Effect of ammonium sulphate fertilization on soil chemical composition, fruit yield and nutrient content of Okra

E. A. ADUAYI,
Soil Science Department,
University of Ife,
Ile Ife, Nigeria.

Abstract

The effects of continuous nitrogen fertilization $(NH_4)_2SO_4$ on changes in soil chemical composition and on the yield and nutrient content of Okra *(Hibiscus esculentus L.)* leaves were studied in the field. Ammonium sulphate when applied as N fertilizer source, drastically decreased soil pH and yield. Soil OM (organic matter), K and Ca decreased, NO_3-N and P increased with continuous cropping as compared to soil values prior to cultivation. Leaf nutrient concentration at various stages of the plant growth was affected by nitrogen fertilization. Soil organic matter was positively correlated with leaf K, Ca and Mg (r = 0.72, 0.67o** 0.72** respectively), whereas soil pH correlated positively with leaf NO_3-N and P (r=0.67**, 0.91*** respectively). A positively significant correlation was established between okra yield and leaf Mg when sampled at the vegetative (r = 0.59*) and at the flowering (r = 0.72**) stages of growth, and with leaf P (r = 0.92***) at the fruiting stage of growth. It is suggested that $(NH_4)_2SO_4$ fertilizer if applied to an acid soil, should be combined with a liming material to increase soil pH so as to obtain a more favourable growth and yield of the okra plant.**

Introduction

The okra is fast becoming an important vegetable crop in the tropics, particularly in all the states of Nigeria. It is frequently included in the daily dietary formulation. When cooked fresh, the okra pod contains approximately 86.1% water, 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1.0% fibre and 0.8% ash (11). It is also known to contain a fair amount of vitamin A and to be rich in minerals. The okra is, therefore nutritively valuable. Thus far, however, it is only cultivated largely by peasant farmers for local consumption.

In Nigeria, the okra thrives naturally in the low–land rainforest soils high in moisture and temperature. In areas where peasant farmers are engaged almost solely in the production of this crop, extension agents often recommend the use of nitrogen fertilizers, because it is supposed to be the single element that most limits yield due to its heavy loss through leaching in the torrential rainfall prevalent in the area. The nitrogen fertilizer source available for use until recently had been ammonium sulphate. When applied particularly to slightly acid soils, the result in okra yield has often been discouraging Ahmed and Tulloch–Reid, (1969) working with okra in Trinidad observed that the application of $(NH_4)_2SO_4$ greater than112kg/ha reduced yield in the absence of liming. As if and Greig (1972), and Singh and Singh (1965), found that an increase in nitrogen fertilization greater than 136 kg/ha as $(NH_4)_2SO_4$ produced some decline in the yield of okra. The reasons for this effect were attributed to the acid forming characteristics of ammonium sulphate (Obi, 1976). It is also possible that the applied N, usually in the luxury amount, would lead to an imbalance of other nutrients in the soil, which subsequently would affect plant uptake and accumulation of nutrients in the leaves. The concentration of nutrients in the functioning leves up to the time of sampling represents an integration of all factors that affect plant nutrition. Hence, the leaf content of nutrient elements as a result of nitrogen fertilization would give a fair assessment o the nutritional potential of the okra plant.

The study reported here is aimed at evaluating the effects of the application of $(NH_4)_2SO_4$ as N–fertilizer on the soil chemical composition. It is also aimed at estimating the level of the concentration of macronutrients in the leaves of okra plants at various stages of growth, as affected by N fertilization, and relating those two factors to fruit yield.

Materials and Methods

A field study was conducted to determine the influence of nitrogen fertilization on the macronutrient composition of the soil and the nutrient content of okra (*Hibiscus esculentus* L. cv. 'dwarf') leaves and fruits. The experiment was sited on a soil that had been in fallow for over ten years and belonged to the broad group of Ferruginous Tropical Soils (FAO, 1975). The soil is referred to locally as 'Iwo' soil series (*Oxic Tropudalf*) and is moderately to strongly leached. It is of low to medium humus content with weakly to strongly acid subsoil (Agboola and Fayemi, 1977). It is generally well drained and deep and derived from granitic rocks and gneisses (Smyth and Montgomery, 1962). Average annual precipitation is above 1500mm.

The experimental layout was a rendomised complete block design with 5 replications. There were 5 nitrogen treatments of 0, 20, 40, 80 and 160 kg N/ha applied in the form of sulphate of ammonia. Basal application of P as single superphosphate and K as Muriate of potash each at 100 kg/ha was made prior to treatment and ploughed in.

To maintain efficient utilization of the applied N fertilizer by the okra plant and at the same time reduce excessive loss through leaching caused by terrential rainfall prevalent in the area, the N treatments were applied in splits. Thus, the 20 kg N/ha treatment was applied once, the 40 to 80 kg N/ha treatments were applied in two splits and the 160 kg N/ha treatment was applied in three splits and timed to coincide with early vegetative, flowering and fruiting stages of growth. The N treatments were placed by hand at about 8cm from the base of the plants, using calibrated containers to ensure uniform distribution.

