fig. 6.11). This observation was true in each of the three depths. The variations in available P levels shown in the top soil as a result of residue treatments were minor.

(ii) Effect of Fertilizer Treatment:

The application of P in combination with N or K or N and K caused a sharp increase in available P in the 0-7.5 cm depth under both methods of residue treatment (Fig. 6.12). However, this increase was pronounced in relation to the check and NK treatments only during the first two months after fertilizer treatment. In subsequent months of the study, there were no differences in available P levels in the top soil among the fertilizer treatments.

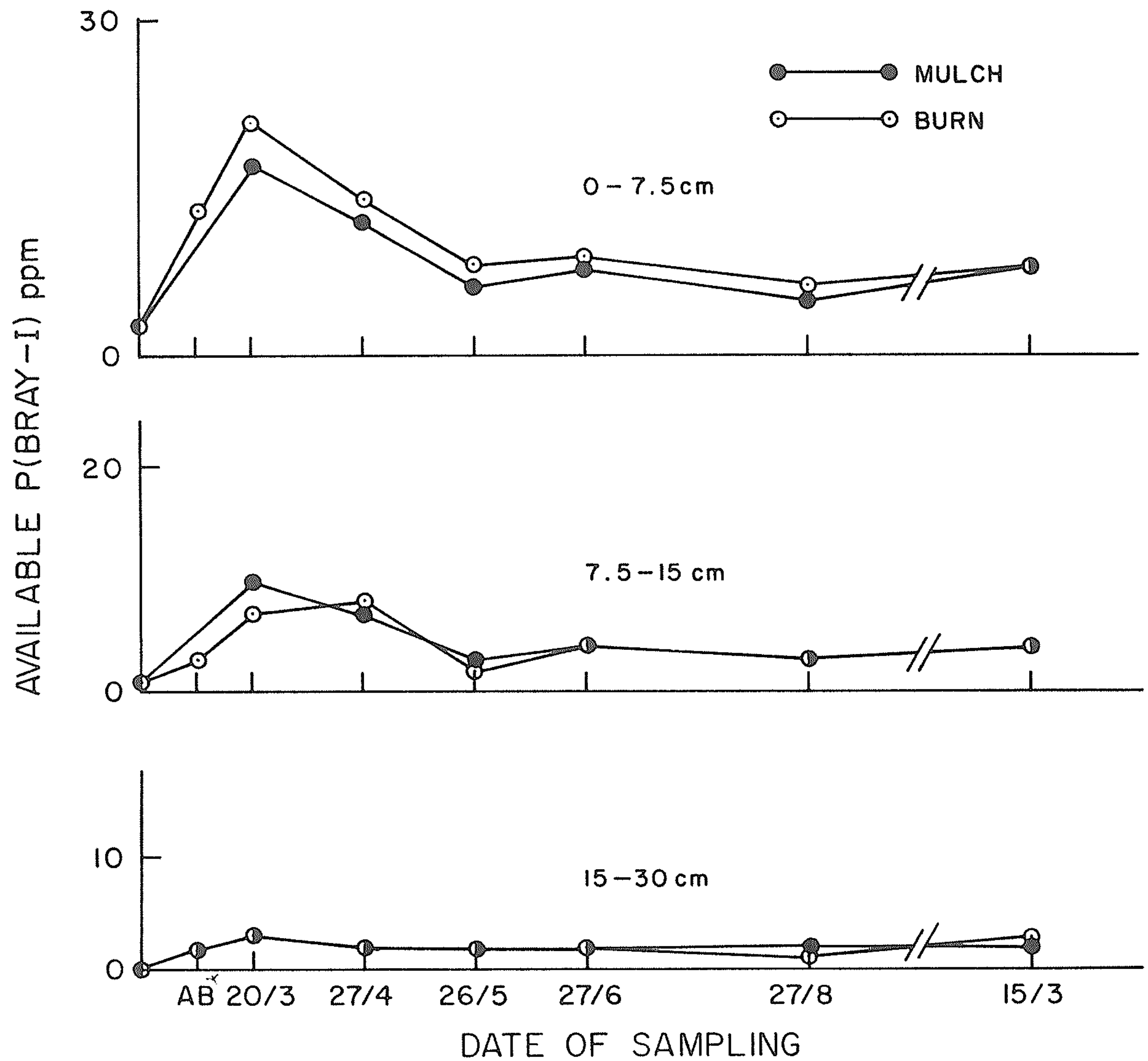

Fig. 6.11 Effect of Residue Management on Available P in different Soil depths

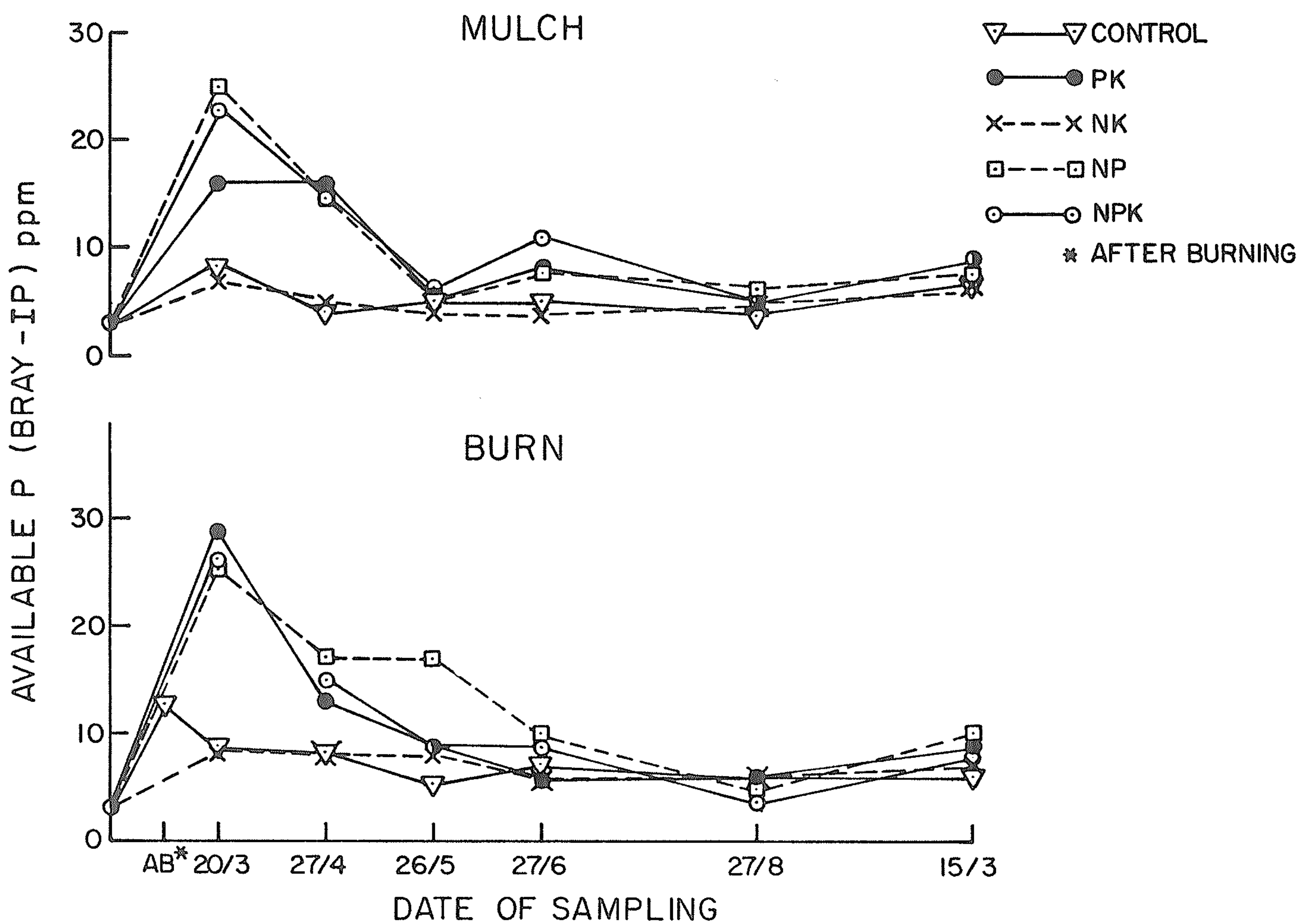

Fig. 6.12 Effect of Fertilizer Application on Available P in 0 - 7.5 cm depth

(d) Exchangeable bases (Ca, Mg and K)

(i) Effect of Residue Treatment:

The average values of the exchangeable bases in the top 0-7.5 cm soil depth suggested that there were no marked variations as a result of the methods of residue treatment (Figs. 6.13, 6.14 and 6.15). The evidence provided by these illustrations indicated that there was no appreciable decrease in the levels of these nutrients over the two year period in which this study was conducted.

The trends obtained in the lower soil depths were similar to those obtained in the top soil. During the latter phase of the investigation, there seemed to be an increase of exchangeable Ca in the lower soil depths. Similar increases were observed at the same time for Mg (in all three depths) and K (especially in the 0-7.5 cm depth). These increases may have followed the application of fertilizer in February, 1979. However, when similar application was made in 1978, it was not reflected in increased levels of Ca, Mg and K.

(ii) Effect of Fertilizer Treatment:

The addition of fertilizer elements did not result in a pronounced deviation from the trends reported above in respect of the exchangeable bases. In general, it would appear that the fertility level of the Alfisol was not markedly depleted as a result of two years of cropping. Probably, there may be the potential for obtaining a good crop yield in

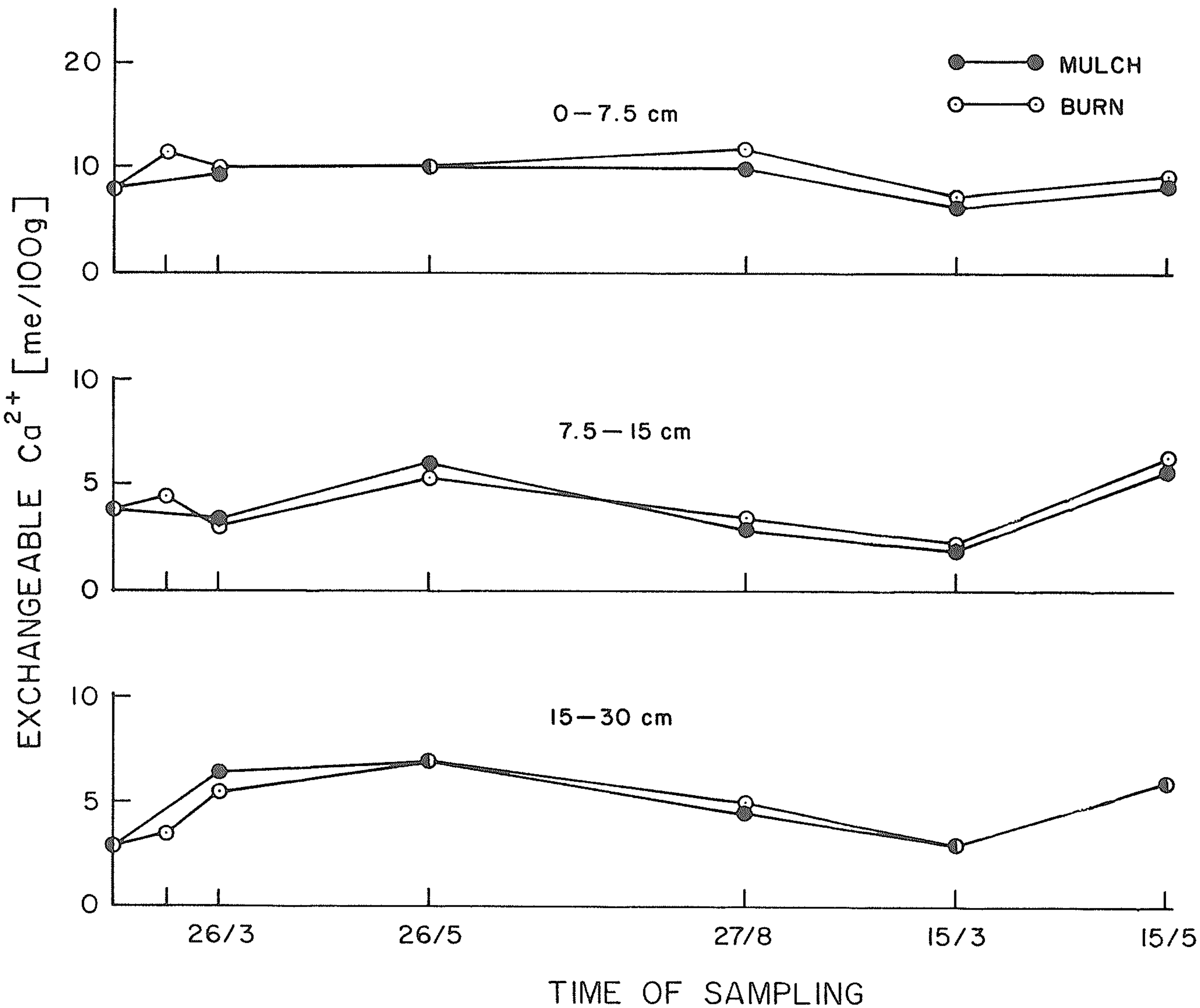

Fig. 6.13 Effect of Residue Management on Exchangeable Ca in different Soil depths

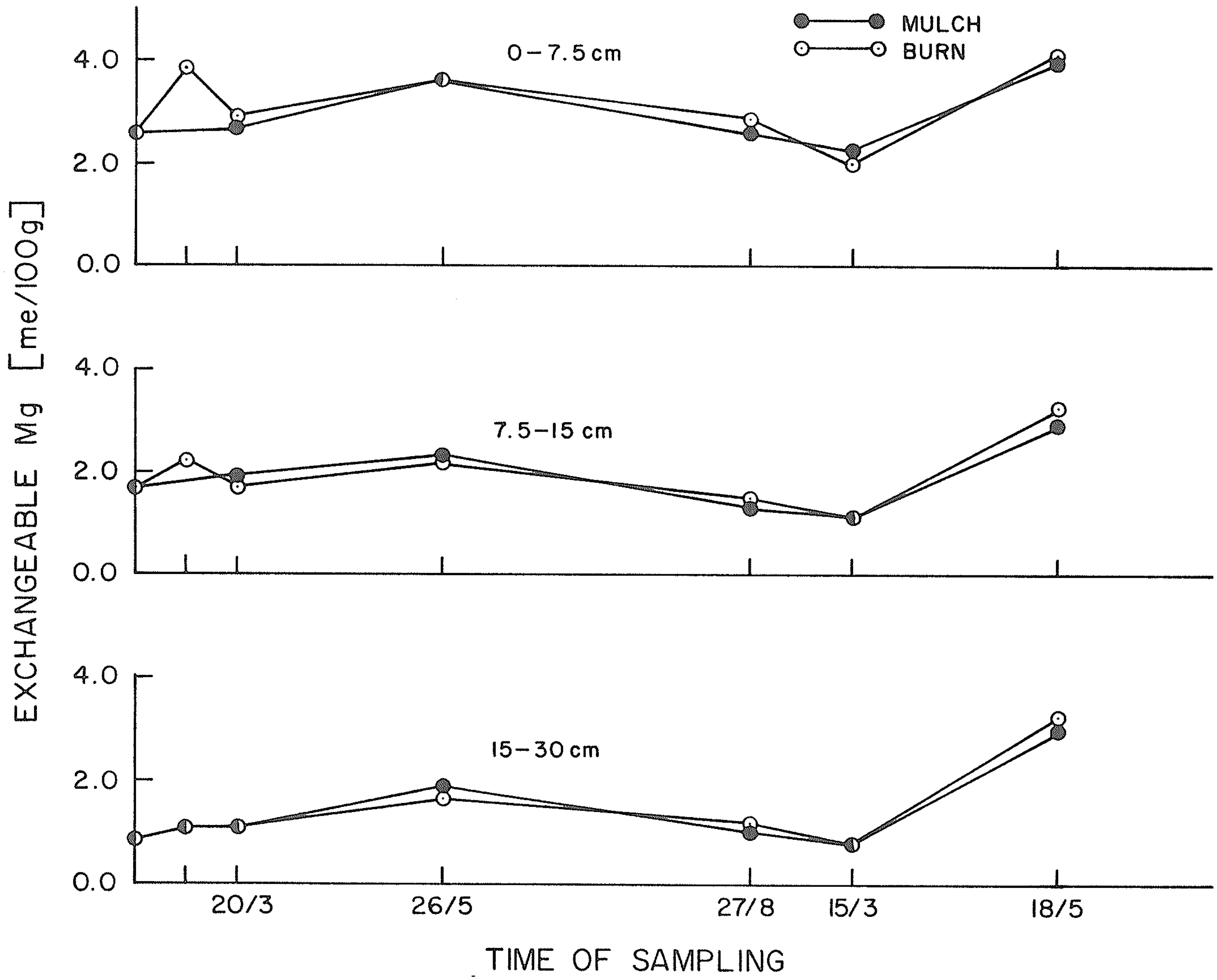

Fig. 6.14 Effect of Residue Management on Exchangeable Mg in different Soil depths

