# THE RESPONSE OF MAIZE (Zea mavs L.) TO SOIL AND FOLIAR APPLIED UREA IN NORTHERN GUINEA SAVANNA OF NIGERIA

BY

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**JUNE, 1999**

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A thesis submitted to the post-graduate school, Ahmadu Bello University, in partial fulfilment of the requirement for the degree of Master of Science in Soil Science

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**DECLARATION**

I hereby declared that this thesis has been written by me and it is a record of my own research work. It has never been presented before in any previous publications for a higher degree.

26/11/99.

Muh. Abubakar
Candidate

Date

The above declaration is confirmed

13/12/99

Prof. V.O. Chude
(Major Supervisor)

Date

## CERTIFICATION

This thesis entitled "The Response of Maize to Soil and Foliar applied Urea in Northern Guinea Savanna of Nigeria" by Mohammadu Abubakar, meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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Ahmadu Bello University, Zaria — Date

## DEDICATION

**To**

my late father, Abdullahi Mustafa;
my late mother, Maryam Mohammad,
my late son, Ibrahim Mohammad

and to the ENTIRE

Technical staff of the Soil Science Department, Ahmadu Bello University, Samaru, Zaria.

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## ABSTRACT

Nitrogen (N) deficiency is the most widely spread macro- nutrient fertility problem in the Northern Guinea Savanna (NGS). Correction of this disorder is usually through the soil application of solid N fertilizers and other N-carriers. The quantities of solid fertilizers required to meet the needs of cereal crops through this approach are usually high and cost ineffective. The fertilizers also undergo various transformation in the soil. There is therefore the need to identify another cost effective and more efficient method of supplying N to cereal crops.

A field study was conducted at Samaru (l1$^{0}$11$^{1}$N and 07°38$^{1}$E) Latitude and Longitude respectively in the NGS agro-ecology in 1997 rainy and 1998 dry seasons to compare the agronomic effectiveness of soil. There were two experiments carried out in each season:

a) Urea application by foliar spray

b) Urea application via the soil

The first trial tested the response of maize (TZESR-W) to five levels of N foliarly applied as 0,1,2,3 and 4% N ha$^{-1}$ (0.00, 22.86, 45.72, 68.58 and 91.44 Kg N ha$^{-1}$). The second trial tested the response of maize to 0, 40, 80, 120 and 160 KgN.ha$^{-1}$ in the form of Urea applied via the soil.

Results obtained indicated that *2%* N ha$^{-1}$ (folia applied) and 120 KgNha$^{-1}$ via the soil produced the highest grain yields of 3921 and 5412 Kgha$^{-1}$ and stover yields of 4936 and 7130 Kgha$^{-1}$ respectively. And for the 1998 trials, highest grain yields of

1197 and 1713 $Kgha^{-1}$ were obtained with 2% N $ha^{-1}$ (foliar applied) and 120 $Kgha^{-1}$ respectively. The corresponding stover yields were 304.3 and 4071 $Kgha^{-1}$. There were 61.4% and 71.3% grain yields increased above the control for foliar and soil applied trials.

The results also indicated that various soil properties, for examples, pH and organic carbon influenced the availability of N in the soils. Parameters such as grain, and stover yields, 50% tasseling and silking time, 1000 grain weight and leaf area were significantly (P=0.05) affected by foliar sprayed N in 1997 trial while only leaf area, 1000 grains weight, grain and stover yields were significantly (p=0.05) affected by soil applied N.

Both methods of N application have significant effect on the nutrients (N, P and K) uptake. Uptake of these nutrients increased with increased N cone, up to 2% in the foliar trials, uptake decreased with further increased N cone, $ha^{-1}$ to 3 and 4%. With soil applied N method, uptake of N, P and K increased with increased N rates from 0 - 120 $KgNha^{-1}$. Uptake in stover did not show out particular trend in P and K uptake.

Leaf area, number of cobs/plant, number of leaves/plant correlated positively with grain and stover yields.

The economic analysis of 1997 rainfed trial gave good returns for producing one hectare of maize. The soil applied N trial gave a net return of N55,238 while the foliar trial gave a return of N37,545.

For the dry season trials, water supplied to the fields was costed by using Hadejia-Jamare River Basin Authority charges and used for economic analysis.

The results from the two seasons trials, clearly showed that foliar N fertilization cannot successfully substitute for soil N fertilization as a means of supplying N to cereal crops. However, it is recommended in situations where the cost of urea fertilizer is prohibitive. To further save cost, it can be applied in combination with insecticides and pesticides in a single spray.

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# CHAPTER ONE

## 1.0 INTRODUCTION

In many areas of the Nigerian Savanna, water supply is the first limiting factor on crop production and on the effectiveness of applied fertilizers (Poulain and Arrivets, 1972).

Major soils of Nigerian Savanna are Alfisols, Entisols, Inceptisols and Vertisols and are predominantly coarse textured, generally low in organic matter, low in CEC, poorly structured and buffered. In general, the soils are initially low in fertility with rapid declining productivity under continuous cultivation.

The challenge that threatens crop productivity is lack of adequate provision of nutrients to the poor soils. Nitrogen (N) is the most limiting nutrient in the Nigerian Savanna followed by phosphorus (P). Crop response to other nutrients is improved with adequate N supply. Therefore, absence of N in the soils limit crop production to a very great extent (Lombin, 1979).

Presently, common forms of artificial fertilizers being used include urea, compound fertilizer (NPK), single super-phosphate (SSP). The cost of these fertilizers is prohibitive to the poor resource farmer. For example in 1996/97 farming season, the cost of one tonne of NPK in the local market was N40,000.00 as against the official price of N20,000.00

The use of chemical fertilizers is for the most part socio-economically unsustainable. This situation has been aggravated by currency devaluations due to implementation of the Structural Adjustment Programme (SAP) which includes gradual reduction in subsidies on agricultural inputs distribution of which is highly inconsistent. As a result of these problems subsistent farmers are likely to greatly cut down or even drop the use of chemical fertilizers which will drastically affect crop yields. In an effort to overcome these problems, farmers may decide to turn to animal manure. Its use is however seriously limited because it is needed in large quantities and its transportation and handling costs constitute a major constraint.

Since it has been established that plants need mineral nutrients for growth and development, the nutrients are supplied via the soil. Nutrient deficiency correction is likewise done through the soil.

There are certain advantages in fertilizing crops via the soil. This method provides many ways of applying fertilizers to the soil. Fertilizers can be banded, broadcast or punched in and covered. The banding and punching eliminate fertilizer drift and waste because it is placed within crop reach. Some fertilizers are not readily soluble in water and are retained in the soil. The nutrients are later slowly made available to the crops. Nitrogen fertilizers are very soluble in water and can readily be lost by leaching as nitrate N ($NO_3^-$-N) while ammonium counterpart is fixed by positive charges in the clay matrix but later released to crops.

Many macronutrient fertilizers can be combined and soil applied to crops without fear of concentration effect. With exception of N fertilizers, in many cases macro nutrient fertilizers are applied once to the crops via the soil. Those fertilizers containing N are split applied if needed in large amounts. This minimizes their tendency to leach.

The traditional fertilizer application via the soil has many drawbacks most especially in use efficiency and its effects on environment. Nitrogen which is highly mobile and easily leached is also lost by denitrification, volatilization and as gaseous Nitrogen compounds from flooded soils. Soil acidification also is due to continuous use of N containing fertilizers (Jones, 1976). Leaching of nitrates causes ground water polution. Soil reduces agronomic efficacy of fertilizers other than nitrogenous ones. Soils of high pH fix P because of high presence of calcium ions and those of alumina, iron and manganese at low pH. Kaolinite fixes ammonium ions ($NH_4^+$), Potassium (K) availability is dependent on soil moisture and texture. A lot of energy was expended by the crops to absorb nutrients from the soil to photosynthetic template. All the drawbacks lead to the increase in the amount of the nutrient fertilizers to be applied to the soil so as to meet the crops needs.

In the face of dwindling foreign exchange and rising prices of agricultural inputs it is very imperative to look for alternative method of fertilizer application to the crops which is easier, cheaper, environmentally friendly and sustainable. Foliar method of crop fertilization readily comes to mind. It is cheaper in the long run to operate, less quantity of fertilizer would be needed. The crops expend less energy to get the much needed nutrients and to photosynthetic template. With foliar method, fertilizer can be combined with insecticides for application to the crops. This method is environmentally friendly because of its non pollution of environment especially underground and surface sources of water.

Foliar application method of crop fertilization has its attendant problems beginning with its initial cost of spraying equipment, there should be a source of water supply on or close to the farms. Care must be taken to ensure that correct fertilizer concentration is sprayed on the crop to avoid crop damage by scorching.