The okra seeds were planted by hand and thinned to a single plant at a spacing of 1 by 1 meter. Block size was 20 by 4 meters. Cultural practices during growth of the crop were typical for the area. The duration of the experiment was from March to July 1975 and repeated for the same duration in 1976 and 1977. The data presented here represent the mean of three years.

Sampling and Chemical determinations

Soil

Soil samples were taken from the fallowed site before clearing and at the end of each season of growth of the okra plant, for three seasons (3 years). All soil samples were taken at 0 to 20 cm depth as a composite of about 40 to 50 cores. The samples were air dried, ground to pass a 2mm sieve for chemical analysis.

Soil pH was measured potention metrically in a 1:2.5 soil : 0.0 1M CaC12 solution ratio. Organic matter was measured by chromic acid digestion method. NO_3–N by phenol disulphonic acid, P by Bray –1, K and Ca by neutral ammonium acetate extraction and read in a flame photometer.

Leaf

The first lead samples were taken from fully expanded nearly mature leaves (laminae plus petioles) from about the middle of the plant during the vegetative stage of growth which was about 4 weeks (April) after germination, the second sampling was at flowering (May) and the third sampling was made at the fruiting stage of growth (late May/June). In all cases, leaf samples were taken about a week after fertilizer application. Okra fruits were harvested fresh twice weekly starting from mid–June to the first week in August.

Leaf samples were washed in distilled deionized water following standard procedures aimed at eliminating micronutrient contamination, and then dried in an over at 65 to 70°C and ground in a Willey microhammer stainless steel mill. The ground sample were redried at 105°C before chemical analysis. Fresh fruits were weighed soon after each harvest and dried similar to the procedure described for the leaf samples.

Analysis for NO_3–N was done colorimetrically using the phenoldisulfonic acid method, P by the nitricperohloric acid wet digestion method of Lott et al. (1956), K and Ca by flame photometry and Mg by the thiazole yellow colorimetric method.

Results

Examination of the foliage o the okra plants after three years of continuous nitrogen fertilization failed to reveal the usual N deficiency symptoms in the minus–N fertilizer plots.

Soil Chemical Composition.

Figure 1 shows the effect of increasing rate of N fertilizer of soil pH and organic matter.

The soil pH and organic matter content prior to treatment were about 6.0 and 2.4% respectively. However, the addition of the N fertilizer produced a marked decrease in pH in the 40 to 160 kg N/ha treatments. Soil organic matter decreased with increasing N fertilization, up to 40 kg/ha and thereafter increased at the 80 and 160 kg N/ha plots.

The addition of N fertilizer increased soil NO_3-N (Figure 2). The uncultivated field was relatively low in NO_3-N Nitrogen fertilizer application increased soil P particularly at the 80 and 160 kg N/ha treatments but decreased it at the lower levels of N application.

As shown in Table 1, soil K and Ca were depressed at all levels of N fertilizer treatments relative to the uncultivated soil which contained apparently high levels of K and Ca. Compared to the minus – N plots, continuous fertilization with N produced significant increases in soil K with the highest K level being obtained at the 40 kg N/ha application. The effect of N on soil Ca was inconsistent. The highest soil Ca was obtained at the 20 kg N/ha treatment followed by a decrease at the 80 kg N/ha and an increase at the 160 kg N/ha treatment.

Leaf Nutrient Composition at Various Stages of Plant Growth

Figure 3 shows the concentration of NO_3-N in the leaves at the vegetative, flowering and fruiting stages of growth.

Nitrogen fertilization resulted in a marked increase in leaf NO_3-N at the vegetative stage with the increase being more marked at N treatment above 40 kg/ha. In contrast, the okra leaf accumulated relatively lower NO_3-N at the flowering and fruiting stages of growth. Leaf P at flowering was highest relative to the fruiting and vegetative stages of growth (Figure 4). Nitrogen application had no consistent effect on leaf P.

Figure 5 indicates that the accumulation of K in the leaves decreased at the vegetative and flowering stages of growth in the absence of N fertilization and increased at the 20 and 160 kg N/ha treatment only at the vegetative stage. At fruiting, the increase in N fertilization depressed leaf K with the unfertilized plot establishing the highest level. Leaf Ca was generally higher in the unfertilized treatment and declined with increase in N fertilization. The highest leaf Ca was obtained at the fruiting stage with the lowest being obtained at the vegetative stage of plant growth.

As shown in Figure 6, N at 20 kg/ha induced increased leaf Mg followed by a marked decrease in the vegetative and flowering stages as N fertilizer increased. At fruiting, leaf Mg was relatively high in the unfertilized plots and declined as N rates were increased from 20 to 40 kg/ha. The highest leaf Mg was obtained at the flowering stage when N was applied at 20 kg/ha.