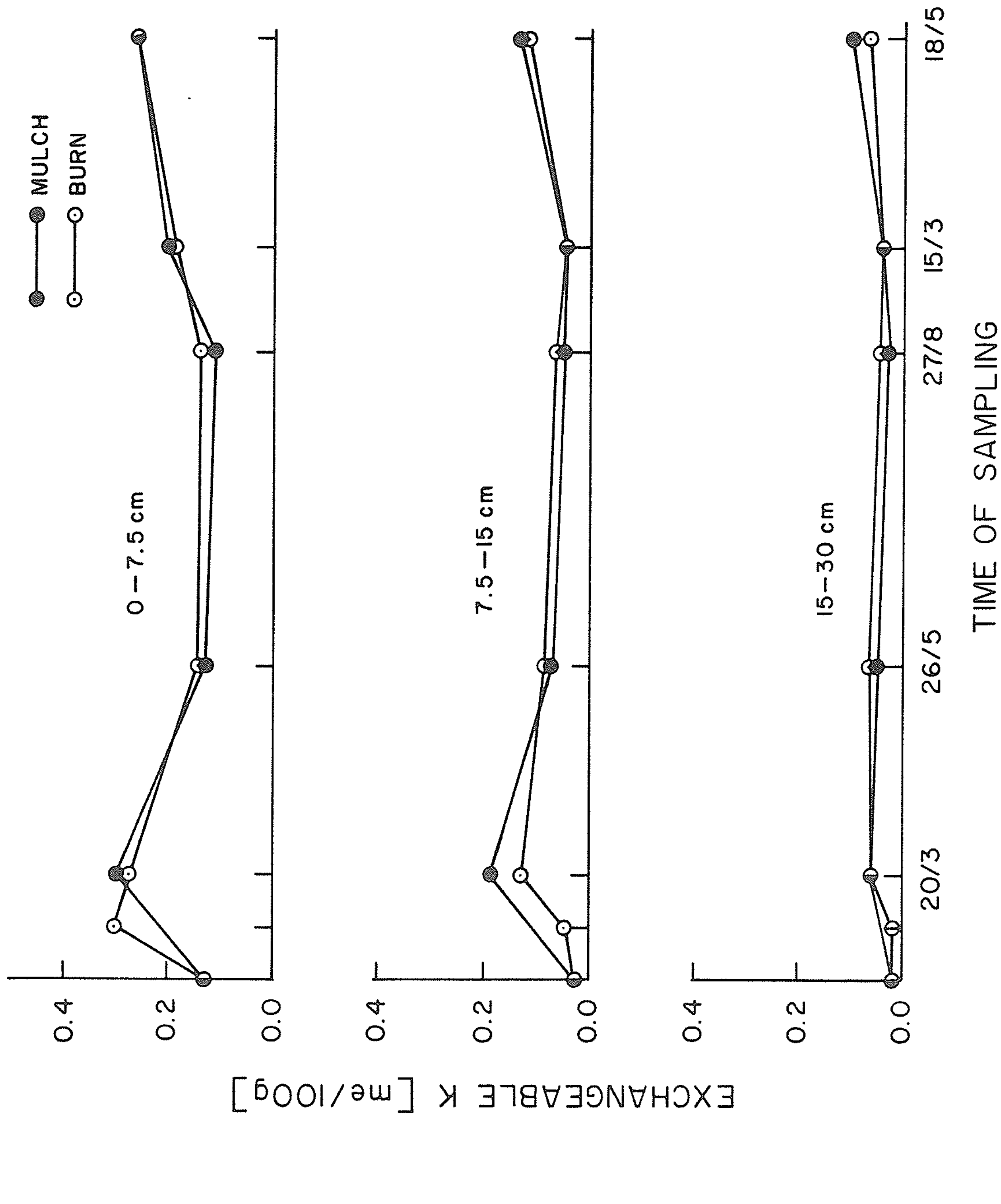

Fig. 6.15 Effect of Residue Management on Exchangeable K in different Soil depths

a third year following a similar management practice as in the preceeding two years.

(e) *Exchangeable Mn*

(i) Effect of Residue and Fertilizer Treatments:

There was no difference in the exchangeable Mn level in the top soil between mulching and burning when check and the PK treatments were compared (Fig. 6.16). When fertilizer treatments containing N were applied, the Mn level in the top soil became higher under mulching than under burning.

Under the mulch treatment, the Mn levels were the same for both check and PK treatments and they were lower than for other fertilizer treatments. Where the residues were burned, there were no real differences in the Mn levels among the fertilizer treatments. These results seem to be related to the soil pH discussed earlier. Nitrogen caused a pH depression especially under mulching and also favoured the increase in soil Mn level. Low soil pH and high Mn level may be related to a possible high N accretion from decomposing mulch residues.

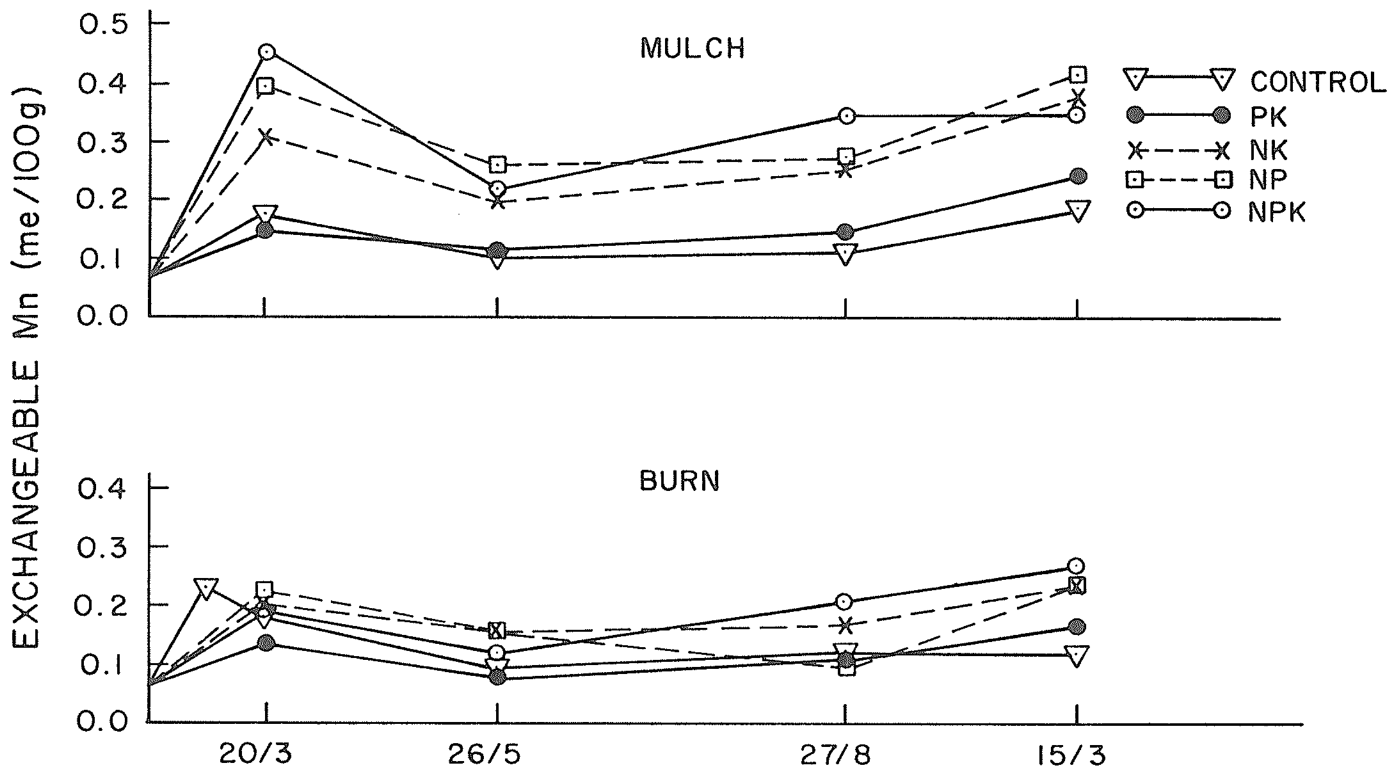

Fig. 6.16 Effect of Residue Management and Fertilizer Application on Exchangeable Mn in 0 - 7.5 cm depth

6.3.4 A Comparison of Mulching and Burning with and without Fertilizer and Lime Application on the Chemical Properties of the Onne Ultisol.

(a) Soil pH

(i) Effect of Residue Treatment:

The soil pH values taken at different dates were higher in the 0-7.5 and 7.5 cm depths where the fallow residues were burned than where they were retained as mulch (Fig. 17). The higher soil pH values at these depths were more pronounced during the first six months than at the latter stage of the study. Differences in soil pH at the 15-30 cm depth between the two residue treatments were small throughout the study period.

Where the fallow residues were used as mulch, the soil pH in the top 0-7.5 cm depth was higher than in the two lower depths. The pH values at the lower two depths were about the same for much of the period of sampling. In contrast, where the residues were burned, there were considerable differences in pH values among the depths sampled. With this residue treatment, the pH values in the top 0-7.5 cm depth were higher than in the 7.5-15 or 15-30 cm depth. During the first five months in particular, the differences in pH values between 0-7.5 and 7.5-15 cm soil depths were less pronounced than those between 7.5-15 and 15-30 cm depths. However, in subsequent months, the difference in the pH values between the two lower soil depths became less as compared with that between 0-7.5 and 7.5-15 cm depths.

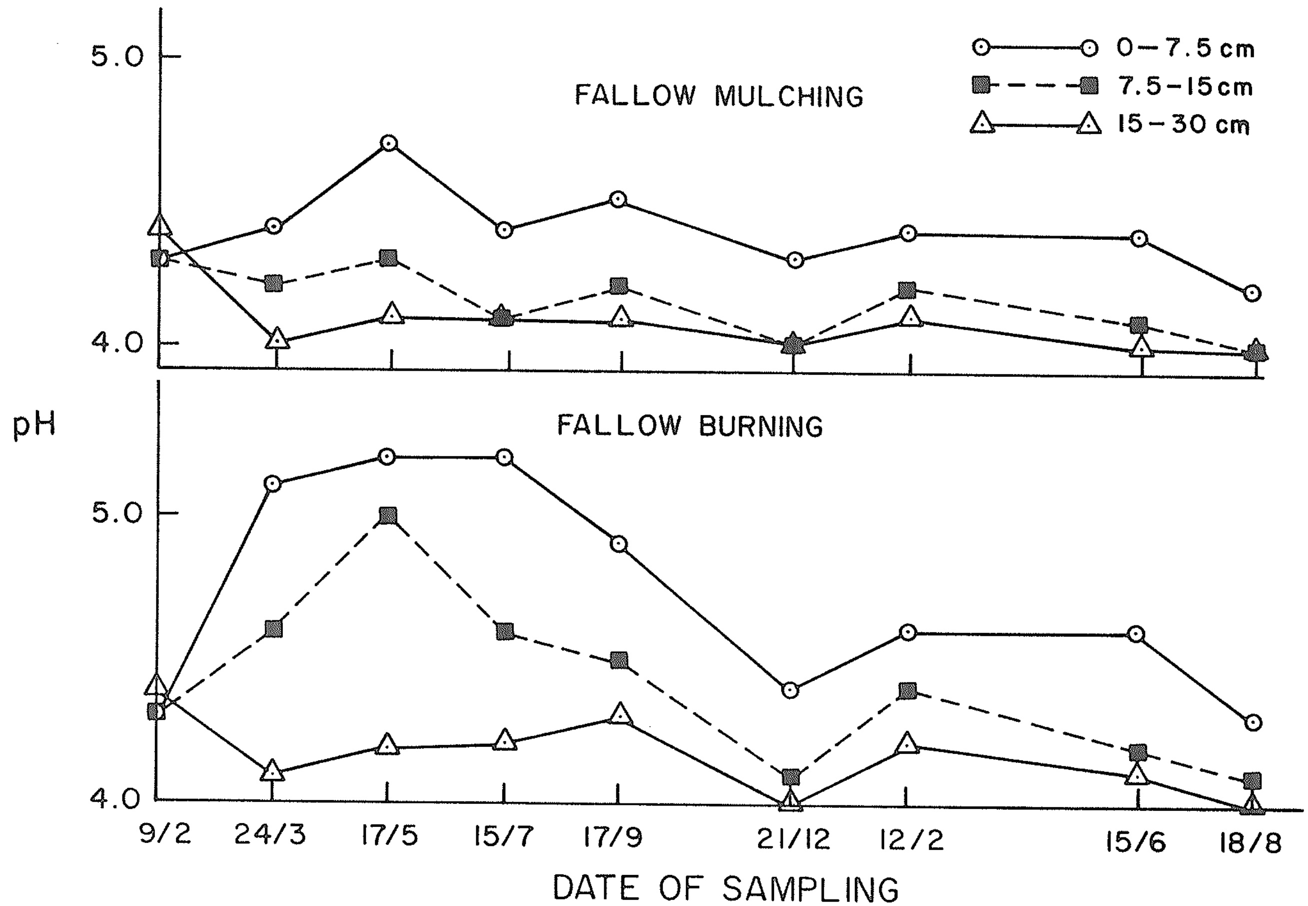

Fig. 6.17 Effect of Residue Management on Soil pH in different Soil depths

(ii) Effect of Fertilizer and Lime Treatments:

With the mulch treatment, there were no real changes of soil pH in all the three depths following the addition of NPK alone or MgZn in combination with NPK (Fig. 6.18). However, liming had a pronounced effect on pH of the top 0-7.5 cm depth. Although there was some effect of liming on pH at the 7.5-15 cm depth, this was noticeable only after the first six months of 1978, probably due to downward movement of lime.