A study to investigate an alternative approach to soil applied N was therefore embarked upon with the following objects:

a) to assess the differential response of maize to foliar and soil applied urea fertilizer.

b) to establish the safe and toxic rates of foliar applied urea fertilizer

c) to examine the effect of foliar and soil applied urea fertilizer on stover yields and nutrient uptake by the crop.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

## 2.1 UPTAKE AND TRANSLOCATION OF UREA NITROGEN (U - N)

### 2.1.1 Foliar U-N Application

Nitrogen from urea enters leaf through the cuticular membrane (Franke, 1967). This is shown in the cuticles of onions and tomatoes (Yamada et al., 1965). Considerable quantities of nutrients appear to reach the leaf interior directly through the epidermis. Foliar uptake has been inferred but not proved by the rapid production of the hydrolytic products following urease activity as follows:

$$NH_2\text{-}CO\text{-}NH_2 + H_2O \text{ Urease } 2NH_3 + CO_2.$$

Application of labeled urea to potted maize plants showed a rate of 50% absorption in one to six hours (Hinsvark et al., 1953; Witterwer et al., 1963). The rapid disappearance of foliar applied urea from the leaf surface of both maize (Foy et al., 1953) and winter wheat (Lawlor et al., 1989) on the trials provides reliable evidence for foliar absorption. The removal of urea by rain, dew and its hydrolysis before foliar absorption made the above observations inconclusive. Alkier et al., (1972), Below et al., (1985) in their work with $^{15}N$ as urea sprays on maize grown on the field concluded that the leaves are the main organs of uptake of urea-nitrogen. Similarly, studies with $^{15}N$ on wheat in Australia by Smith, (1992) at 59 days after germination growth stage and Zadocks et al., (1974) showed $^{15}N$ was rapidly absorbed into leaves though some reached the soil after rainfall. Poulton et al. (1990) in UK experimented with wheat, and 11% of added $^{15}N$ was recovered in the soil after harvest following different labeled urea sprays between 32 and 59 days growth stage. At this time, the leaf area index and spray interception might have been maximal. From this work, total $^{15}N$ recovery from soil and plant after harvest was 57%. Good part of the loss was through volatilization of ammonia following urease activity. This may be the cause of low recoveries of $^{15}N$ in other trials (Alkier et al., 1972; Below et al., 1985).

Recent reports suggest that ammonia ($NH_3$) volatilization following urease activity on the leaves does occur (Smith, 1992), but most $NH_3$ lost occurred after urea reached the soil. Bowman et al, (1990) reported occurrence of hydrolysis on the leaf surfaces at low rates.

Volatilization occuring on the leaf surfaces, may have both environmental and commercial implications as it could detract from any advantage foliar sprays may have with regard to reduced nitrate leaching compared to soil application (Kruse et al, 1987).

Factors influencing the degree of foliar absorption on losses of urea-N have not been reported in details for cereals. An appropriate leaf area index for maximizing spray interception is a primary requisite (Gooding et al, 1992). Treatments which improve leaf area index, such as adequate fertilization and disease control have sometimes increased responses to subsequent foliar liquid N fertilizers containing urea (Penny et al, 1978).

High rates of foliar uptake are widely assumed to be also dependent on high relative humidity as rapid drying can lead to crystallization on the leaf surface (Gamble et al., 1987). Applications of sucrose with urea reduced the rate of urea accumulation in maize leaves (Foy et al., 1953, Hinsvark et al., 1953). Once within cereal leaves, urea is reported to largely disappear in about three or four days either by hydrolysis or translocation (Foy et al., 1953; Lawlor et al., 1989), during which period there can be an increase in nitrate ($NO_3$) protein and soluble amino acid concentrations (Below et al., 1984; Lawlor et al, 1989). Following foliar urea application, Burlaku (1975), reported increased total leaf N, this effect lasts through to senescence (Polous, 1977) and grain maturity in some instances (Grama et al., 1978, Saradon et al., 1990). In contrast, foliar N applications around anthesis did not increase leaf N contents in leaf during grain filling (Below et al., 1984; Gooding, 1968).

Below et al., (1985), applied $^{15}N$-labeled urea to maize and reported the quick demobilization of urea N from the leaf and its incorporation into different pools of N. In one experiment, application of 80kg $Nha^{-1}$ was applied to the flag leaves of winter wheat, there was increased flag leaf protein content but no similar increase when 200kg $Nha^{-1}$ was applied (Lawlor et al., 1989). Some experiment on maize by Below et al, (1984) made him to suggest that N from urea is stored in the stem after translocation out of the leaf before being lodged in the grains. But other workers have advanced that the stem just acts as a pipe between leaves and the cob. Such differences may be due to size of the sink and the amount of N available from the soil and other plant parts before and after the time of urea application.

All experiments monitoring distribution of $^{15}N$ after foliar application of labeled urea show that at least 80% urea-N recovered in the above ground plants, is found in the grain (Gooding et al, 1992). Once taken by the plants, urea-N is efficiently translocated to the grain.

### 2.1.2 Soil U-N application

Maize production in the Northern Guinea Savanna is mostly done by using inorganic fertilizers. These fertilizers are provided to the crops via the soil (Lombin 1986). Likewise corrections of deficiencies have traditionally been through soil application (Chude, 1994).

## 2.2. Advantages of Foliar urea nitrogen

### 2.2.1 On cereal grain yield

The effect of foliar applied urea on grain yield have been reported for wide range of sites and climates on wheat, for example in Argentina (Sarandon et al, 1990) and on maize in the US with grain yield increases (Foy et al, 1953).

Like soil applied N, urea foliar sprays imparts deep green coloration to crops (Hanley et al, 1966) making it to attain faster maximal rates of photosynthesis and delay senescence (Lawlor et al, 1989).

Spraying urea between flag leaf and ear emergence increased grain number per ear and/or average grain weight (Gooding, 1988; Lawlor et al, 1989).

Yield due to urea sprays is highly variable. Sylvester et al, (1984) compared foliar N application with yield responses to N from other sources. On such early experiment Finnery et al, (1957) had shown a response of 57 kgdm/kgha with foliar urea applied after anthesis. Several other studies showed neither yield benefits for wheat (Curie, 1988, Smith, 1992) nor for maize (Below et al, 1984).

In some studies however, decreased yield were observed (Dampney et al, 1990; Peltönen et al., 1991.

### 2.2.2 Influence of Foliar Urea on Cereal Disease

Urea applied to the leaves of wheat has been found to reduce levels of *Septoria tritici, S. nodorun,* powdery mildew *(Erysiphe graminis)* and brown rust *(Puccinia recondita)* in some experiments (Gooding et al., 1988; Peltonen et al., 1991). With increased leaf N contents, Zadocks et al., (1974) suggested a probable improvement in resistance to *Septoria* ssp. This is consistent with Davies et al., (1988) findings on *S. tritici* using granular ammonium nitrate in the spring.

### 2.2.3 Effect of Foliar applied Urea on grain quality

**2.2.3.1** On grain quality it is the N content that was mostly reported of the foliar urea effect. It increases the N content (or crude protein) which is desirable because it improves the nutritive value of cereal food crops (Stoskopf, 1985) and increased seedling vigour in seed crops (Ayers et al., 1976).

Increases in grain N content were obtained for maize grains (Below et al., 1984) and rice grains in U.S. (Thorne et al., 1981).

Few out of series of trials showed that urea can occasionally fail to increase N content (Gooding, 1988), but negative influences do not seem to have been reported. The magnitude of response varies between trials and as with grain yield, timing of application is the most important factor. Gooding (1988) stated lower grain or responses to application after ear emergence could be due to reduced chlorophyll area to intercept the spray and/or reduced translocation to the grain. When large amount of N have been previously applied, and as regards to yield, urea application is less effective at increasing grain N content (Astbury et al., 1991). There have also been variations among different genotypes of maize (Below et al., 1984). However, similar urea effect on different varieties were obtained in other experiments (Gooding et al., 1991).

In another trial, grain protein content increased when late urea spray was applied followed by application of molybdenum (Grifanov et al., 1972).

When similar timings of soil and foliar N fertilization were considered, it appeared the soil applied were most effective at improving grain N content before anthesis (Strong, 1982) while after the anthesis largest increases in N uptake occurred (Curic, 1988). This may be attributed to reduced root activity after anthesis (Powlson et al., 1987).

### 2.2.3 Grain Protein quality

Loaf baking characteristics of wheat grain usually improves with increasing grain N content (Finney et al., 1957) while a beneficial effect of urea sprays on loaf quality which is linked with higher grain N concentrations have been reported for a wide range of application timings at least after 75 days growth stage (Salmon, 1990).

In the United Kingdom, Pushman et al., (1976) applied urea sprays at anthesis which gave an average increase in protein content from 11.9 to 12.96% but not loaf volume.

## 2.3 FOLIAR SPRAYS AND THE ENVIRONMENT

Foliar fertilization does not cause polution of the environment and water sources unlike soil applied which polute not only the rivers, dams but also the underground water.

Less quantities of fertilizer are used if compared to that needed for soil application thus cutting down on costs of fertilizers, labour and transportation.

With foliar sprays, fertilizers can be combined with insecticides and micro nutrients in one application without fear of concentration effect on the crops. Thus foliar spray is safer to the environment.

## 2.4 HARMFUL EFFECT OF UREA SPRAYS

### 2.4.1 Leaf Scorching

With foliar urea application to cereal plants even at low rates of 15kg $Nha^{-1}$, leaves show visual symptoms of leaf scorching (Gooding, 1988). The pattern of the drainage varies but with maize, bleaching around the leaf margin and in interveinal patches over the whole leaf have been reported (Chesnin et al., 1953).