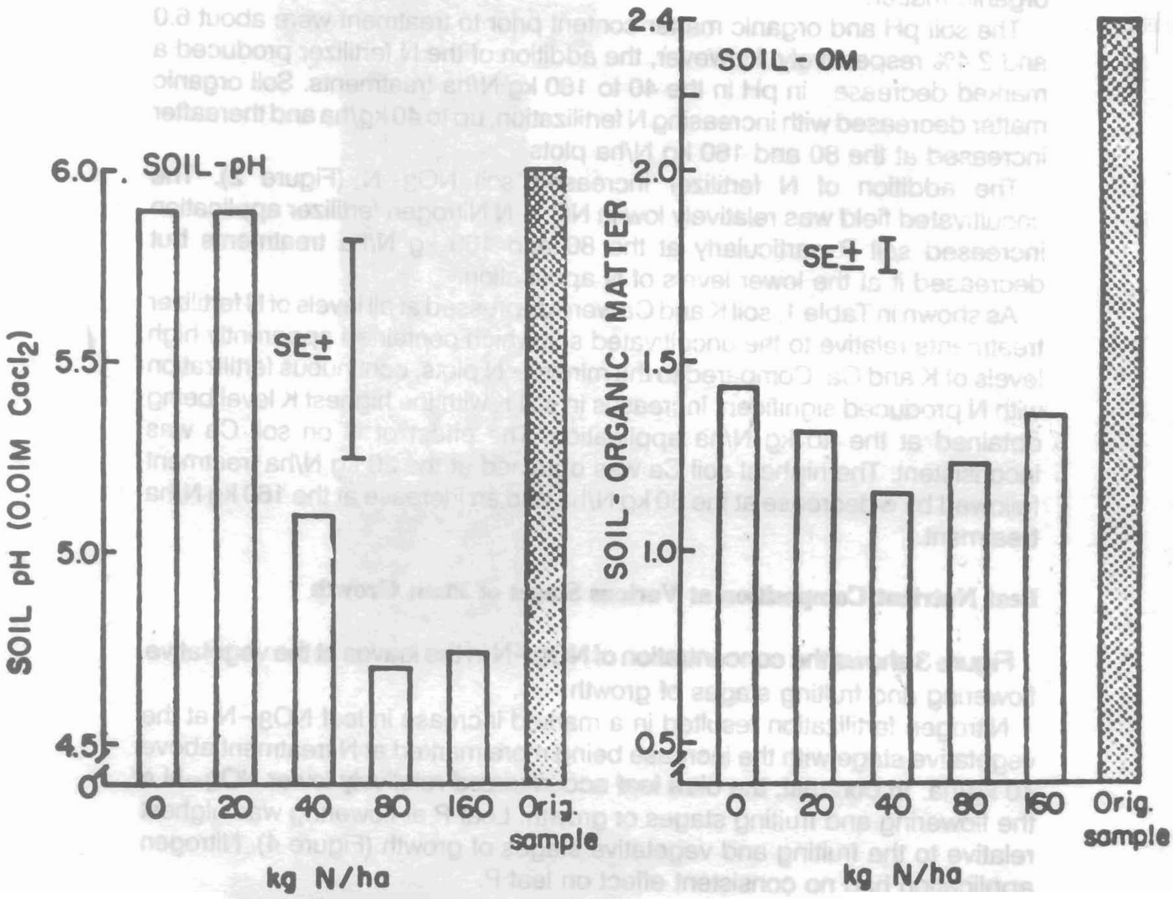

Figure 1. Effect of nitrogen fertilization on changes in soil-pH and -OM.