Similar results were obtained where the residues were burned but the effect of liming on the pH of the 7.5-15 cm soil depth was noticeable as early as the second month after cultivation (Fig. 6.19). This may have been due to the downward movement of both ash and lime. Liming had no effect on the soil pH in the 15-30 cm depth with both mulching and burning treatments.

(b) *Soil Organic matter*

(i) Effect of Residue Treatment:

The soil organic matter levels in all three depths and at the different dates of sampling were about the same with both residue treatments (Fig. 6.20). Generally, there was no pronounced decline in the soil organic matter level after two years of cropping as compared with the level prior to cultivation. This result seems to contradict Bram's observation (1971) in Sierra Leone where a rapid organic matter decline occurred after only one year of cultivation on a similar soil.

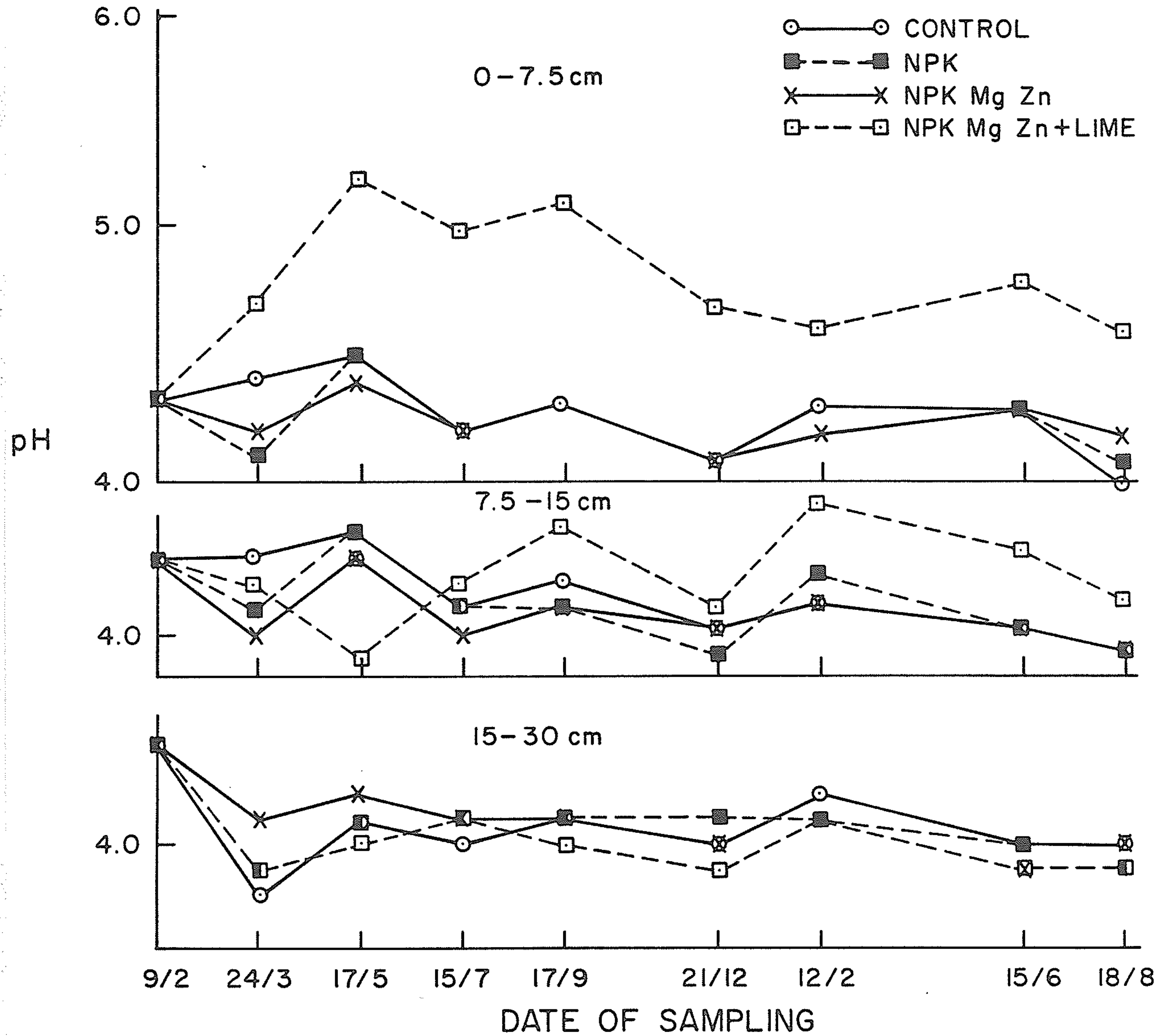

Fig. 6.18 Effect of Fertilizer/Lime Application and Mulching on Soil pH in different Soil depths

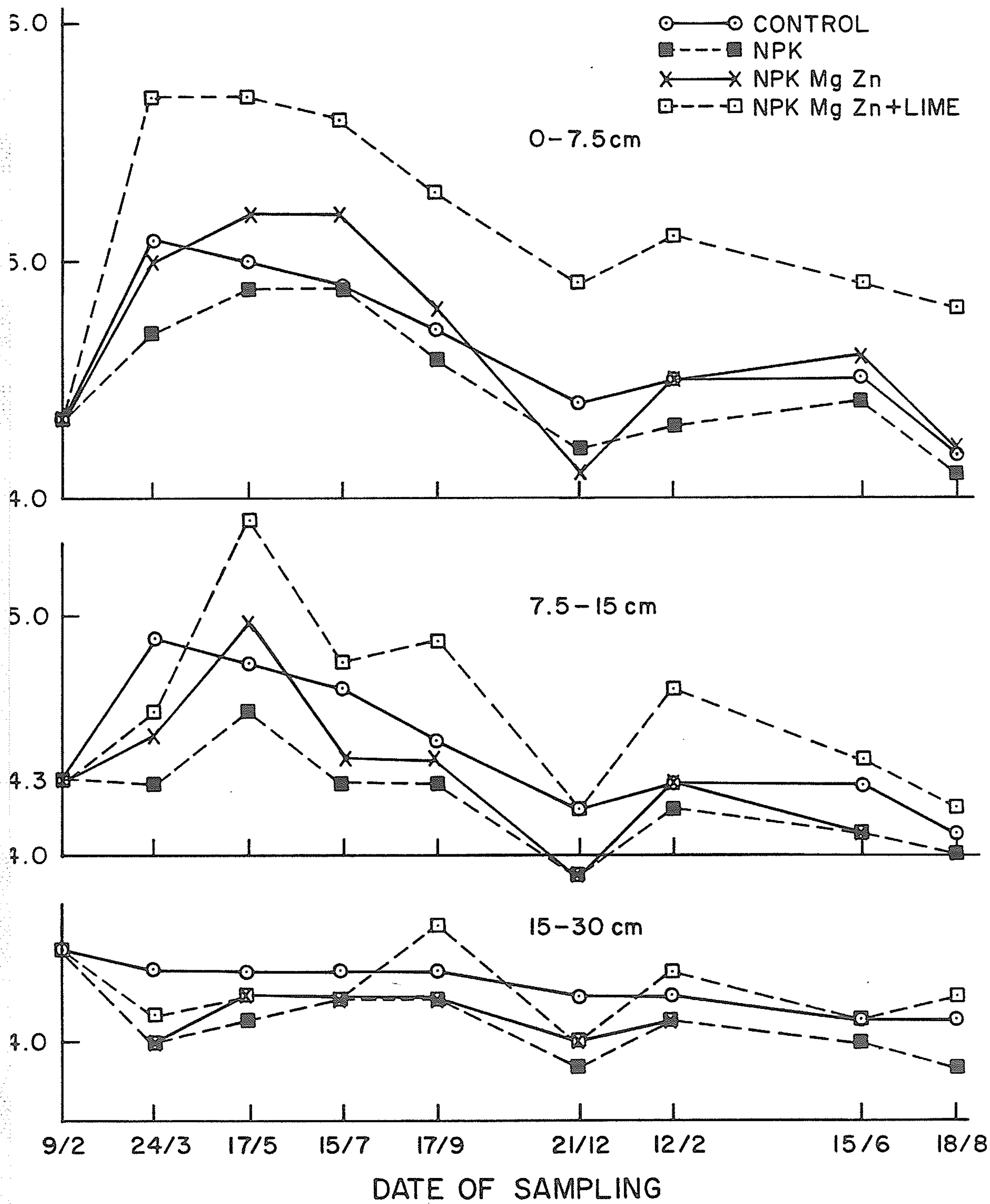

Fig. 6.19 Effect of Fertilizer/Lime Application and Burning on Soil pH in different Soil depths

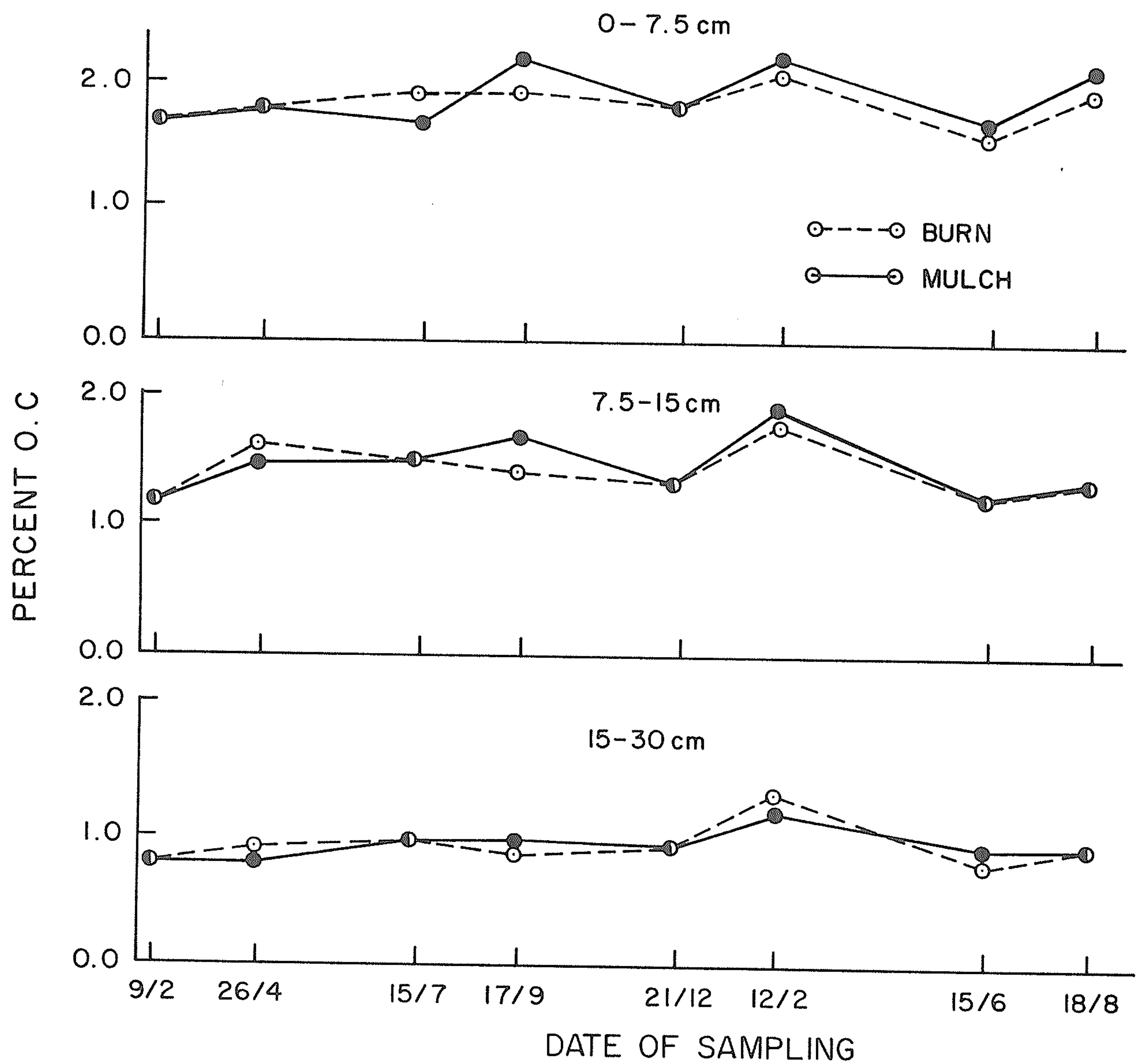

Fig. 6.20 Effect of Residue Management on Organic Matter Status in different Soil depths

However, the present study confirms results of Nye and Greenland (1964); NCSU (1973) who found no marked depletion of soil organic matter status after the first year of slash and burn cultivation.

The effect of retention of crop residues could not be ascertained in this trial but, as suggested by Lal (personal communication), the practice of retaining crop residues effectively reduces the magnitude of soil degradation in high rainfall areas of Southern Nigeria.

(ii) Effect of Fertilizer and Lime Treatments:

There were no major changes in soil organic matter contents as a result of the addition of nutrient and lime.

(c) *Available P*

(i) Effect of Residue Treatment:

The available P contents in the top 0-7.5 cm soil depth, as determined by Bray I-method indicated that there were no differences as a result of the method of residue management (Fig. 6.21). Generally, available P levels reported are very high even when no P was added. This observation is probably an indication that the procedure used for determining available P in this soil may not really be a reliable measure of plant available P.

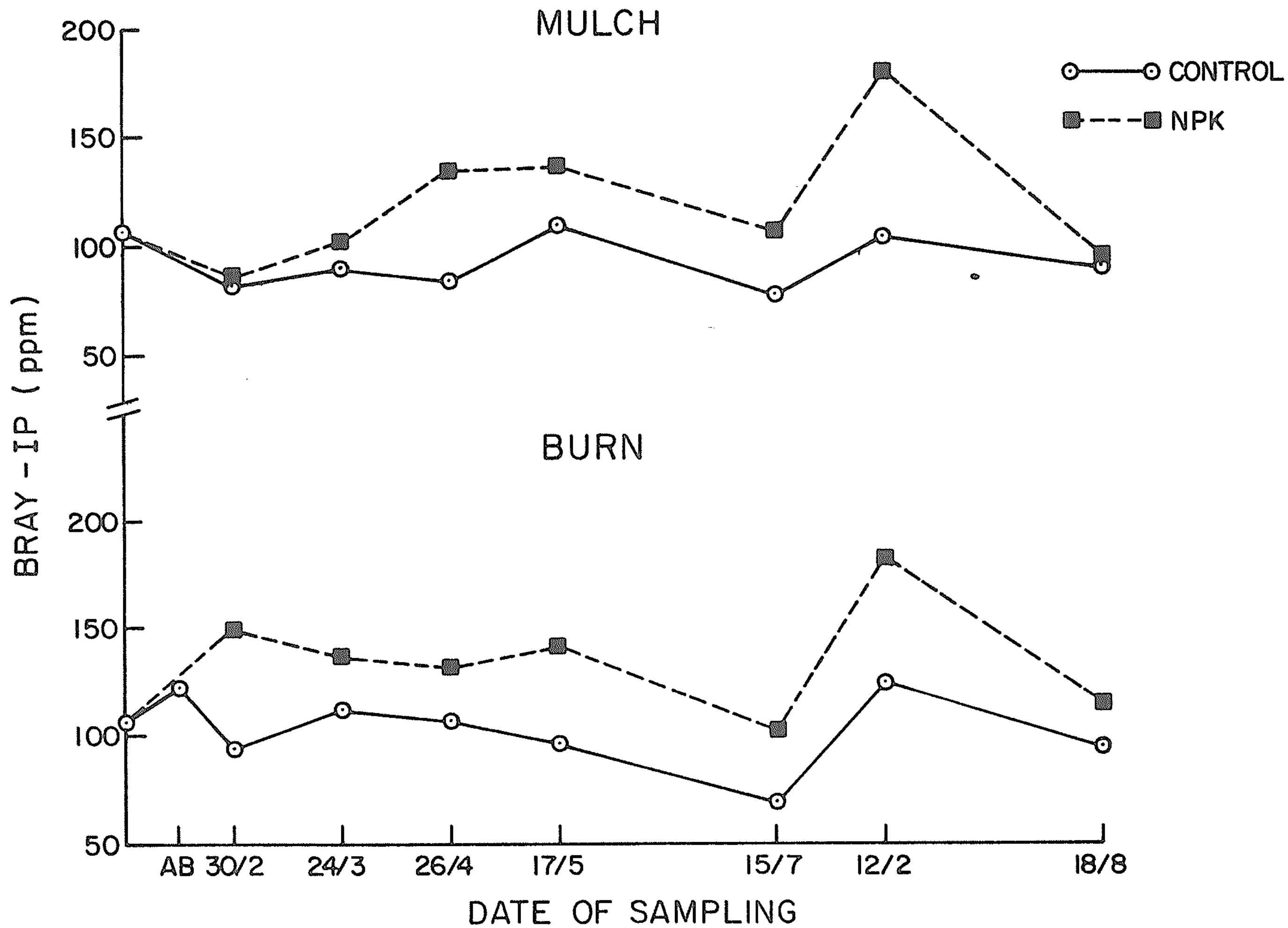

Fig. 6.21 Effect of Residue Management and NPK Application on Available P in 0 - 7.5 cm depth

(ii) Effect of Fertilizer Application:

With both residue treatments, the addition of NPK caused an increase in available P contents in the top 0-7.5 cm soil depth. The increase observed was not pronounced in the first month after application where the residues were treated as mulch. With both residue treatments, the increase was sustained only during the first three months of cultivation in 1978. The lowest P content in the soil was obtained in July, 1978 even where fertilizer was applied.