Urea has a low salt index thus it reduces dessication of leaf cells through osmosis (Gray, 1977). Dessication from urea application is shown in the shriveling of maize epidermal and mesophyll cells (Gamble and Emino, 1987). Fertilizer solution high in urea content applied to rice after flowering resulted in severe decolorization of the lemina and palea and the dessication of the rice kernels (Singh and Rai, 1980). Rapid drying of foliar applied urea solutions on the leaves in dry weather reduces the risk of scorch (Fink, 1982). Peltonen et al (1991) from greenhouse trial stated that foliar applied urea solution causes most scorch if leaf tissue remains wet with urea solution for a long period. When urea is sprayed early in the morning when dew is still on the wheat crops, it causes severe scorch (Gooding et al, 1988).

Other ways by which urea could damage plant tissue besides dessication is itself and its hydrolytic products such as aqueous ammonia which may be phototoxic (Hinsvark et al., 1953) and may prevent photophosphorylation and/or inhibit respiration (Mengel et al., 1987).

Bleaching of leaf margins in maize bore no relationship with the aqueous ammonia concentration (Foy et al., 1953) indicating that other factors might be responsible.

Urease inhibitor (phenyl phosporodiamide) was used as an additive to reduce the rate of urea hydrolysis on wheat but it caused more leaf damage (Powlson et al., 1989). This showed that high leaf concentrations of urea itself might be phototoxic. Beuiret ($NH_2CONHCONH_2$), urea conterminant, may also contribute to leaf damage (Mikkelsen, 1990).

Dilute concentration of urea sprays effectively reduces damage Smith, 1992) while the use of sucrose which reduces accumulation of urea within the leaf can reduce leaf bleaching (Hinsvark et al., 1953) as can application of urea in finer, rather than coarser sprays (Chesnin et al., 1953). This obviously reduces foliar absorption and associated advantages of utilizing urea solution.

Certain wetters used with urea has increased the level of scorch probably through increase in the rate of urea uptake (Poulton et al., 1990). This may explain why the addition of certain fungicides formulated with wetters results in greater levels of visual damage (Gooding, 1988). Variations in the severity of scorch have been reported among different timings of urea application and different varieties (Dampney, 1987; Gooding, 1988).

Besides the visual symptoms of phototoxicity, some available evidence showed that foliar urea applications can cause other interference with plant metabolism. Below et al. (1984) estimated that 6.5 g of glucose is needed to provide the carbohydrate skeletons and energy necessary to convert a gramme of urea-N to amino acids. Below and other colleagues used this to explain the reduced carbohydrates accumulation in maize stalks. Perhaps, this could explain why yield decreases unrelated to visual symptoms of phototoxicity have sometimes occurred (Gooding, 1988). Increasing the levels of N supply often leads to lodging in cereals, for example N supplied by spray as late as twelve and six days pre-anthesis has resulted in lodging of maize (Below et al., 1984).

Foliar urea applications as shown by Singh et al (1980) influences microflora population on cereal leaves and these can interact with cereal harmful microbes (Dickson, 1981). The sprays have increased the severity of Bitrytis cinerea and S. nodorun (Pettonen, et al, 1991). Damage to leaf tissue by urea sprays may encourage secondary invasion of the scorched areas by certain pathogens while microclimate encourages the infections. Increased severity of S. nodorun appears to be more likely when applications of urea are made subsequent to infection (Peltonen et al, 1991). Other crop management practices affect the effect of foliar urea on disease for instance, it was noted that there was a statistically significant negative interactions between foliar urea and fungicide on disease control (Gooding et al, 1988). Root exudation and rhizosphere polution of different types of microorganisms in pot experiment are affected by foliar urea application. The latter may also influence certain soil borne disease (Vuurde, 1978). These reports are reviewed though yet to be tested on cereal production on field scale.

## 2.5 ADVANTAGES OF SOIL APPLIED UREA NITROGEN (U-N)

### 2.5.1 Fertilizer and Soil reaction

Urea has higher N content than any N containing fertilizers for example ammonium sulphate [$(NH4)_2SO4$)]. This reduces transportation cost because less quantity would be needed. Urea forms less acidity which is about half that of ammonium sulphate (Jones, 1974).

Urea did not show any toxic effect to tomato except when bieuret content was very high, up to 100% (Tanev, 1972).

### 2.5.2 Ways of Soil application of fertilizers.

Fertilizer can be banded or broadcast on the field and worked in later before ridges are made. Band application of fertilizer has the following advantages:

a) Restricted contact of such fertilizer with soil reduce its fixation for example phosphorus (P) containing fertilizers.

b) Fertilizer is placed within reach of plant roots

c) Growth of weeds between rows likely to feed on fertilizer is greatly reduced.

### 2.5.3 Disadvantages of soil application of fertilizer

Soil application of fertilizers could be injurious to cereal seedlings especially when moisture is inadequate (Jones, 1974). Fertilizers, such a urea and ammonium sulphate decompose if surface applied (Fox, 1972; Diamond, 1972).

Soil application of fertilizers is environmentally unfriendly as it polutes not only the environment but also surface and underground water and their sources. Extra quantities of fertilizers are always needed to meet the crop requirement and wastes due to fixation, leaching, volatilization and run-off.

### 2.5.3 Economics of fertilizer use

Though the use of fertilizers has become very imperative for both food and cash crop production, it is very pertinent that the cost per a bag of 50kg fertilizer is very prohibitive to our agragarian farmers. If available, it is very belated and its distribution very inadequate. A bag (50kg) of any brand of fertilizer does not sell in the market less than N1200 to N1300. While a bag (100kg) of maize sells at N1300 in the open market.

## 2.6 FACTORS DETERMINING YIELD RESPONSE TO FOLIAR UREA

Timing of applying foliar urea determines the yield response. Response declines if application is carried out beyond flag leaf emergence (Sarandon et al, 1990). Arnold et al, (1967) showed that urea spraying at ear emergence was more effective than when it was done just before its emergence.

The size of the yield response to applied foliar urea differed between maize genotypes though reasons for these have not been clearly defined (Bellow et al., 1984). Works of Grifanov et al., (1972) and Pushman et al., (1976) have shown yield improvements by urea to be consistent over a range of maize varieties.

In higher rainfall areas, Altman et al, (1983) have shown that increase in yield from urea sprays appeared more likely, likewise with irrigated crops (Pushman et al., 1976).

Work done in UK with fungicides applied at the same time with foliar urea had no influence on the yield response to urea (Gooding, 1988).

Little or negative yield response to urea have been associated with excessive levels of leaf scorch (Dampney et al., 1990; Poulton et al., 1990).

Application of 160kg $Nha^{-1}$ by splitting it into 40kg $Nha^{-1}$ by four repeated urea sprays between 32 and 51 days growth stage have only equal or was less effective than the soil applications at improving yield (Poulton et al., 1990). Suggestions by these workers that repeated damage to the leaves and altered timings of spray could have caused yield depression.

Most experiments quoting either advantage or disadvantage of urea sprays over purely soil applications confound the effects of N source with potential effects of timings of application (Smith, 1992). This is true of works claiming benefits for foliar, as opposed to soil application in saline (Seth et al., 1981) and dry environments (Seth et al., 1971). Crops have produced higher yields in these situations when at least part of the N is foliar applied during crop growth rather than all soil applied at sowing. To confirm yield increase due to method of application or different application timings and splits involved is not possible (Gooding et al., 1992).

Urea sprays have either been less effective (Gardner, 1956 and Hanley et al., 1966) or no better than soil applications Dampney, 1987) in improving yield.

# CHAPTER THREE

## 3.0 MATERIALS AND METHOD

### 3.1 Location

The sites used for the field studies were two different plots located within the Institutes for Agricultural Research experimental farms at Samaru (Latitude 11°11'N, Longitude 07°38E). The rainfed trials were sited in an upland area while that of the dry season was run in a lowland area situated in the Northern Guinea Savanna zone (NGS) (Keay, 1959). The soils of the experimental farm have been classified as Typic Haplustulf by the USDA system or Orthic Acrisol by the F.A.O. system (Valette and Ibanga, 1984). Soils of this zone as reported by Kowal (1970) are fairly representative of the loess plain of the most agriculturally important lands of northern states of Nigeria.

Samaru receives an annual rainfall average of 1087 mm per annum in 85 years with a well defined wet season which begins in April/May and ends in September/October (Kowal and Knabe, 1972).

### 3.2 LAND PREPARATION

The field was initially sprayed with round up (Glyphosphate) at the rate of 5 liters/200 liters of water/ha to eliminate the common weed cynadon. dactylon. Two weeks later the field was harrowed and ridged at 75cm apart.

The field was divided into two equal blocks of 30.25m by 23.50m. Each block was subdivided into twenty equal plots of 5.25m x 5.00m (7 ridges x 5.00m). The design used was randomized complete block (RCB).