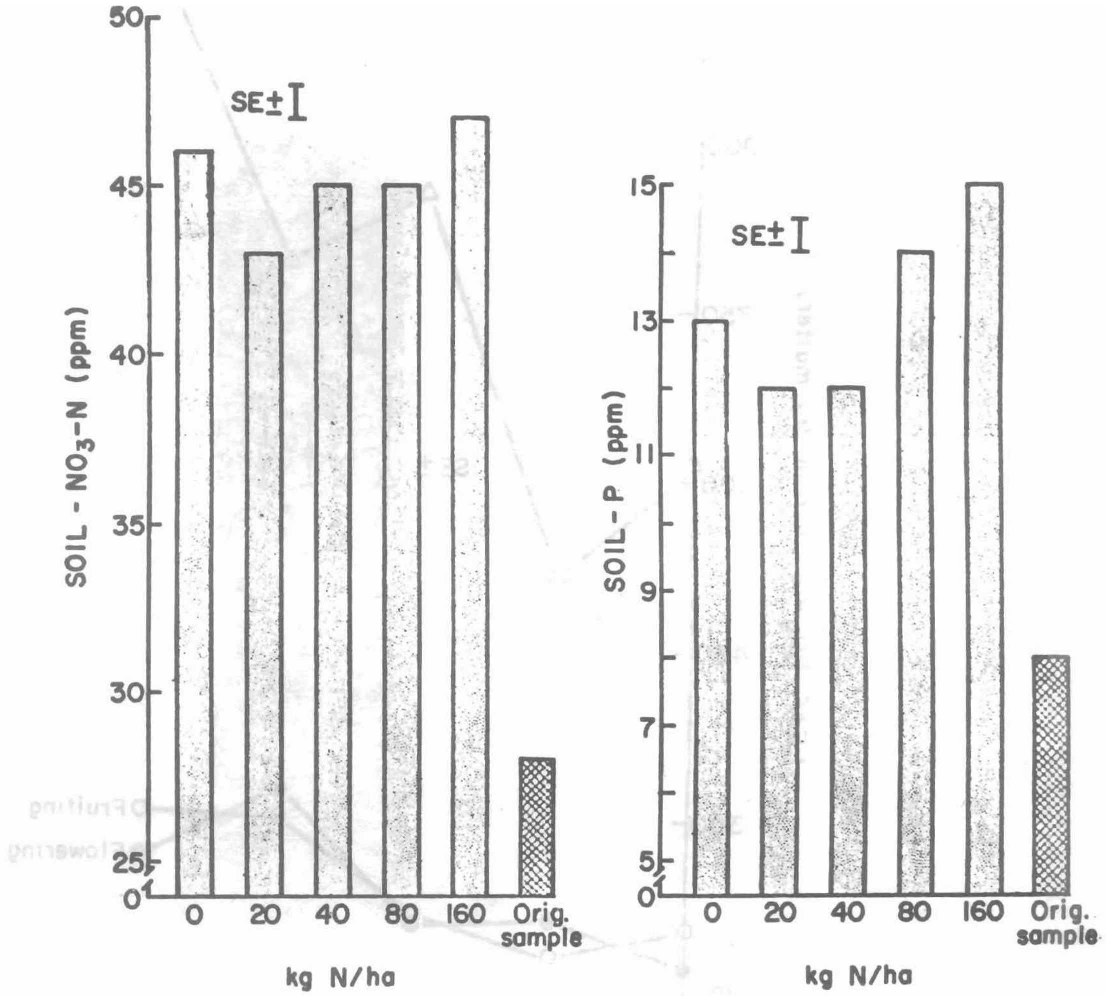

Figure 2. Effect of nitrogen fertilisation on changes in soil-NO_3-N and -P

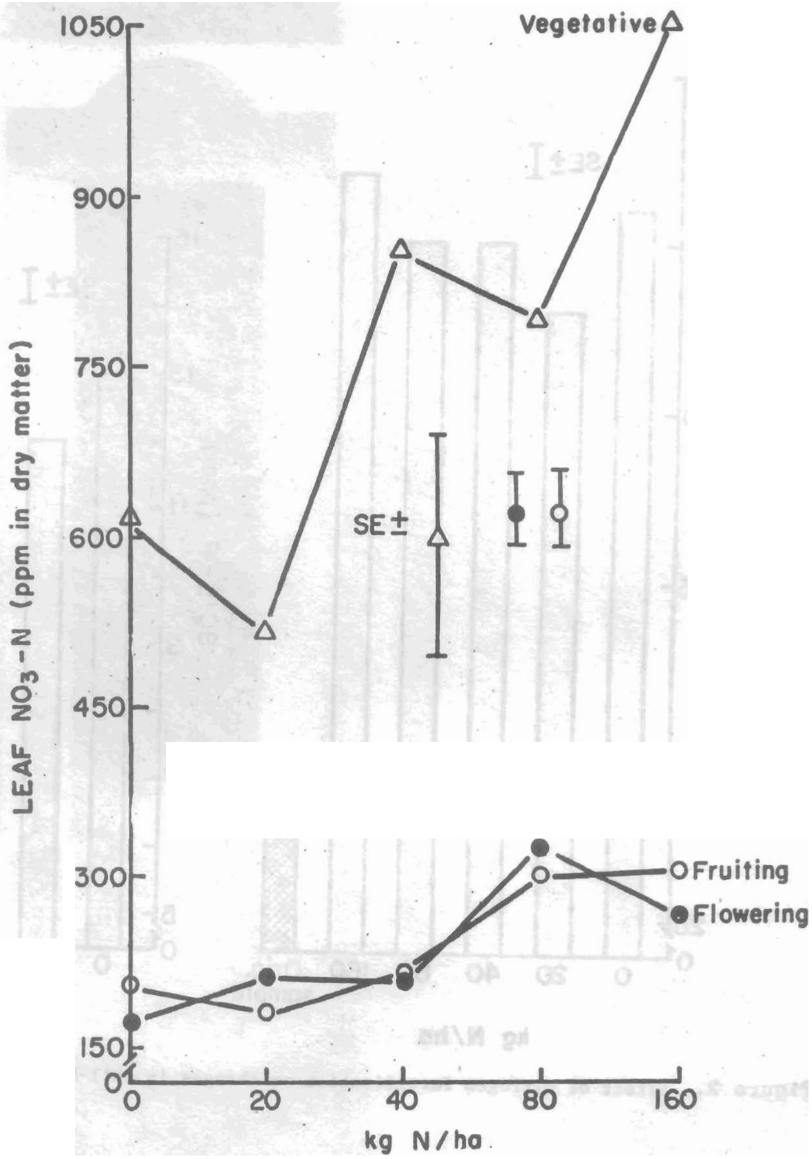

Figure 3. The distribution of NO_3-N in Okra leaves at various stages of growth under Nitrogen fertilization.