There was a rapid increase in available P in the top soil in February 1979. This may have been due to the application of fertilizer prior to cultivation in 1979 but a similar increase noted where no fertilizer was applied suggests other unknown reasons. At the end of the study in 1979, there was no marked difference in available P contents in the top soil between the check and NPK treatments. Phosphorus deficiency symptoms observed in check plots were not observed in NPK plots but tissue analysis (Chapter 5) indicated that P was limiting even where P was applied. Therefore, the deficiency of P may have been masked in the field where P was applied.

(d) *Exchangeable bases (Ca, Mg and K)*

(i) Effect of Residue Treatment:

The average exchangeable Ca values measured at different dates were nearly the same for mulching and burning in all the soil depths (Fig. 6.22). However, the exchangeable

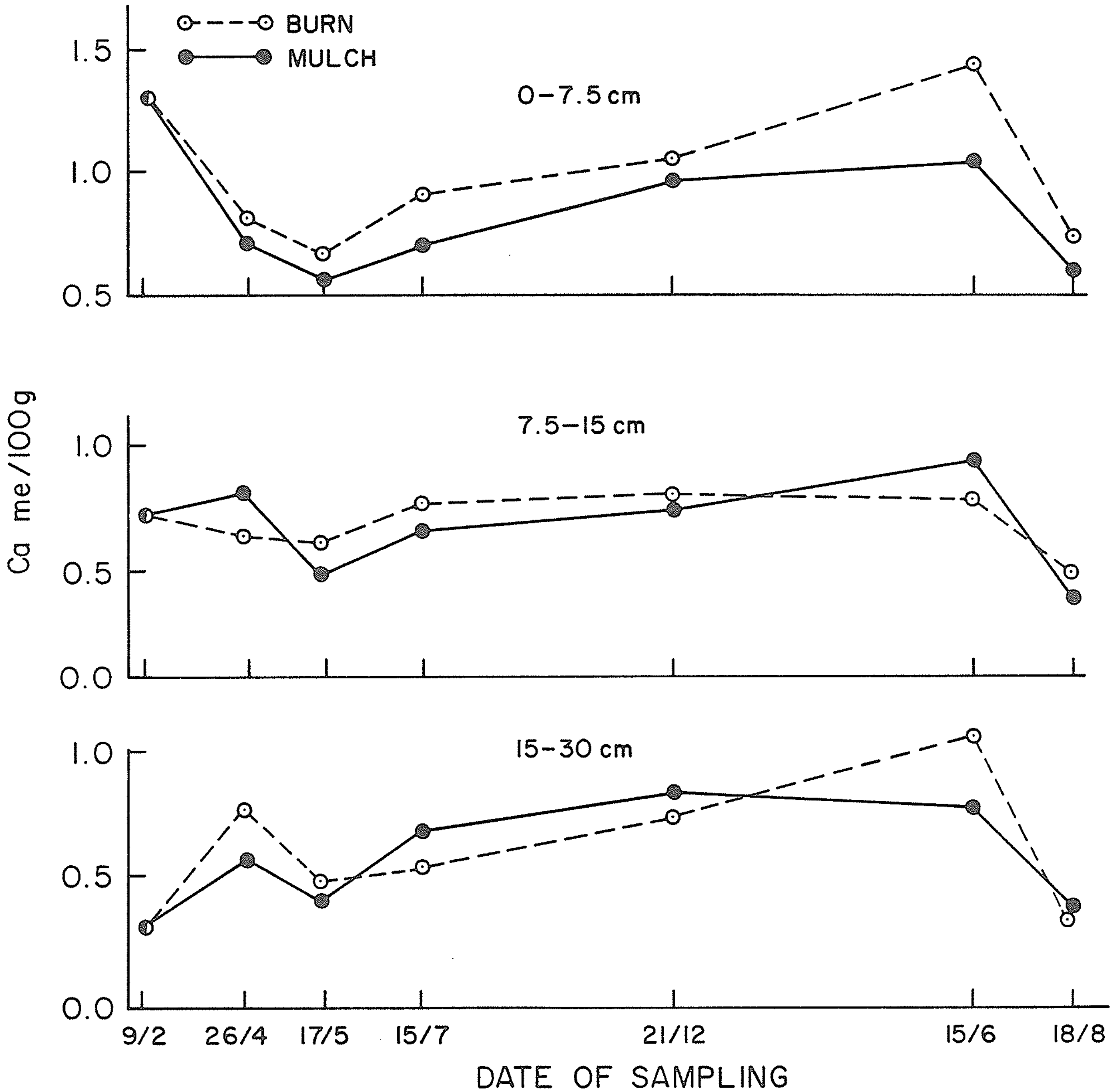

Fig. 6.22 Effect of Residue Management on Exchangeable Ca in different Soil depths

Ca in the top soil (0-7.5 cm) was slightly higher under burning, probably due to the base content of the ash. The difference in exchangeable Ca values between the residue treatments, seemed to increase with time, especially between July, 1978 and June ,1979.

In the 7.5-15 cm soil depth, exchangeable Ca levels due to the two residue treatments were practically the same. Similar observations were made at the underlying soil depth although there appeared to be a pronounced increase under burning in June, 1979. Increase of Ca in this depth (15-30 cm) was evidence of downward movement of Ca from the overlying depths as a result of the increasing trends occurring after July, 1979.

(ii) Effect of Fertilizer and Lime Treatments:

During the first three months of cultivation in 1978, there was no pronounced change in exchangeable Ca level in the top 0-7.5 cm soil depth under mulching as a result of fertilizer and or lime application (Fig. 6.23). The exchangeable Ca in this depth was markedly low in July, 1978 where neither fertilizer nor lime was applied. There was an increase in the level of exchangeable Ca after July, 1978 as a result of lime application. This increase was sustained until June, 1979 after which the level again declined.

There appeared to be a pronounced increase in exchangeable Ca level in the first six months of 1979 as a result of

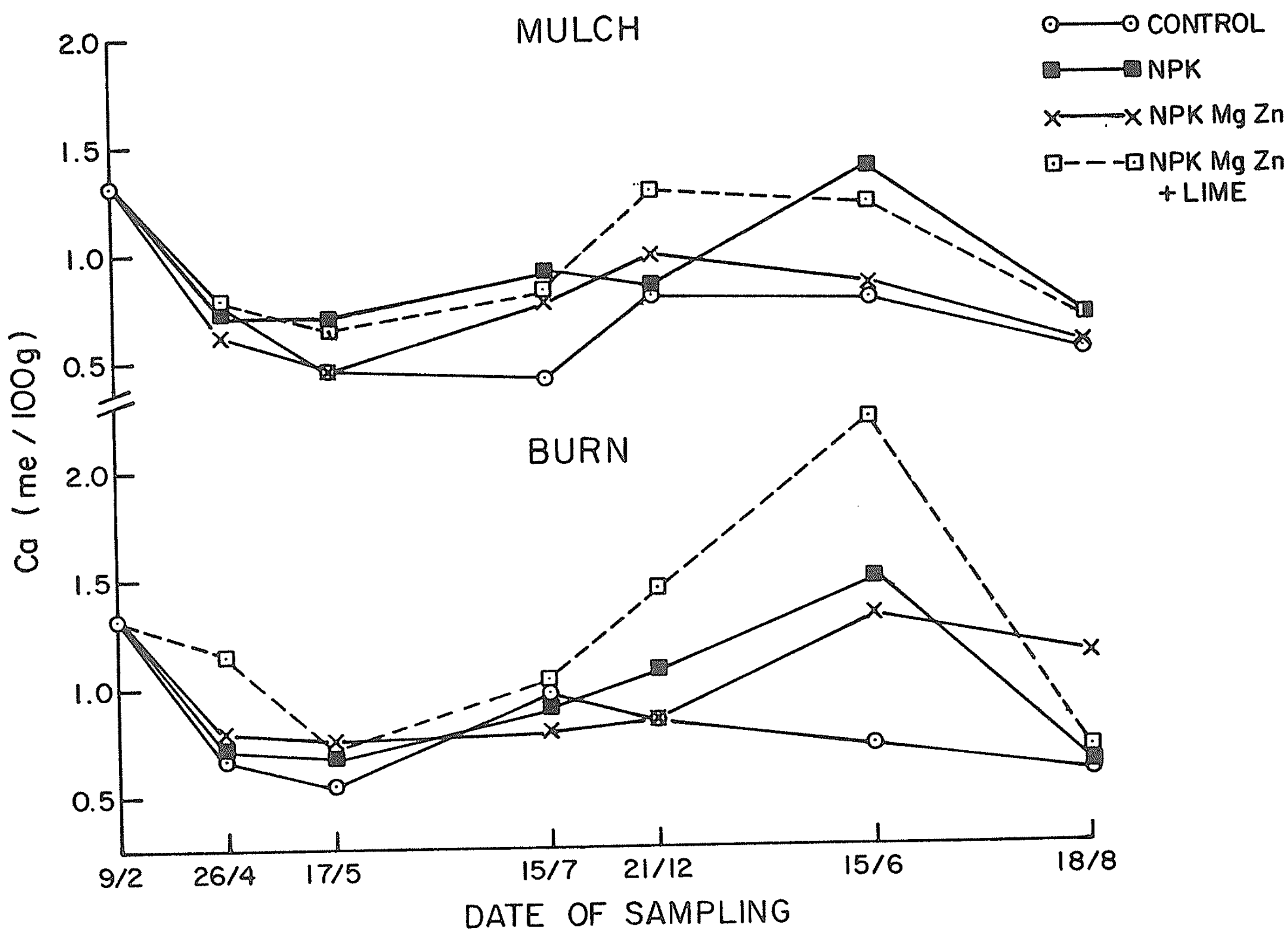

Fig. 6.23 Effect of Residue Management, Fertilizer and Lime Application on Exchangeable Ca in 0 - 7.5 cm depth

NPK application. At the same time, NPK applied in combination with Mg and Zn caused a decrease of exchangeable Ca. This decrease persisted till the end of the study at which time, the exchangeable Ca levels were nearly the same for all treatments.

Similar results were obtained where the residues were burned except that in 1978, the effect of liming was noticeable during the first three months of cultivation. Between July, 1978 and June 1979, exchangeable Ca level in the top 0-7.5 cm depth under burning increased tremendously as compared with levels prior to July, 1978. The increases were comparable between NPK applied alone and NPK applied with Mg and Zn but the increase due to lime was most profound and difficult to explain. In subsequent months, the decline was as rapid as the previous increase except for the treatment where NPK was applied with Mg and Zn.

The effects of residue management and fertilizer treatments on exchangeable Mg and K as shown by the average values used in Fig. 6.24 and 6.25, respectively, indicated that there were very minor differences between the residue treatments. The changes in these chemical properties during the sampling periods were more subtle than those observed in respect of Ca. This is probably due to the difference in the amounts added or may be related to the mobility of the different ions. Where differences occurred, as in the case of K, they were noticeable in the first one or two months after cultivation.

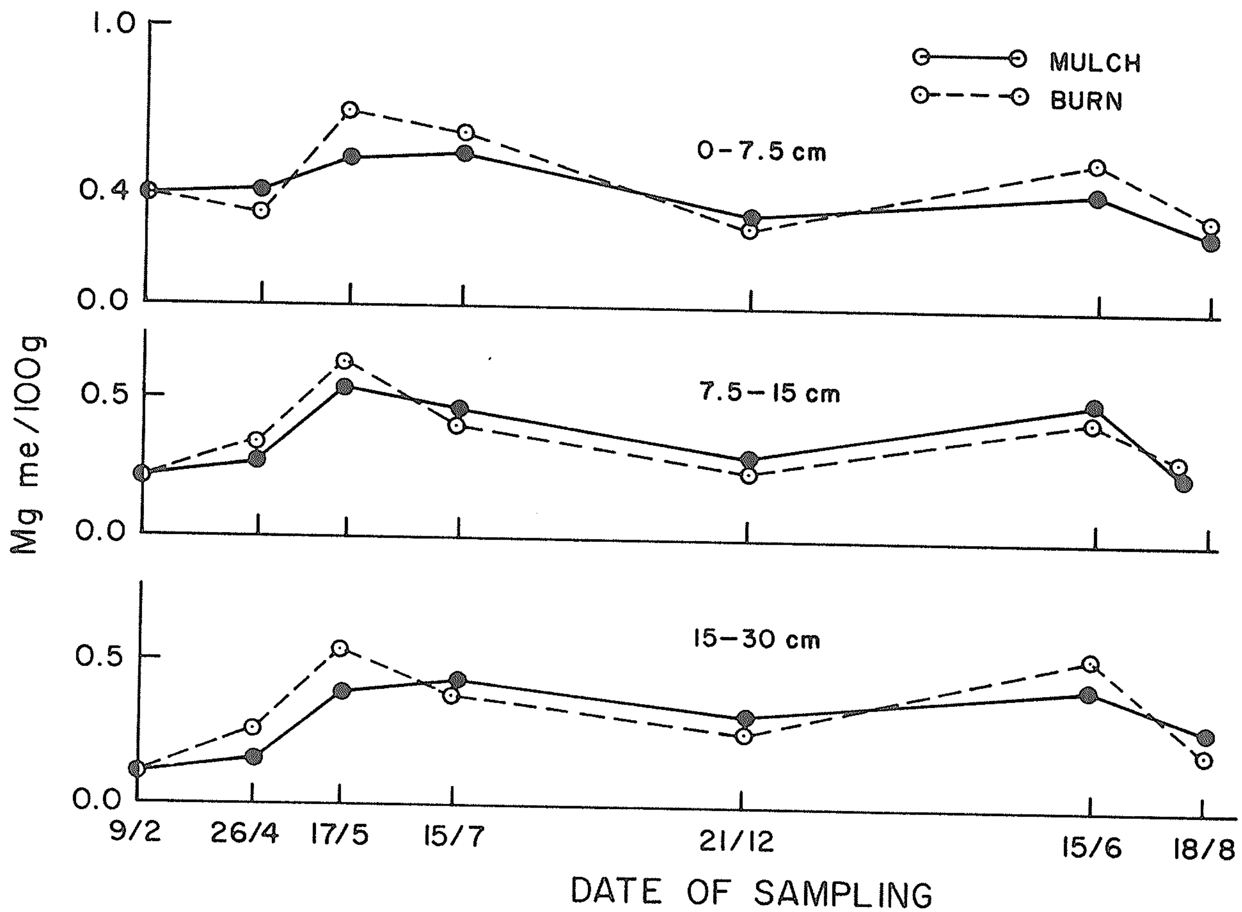

Fig. 6.24 Effect of Residue Management on Exchangeable Mg in different Soil depths