## 3.3 SOIL SAMPLING

Samples were taken from forty spots within area of 520m$^2$ from 0 to 30 cm depth. After thorough mixing, the samples were bulked and air dried on clean plastic sheets in a soil room. Air dried samples were ground and pass through a 2mm sieve. Sub-sample was taken and stored in plastic container for laboratory analyses.

### 3.3.1 Laboratory studies

This consisted of soil, plant tissue and grain analyses.

## 3.4.0 Soil Analysis

### 3.4.1 Particle size Distribution

To completely disperse soil aggregate, the soil samples were treated with 5% calgon (Sodium hexametaphosphate) dispersant solution. The mixture was shaken on a reciprocating shaker for 6 hours. The particles size distribution was then determined by the hydrometer method as described by Day (1965).

The total sand fraction was further fractionated by using a set of sieves (1000, 500, 200 and 53 micrometre sieves) and shaken for 20 minutes on mechanical sieve shaker.

### 3.4.2 Soil reaction (pH).

Soil pH was determined in both water and 0.01 Calcium Chloride 0.01m $CaCl_2$) solution using a 1:2.5 soil/water or solution ratio (Peach, 1965). The pH was then read with a glass electrode on a PYE Unicam model 290 MK pH metre upon equilibrium.

### 3.4.3 Total nitrogen (N).

A known weight of soil or plant material was used. The sample was transferred into Kjeldhal flask. 20ml of canc sulphuric acid was added and the mixture was heated until it was properly digested. The digest was transferred into a flask and made to 100mls. From this 10mls is transferred into microkjeldhal flask to which was added 50mls. of 0.1N Sodium hydroxide solution. The solution was distilled into boric acid indicator and 50mls of the distillate was collected and titrated against 0.1 N sulphuric acid (Bremmer, 1965).

### 3.4.4 Organic Carbon (OC)

The organic carbon was determined by the Walkley-Black dichrometer wet oxidation method as described by Nelson and Summers (1982). Concentrated sulphrated dihydrogen tetroxide ($H_2SO_4$) was added to act as a catalyst.

### 3.4.5 Available phosphorus (P)

Available phosphorus was extracted by the Bray-1 method (Bray and Kurtz, 1945). Phosphorus in solution was then determined by the ascorbic acid method (Murphy and Riley, 1962).

### 3.4.6 Exchangeable bases (CEC)

The exchangeable bases were extracted with neutral (pH 7.0) ammonium acetate (NH4OAC) solution by shaking on reciprocating shaker for two hours and centrifuging at 10,000 rpm for 20 minutes (IITA, 1979). Potassium (K) and sodium (Na) were read from the undiluted extracts on a Gallemkanp flame analyzer. The extracts were diluted two times with the addition of 2ml of 6.5% Lanthanum chloride solution to prevent ionic interference before calcium (Ca) and magnesium (Mg) were determined. Ca and Mg, in solution were read on a PYE model SP 192 Atomic Absorption Spectrophotometer (AAS) at 423 and 285 nm wavelengths respectively. The sum of the bases gave total exchangeable bases.

### 3.4.7 Effective cation exchange capacity (ECEC)

Effective CEC was obtained by summing up the total exchangeable bases with the values of exchangeable acidity by 1M potassium chloride (1MKCl).

### 3.4.8 Exchangeable Acidity (EA)

The soils were leached with 1MKCl solution. Exchangeable acidity (H+Al) was determined by titrating the extract with standard sodium hydroxide (NaOH) solution (Thomas, 1982).

### 3.5.0 Plant Tissues Analyses

Plant samples from field were analyzed for N, P and K. Ground plant materials such as stover, grain and leaves were separated and digested with a mixture of nitric acid ($HNO_3$), $H_2SO_4$ and perchloric acids ($HClO_4$) on a hot plate (Juo, 1979).

The amount of P in the digest was determined Calorimetrically, while flame photometry was used for K. The N was determined by Kjeldhal method.

### 3.6.0 Experiment 1 (Rainfed trials)

Two trials were carried out in the wet season. The trials were to evaluate effect of soil (SA) and foliar (FA) applied urea on maize production.

For the two trials, each has twenty plots each plot was 5.25m x 5.0m (26.25m2). The maize seeds (TZESR-Wc) was dressed with Browo Powder at a rate of 1 packet/5kg of seeds.

Maize was used as test crop. Responses to N and P have been most pronounced on cereals. All cereals and in particular maize, have a high N requirement which is simply impossible to meet from the mineralization of organic matter (Goldsworthy, 1967a).

Maize is generally a short season crop, less labour demanding and easier crop to manage in the field than millet or sorghum.

### 3.6.1 Trial One

### 3.6.2 Soil applied urea on maize

### 3.6.3 Treatment

There were five levels of urea-N applied to the soil for the rainy season trial and were 0, 40, 80, 120 and 160kg N $ha^{-1}$, replicated four times. Superphosphate (SSP 18% $P_2O_5$) and muriate of potash (MOP 60% $K_2O$) were applied at the rates of 60kg $P_2P_5$ and $K_2O$ $ha^{-1}$ each. Seed rate was 15.0 kg $ha^{-1}$.

### 3.6.4 Method

Groove was made on each of the ridges and into each 125g SSP (60kg $P_2O_5$) $ha^{-1}$ and 37.5g. MOP (60kg $K_2O$ $ha^{-1}$) were evenly banded before sowing.

Maize (TZESR-W) were sown on the 18th June, 1997 at three seeds per hole at 25cm intra and 75cm inter rows spacing. Two weeks after emergence (WAE), the seedlings were thinned to one per stand which gave maize population of 53, 333 plants/ha.

Stemborers and ants were controlled by spraying the fields with Karate (100mls/201 of water per spray). A total of three sprays were carried out at 2 days intervals. Weed control was manually carried out at 3, 5, and 8 WAE. The fields were moulded at 9 WAE.

Urea was split applied and the first dose was at 3 WAE, the second at 5 WAE. Applications were at two weeks intervals.

### 3.6.5 Measurements and Observation

Within each plot, net plot was marked out and ten stands in each net plot were selected and marked for observation. Agronomic parameters such as:

i. Plant height

ii. Plang girth

iii. Number of leaves/plant

iv. Leaf area

v. Dry matter

vi. Grain yields

vii. Days to 50% tasseling

viii. Days to 50% silking

were observed and recorded. These measurements were carried out at two weeks intervals and was commenced from 5 WAE to 13 WAE.

### 3.6.6 Plant height

Heights of crop were measured fortnightly from the soil level to the tops of the leaves.

### 3.6.7 Plant girth

Vernier calliper was used to determine the plant girth

### 3.6.8.1 Number of leaves/plant

Green leaves on the ten selected stands in the net plot were fortnightly recorded.

### 3.6.9 Leaf area

This is determined by Stickler et al. (1961) method.

Ten leaves were randomly sampled from each plot at the 13 WAE. The average lengths of the leaves were multiplied by their average widths and the products were multiplied by a factor of 0.75 to obtain the area of each leaf. The method was used because the available leaf area meter was not functional.

### 3.7.0 Plant dry matter

At harvest, plant population/plot was recorded. Stands were harvested at soil level and weighed (wet weight). From the stover obtained from the net plot subsamples were taken and weighed. The subsamples were oven dried at 70°C to constant weight (dry weight).

### 3.7.1 Grain Yield

Harvested cobs from each of the net plot were weighed (wet weight. Ten cobs from each net plot were subsampled and weighed (wet weight). The subsampled cobs were air dried to constant weight (dry weight). The ten dried cobs were shelled and the grains weighed. One thousand grains were randomly picked from each net plot grains and weighed to give the weight of 1000 grains.

$$\text{Grain yield ha}^{-1} = \frac{g \times i \times j}{h \times i \times y \times x \times d} \text{ kg ha}^{-1}$$

where:

i is dry weight of unshelled 10 cobs in kg.

h is wet weight of unshelled 10 cobs in kg.

g is wet weight of total cobs/plot in kg

j is dry weight of shelled 10 cobs in kg.

x is plant spacing in meter

y is row spacing in meter

d is total number of stalk harvested per net plot.

### 3.7.2 Threshing percentage

This was determined as follows:

$$\text{Threshing \%} = \frac{\text{Weight of 10 cobs' grains}}{\text{Weight of unshelled cobs}} \times 100$$

### 3.7.3 Days to 50 tasseling

Counting of tassels commenced with obserbance of one stand carrying tassel. Counting continued until half of the plot maize carried tassels.

Days from commencement of counting to the day half of the plot bore tassels were calculated and recorded.

### 3.7.4 Days to 50% silking

As explained above only silk bearing stands were counted.

### 3.7.5 STATISTICAL ANALYSIS

Analysis of variance was done to test for treatment effects for each of the observed parameters. Significance of mean differences was tested using the Duncan's Multiple Range Test (DMRT).

### 3.8.0 Trial II

### 3.8.1 Effect of foliar applied urea on maize

### 3.8.2 Location

Location and land preparation were as explained in unit 3.1 and 3.2 above.

The trial was laid side by side with trial one. This was done to avoid fertilizer drift from one block to the other especially this time the N will be spray applied to the crops.