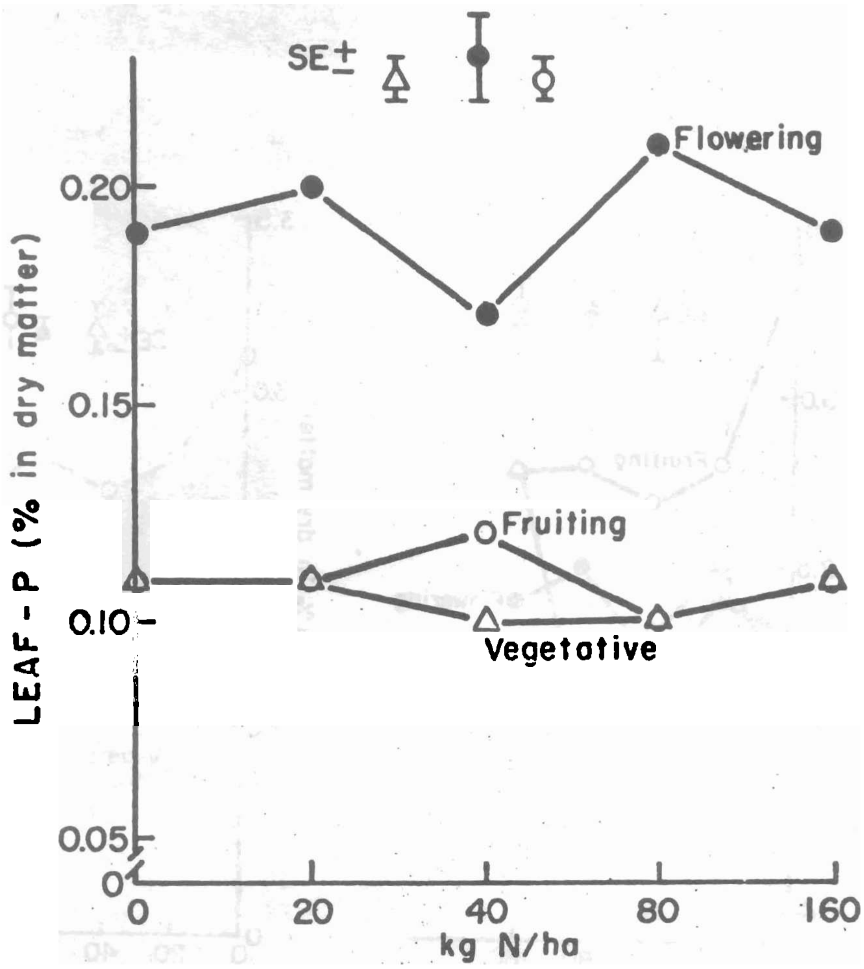

Figure 4.The distribution of P in Okra leaves at various stages of growth under nitrogen fertilization.

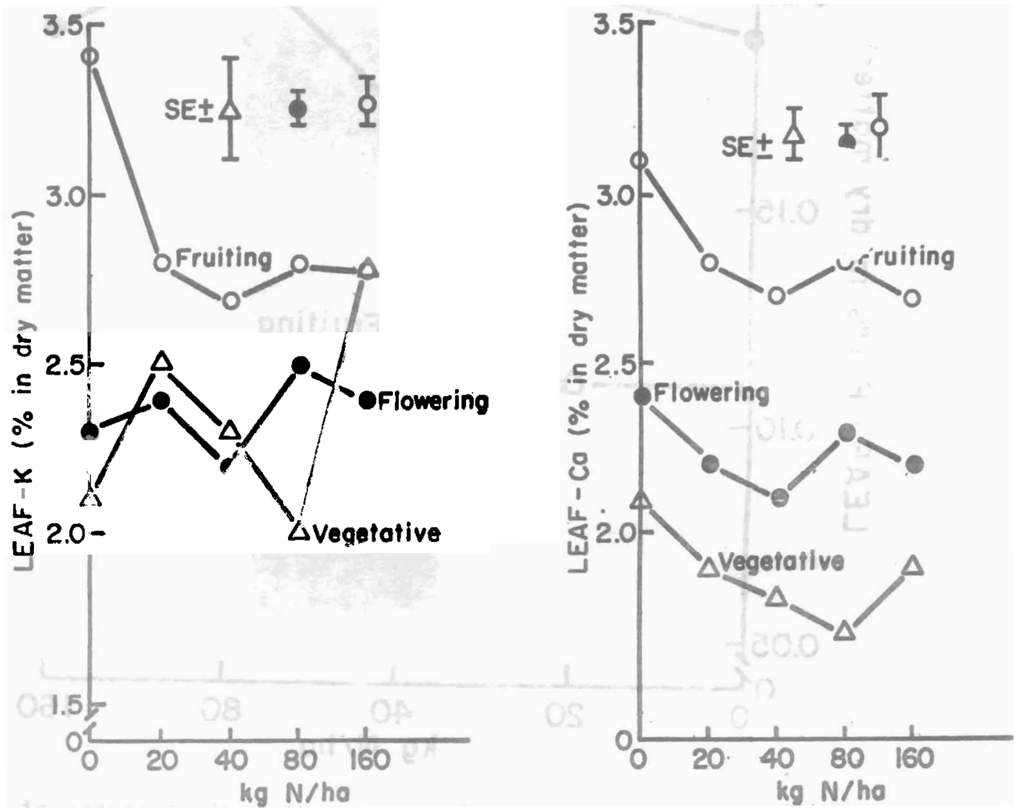

Figure 5. The influence of nitrogen fertilization on Leaf-K and -Ca of the okra plant sampled at various stages of growth.