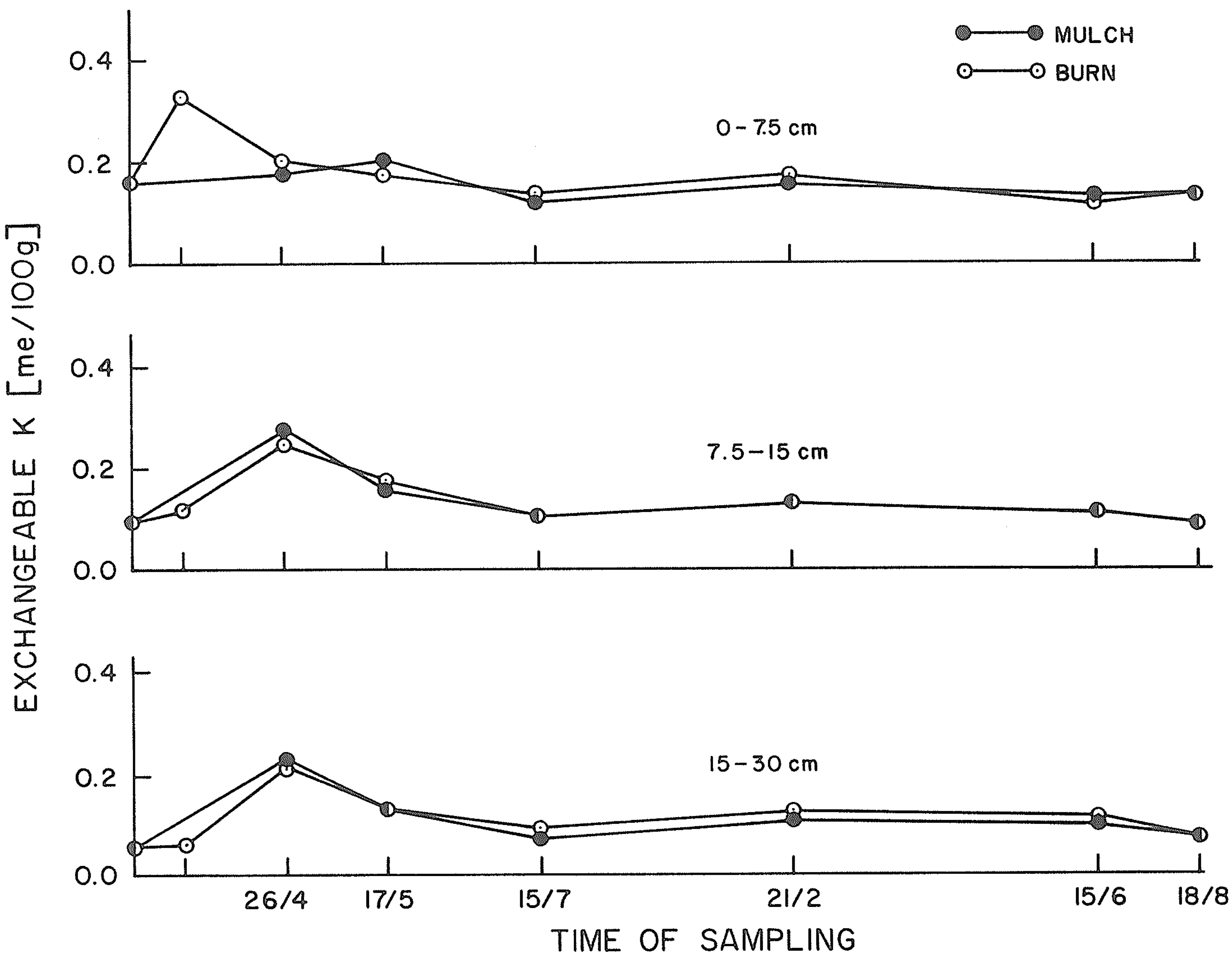

Fig. 6.25 Effect of Residue Management on Exchangeable K in different Soil depths

(e) *Exchangeable Al and Total Soil Acidity (H + Al).*

(i) *Effect of Residue Treatment:*

The exchangeable Al in the top 0-7.5 cm soil depth was much reduced in burned, as compared to the mulched plots (Fig. 6.26). The effect of burning on the exchangeable Al was most marked during the first two to three months after burning. Although the exchangeable Al was shown to decline considerably in those first months under both residue treatments, the effect under mulch was attributed to the influence of lime application.

Generally, exchangeable Al in the top soil depth increased rapidly with time, attaining fairly high levels by the end of 1978. There was little noticeable change in exchangeable Al levels in the first six months in 1979. However, by August, 1979, exchangeable Al contents in the top soil had increased beyond the precultivation levels where the residues were burned.

The total soil acidity trends, as with the other chemical properties, were similar for the two residue treatments (Fig. 27). This parameter was unaffected by fertilizer treatments. The minor differences observed were probably due to sampling variations. The changes in total acidity due to fertilizer treatments under mulching were more uniform as compared to the observed changes under burning. Again, this difference may be due to the additional neutralizing effect of ash. The effect of the ash was quite noticeable under burning where it

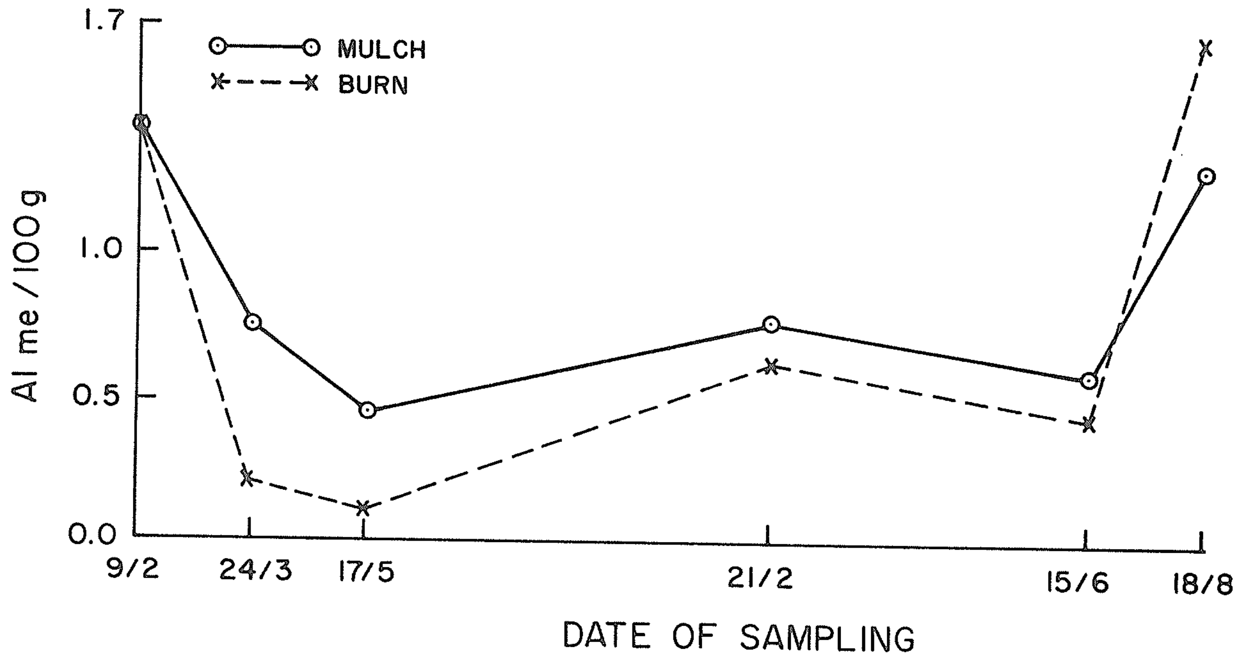

Fig. 6.26 Effect of Residue Management on Exchangeable Al in 0 - 7.5 cm depth

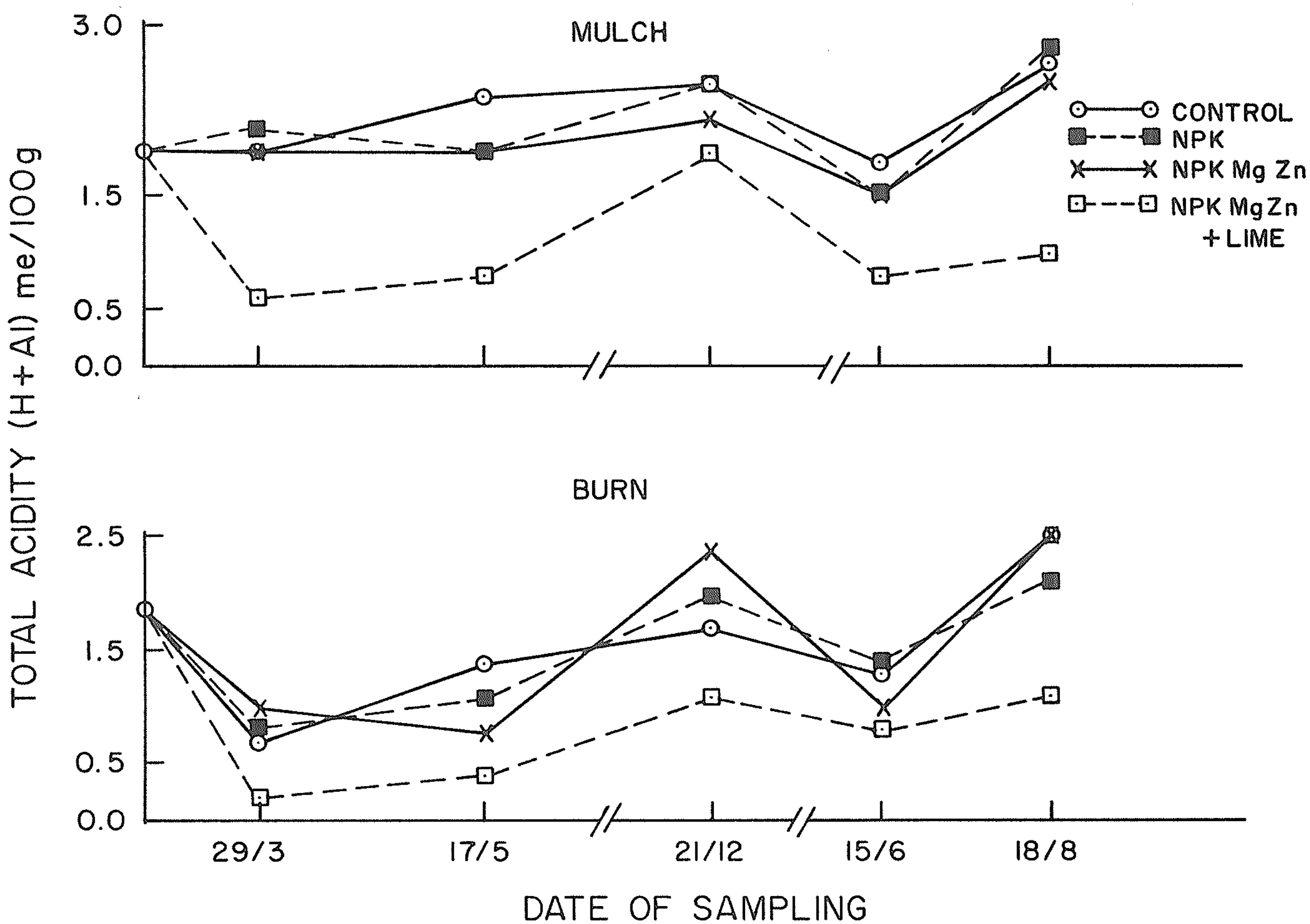

Fig. 6.27 Effect of Residue Management, Fertilizer and Lime Application on Total Soil Acidity in 0 - 7.5 cm depth

reduced the total acidity during the first month after burning.

Liming reduced total soil acidity especially under mulching. The differences in total acidity between fertilizer and lime treatments under the mulch were more pronounced than similar differences under burning. Therefore, the ash appeared to diminish the effect of applied lime. Liming in general helped to maintain low levels of soil acidity in the Ultisol during the period of the investigation.

6.4 Summary and Conclusions

The effect of bush fallow burning on soil chemical properties and changes in these properties as a result of fallow residue management, fertilizer and lime application were investigated in two representative Alfisol and Ultisol soils in Southern Nigeria.

Soil samples for the study were taken from 0-7.5; 7.5-15; and 15-30 cm depths after burning and through the two years of cropping on both soils. Lime was applied only to the Ultisol which had a lower soil pH.

Burning of fallow residues increased soil pH, organic carbon, available P and exchangeable bases but the increases were confined to the top 0-7.5 cm soil depth. The resulting increases in exchangeable bases could not be accounted for by nutrient content of ash suggesting that other processes besides burning might be involved in these increases. The effect of the increase in these properties was short-lived probably due to the low amounts of nutrients added by the ash per se.

Burning and mulching regarded as residue management methods, had similar effects on the soil nutrient contents during the two years. Where differences were observed, they were noticeable during the first few months of cropping in the first year. Other minor differences were regarded as sampling variations rather than a reflection of real differences. Generally, chemical fertilization increased the level of the specific element applied but the effect of fertilizer on soil chemical properties diminished as cultivation was extended beyond the first year.

The reduction in base contents of the Ultisol was more pronounced than those of the Alfisol which had a relatively higher cation exchange capacity.

Liming the Ultisol caused a marked decrease in the exchangeable Al and total acidity (H + Al). However, as cropping was extended, the exchangeable Al increased to a greater extent than did the total acidity. The total soil acidity was maintained at levels lower than the initial level before cultivation in the first year.

The conclusions drawn from these results are summarized as follows:

The effect of bush fallow residue burning is confined to the top soil horizons where the nutrient contents of plant ash are immediately deposited during burning. However, the nutrient supply from the ash may be quite small when short fallows are subjected to burning. The factors which may influence the nutrient contents of the ash were discussed elsewhere in this thesis.

The increases in the chemical properties of the soil, such as pH, available P and exchangeable bases after burning are short-lived and not wholly due to the effect of ash. Mineralization of organically-bound nutrients from roots of fallow plants and decomposing residues can occur if the interval between slashing and burning is long. This mineralization as well as the effect of heating may add to the increase in soil nutrients.

A comparison of the effects of mulching and burning on soil chemical properties of the two soils showed that at least for the short fallows studied, both methods of residue management are really similar, with and without fertilizer application.