### 3.8.3 Treatment

Five levels of urea concentrations were used. Randomized complete block (RCB) design was used. The N levels were:

0% N $ha^{-1}$ (F) Control

1% N $ha^{-1}$ (22.86kg N $ha^{-1}$ in 2286 liters of water) (G)

2% N ha (45.71 " " " " " " ) (H)

3% " " (68.57 " " " " " " ) (H)

4% " " (91.43) " " " " " " ) (H)

There were three sprays for each treatment. Quantity of urea needed for each concentration was calculated as follows:

For 1% N $ha^{-1}$

Area of plot was 5.25 x 5.0 = $26.25m^2$

Volume/Plot/Spray was 2 liters

First fertilizer spray was at 3 WAE with subsequent ones at two weeks intervals. Total number of sprays was three.

0.46g N is contained in 1g area (46%N).

$$1g.N \text{ will be in } \frac{1 \, x \, 1}{0.46} - 2.1739g. \, area$$

2.174g. Urea (1g.N) m 100mls of water gives 1%N

In 6 liters there will be $\dfrac{6 \times 0.002174\text{kg Urea}}{0.1 \text{ litre } H_2O}$

= 0.13044kg Urea in 6 liters gives 1% N/26.25$m^2$ plot

Urea needed for 1 ha (10,000$m^2$) is:

$$\frac{0.13044 \times 10{,}000}{26.25}$$

= 49.6914 Kg Urea $ha^{-1}$

Volume of water needed $ha^{-1}$ will then be:

$$\frac{49.6914}{0.13044} \times 6 \text{ liters}$$

= 2285.7 liters of water

49.6914 kg Urea in 2285.7 liters of water is 1% N $ha^{-1}$. Concentration increases while the volume of water needed remains constant, then the different quantity of urea per concentration would be:

a) 0% N $ha^{-1}$ control (F)

b) 1% N $ha^{-1}$ (G) 49.69kg urea $ha^{-1}$ in 2285.7 liters of water

c) 2% " (H) 99.38 " " " " " " "

d) 3% " (J) 149.07 " " " " " " "

e) 4% " (J) 198.76 " " " " " " "

### 3.8.4 Method

The trial two was a replica of trial one, however, N fertilization was achieved through spraying. Problems of insect pests encountered in establishing the crops were controlled as earlier stated in the trial one.

The first spray was at 4 WAE using knapsack sprayer at the rate of 0, 1, 2, 3, and 4% N $ha^{-1}$. Subsequent sprays were at 6 and 8 WAE. There were a total of three sprays altogether. Sprays were carried out in the mornings between 8.30 - 10.30 a.m. local time. Adequate care was taken to greatly minimize drift within plots and to the adjacent experiment one block. This was achieved by low spraying, not spraying on windy days and not in the direction of the wind. During spraying the nozzle of the sprayer was always lowered and directed to the foliage as much as practicable to attain even sprays on the foliage. Stalks were not drenched to avoid urea sprays reaching the soil.

### 3.8.5 Measurements and Observation

The same parameters and observations as in experiment I applies here.

These two trials were repeated under irrigation condition.

### 3.8.6 Experiment II (Dry Season Trials, 1998).

There were two trials carried out as in rainy season.

All other things in carrying out the two trials in 1998 were replicas of the 1997 rainy season trials.

Major differences were in source of water, its application to the crops and weather conditions. Fertilizers SSP and MOP were applied evenly in the grooves made by the sides of the ridges and covered. Likewise the split applied urea which was spot applied on the sides of the ridges near the stands. This was to get the fertilizers dissolved by the irrigation water in the furrows.

The trial fields were sown with the same maize (TZESR-W) variety on the 2nd Jan. 1998.

The following weather data were used:

i) Minimum and maximum temperatures
ii) Relative Humidity (RH)
iii) Sunshine
iv) Wind speed.

Table 1: Weather data during the two growing seasons.

| MONTH | 1997 Rainy Season | | | | | 1998 Irrigation Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mint° | Maxt° | %RH | mm Rainfall | $Kmdy^{-1}$ Wind | Minto | Maxto | %RH | mm Rainfall | $Kmdy^{-1}$ Wind |
| Jan | | | | | | 13.5 | 30.0 | 17.2 | 113 | 0.00 |
| Feb | | | | | | 17.3 | 33.0 | 12.1 | 109.9 | 0.00 |
| Mar | | | | | | 20.2 | 34.0 | 11.4 | 122.0 | 0.00 |
| Apr | | | | | | | | | | |
| May | | | | | | | | | | |
| Jun | 20.5 | 30.1 | 79.6 | 155.2 | 111.75 | | | | | |
| Jul | 19.9 | 28.8 | 84.5 | 213.8 | 118.75 | | | | | |
| Aug | 19.9 | 28.8 | 83.4 | 290.2 | 77.11 | | | | | |
| Sept | 19.9 | 29.8 | 80.8 | 182.6 | 63.71 | | | | | |
| Oct | 20 | 31.2 | 79.6 | 82.4 | 56.26 | | | | | |
| Nov | 14.8 | 32.9 | 43.3 | 0.00 | 52.59 | | | | | |

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

## 4.1 PHYSICOCHEMICAL PROPERTIES OF THE SOILS OF THE TRIAL SITES

Physicochemical characteristics of the trial sites before cropping are shown in Table 2.

### 4.1.1 Particle Size Distribution

The soils are light textured with low clay contents which varied from 200 to 300 $gKg^{-1}$ (Table 2) for rainfed trial site and 120 to 140 $gKg^{-1}$ for the irrigated site. The silt contents of the sites also varied between 380 $gKg^{-1}$ to 460 $gKg^{-1}$ and 440 $gKg^{-1}$ to 460 $gKg^{-1}$, sand varied from 320 - 340 $gKg^{-1}$ and 400 - 440 $gKg^{-1}$.

The particles size fraction indicates that soils are generally loam. These data fit in within the recommended textural classes for the growth of cereals (Jones and Wild, 1975).

Soil texture has a direct relationship with nutrients retention, drainage, aeration, water holding capacity and water supply to the crops in soils. The texture of these soils are desirable for adequate root growth and development.

### 4.1.2 Soil reaction (pH)

Two sites used for the trials I and II of experiment one have pH in water of 5.3 and 5.7 respectively. In salt solution (0.01M.$CaCl_2.2H_2O$) pH values of the sites were 4.8 and 5.00 in order mentioned above.

For experiment two pH of trial one and two in water were 5.8 and 6.00 respectively and 4.9 and 5.4 in salt solution for trial I and II respectively.

The soil test values showed that the soils have pH (in water) values which fall in the slightly acid range (Table 2).

Table 2: Physico-chemical characteristics of soils of the trial sites

| SOIL PROPERTY | SITE | | | | |
|---|---|---|---|---|---|
| | | RAINY SEASON | | IRRIGATED | |
| SOIL PROPERTY | UNIT | FOLIAR | SOIL | FOLIAR | SOIL |
| Clay | (g/Kg) | 300 | 200 | 140 | 120 |
| Silt | " | 380 | 460 | 460 | 440 |
| Sand | " | 320 | 340 | 400 | 440 |
| Textural class | | LOAM | LOAM | LOAM | LOAM |
| pH(1:2.5 W/V;H20) | | 5.7 | 5.3 | 6.0 | 5.8 |
| pH(1:2.5W/V; 0.01M CaCl2) | | 5.0 | 4.8 | 5.4 | 4.9 |
| Organic carbon | (g/Kg) | 4.9 | 4.9 | 4.1 | 4.15 |
| Total N | " | 1.05 | 0.70 | 0.53 | 0.70 |
| Bray-1 Available Phosphorus | (mg/Kg) | 4.48 | 3.58 | 4.14 | 3.80 |
| Exchangeable Ca | (cmol/kg) | 1.30 | 1.00 | 1.75 | 1.81 |
| Exchangeable Mg | " | 0.68 | 0.63 | 0.72 | 0.65 |
| Exchangeble Na | " | 0.17 | 0.16 | 0.05 | 0.06 |
| Exchangeable K | " | 0.20 | 0.19 | 0.18 | 0.18 |
| Cation Exchange Capacity (CEC) | " | 2.55 | 2.10 | 2.84 | 2.86 |

### 4.1.3 Organic Carbon

Organic carbon contents in the soils fell in the low to medium class for both 1997 and 1998 trial fields. The values were 4.90 $gKg^{-1}$ for 1997 fields and 4.13 $gKg^{-1}$

for the 1998 fields (Table 2), respectively. Samaru soils are generally low in organic carbon. (Jones and Wild, 1975).

The low levels of organic carbon in the soils may not be unconnected to bush burning and very low litter addition to the soil (Jones, 1973). Fast oxidation of organic matter, termites activities also reduce soil organic matter. To attain sustainable crop production, adequate fertilization of crops to increase biomass production is necessary. Addition of farm manure, compost and green manure to the land will also ameliorate the organic carbon content of the soils.