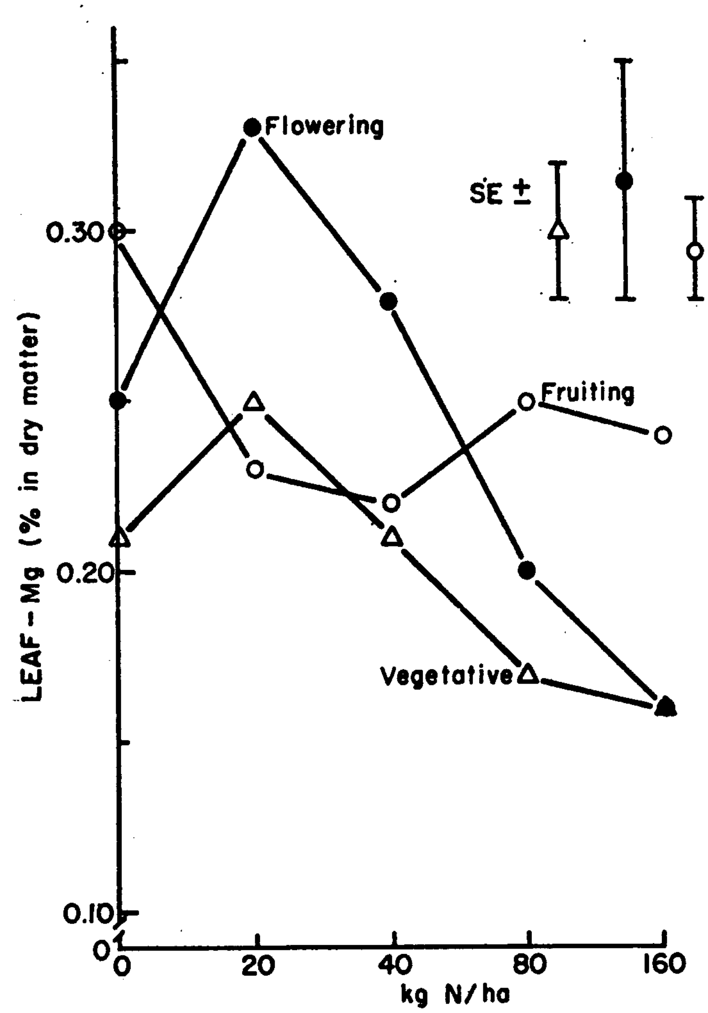

Figure 6. The distribution of Mg in okra leaves at various stages of growth under nitrogen fertilization.

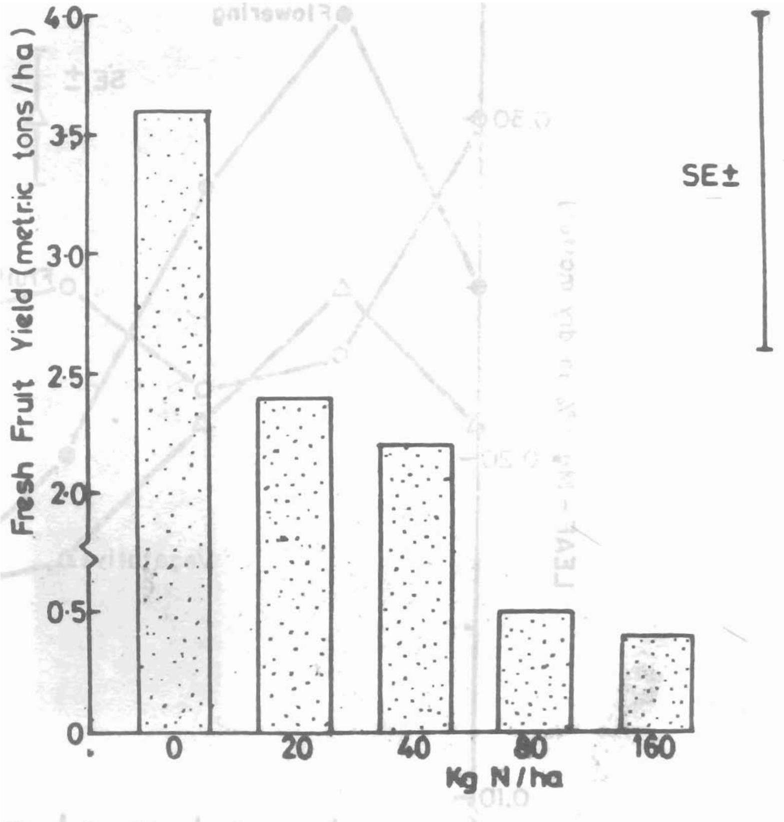

Figure 7. Effect of Nitrogen fertilization on Okra fruit yield.

Relationship among Soil Chemical Composition, Leaf Content and Yield.