The more pronounced decline in soil chemical constituents as well as the increasing acidification of the Ultisol with cropping as compared with the Alfisol suggested that the former soil poses a greater management problem than the latter. To sustain the fertility status of the Ultisol for profitable yields with continuous cropping, will require high fertilizer and lime applications. These inputs are not only uneconomical but also beyond the resources of the farmers. In contrast, the Alfisol may be cropped continuously for up to two or more years with modest increase in the levels of soil nutrients as compared to those added in the first year of cultivation.

The Ultisol soil may be better utilized by planting crops which make less demand on soil nutrients and which also have a tolerance for high soil acidity.

Chapter 7: General Summary and Conclusions

The improvement or replacement of bush fallow as practised in Southern Nigeria with a viable alternative must be based on a good understanding of the present system. As a contribution to understanding this practice, field and laboratory studies were undertaken. The investigations were designed to:

(i) qualitatively describe fallows and the practice of fallowing;

(ii) quantitatively evaluate the contributions of the several components making up this agricultural system and

(iii) assess how these may be managed to achieve profitable crop production for more than two years on the more regularly cultivated Alfisol and Ultisol soils.

An assessment of the dry matter yields of the above-ground parts of the fallow biomass in four locations showed that these yields varied with the type of vegetation, the length (age) of the fallow, the amount of rainfall and the fertility status of the soil. Secondary bush regrowths and forest-type vegetation produced higher dry matter yields than the fallows dominated by grasses. While high rainfall favoured intense growth of fallow species, the fertility of the soil determined the extent of growth during the fallow period.

Although time (length of fallow) seemed very important in this assessment, it had no dominant influence over the amount of dry matter produced.

Both yield of plant biomass and nutrient content per gram of dry fallow material varied considerably and this resulted in pronounced differences in nutrient storage among the fallows. Nutrient storage like the yields of the fallow biomass varied with type of plant species in the vegetation, age of the fallow and climate. Predominantly grass-type fallow vegetation and young bush regrowths had lower nutrient storage as compared with fallows dominated by mixed and hardy plant species that developed through several years of growth. Climate influenced nutrient storage by affecting the fertility of the soil. High rainfall may have increased the loss of nutrients by leaching and thereby limited the ability of the fallow species to recover and hence store nutrients in the above-ground parts.

The quantity of nutrients collected as plant ash at each location was much less than the amounts of nutrients present in the fallow biomass. This was probably due to a low nutrient storage in the plant material produced during the fallow period or in part due to incomplete burning so that some of the mineral constituents remained in organic form. The factors which influenced the dry matter yields of the fallow biomass also affected the nutrient storage in the plant biomass and in the ash. In addition, the intensity or degree of burning was another factor which may have influenced the nutrient contents of the ash.

Temperatures attained during burning were monitored at the soil-litter interface and at the 5 cm soil depth. The temperatures were found to be influenced by the duration and intensity of burning. Both of these variables were determined by the amount, type and spatial distribution of the fallow residues. At the soil-litter inferface and at the 5 cm soil depth, temperatures obtained ranged from 60 to 570 C and from 30 to 70 C, respectively. High temperatures at the soil-litter interface were not sustained for more than 15 minutes, and at the 5 cm soil depth, the duration of maximum temperature was even less. There were no noticeable changes in color of the soil in the two zones as a result of burning. However, in a few isolated spots in the field where logs of wood were left burning for over twenty-four hours, soil temperatures beyond 90 C were sustained for a longer period. In these spots, the soil color varied from black to red while the soil became grittier to the feel suggesting that high temperatures sustained over a certain length of time could cause a marked change in the physical and chemical properties of the soil.

Under laboratory conditions, heating the soils to temperatures less than 200 C had no beneficial or detrimental effects, but heating to 200 C darkened the soil color and reduced soil organic carbon content. At temperatures of 400 - 600 C, soil color was changed to redder hues. Soil organic carbon was virtually destroyed and the proportion of sand-size particles increased. At the same time, extractable NH_4-N, available P, exchangeable Mn and Fe increased. Heating the soils beyond 6 hours at the selected temperatures did not change the results.

Growth and nutrient uptake by maize grown on a previously heated Ultisol soil was studied in the greenhouse. The effect of heating on crop performance depended more on the temperature of heating than on the nutrients added to the soil. At temperatures lower than 200 C, plant height, dry matter yields and nutrient uptake of maize were not significantly affected. However, at 200 and 600 C, they were depressed and the reduction was significant at 200 C. Although the addition of fertilizer improved maize performance on the heated soil, the depression caused by heating was still observed.

The effects of plant ash on maize dry matter yields and nutrient uptake were also investigated in the greenhouse. The ash was added at levels which were estimated to be the same as or up to four times as much as was obtained in the field after burning. Neither the dry matter yield nor the uptake of nutrients was significantly improved using the amounts of ash equivalent to the field levels. Adding levels of ash in excess of the field amounts increased maize dry matter yields. Plant recovery of nutrients such as K and Mg was increased when the excess amounts of ash were broadcast as compared to when they were mixed in the soil. However, this improvement was not pronounced suggesting that the importance of the ash as a source of nutrients was small. The plant recovery of N, P and K, even with high amounts of ash, was low.

The greenhouse studies confirmed results obtained in the field that P was more limiting than either N or K on both the Alfisol and Ultisol soils used. The low recovery of P by the maize even with high levels of ash suggested that the ash was a poor direct source of P. Incubation studies showed that the ash was inferior to KH_2PO_4 as a means of increasing the level of P in the soil solution. However, the ash decreased the adsorption of P added to the Ultisol as KH_2PO_4.

A comparison of the ash and hydrated lime as sources of lime on the Ultisol was made using the incubation studies referred to above. The lime was added at a level equivalent to the neutralizing value of the ash. The recovery of Ca by maize from the two sources was similar although the Ca content of the ash was smaller than that of the lime. The pH of the soil solution increased progressively as the amount of ash incubated with the soil was increased. Such an increase in soil pH may occur in localized spots in the field.

Field studies were undertaken on representative Alfisol and Ultisol soils to compare the influence of bush fallow residue management, fertilizer and lime treatments on the productivity and fertility of these soils during a two-year period. Bush fallowing had a beneficial effect on crop yields. The yields of maize on the two soils were high following the fallow even without the addition of fertilizer. Cowpea yields after the first maize crop were comparable to those reported from other studies in the area.

The average yields of maize and cowpea on the Alfisol in the first year were higher with the mulch treatment than where the fallow residues were burned but the yield differences were not statistically significant. There were significant yield increases of maize in the first year due to NPK application but the increase due to any one element was not significant. The addition of Mg and Zn applied with NPK caused a significant yield increase of maize on the Alfisol during the first year. Cowpea on this same soil did not respond significantly to the residual effect of fertilizer. There was, however, evidence from the higher cowpea yields obtained where NPK was applied with Mg and Zn that fertilizer addition might have been essential for higher cowpea yields.

In the second year, maize yields on the Alfisol declined slightly. Despite this reduction, yields obtained were good even without fertilizer. There was a significant increase in yields as a result of NPK application and the response to P was significant in the second year. At this time also, the response to Mg and Zn was not significant as was the case in the first year. The lack of significant response to N on the Alfisol during the second year may possibly be due to the enhancement of N status of the soil by cowpea in the first year. This suggests that the introduction of a good legume into the rotation in the first year may reduce the amount of N needed in the second year of cultivation on the Alfisol.

In the first year, maize and cowpea yields on the Ultisol were similar to those reported on the Alfisol. However, when maize yields on the two soils were compared, yields on the Alfisol were two and three times higher than yields on the Ultisol, with and without fertilizer, respectively. The addition of NPK in the first year significantly increased maize yields. Magnesium and Zn applied with NPK did not result in significantly increased yields of maize on the Ultisol. Tissue analysis showed that both N and P were low suggesting that they may have been limiting. Liming the Ultisol increased yields of maize but the increase was not significant.

In the second year, maize yields declined considerably on the Ultisol even with fertilizer application. The reduction in yields, with and without fertilizer application was 32 and 60 per cent, respectively. Calculated as a percentage of first year yields, these yield reductions were exactly twice as much as occurred on the Alfisol.

The yields on the burned plots were significantly higher than those under mulching in the second year but the total maize yields during the two years were still higher with the mulch treatment. Yield responses to fertilizer application were similar to those in the first year. There was also further evidence that both N and P contents in the tissue were low confirming that the two elements may have been mutually limiting.

Response to residual lime in the second year was not significant although there was an increase in maize yields with the lime treatment.

Burning the bush fallow residues resulted in an increase in soil pH, organic carbon, available P and base contents of the two soils. Burning also decreased the exchangeable Al and total soil acidity of the Ultisol. However, neither the increases in the above properties nor the decrease in the acidity of the Ultisol were sustained at their new levels for more than a few months. Changes in these properties were used in assessing the fertility status of both soils during the study period. On the Alfisol, these changes were remarkably similar between mulching and burning treatments. Many of the differences observed were slight and more due to sampling variability.

The soil pH values declined with time under both residue treatments but the decline was more noticeable where the residues were retained as mulch than where they were burned. Nitrogen application induced a decline in soil pH values in the Alfisol. There was no measurable decline in soil organic matter level throughout the two years. While burning and the addition of P fertilizer increased available P on this soil, the level of P decreased with time such that a lower level of P was present in 1979 than in 1978 prior to cultivation. Changes in exchangeable Ca, Mg and K levels were similar to those of the available P but the decline was not very pronounced in the second year on the Alfisol.

The changes in the soil chemical properties on the Ultisol were again similar to those reported on the Alfisol except that the changes were more pronounced in the second year than was the case on the Alfisol. Liming the Ultisol increased the soil pH and caused a pronounced drop in exchangeable Al and total soil acidity. Where the residues were burned, liming further increased soil pH and decreased the parameters of soil acidity. However, as cropping was extended, soil pH decreased while exchangeable Al and total acidity increased. Although the exchangeable Al level was higher in 1979 than in 1978, the total acidity in 1979 was still below the level in 1978. The increasing soil acidification was due to the rising level of exchangeable Al on the Ultisol.

The conclusions drawn from the results of these studies may be briefly summarized as follows:

(1) Bush fallowing as is practised on the short fallows studied is beneficial not only to crop yields but also to soil fertility. This beneficial effect of fallowing is not due to the burning of the residues for ash since the ash has little potential to supply nutrients in the amounts and for the duration required for profitable crop production. There seems to be no pronounced difference between the retention of the residues as mulch and the burning of these residues as is commonly done by the local farmers. Mulching may be a better method of handling the residues on lands that

are predisposed to erosion as on the slopes of some areas in Southeastern Nigeria. In areas where soil erosion is not a problem, mulching may still be an efficient way of conserving nutrients in the system since they will become slowly available.

(2) The Alfisol soil is relatively more fertile than the Ultisol soil and has the potential for supporting continuous cropping profitably, with modest nutrient inputs, appropriate crop rotations and a good crop husbandry. The changes in the fertility status of the Alfisol support this conclusion and further indicate that this soil could be used mainly for grain production.

(3) The Ultisol soil would appear to be capable of producing fairly good yields of maize and cowpea with fertilizer application in the first year at least. High nutrient and lime application would appear to be essential if reasonable yields are to be obtained in the second year. There is no evidence at this time that higher nutrient inputs will achieve the objective of high grain yields in the third year or subsequent years if continuous cropping is practised on this soil. Besides, such nutrient levels will be unprofitable and hence unrealistic. The rapid depletion in soil nutrients in the second year on the Ultisol would seem to suggest that this soil may be profitably utilized in the second and subsequent years for root crops such as cassava. These are the main staples in the area and have the advantage of easy planting

and management. They are usually more productive on lands with short fallows.

(4) The maintenance of adequate N and P levels in both soils and the reduction of exchangeable Al contents in the Ultisol in particular appear to be the most important factors limiting the yield potential of crops in these areas.

Suggestions for Future Research

Attention in the future should be given to the development of small farm machinery which can be used for thorough slashing of fallow residues and can also be adapted for planting through the residues. Such machinery will make planting easier, retain the residues with their nutrient contents and reduce the problem of erosion. It will also eliminate burning and the likely negative effect of heat on soil properties and plant growth.

Knowledge of the appropriate P sources, rates and placement methods will be valuable in meeting the objective of high crop yields on the two soils. Research may be directed towards the establishment of adequate nutrient combinations especially of the three major elements, to ensure balanced fertilization and profitable economic returns.

The introduction of efficient N-fixing legumes into the cropping rotations should be explored especially on the Alfisol where there is an increased chance of reducing the N levels required in subsequent years. The reduction in N costs as well as the dietary variety obtained by a grain-legume based cropping system cannot be overlooked.

Since the Ultisol does not appear to have the potential for the continuous cultivation of grain crops, future research should be directed to the likely benefits of root and tuber crops which have lower nutrient demands than the grains, and which have tolerance for high soil acidity caused by Al. Liming of the acid soil will still be necessary if the root crops are to be interplanted with other crops. Therefore, it is suggested that some studies recognize the need to determine the most suitable time for lime application. The level of lime required will be based on the knowledge of the concentration of exchangeable Al and its changes with time.

In primary forest areas, burning may still be used as a means of reducing the quantity of residues before planting. To this end, the exact effect of ash on the availability of applied P, especially on the low pH Ultisol soil with high P adsorbing characteristics, should be investigated. On-going research at several centres in the area on the amounts and sources of other essential elements required to produce good yields should be strengthened. Special attention, however, should be paid to the economics of production. These studies properly co-ordinated will provide a balanced picture and establish the base for the expected green revolution in Nigeria.

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APP.

1. Information on the site (Ikenne - Alagba soil series).

- Soil Classification: Eutric Nitosol (FAO); Oxic Paleustalf (USDA);
- Date of examination: 12 July 1973 by F.R. Moormann and P. Le Mare
- Location: 6^{O} 50 'N, 30 41' E, IKENNE, IART Station, Western State, Nigeria, near S.W. corner of Block 27.
- Elevation: 55 m
- Land form: Gently undulating Pleo-Pleistocene terrace (Continental Terminal).
- Slope: 4% SW, the profile is situated on the lower part of a long straight slope.
- Vegetation: Dense regrowth of *Eupatorium adoratum* after clearing and several years of cultivation.

2. General information on the soil

- Parent material: deeply weathered clayey sediments, uniform in lithology and texture to a depth of at least 4 metres.
- Drainage: well drained; rapid permeability; no visible impedence in any layer or horizon to depth of observation.
- Moisture conditions: moist profile throughout; wet in upper 40 cm after heavy rains.
- Groundwater: no groundwater at any time of the year to profile depth.
- Biological activity: worm casts at the surface; subterranean termite chambers, up to 15 cm deep in several places in the profile.
- Human activities: pieces of pottery scattered through upper 50 cm.

3. General aspect of the soil

Deep, red clayey soil with coarse loamy surface soil up to 30 cm in depth.

APP.

1. Information on the site (Onne ¬).

- Soil Classification: Typic Paleudult (Calabar Fasc. of H. Cline). Fine loamy silicic isohyperthermic.
- Date of examination 17/8/75; F.R. Moormann and W. Veldkamp.
- Location: Bush regrowth immediately west of cleared area, approximately 150 miles from the substation.
- Land form: Lower terrace, flat, no microtopography
    - (i) Physiographic position: Lower terrace
    - (ii) Surrounding land form : Flat
    - (iii) Microtopography: nil
- Slope: Flat; less than 1%
- Vegetation: Fairly dense bush regrowth after shifting cultivation. Fallow species dominated mainly by *Anthonata macrophylla* and *Alchornea cordifolia*.