### 4.1.4 Exchangeable Cations

Exchangeable cations of soils of sites for experiment one (rainfed) trials I and II were: $Ca^{2+}$ was 1.00 and 1.300 cmole $Kg^{-1}$ respectively and 1.81 and 1.75 cmole $Kg^{-1}$ for the dry season trials I and II respectively. Magnesium ($mg^{2+}$) was 0.63 and 0.68 comle $Kg^{-1}$ for sites for rainfed trials I and II and 0.65 and 0.7 for the two irrigated sites. Sodium ($Na^{+}$) was 0.16 and 0.17 cmole $Kg^{-1}$ for farm used for rainfed trials I and II and 0.06 and 0.05 cmole $Kg^{-1}$ for sites for dry season trials. Potassium (K+) was 0.19 and 0.20 cmole $Kg^{-1}$ for experiment I trials and 0.18 cmole $Kg^{-1}$ for the trial I and II sites of irrigated sites.

### 4.1.5 Exchangeable acidity

This is generally low with a mean of 0.2 Cmole $Kg^{-1}$ for 1997 trial fields and 0.062 Cmole $Kg^{-1}$ for the 1998 fields (Table 2). $Al^{3+}$ and $H^{+}$ ions being a measure of exchangeable acidity which if it is low showed that there are low amounts of $Al^{3+}$ and $H^{+}$ ions. Therefore, there is no threat from Al toxicity in the soils.

### 4.1.6 Available Phosphorus (P)

Phosphorus was low. The values varied from 3.35 - 4.48 $mgKg^{-1}$ and 3.80 - 4.14 $mgKg^{-1}$ for 1997 and 1998 sites respectively.

Jones et al, (1975) indicated low available P in the soil of the Nigerian Savanna which may be due to fixation by hydrous oxides of iron (Fe) and aluminum (Al), (Brandy, 1974, Kowal and Kassam, 1978). Bad management also affects soil P.

Therefore, the soils need to be fertilized with P fertilizer to sustain plant growth and economic yields.

### 4.1.7 Total nitrogen (N)

Nitrogen was low in both fields used for the two trials in the two seasons. Mean N values were 0.985 $gKg^{-1}$ and 0.0615 $gKg^{-1}$ for the 1997 and 1998 seasons respectively (Table 2).

The problem of N deficiency in Savanna soils are due to general low values of organic matter. (Jones and Wild, 1975).

The differences in N content are attributed to rainfall and dry matter contents of the Savanna soils. Inorganic fertilizer other than legumes has to be applied for crop production in this region. Crop rotation involving legumes will help to improve the low levels of N in Savanna soils.

## 4.2 Effects of Nitrogen on determined parameters.

### 4.2.1 Effect of N rates on the morphological appearance of maize plant.

Applied N influenced the vegetative growth of maize irrespective of the method of application. In the rainy season effect of N on sprayed maize with 0, 1% N $ha^{-1}$ showed yellow leaves a sign of lack of N while 1 to 4% N concentration scorched maize foliage. The scorch commenced mainly from the leaf tips running along the margin and towards the midrib as observed by Gooding (1990). But patches of scorched areas could be seen on the leaf surfaces. The scorched areas regained chlorophyll but at decreasing rate with increased N concentration and age of the maize crops. At 8 WAE maize sprayed with 4% failed to regain the chlorophyll while 3% N concentration sprayed maize partially regained chlorophyll.

Those sprayed with 1 and 2% N concentration fully regained chlorophyll. The partial and non-regained chlorophyll maize have decreased leaf area and number of stomata for light interception and carbon dioxide ($CO_2$) absorption which reduced their stover and grain yields.

Soil fertilized maize were more luxuriant with thicker stalks than those foliarly fertilized. In the two trials, controls, 1% N concentration and 40kg $Nha^{-1}$ fertilized maize showed yellow appearance due to inadequate N supply. This decreased the chlorophyll content of the maize hence the yields.

The effect of N. on the morphology of maize during the dry season trials were similar to those of rainfed trials explained above.

### 4.2.2 Effect of N rate on maize plant height (Rainfed)

Nitrogen effect on maize height was not significant at five weeks after emergence (WAE). It was significant at 7 WAE at 5%. From 9 to 13 WAE, the effect was highly significant (P = 0.01). The tallest plant (270.10cm) was recorded at 13 WAE in the 4% N $ha^{-1}$ treatment. From 9 to 13 WAE, maize height increased with increased N concentration (Table 3).

With soil applied N trial (Table 3), effect of N on maize height was significant at 5 WAE and not significant from 7 to 13 WAE. There were slight not significant increases in heights with increased N rates to 120 $KgNha^{-1}$.

Significant effect on maize height by N was due to N enhancement of vegetative growth of maize. This was in agreement with those results obtained by Gagro (1978) in Yugoslavia and Mohammed et al, (1978) in Somalia who found significant increase in height with increase N rates.

### 4.2.3 Effect of N rates on maize height (Dry season)

Effect of foliar applied N on irrigated maize height from 5 to 13 WAE was statistically not significant at P/0.05 (Table 4).

Results obtained with soil fertilization decreased maize height 5 to 7 WAE (Table 4).

Rainfed trials performed better than the irrigated trials because of the differences in weather conditions and means of water applications have not been adequate because irrigation schedule could not be effectively followed.

Table 3: Effect of foliar applied N on maize performance under rainfed condition (1997)

| N rate | Performance Parameter: Maize height (cm) | | | | |
|---|---|---|---|---|---|
| | | Foliar | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $F_o$ | 73.30 | 124.7$^{b}$ | 182.8$^{b}$ | 241.5$^{c}$ | 244.8$^{b}$ |
| $F_1$ · | 77.20 | 137.4$^{ab}$ | 199.1$^{b}$ | 253.3$^{bc}$ | 254.3$^{ab}$ |
| $F_2$ | 67.80 | 130.7$^{b}$ | 202.5$^{ab}$ | 268.0$^{ab}$ | 269.6$^{a}$ |
| $F_3$ | 73.2 | 131.8$^{b}$ | 209.1$^{ab}$ | 265.6$^{ab}$ | 266.8$^{a}$ |
| $F_4$ | 75.0 | 145.3$^{a}$ | 219.0$^{a}$ | 274.0$^{a}$ | 270.1$^{a}$ |
| F ratio | NS | * | ** | ** | ** |
| SE $\pm$ | - | 8.54 | 12.67 | 10.55 | 10.45 |
| % CV | - | 6.4 | 6.3 | 4.1 | 4.0 |
| LSD | - | 13.16 | 19.52 | 16.26 | 16.10 |
| | | Soil | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $S_o$ | 73.98$^{a}$ | 139.5 | 213.3 | 250.1 | 259.0 |
| $S_{40}$ | 68.75$^{ab}$ | 135.9 | 212.9 | 244.8 | 271.0 |
| $S_{80}$ | 68.95$^{ab}$ | 138.8 | 216.9 | 249.0 | 263.2 |
| $S_{120}$ | 65.18$^{b}$ | 130.4 | 219.5 | 260.9 | 270.1 |
| $S_{160}$ | 72.50$^{a}$ | 139.1 | 226.3 | 253.3 | 269.3 |
| F ratio | * | NS | NS | NS | NS |
| SE $\pm$ | 3.664 | - | - | - | - |
| % CV | 5.2 | - | - | - | - |
| LSD | 5.65 | - | - | - | - |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

TABLE 4: Effect of foliar applied N on maize performance under irrigation (1998).

| N rate | Performance Parameter: Maize height (cm) | | | | |
|---|---|---|---|---|---|
| | | Foliar | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $F_o$ | 74.9 | 86.3 | 124.2 | 141.2 | 141.9 |
| $F_1$ | 69.8 | 82.2 | 124.6 | 148.0 | 150.2 |
| $F_2$ | 77.5 | 91.8 | 133.7 | 153.7 | 155.3 |
| $F_3$ | 70.4 | 83.2 | 128.7 | 143.6 | 153.5 |
| $F_4$ | 71.7 | 84.6 | 135.2 | 155.8 | 158.8 |
| | | Soil | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $S_o$ | 57.7 | 71.9 | 95.2 | 127.1 | 138.7 |
| $S_{40}$ | 56.6 | 69.5 | 94.2 | 145.4 | 153.5 |
| $S_{80}$ | 52.9 | 65.4 | 113.6 | 149.9 | 158.5 |
| $S_{120}$ | 56.5 | 70.4 | 116.7 | 147.3 | 159.2 |
| $S_{160}$ | 47.8 | 61.1 | 102.8 | 140.9 | 150.0 |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

### 4.2.4 Effect of N rates on maize stalk girth (Rainfed)

Nitrogen effect on the girth of maize stalks foliarly fertilized with urea was highly significant at 5 to 9 WAE but not significant at 11 and 13 WAE (Table 5).

Although the N effect on the girth was significant at 5 - 9 WAE, the trend was the same from 5 - 13 WAE. as N rates increased.

As N rates increased from 0 - 1% N $ha^{-1}$ there was increase in girth from 5 - 9 WAE then, decreased at 11 WAE. Girth remained constant at 13 WAE. Further increase in N concentration from 2% to 3% $Nha^{-1}$ decreased girth from 5 - 9 WAE but increased at 11 WAE with 2% N $ha^{-1}$ concentration and decreased at 3% $Nha^{-1}$. The pattern was the same at 13 WAE. With the 4% $Nha^{-1}$ concentration, girth increased from 5 - 13 WAE.