Data from simple correlation coefficient (Table 2) show that soil pH was significantly correlated with leaf NO_3–N and P. There was no effect of pH on leaf K. Ca and Mg. Soil organic matter showed a significantly positive correlation with leaf K. Ca and Mg. Except for a highly negative significant correlation between soil P (Bray–I) and leaf P, the correlation between soil P and other leaf nutrient elements was non–significant. Soil K correlated positively with leaf P and K, and negatively with leaf Ca and Mg. The relationship between soil Ca and the leaf cations was non–significant. However, soil Ca showed significantly negative relationship with leaf NO_3–N and a positive relationship with leaf P.

With the increase in N fertilization, okra fruit yield consistently decreased (Figure 7). The highest fruit yield was obtained in the unfertilized plots, while the 160 kg N/ha application showed the lowest fruit yield. Fruit yield correlated positively with leaf Ca and Mg when leaf sampling was done at the vegetative stage of growth of the plant (Table 3). At flowering, all leaf nutrient elements were negatively correlated with yield, except for a marked positive correlated with leaf Mg. At fruiting, yield and leaf NO_3–N were negatively correlated while a highly significant positve relationship was obtained for leaf P

Fruit elemental composition

Table 4 shows the concentration of nutrient elements in the okra fruit at increasing N fertilizer rates.

Fruit NO_3–N increased slightly with increase in N fertilization reaching significance at the 160 kg/ha treatment. There was no effect of N fertilizer on fruit P, K and Ca. However, fruit Mg at the 20 kg N/ha treatment was significantly increased.

Discussion

Soil Composition

The decrease in soil pH resulting from the use of $(NH_4)_2SO_4$ as N fertilizer source was caused by adsorption of NH_4+ ion to the surface of the colloids in the soil, thus replacing equivalent quantities of other cations including H+ with subsequent increase in soil acidity. Soon and Miller, (1977), reported that the acid inducing effect of $(NH_4)_2SO_4$ may be a reslt of the sorption of NH+4 with the release of the $SO_4=$ acid radical in solution:

$$SO_4^{=} + 2H^+ \rightleftharpoons H_2SO_4$$

Another important cause of acidity following $(NH_4)_2SO_4$ fertilization is the direct nitrification of NH_4+ by nutrifying bactera, as follows:

TABLE 1 – EFFECT OF NITROGEN FERTILIZATION ON CHANGES IN SOIL-POTASSIUM AND CALCIUM

Treatments (kg N/ha)	Nutrient content (ppm)	
	K	Ca
0	60	186
20	76	282
40	82	192
80	74	152
160	76	184
SE ±	2	19
Pretreatment Sample	582	1055

TABLE 2. RELATIONSHIP BETWEEN SOIL CHEMICAL COMPOSITION AND LEAF NUTRIENT CONTENT

Sources	Correlation coefficient (r)
Soil-pH versus Leaf - NO_3-N	0.67**
" " " - P	0.91***
" " " - K	0.26
" " " - Ca	0.26
" " " - Mg	0.01
Soil Organic Matter versus Leaf - NO_3-N	-0.41*
" " " " " - P	-0.24
" " " " " - K	0.72**
" " " " " - Ca	0.67**
" " " " " - Mg	0.72**
Soil-P versus Leaf - NO_3-N	0.38
" " " - P	-0.65**
" " " - K	0.19
" " " - Ca	-0.09
" " " - Mg	0.34
Soil-K versus Leaf - NO_3-N	-0.12
" " " - P	0.56**
" " " - K	8.82***
" " " - Ca	-0.84***
" " " - Mg	-0.91***
Soil-Ca versus Leaf - NO_3-N	-0.58**
" " " - P	0.45*
" " " - K	-0.20
" " " - Ca	0.05
" " " - Mg	-0.32

*Significant at 5% Level

**Significant at 1% Level

***Significant at 0.1% Level.

TABLE 3. RELATIONSHIP BETWEEN OKRA FRUIT YIELD AND LEAF NUTRIENT CONCENTRATION SAMPLED AT THREE STAGES OF GROWTH'.

Source	Correlation Coefficient (r)		
	Stages of Growth		
	Vegetative	Flowering	Fruiting
Yield versus Leaf-NO_3-N	-0.39	-0.95***	0.79***
Yield versus Leaf-P	0.10	-0.73***	0.92***
Yield versus Leaf-K	0.11	-0.97***	0.17
Yield versus Leaf-Ca	0.47	-0.09	0.34
Yield versus Leaf-Mg	0.59	0.72***	0.01

Table 4. The influence of nitrogen fertilization on okra fruit nutrient concentration 9ppm or % in DM).

Treatments (kg N/ha)	Nutrient concentration				
	NO_3-N (ppm)	P (%)	K (%)	Ca (%)	Mg (%)
0	260	0.10	2.7	0.93	0.13
20	280	0.10	2.8	0.94	0.17
40	340	0.11	2.7	0.93	0.15
80	340	0.10	2.8	0.89	0.12
160	370	0.10	2.9	0.91	0.11
SE ±	46	0.004	0.08	0.02	0.02

$$NH_4^+ + 2O_2 \rightleftharpoons NO_3^- + 2H^+ + H_2O$$

Similar effects were stated by Anderson, (1970) and Obi (1976).