2. General informaton on the soil

(a) Parent material: Pleo-Pleistocene marine terrace, clayey.

(b) Drainage: Well to moderately well drained, no mottling at depth of observation.

(c) Moisture conditions in profile: Moist to wet throughout.

(d) Depth of groundwater: Deeper than observation; stagnant water in drainage ditch or sealed ditch bottom at 70 cm.

3. Profile

Deep brownish clayey profile with thin dark somewhat more sandy surface soil.

APP. 3.1 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON MAIZE PLANT HEIGHTS (CM) AT 2WAP.

Nutrient Addition	Temperature of Heating (C) '0'	100	200	600	Nutrient Addition Means
No Fertilizer	22.4	22.5	13.0	18.5	19.1
NPKCaMgZnS	24.9	25.5	17.8	27.1	23.8
-N	21.4	20.1	18.7	21.2	20.4
-P	22.5	25.5	13.2	30.7	23.0
-K	20.0	26.7	14.2	24.6	21.4
-Ca	25.8	20.2	14.5	27.3	21.9
-Mg	27.5	21.0	19.5	26.5	23.6
-Zn	25.2	22.6	17.6	27.6	23.3
-S	27.7	26.7	18.2	23.0	23.9
Temperature Means	24.2	23.4	16.3	25.2	22.3

Lsd (0.05)
(i) Between Temperature means (2.70)
(ii) Between Nutrient Combination means (3.65)
(iii) Between Nutrient Combinations at one Temperature level. (7.30)
(iv) Between Temperature levels at one Nutrient Combination (7.40)

APP. 3.2 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON MAIZE PLANT HEIGHTS (CM) AT 3WAP.

Nutrient Addition	Temperature of Heating (C) '0'	100	200	600	Nutrient Addition Means
No Fertilizer	29.1	28.8	23.0	20.8	25.4
NPKCaMgZnS	42.0	38.6	31.6	35.1	36.8
-N	36.9	38.1	30.7	26.1	33.0
-P	29.9	34.2	26.6	38.2	32.2
-K	40.7	43.6	24.8	35.4	36.1
-Ca	40.7	33.8	27.6	34.2	34.1
-Mg	44.9	33.7	34.8	34.3	36.9
-Zn	44.5	38.0	33.3	39.5	38.8
-S	42.2	41.8	31.2	33.1	37.1
Temperature Means	39.0	36.7	29.3	33.0	34.5

Lsd (0.05)
(i) Between Temperature means (2.73)
(ii) Between Nutrient Combination means (4.51)
(iii) Between Nutrient Combinations at one Temperature level (9.02)
(iv) Between Temperature levels at one Nutrient Combination (8.92)

APP. 3.3 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON MAIZE PLANT HEIGHT 4WAP.

Nutrient Addition	Temperature of Heating (C) '0'	100	200	600	Nutrient Addition Means
No Fertilizer	35.3	37.5	29.4	23.6	31.5
NPKCaMgZnS	56.2	49.3	45.1	41.8	48.1
-N	48.1	51.0	45.3	29.7	43.5
-P	34.5	39.8	39.3	41.1	38.7
-K	61.5	58.1	44.5	42.2	51.6
-Ca	52.2	49.4	43.2	38.6	45.9
-Mg	54.4	48.5	51.8	40.9	48.9
-Zn	56.8	57.4	47.4	47.8	52.4
-S	56.1	55.1	44.6	39.9	48.9
Temperature Means					

Lsd (0.05)	(i)	Between Temperature means	(3.16)
	(ii)	Between Nutrient Combination means	(4.71)
	(iii)	Between Nutrient Combinations at one Temperature level	(9.42)
	(iv)	Between Temperature levels at one Nutrient Combination	(9.41)

APP. 3.4 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON MAIZE DRY MATTER OF TOPS 4WAP.

Nutrient Addition	Temperature of Heating (C) '0'	100	200	600	Nutrient Combination Means
	gm/pot				
No Fertilizer	0.72	0.79	0.37	0.42	0.58
NPKCaMgZnS	1.93	1.44	0.87	1.48	1.43
-N	1.69	1.52	0.87	0.70	1.20
-P	0.61	0.91	0.62	1.17	0.83
-K	1.76	1.80	0.55	1.31	1.36
-Ca	1.85	1.37	0.78	1.53	1.38
-Mg	1.79	1.38	1.18	1.40	1.44
-Zn	2.17	1.75	1.02	1.50	1.61
-S	2.13	2.30	1.01	1.26	1.68
Temperature Means	1.63	1.47	0.81	1.20	1.28

Lsd (0.05) (i) Between Temperature means (0.31)

(ii) Between Nutrient Combination means (0.24)

(iii) Between Nutrient Combinations at one Temperature level (0.48)

(iv) Between Temperature levels at one Nutrient Combination (0.55)

APP. 3.5 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON NITROGEN COMPOSITION OF MAIZE TOPS.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Means
			% N		
Control	2.44	2.53	5.32	1.10	2.85
NPKCaMgZnS	2.60	3.27	5.32	1.43	3.16
-N	1.45	1.80	4.68	0.83	2.19
-P	3.51	3.27	4.69	1.06	3.13
-K	2.90	3.09	5.85	1.48	3.33
-Ca	2.67	3.40	4.91	1.50	3.12
-Mg	2.54	3.22	4.66	1.63	3.01
-Zn	2.42	3.26	4.51	1.48	2.92
-S	2.38	2.55	4.46	1.80	2.80
Means	2.55	2.93	4.93	1.37	2.95

Lsd (0.05)
(i) Between Temperature means (0.26)
(ii) Between Nutrient Combination means (0.19)
(iii) Between Nutrient Combinations at one Temperature level (0.76)
(iv) Between Temperature levels at one Nutrient Combination (0.96)

APP. 3.6 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON TOTAL N UPTAKE BY MAIZE TOPS.

Nutrient Addition	Temperature of Heating (C) '0'	100	200	600	Means
		mg N/pot			
Control	17.6	20.0	19.7	4.6	15.5
NPKCaMgZnS	50.2	47.1	46.3	21.2	41.2
-N	24.5	27.4	40.7	5.8	24.6
-P	21.4	29.8	29.1	12.4	23.2
-K	51.0	55.6	32.2	19.4	39.6
-Ca	49.4	46.6	38.3	23.0	39.3
-Mg	45.5	44.4	55.0	22.8	41.9
-Zn	52.5	57.1	46.0	22.2	44.5
-S	50.7	58.7	45.1	22.7	44.3
Means	41.6	43.1	40.0	16.4	35.3

Lsd (0.05)
(i) Between Temperature means (8.9)
(ii) Between Nutrient Combination means (9.3)
(iii) Between Nutrient Combination at one Temperature level (18.6)
(iv) Between Temperature levels at one Nutrient Combination (19.6)

APP. 3.7 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON P COMPOSITION OF MAIZE TOPS.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Means
	% P				
Control	0.08	0.11	0.15	0.15	0.12
NPKCaMgZnS	0.12	0.10	0.17	0.05	0.11
-N	0.24	0.17	0.15	0.12	0.17
-P	0.10	0.09	0.13	0.13	0.09
-K	0.18	0.19	0.25	0.06	0.17
-Ca	0.19	0.16	0.15	0.05	0.14
-Mg	0.12	0.13	0.16	0.05	0.12
-Zn	0.14	0.13	0.16	0.05	0.12
-Z	0.11	0.12	0.13	0.06	0.11
Means	0.14	0.13	0.16	0.07	0.13

Lsd (0.05)	(i)	Between Temperature means	(0.02)
	(ii)	Between Nutrient Combination means	(0.02)
	(iii)	Between Nutrient Combination at one Temperature level	(0.04)
	(iv)	Between Temperature levels at one Nutrient Combination	(0.05)

APP. 3.8 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON TOTAL P UPTAKE IN MAIZE 4WAP.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Nutrient Addition Means
	mg P/pot				
No Fertilizer	0.58	0.85	0.56	0.64	0.66
NPKCaMgZnS	2.40	1.41	1.45	0.74	1.50
-N	4.05	2.61	1.32	0.83	2.20
-P	0.61	0.79	0.83	0.63	0.72
-K	3.17	3.30	1.37	0.79	2.16
-Ca	3.43	2.26	1.14	0.71	1.89
-Mg	2.08	1.75	1.97	0.79	1.65
-Zn	3.03	2.35	1.58	0.75	1.93
Temperature Means	2.42	2.01	1.29	0.74	1.62

Lsd (0.05)

(i) Between Temperature means (0.55)

(ii) Between Nutrient Combination means (0.49)

(iii) Between Nutrient Combinations at one Temperature level (0.98)

(iv) Between Temperature levels at one Nutrient Combination (1.07)

APP. 3.9 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON K COMPOSITION OF MAIZE TOPS 4WAP.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Means
		% K			
Control	2.40	2.06	1.49	1.35	1.83
NPKCaMgZnS	2.70	3.32	3.35	2.50	2.97
-N	3.55	3.64	3.09	2.98	3.32
-P	5.25	3.75	3.93	2.49	3.86
-K	1.22	1.15	2.02	0.79	1.30
-Ca	2.61	2.83	3.98	2.11	2.88
-Mg	2.75	3.04	3.63	2.28	2.93
-Zn	2.60	2.85	3.21	2.36	2.76
-S	2.75	2.55	3.43	2.70	2.87
Means	2.87	2.80	3.13	2.17	2.75

Lsd (0.05) (i) Between Temperature means (0.32)

(ii) Between Nutrient Combination means (0.26)

(iii) Between Nutrient Combinations at one Temperature level (0.52)

(iv) Between Temperature levels at one Nutrient Combination (0.50)

APP. 3.10 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON TOTAL K UPTAKE IN MAIZE 4WAP.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Nutrient Addition Means
		mg K/pot			
No Fertilizer	16.90	16.33	5.51	5.53	11.07
NPKCaMgZnS	51.53	45.60	27.68	36.96	40.44
-N	60.03	55.63	27.53	20.57	40.94
-P	31.88	34.00	24.48	29.28	29.91
-K	21.07	20.53	10.95	10.31	15.72
-Ca	48.17	38.77	31.11	32.37	37.61
-Mg	49.10	41.90	41.45	31.33	40.95
-Zn	55.80	49.93	33.21	35.47	43.60
-S	58.10	57.20	34.56	33.91	45.94
Temperature Means	43.62	38.88	26.16	26.19	33.71

Lsd (0.05)

(i) Between Temperature means (6.30)

(ii) Between Nutrient Combination means (6.06)

(iii) Between Nutrient Combinations at one Temperature level (12.00)

(iv) Between Temperature levels at one Nutrient Combination (13.00)

APP. 3.11 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON Ca COMPOSITION OF MAIZE TOPS 4WAP.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Means
	% Ca				
Control	0.40	0.49	0.19	0.53	0.40
NPKCaMgZnS	0.24	0.28	0.20	0.40	0.28
-N	0.19	0.23	0.16	0.26	0.21
-P	0.48	0.37	0.35	0.35	0.39
-K	0.25	0.28	0.25	0.41	0.30
-Ca	0.20	0.23	0.19	0.36	0.25
-Mg	0.23	0.25	0.13	0.43	0.26
-Zn	0.20	0.22	0.16	0.36	0.24
-S	0.22	0.20	0.17	0.41	0.25
Means	0.27	0.28	0.20	0.39	0.29

Lsd (0.05) (i) Between Temperature means (0.06)

(ii) Between Nutrient Combination means (0.07)

(iii) Between Nutrient Combinations at one Temperature level (0.14)

APP. 3.12 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON TOTAL Ca UPTAKE IN MAIZE 4WAP.

Nutrient Addition	'0'	100	200	600	Nutrient Addition Means
		mg Ca/pot			
No Fertilizer	2.76	3.85	0.68	1.97	2.32
NPKCaMgZnS	4.61	3.81	1.73	5.88	4.01
-N	3.21	3.10	1.47	1.81	2.40
-P	2.94	3.24	2.16	4.13	3.12
-K	4.50	5.05	1.30	5.44	4.07
-Ca	3.65	3.04	1.50	5.54	3.43
-Mg	4.09	3.46	1.42	5.95	3.73
-Zn	4.43	3.84	1.68	5.47	3.86
-S	4.64	4.65	1.78	5.24	4.08
Temperature Means	3.87	3.78	1.52	4.60	3.44

Lsd (0.05)	(i)	Between Temperature means	(1.04)
	(ii)	Between Nutrient Combination means	(0.95)
	(iii)	Between Nutrient Combinations at one Temperature level	(1.90)
	(iv)	Between Temperature levels at one Nutrient Combination	(2.06)

APP. 3.13 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON Mg CONTENT OF MAIZE TOPS 4WAP.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Means
		% Mg			
Control	0.30	0.35	0.28	0.66	0.40
NPKCaMgZnS	0.20	0.24	0.19	0.47	0.28
-N	0.19	0.20	0.15	0.38	0.23
-P	0.38	0.33	0.28	0.41	0.35
-K	0.24	0.21	0.22	0.63	0.33
-Ca	0.16	0.18	0.22	0.48	0.26
-Mg	0.15	0.14	0.13	0.44	0.22
-Zn	0.16	0.17	0.19	0.43	0.24
-S	0.18	0.15	0.19	0.46	0.25
Temperature Means	0.23	0.22	0.21	0.48	0.29

Lsd (0.05) (i) Between Temperature means (0.5)

(ii) Between Nutrient Combination means (0.4)

(iii) Between Nutrient Combinations at one Temperature level (0.9)

(iv) Between Temperature levels at one Nutrient Combination (0.10)

APP. 3.14 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON TOTAL Mg UPTAKE IN MAIZE 4WAP.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Nutrient Addition Means
		mg Mg/pot			
No Fertilizer	2.09	2.75	1.00	2.79	2.16
NPKCaMgZnS	3.84	3.24	1.68	6.97	3.93
-N	3.23	3.09	1.45	2.62	2.60
-P	2.34	2.88	1.76	4.74	2.93
-K	4.26	3.72	1.16	8.29	4.36
-Ca	3.00	2.36	1.68	7.38	3.61
-Mg	2.64	1.98	1.41	6.15	3.05
-Zn	3.45	3.06	1.92	6.45	3.72
-S	3.79	3.50	1.70	5.85	3.71
Temperature Means	3.18	2.95	1.53	5.69	3.34

Lsd (0.05)

(i) Between Temperature means (0.88)

(ii) Between Nutrient Combination means (0.62)

(iii) Between Nutrient Combinations at one Temperature level (1.23)

(iv) Between Temperature levels at one Nutrient Combination (1.45)

APP. 3.15 THE EFFECT OF SOIL PREHEATING AND NUTRIENT ADDITION ON THE Zn COMPOSITION OF MAIZE TOPS.