The effect of N on the maize girth at 5 - 7 WAE was significant at 5% level of probability with soil fertilized maize (Table 5). From 9 - 13 WAE the effect was not significant. Lack of response of girth to N application may be due to the fertility level of the experimental soil.

### 4.2.5 Effect of N on maize girth (Dry season).

Nitrogen fertilization has no significant effect on maize girth (Table 6).

The differences between the rainfed and irrigated trials were due to environmental factors such as low temperature, high wind and low relative humidity.

Table 5: Effect of foliar applied N on maize performance under rainfed condition (1997)

| N rate | Performance Parameter: Maize height (cm) | | | | |
|---|---|---|---|---|---|
| | | Foliar | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $F_0$ | $1.250^{c}$ | $1.725^{b}$ | $2.225^{b}$ | 2.650 | 2.650 |
| $F_1$ | $1.600^{a}$ | $2.425^{a}$ | $3.375^{a}$ | 2.600 | 2.650 |
| $F_2$ | $1.550^{b}$ | $2.375^{a}$ | $3.300^{a}$ | 2.775 | 2.800 |
| $F_3$ | $1.550^{b}$ | $2.325^{a}$ | $3.275^{a}$ | 2.650 | 2.600 |
| $F_4$ | $1.600^{a}$ | $2.400^{a}$ | $3.350^{a}$ | 2.775 | 2.800 |
| F ratio | ** | ** | ** | NS | NS |
| SE ± | 0.0447 | 0.0949 | 0.0890 | - | - |
| % CV | 3.0 | 4.2 | 2.9 | - | - |
| LSD | 0.07 | 0.15 | 0.16 | - | - |
| | | Soil | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $S_0$ | $1.725^{a}$ | $2.575^{ab}$ | 2.825 | 3.025 | 3.025 |
| $S_{40}$ | $1.575^{b}$ | $2.650^{a}$ | 2.950 | 3.075 | 3.225 |
| $S_{80}$ | $1.575^{b}$ | $2.475^{b}$ | 2.800 | 3.025 | 3.175 |
| $S_{120}$ | $1.575^{b}$ | $2.425^{b}$ | 2.800 | 3.300 | 3.175 |
| $S_{160}$ | $1.700^{a}$ | $2.675^{a}$ | 3.000 | 3.225 | 3.375 |
| F ratio | * | * | NS | NS | NS |
| SE ± | 0.0876 | 0.1197 | - | - | - |
| % CV | 5.4 | 4.7 | - | - | - |
| LSD | 0.13 | 1.18 | - | - | - |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

Table 6: Effect of foliar applied N on maize performance under rainfed condition (1997)

| N rate | Performance Parameter: Maize height (cm) | | | | |
|---|---|---|---|---|---|
| | | Foliar | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $F_o$ | 1.600 | 2.225 | 2.150 | 1.980 | 1.975 |
| $F_1$ | 1.575 | 2.150 | 2.250 | 2.025 | 2.025 |
| $F_2$ | 1.550 | 2.225 | 2.275 | 2.075 | 2.125 |
| $F_3$ | 1.475 | 2.175 | 2.275 | 2.050 | 2.075 |
| $F_4$ | 1.525 | 2.150 | 2.400 | 2.100 | 2.150 |
| | | Soil | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $S_o$ | 1.450 | 2.000 | 2.125 | $1.925^{b}$ | $2.025^{b}$ |
| $S_{40}$ | 1.375 | 1.925 | 2.125 | $2.175^{ab}$ | $2.250^{ab}$ |
| $S_{80}$ | 1.325 | 1.850 | 2.300 | $2.225^{a}$ | $2.300^{a}$ |
| $S_{120}$ | 1.325 | 1.900 | 2.400 | $2.400^{a}$ | $2.425^{a}$ |
| $S_{160}$ | 1.225 | 1.775 | 2.225 | $2.225^{aa}$ | $2.300^{a}$ |
| F ratio | NS | NS | NS | * | * |
| SE ± | - | - | - | 0.1889 | 0.1686 |
| % CV | - | - | - | 8.6 | 7.5 |
| LSD | - | - | - | 0.26 | 0.23 |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

### 4.2.6 Effect of N rates on number of leaves per maize plant (Rainfed)

In the foliar trial, N effect on the number of leaves was not significant between 5 - 9 WAE and 13 WAE but significant at 11 WAE (Table 7). The trend was leaf increased up to 9 WAE and decreased with age due to senescence. At 11 WAE the trend was clear and the number of leaves increased with increased N concentration from 0 to 4% $Nha^{-1}$.

The N effect on the number of leaves per maize was significant at P/0.05 at 9 to 13 WAE and not significant (P/0.05) at 5 to 7 WAE. Number of leaves decreased with increased N rates to 160 $KgNha^{-1}$ at 5 WAE. There was slight increase in the number of leaves though statistically not significant at 7 WAE. From 9 to 13 WAE number of leaves per stand increased with incremental N to 160 $KgNha^{-1}$ (Table 7).

### 4.2.7 Effect of N on number of leaves per plant.

Leaf count is usually regarded as an index of the amount of vegetative growth before flowering (Epstein, 1972).

Increase in leaves as N rates increased showed that N is important for vegetative growth in maize crop. Green leaves are the sites of photosynthesis in plant. Photosynthesis play a major role in growth determination of growth indices which affect dry matter and fruit yields (Zelitch, 1971; Epstein, 1972).

Although there were slight increases in the number of leaves, the effect was not significant (Table 8).

Similar results were obtained with soil fertilized maize (Table 8).

The difference between the rainfed and irrigated maize number of leaves/plant between rainfed and the irrigated maize was due to factors such as inadequate moisture to dissolve the fertilizers applied in the irrigated trials. The levelling of the trial sites may not be properly done hence there was no gradual and smooth water flow to all parts of the fields. These have adversely affected the maize growth and development while high winds and dust prevented adequate absorption of sprayed fertilizer and carbon dioxide which was not in good concentration.

Table 7: Effect of foliar applied N on number of leaves/maize plant under rainfed condition (1997)

| N rate | Performance Parameter: Maize height (cm) | | | | |
|---|---|---|---|---|---|
| | | Foliar | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $F_o$ | 8.50 | 9.00 | 12.25 | $9.25^b$ | 7.75 |
| $F_1$ | 9.00 | 9.25 | 12.75 | $10.25^a$ | 8.25 |
| $F_2$ | 8.25 | 9.25 | 12.50 | $9.75^a$ | 8.50 |
| $F_3$ | 8.75 | 9.00 | 13.00 | $10.50^a$ | 8.50 |
| $F_4$ | 8.50 | 9.50 | 13.25 | $10.50^a$ | 9.00 |
| F ratio | NS | NS | NS | ** | NS |
| SE ± | - | - | - | 0.524 | - |
| % CV | - | - | - | - | - |
| LSD | - | - | - | 0.81 | - |
| | | Soil | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $S_o$ | 8.50 | 9.75 | $13.00^b$ | $11.25^b$ | $9.00^b$ |
| $S_{40}$ | 8.25 | 9.75 | $13.00^b$ | $11.00^b$ | $9.00^b$ |
| $S_{80}$ | 7.75 | 9.75 | $12.75^b$ | $11.25^b$ | $9.50^b$ |
| $S_{120}$ | 8.00 | 9.50 | $13.75^a$ | $12.75^a$ | $11.25^a$ |
| $S_{160}$ | 8.00 | $10.00^a$ | $14.00^a$ | $13.00^a$ | $11.25^a$ |
| F ratio | NS | NS | * | * | * |
| SE ± | - | - | 0.585 | 0.935 | - |
| % CV | - | - | 4.4 | 7.9 | - |
| LSD | - | - | 0.9 | 1.44 | - |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

Table 8: Effect of foliar applied N on number of leaves per maize plant under rainfed condition (1997)

| N rate | Performance Parameter: Maize height (cm) | | | | |
|---|---|---|---|---|---|
| | | Foliar | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| OF | 7.50 | 9.75 | 10.00 | 7.25 | 7.75 |
| $F_1$ | 6.75 | 9.50 | 11.25 | 7.25 | 8.00 |
| $F_2$ | 7.00 | 9.50 | 11.25 | 7.50 | 8.25 |
| $F_3$ | 6.75 | 9.50 | 11.25 | 8.50 | 8.50 |
| $F_4$ | 7.50 | 9.50 | 11.50 | 7.75 | 8.00 |
| | | Soil | | | |
| | 5WAE | 7 | 9 | 11 | 13 |
| $S_0$ | 7.00 | 9.50 | 10.50 | 8.75 | 8.75 |
| $S_{40}$ | 6.75 | 9.00 | 10.50 | 9.50 | 9.00 |
| $S_{80}$ | 7.00 | 9.50 | 11.25 | 9.75 | 9.50 |
| $S_{120}$ | 7.25 | 9.75 | 11.00 | 10.00 | 10.00 |
| $S_{160}$ | 6.75 | 8.75 | 10.50 | 9.00 | 9.00 |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

### 4.2.8 Effect of N rates on leaf area (Rainfed)

Effect of N foliarly applied to maize was highly significant (P=0.01) (Fig. 1). Though differences between the means of the treatment were not significant, there were increases in leaf area with increased N concentrations up to 2% $Nha^{-1}$. The highest leaf area was obtained with 2% $Nha^{-1}$ treatment and the least with the control. Though there were decreases in the leaf area from 3 to 4% $Nha^{-1}$ with increased conc. the increases were not significant.