The organic matter content of the soil was originally about 2.4%. However, as the fallowed site was cleared and put on continuous cropping, the level of organic matter decreased probably as a result of increase in the rate of decomposition of the biomass in the soil, the soil temperature and exposure to rainfall (increased moisture) would have provided adequate environment for the microorganisms (Seubert et al. 1977). The observed increase in soil - K at higher rates of N fertilization (Table 1) may be partly due to the displacement of K+ on the exchange sites by the apparently saturated concentration of NH_4^+ caused by the $(NH_4)_2SO_4$ fertilization. It is also possible that as N application increased, the rate of microbial decomposition of OM would increase; consequently increasing the K+ supply in the soil. Nitrogen fertilization, particularly at 40 and 80 kg/ha resulted in a substantial decrease in organic matter. There is the possiblity that with the addition of N, the C/N ratio in the soil would decrease, a situation which would provide adequate nutrition for the microbes for more effective decomposition processes. These possibilities are reflected in the increase in soil NO_3–N and P over that of the original soil. Agboola et al. (1974), noted that N fertilization increased the rate of mineralization and hence the release of mineral N and P in the soil.

Relative to the levels of K and Ca in the fallowed soil (original soil), continous cultivation resulted in a decrease in these elements due to nutrient removal by plants. Agboola et al (1974) found that when a field has just come out of fallow, the exchangeable bases were very high but with continued cultivation these elements were leached down the soil profile beyond the ploughable depth. It should be noted also that the organic matter content during cultivation decreased (Figure. 1). consequently the level of released bases during decomposition would be reduced.

leaf nutrient composition and fruit yield

Nutrient concentration in the leaves, particularly dueing fruit formation is important for assessing nutrient need and utilization by the plant. During flowering and fruiting (the productive stages of the okra plant) a greater demand was made for NO_3–N for the formation of the fruits, and for K for the translocation of carbohydrates from the leaves to the fruits. This phenomenon would have been responsible for the reduction of NO_3–N and K in the leaves during the flowering and fruiting stages of growth of the okra plant. Thus when fertilizer application is timed to coincide with period of greatest demand by the plant, enhanced fruit production may be achieved. As it was observed from this study, the side–effects of ammonium sulphate as a source of N fertilizer on Ca and K is the increased. demand of the crop for these elements which resulted in fast depletion of soil Ca and K. This situation apparently affected okra yield, adversely. Ahmed and Tulloch Reid (1968), found that without liming to counteract the acidifying effect of $(NH_4)_2SO_4$ in the soil, okra yields were adversely affected. Thus, the decrease in yield may not be attributed to the level of NO_3–N in the leaf but to the source of N fertilizer applied.

Relationship among soil composition, leaf nutrient content and yield

Simple correlation coefficient between soil chemical composition and leaf nutrient content suggests that soil organic matter plays a vital role in the availability of the exchangeable cations in the soil and their eventual uptake by the plant roots and accumulation in the leaves. Soil pH correlated significantly with leaf NO_3–N and P, suggesting that leaf contents of NO_3–N and P are functions of soil pH. This observation contrasts with that of Agboola and Corey, (1973) who found a high correlation between soil pH and the exchangeable K and Ca. There is an indication from the data in this study that Bray–1–P does not necessarily predict the magnitude of P absorption by plant roots and hence accumulation by the leaves, considering the negative relation between soil extractable P and leaf. It is thus possible that an alkaline extractant instead of the acid extractant (Bray–1) usually applied to inherently acid soils such as the type used in this study, may produce a better correlation.

A positive relationship exists between yield and leaf Ca ($r = 0.47^*$) and Mg ($r = 0.59^{**}$) when okra leaves were sampled at the vegetative stage of growth, while yield was highly correlated with leaf Mg ($r = 0.72^{***}$) at flowering. Thus, these elements when determined in the leaves at the various stages of plant growth could give a fair assessment of the yield potential of the plant. Leaf P at fruiting was positively correlated with yield ($r = 0.92^{***}$). In general, sampling may be made at the vegetative stage of growth of the plant for Ca, at both vegetative and flowering stages for Mg. and at fruiting for P for predicting the yield of the okra plant.

The study of plant nutrition and soil fertility should emphasize fruit quality in relation to elemental concentration for animal and human needs. With this in view, the okra fruits were analyzed for the content of micronutrients. The result indicated that NO_3–N increased as a result of increasing N fertilization. Although NO3–N itself is not very toxic to animals, high concentration in food and feed crops are generally undesirable, because of its conversion in the digestive tract or in stored food to nitrites. The nitrites often become toxic to animals because once absorbed into the blood system, they react with hemoglobin in a way that interferes with the transport of oxygen n the hemoglobin (Allaway, 1975). While no attempt was made in the present study to relate the okra fruit NO_3–N to human dietary needs it is important to note the gradual increase of this element as a result of increasing rates of N fertilization.

It is inferred that the continuous use of $(NH_4)_2SO_4$ as a source of N–fertilizer for okra production resulting in increased soil acidity would limit the availability of micronutrients particularly the cation concentration in the plant. This situation would undoubtedly be detrimental to plant growth unless a liming material is used when applying $(NH_4)_2SO_4$ fertilizer to a slightly or strongly acid soils.

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