Nutrient Addition	Temperature of Preheating (C) '0'	100	200	600	Means
			ppm Zn		
No Fertilizer	31	41	-	27	27
NPKCaMgZnS	55	74	65	27	55
-N	72	54	55	21	51
-P	152	118	87	24	96
-K	54	56	58	23	48
-Ca	63	49	100	35	62
-Mg	81	53	56	25	54
-Zn	20	21	30	12	21
-S	63	51	65	36	54
Temperature Means	66	57	58	26	52

Lsd (0.05)

(i) Between Temperature means (15)

(ii) Between Nutrient Combination means (15)

(iii) Between Nutrient Combinations at one Temperature level (30)

(iv) Between Temperature levels at one Nutrient Combination (32)

APP. 4.1 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON TOTAL NUTRIENT UPTAKE IN MAIZE EARLEAF AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		mg/leaf					µg/leaf	
Mulch	Control	93	8	64	18	20	96	201
	PK	96	15	77	20	21	77	211
	NK	96	8	71	20	22	108	259
	NP	118	16	63	31	36	109	373
	NPK	117	16	86	28	31	98	344
	NPKMgZn	123	15	75	28	31	108	356
	Means	107	13	73	24	27	99	291
Burn	Control	77	9	61	18	18	77	182
	PK	93	13	81	21	21	79	207
	NK	98	11	74	20	21	90	285
	NP	103	13	58	26	30	89	345
	NPK	118	15	76	30	32	96	336
	NPKMgZn	127	15	83	28	30	101	299
	Means	103	13	72	24	25	89	276
	Lsd (0.05) (i)	25	3	24	3	3	13	75
	(ii)	15	1	13	4	4	10	54
	(iii)	21	2	18	5	6	15	77
	(iv)	31	4	28	5	6	18	100

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

APP. 4.2 THE EFFECT OF FERTILIZER APPLICATION ON THE NUTRIENT UPTAKE IN MAIZE EARLEAVES.

Fertilizer Treatment	Nutrient Uptake						
	N	P	K	Ca	Mg	Zn	Mn
	mg/leaf					µg/leaf	
Control	85	9	63	18	19	87	192
PK	95	14	79	21	21	78	209
NK	97	10	73	20	22	99	272
NP	111	15	61	29	33	99	359
NPK	118	16	81	29	32	97	340
NPKMgZn	125	15	79	28	31	105	328
Lsd (0.05)	15	1	13	4	4	10	54

APP. 4.3 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE STOVER YIELDS IN IKENNE.

Nutrient Combinations	Residue Management Mulching	Burning	Nutrient Combination Means
	kg/ha		
Control	4347	2969	3658
NPK	7145	5095	6120
NK	4552	5543	5048
NP	4776	4616	4696
NPK	6037	5470	5754
NPKMgZn	6190	5648	5919
Residue Management Means	5508	4890	5199

Lsd (0.05) (i) Between Main treatment means (1007)

(ii) Between Fertilizer means (1305)

(iii) Between Fertilizer treatments under one Main treatment (1845)

(iv) Between Main treatments at the same Fertilizer treatment (1935)

APP. 4.4 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE STOVER NUTRIENT COMPOSITION AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
				%			ppm	
Mulch	Control	0.72	0.06	0.98	0.68	0.39	341	75
	PK	0.66	0.12	1.06	0.61	0.33	313	66
	NK	0.81	0.06	1.17	0.53	0.39	339	80
	NP	0.89	0.09	0.82	0.79	0.47	337	90
	NPK	0.80	0.09	1.08	0.68	0.46	331	82
	NPKMgZn	0.86	0.09	1.06	0.65	0.39	328	65
	Means	0.79	0.09	1.03	0.66	0.41	332	76
Burn	Control	0.73	0.08	1.13	0.70	0.37	361	77
	PK	0.71	0.09	1.03	0.48	0.38	346	64
	NK	0.80	0.06	1.29	0.61	0.33	305	89
	NP	0.83	0.12	1.20	0.74	0.39	349	146
	NPK	0.93	0.10	1.20	0.90	0.47	352	101
	NPKMgZn	0.92	0.09	1.06	0.84	0.40	323	64
	Means	0.82	0.09	1.15	0.71	0.39	339	90

APP. 4.5 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE STOVER NUTRIENT CONTRIBUTION AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combinations	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)	Zn (gm/ha)	Mn (gm/ha)
Mulch	Control	31	3	43	30	17	1.48	326
	PK	47	9	76	44	24	2.24	472
	NK	37	3	53	24	18	1.54	364
	NP	43	4	39	38	23	1.61	430
	NPK	48	5	65	41	28	2.00	495
	NPKMgZn	53	6	66	40	24	2.03	402
	Means	43	5	57	36	22	1.80	415
Burn	Control	22	2	34	21	11	1.07	229
	PK	36	5	53	25	19	1.76	326
	NK	44	3	72	34	18	1.69	493
	NP	38	6	55	34	18	1.61	674
	NPK	51	6	66	49	26	1.93	553
	NPKMgZn	52	6	66	49	26	1.93	553
	Means	41	5	57	35	19	1.70	440

APP. 4.6 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON NUTRIENT COMPOSITION OF COWPEA (CV TVx 1173 - 7D) GRAIN.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Mn	Zn
		%					ppm	
Mulch	Control	3.91	0.30	1.19	0.02	0.22	26	48
	PK	3.78	0.38	1.17	"	0.23	23	44
	NK	3.87	0.30	1.19	"	0.21	26	47
	NP	3.67	0.36	1.13	"	0.22	30	45
	NPK	3.77	0.38	1.16	"	0.23	19	46
	NPKMgZn	3.87	0.36	1.16	"	0.21	23	46
	Means	3.81	0.35	1.17	0.02	0.22	24	46
Burn	Control	3.83	0.34	1.13	0.02	0.22	26	46
	PK	3.93	0.43	1.19	"	0.23	23	43
	NK	3.94	0.34	1.19	0.03	0.23	23	45
	NP	3.83	0.44	1.13	0.02	0.22	23	44
	NPK	4.12	0.43	1.16	0.02	0.22	34	42
	NPKMgZn	3.94	0.40	1.15	0.02	0.22	23	46
	Means	3.93	0.40	1.16	0.02	0.22	25	44

APP. 4.7 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE 100 GRAIN-WT OF COWPEA (CV TVx 1193-7D) AT IKENNE.

Nutrient Combinations	Residue Management Mulching (gm/100 grains)	Residue Management Burning (gm/100 grains)	Nutrient Combination Means
Control	14.9	15.6	15.3
PK	14.9	14.4	14.7
NK	14.4	14.2	14.3
NP	14.7	15.4	15.1
NPK	15.7	15.2	15.5
NPKMgZn	14.4	15.3	14.9
Residue Management Means	14.8	15.0	14.9

Lsd (0.05)	(i)	Between Main treatment means	(1.6)
	(ii)	Between Fertilizer means	(0.8)
	(iii)	Between Fertilizer treatments under one Main treatment	(1.2)
	(iv)	Between Main treatments at the same Fertilizer treatment	(1.8)

APP. 4.8 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE TOTAL MINERAL CONTENT OF MAIZE (CV TZB) EARLEAF AT SILKING.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		mg/leaf					μg/leaf	
Mulch	Control	112	6	60	50	14	218	1010
	PK	122	8	78	47	12	187	1052
	NK	105	6	70	50	13	201	1027
	NP	135	9	88	53	13	212	1219
	NPK	157	10	115	62	18	237	1369
	NPKMgZn	129	8	94	52	12	227	1205
	Means	127	8	84	52	14	214	1147
Burn	Control	87	7	58	50	15	201	1013
	PK	123	10	100	56	14	205	1266
	NK	127	7	71	52	13	197	1115
	NP	129	9	94	54	12	223	1291
	NPK	140	9	101	56	13	198	1136
	NPKMgZn	143	11	109	58	15	221	1271
	Means	125	9	89	54	14	208	1182
	Lsd (0.05) (i)	2	1	13	4	2	15	105
	(ii)	22	1	13	7	2	24	176
	(iii)	32	2	18	9	3	33	248
	(iv)	29	2	21	9	4	33	247

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

APP. 4.9 THE EFFECT OF FERTILIZER APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE TOTAL MINERAL UPTAKE IN MAIZE GRAIN AT IKENNE.

Treatment: Residue Management	Treatment: Nutrient Combinations		N	P	K	Ca	Mg	Zn
			kg/ha					gm/ha
Mulch	Control		47	7	15	0.29	4	77
	PK		62	10	22	0.45	6	98
	NK		57	7	18	0.35	5	90
	NP		74	10	25	0.52	7	122
	NPK		73	12	28	0.49	7	125
	NPKMgZn		72	10	24	0.52	7	125
	Means		64	9	22	0.44	6	106
Burn	Control		45	10	14	0.45	4	78
	PK		69	11	25	0.53	7	105
	NK		58	8	20	0.53	6	98
	NP		79	15	32	0.50	9	140
	NPK		65	12	24	0.58	7	116
	NPKMgZn		75	12	27	0.59	8	131
	Means		65	11	24	0.53	7	111
	Lsd (0.05)	(i)	11	2	5	0.05	2	23
		(ii)	8	1	4	0.09	1	15
		(iii)	12	2	5	0.13	1	21
		(iv)	15	3	7	0.12	2	29

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

APP. 4.10 TOTAL GRAIN YIELDS OF TWO MAIZE CROPS AT IKENNE.

Nutrient Combinations	Residue Management Mulching (kg/ha)	Residue Management Burning (kg/ha)	Nutrient Combination Means
Control (no fertilizer)	7092	6381	6737
PK	9167	9216	9192
NK	7955	8197	8076
NP	9571	9246	9409
NPK	9781	9723	9752
NPKMgZn	10,154	10,333	10,244
Residue Management Means	8953	8849	8901

APP. 5.1 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON TOTAL NUTRIENT UPTAKE IN MAIZE EARLEAF AF ONNE.

Residue Management	Treatment Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		mg/leaf					µg/leaf	
Mulch	Control	65	16	72	5	9	52	429
	NPK	105	23	105	12	10	89	963
	NPKMgZn	98	20	86	10	12	99	651
	NPKMgZn + Lime	129	21	101	21	17	142	551
	Means	99	20	91	12	12	96	649
Burn	Control	60	10	57	5	8	42	286
	NPK	105	21	80	16	15	77	562
	NPKMgZn	114	18	74	16	16	110	552
	NPKMgZn + Lime	126	20	102	24	19	113	433
	Means	101	17	78	15	14	85	458
	Lsd (0.05) (i)	10	nd	nd	1	3	17	132
	(ii)	33	"	"	6	5	33	242
	(iii)	47	"	"	8	8	46	342
	(iv)	42			7	7	43	322

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

APP. 5.2 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON THE NUTRIENT CONCENTRATION AND UPTAKE IN THE GRAIN.

Fertilizer Application	Nutrient Contents					
	N	P	K	Ca	Mg	Zn
			%			ppm
Control	1.69	0.43	0.59	0.18	0.17	37
NPK	1.69	0.36	0.45	0.16	0.13	28
NPKMgZn	1.62	0.39	0.50	0.15	0.15	32
NPKMgZn + Lime	1.63	0.44	0.59	0.16	0.17	38
Lsd (0.05)	0.13	nd	nd	0.09	nd	nd

APP. 5.3 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE MAIZE STOVER NUTRIENT COMPOSITION AT ONNE.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		%					ppm	
Mulch	Control	0.78	0.29	1.55	0.40	0.21	285	277
	NPK	0.82	0.28	1.69	0.51	0.15	242	174
	NPKMgZn	0.85	0.29	1.66	0.53	0.22	241	213
	NPKMgZn + Lime	0.73	0.25	1.72	0.58	0.19	280	182
	Means	0.80	0.28	1.66	0.51	0.19	262	199
Burn	Control	0.61	0.19	1.41	0.30	0.18	257	125
	NPK	0.63	0.19	1.13	0.44	0.26	282	148
	NPKMgZn	0.67	0.18	1.24	0.54	0.21	223	189
	NPKMgZn + Lime	0.77	0.21	1.24	0.54	0.23	247	111
	Means	0.67	0.19	1.26	0.46	0.22	252	143

APP. 5.4 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE STOVER NUTRIENT CONTRIBUTION AT ONNE.

Treatment: Residue Management	Treatment: Nutrient Combinations	N	P	K	Ca	Mg	Zn	Mn
		kg/ha					gm/ha	
Mulch	Control	12	4	24	6	3	445	345
	NPK	22	8	46	14	4	654	486
	NPKMgZn	23	8	44	14	6	649	549
	NPKMgZn + Lime	22	8	53	18	6	880	530
	Means	20	7	42	13	5	657	478
Burn	Control	7	2	16	3	2	294	141
	NPK	15	5	27	10	6	661	344
	NPKMgZn	17	5	31	13	5	567	477
	NPKMgZn + Lime	21	6	35	14	6	687	313
	Means	15	4	28	10	5	552	319

APP. 5.5 THE EFFECT OF FERTILIZER AND LIME APPLICATION ON NUTRIENT CONTENT IN COWPEA INDEX LEAF AND GRAIN.

a) Fertilizer Application	Nutrient Content						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	5.05	0.43	2.02	1.24	0.45	45	668
NPK	5.30	0.45	2.01	1.72	0.40	43	657
NPKMgZn	5.30	0.42	1.84	1.70	0.41	55	636
NPKMgZn + Lime	5.30	0.43	1.94	2.24	0.40	51	402
Lsd (0.05)	0.47	0.04	0.36	0.64	0.06	8	152

b) Fertilizer Application	Nutrient Content (grain)						
	N	P	K	Ca	Mg	Zn	Mn
			%			ppm	
Control	3.71	0.50	2.36	0.02	0.24	44	78
NPK	3.84	0.48	2.47	0.02	0.24	41	74
NPKMgZn	3.69	0.47	2.30	0.02	0.23	49	70
NPKMgZn + Lime	3.74	0.47	2.31	0.02	0.22	44	59
Lsd (0.05)	0.30	0.02	0.11	nd	0.02	3	11

APP. 5.6 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON THE TOTAL NUTRIENT CONTENT OF MAIZE EARLEAF AT ONNE.

Treatment: Residue Management	Treatment: Nutrient Addition	N	P	K	Ca	Mg	Zn	Mn
		mg/plant					µg/plant	
Mulch	Control	61	15	67	36	8	133	1192
	NPK	117	22	98	51	7	187	1406
	NPKMgZn	118	20	93	51	9	228	1451
	NPKMgZn + Lime	121	20	101	55	8	213	1291
	Means	104	19	90	48	8	190	1335
Burn	Control	57	12	72	29	5	102	772
	NPK	103	18	95	44	6	144	1184
	NPKMgZn	119	19	95	55	8	251	1375
	NPKMgZn + Lime	122	17	109	55	8	228	1284
	Means	100	17	93	46	7	181	1154
	Lsd (0.05) (i)	18	1	20	10	2	45	244
	(ii)	15	4	18	7	1	41	145
	(iii)	21	5	26	10	2	57	205
	(iv)	25	4	29	13	3	66	296

(i) Between Main treatment means

(ii) Between Fertilizer means

(iii) Between Fertilizer treatments under one Main treatment

(iv) Between Main treatments at the same Fertilizer treatment

APP. 5.7 THE EFFECT OF FERTILIZER/LIME APPLICATION AND FALLOW RESIDUE MANAGEMENT ON MAIZE (CV TZB) STOVER YIELDS ON AN ULTISOL.

Nutrient Combination	Residue Management Mulching	Burning	Nutrient Combination Means
	kg/ha		
Control	1170	1211	1191
NPK	1747	1977	1862
NPKMgZn	1923	1950	1937
NPKMgZn + Lime	1983	2066	2025
Residue Management Means	1706	1801	1754

Lsd (0.05)	(i)	Between Main treatment means	(153)
	(ii)	Between Fertilizer means	(304)
	(iii)	Between Fertilizer treatments under one Main treatment	(430)
	(iv)	Between Main treatments at the same Fertilizer treatment	(399)