The leaf area of soil fertilized maize responded positively to N rates. The leaf area increased with increased N rates from 0 to $120KgNha^{-1}$. The leaf area decreased with 160 $kg^{-1}$ though not significant.

### 4.2.9 Effect of N on leaf area (Dry season).

The trend was the same under irrigated trial. The higher the leaf area the better chances for light interception which goes to increase photosynthesis hence more photosynthates for better grain and dry matter yields (Fig. 1).

### 4.2.10 Effect of N rates on shelling percentage (Rainfed)

Shelling percentage of the maize cobs from foliar fertilized trials was not significantly affected by the sprayed urea N at P=0.05 (Table 9). There was no clear trend of the N effect on the shelling percentage with increased N concentration. However, there was an increased of 0.7% from 0 - 1% N $ha^{-1}$ concentration and a decrease of 1.9% from 0 - 2% N concentration.

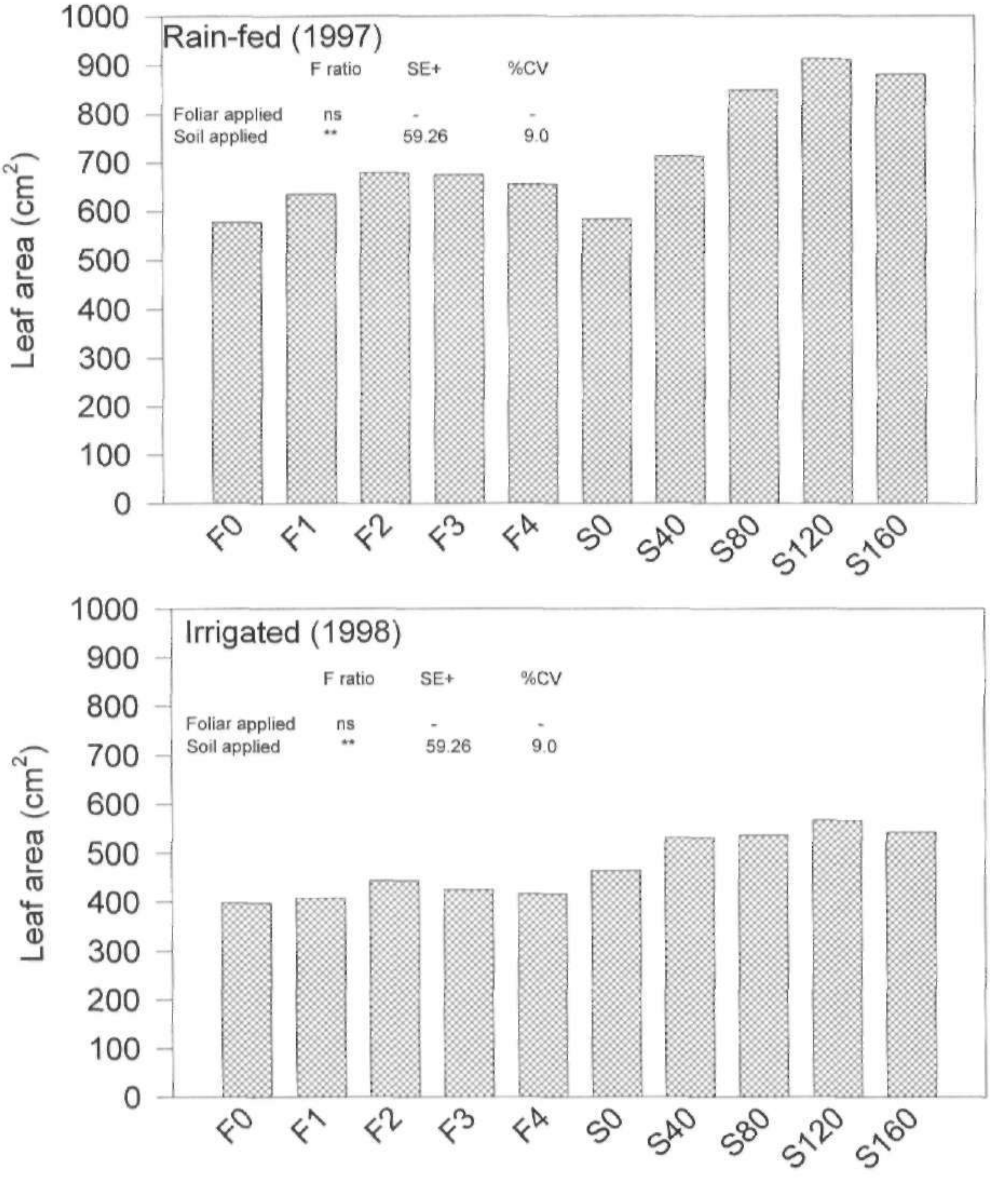



Fig.1: Effect of nitrogen rate and method of application on leaf area of maize under rain-fed and irrigated conditions

Effect of soil applied on shelling percentage was not significant (P=0.05) but slightly increased with increased N level from 0 - 120 KgN $ha^{-1}$. It increased by 4.3%. With further N increment to 160 $KgNha^{-1}$, shelling percentage increased by only 3.4%.

Diferences in response observed by different workers on the effect of soil applied N to the crops on shelling percentage of maize may not be unconnected to the method of determination, location, date of planting, cultivar sown and cultural practices (Harrocks and Zuber, 1970).

Effect of N on shelling percentage in irrigated trials were not different from those of rainfed trials (Table 10).

### 4.2.11 Effect of N rates on days to 50% tasseling and silking (Rainfed)

Number of days to 50% tasseling and silking was highly significantly affected by the foliar application of urea. (Table 9).

The number of days to 50% tasselling decreased with increased N concentration. Same result was obtained with number of days to 50% silking. Number of days to 50% tasseling decreased by 6 to 8 days, while days to silking decreased by 9.8 days (table 9).

The number of days to 50% tasseling and silking was not significant with soil application (Table 9). Control to 80 $KgNha^{-1}$ the days to 50% tasseling increased with N increment by 2 days and decreased by about 3 days at $160KgNha^{-1}$. Thus, a well fertilized maize attained 50% tasseling and silking (Table 9), earlier than less fertilized. This agreed with the finding of Rathore et al. (1976) who observed decreases in number of days to 50% tasseling and silking when N rates increased from 0 to 240 $KgNha^{-1}$. Shurma (1973) also reported increase in N rates from 0 to 150 $KgNha^{-1}$ decreased the days to 50% silking.

### 4.2.12 Effect of N on 50% tasseling and silking (Dry season).

This was similar to rainfed trials explained above (Table 10).

### 4.2.13 Effect of N on number of ears/plant (Rainfed)

Number of ears/plant was not significantly affected by foliar application (Table 9). Similarly with the soil applied N, the effect on the numbers of ears/maize was not significant. The non significant effect of N on the number of ears/plant was probably due to cultivar effect, which had the potential of producing only one ear per plant.

### 4.2.14 Effect of N levels on number of ears per maize plant (Dry season).

The N effect on both foliar and soil applied N is not statistically significant (P=0.05). This indicated that N had no effect on the number of ears and appeared to be the genetics characteristics of the maize variety used.

Same results were obtained with the soil N fertilized maize due to reason stated earlier (Table 10).

Table 9: Effect of foliar applied N on maize performance under rainfed condition (1997)

| N rate | Performance Parameter: Maize height (cm) | | | |
|---|---|---|---|---|
| | | Foliar | | |
| | No. of Ears per plant. | Shelling percentage | Days to 50% tasseling | Days to 50% silking |
| $F_o$. | 0.88 | 80.8 | 62.5[a] | 68.3[a] |
| $F_1$ | 0.95 | 81.4 | 61.3[a] | 66.3[a] |
| $F_2$ | 0.98 | 79.2 | 60.3[a] | 63.3[a] |
| $F_3$ | 0.98 | 79.3 | 54.5[b] | 58.5[b] |
| $F_4$ | 0.93 | 81.8 | 56.5[b] | 58.5[b] |
| F ratio | NS | NS | ** | ** |
| SE ± | - | - | 3.0 | 3.7 |
| % CV | - | - | 5.0 | 59 |
| LSD | - | - | 4.59 | 8.49 |
| | | Soil | | |
| | No. of Ears per plant | Shelling percentage | Days to 50% tasseling | Days to 50% silking |
| $S_o$ | 1.025 | 9.75 | 58.50 | 69.00 |
| $S_{40}$ | 1.000 | 9.75 | 60.25 | 65.75 |
| $S_{80}$ | 1.050 | 9.75 | 60.50 | 67.50 |
| $S_{120}$ | 1.050 | 9.50 | 58.75 | 65.50 |
| $S_{160}$ | 1.075 | 10.00[a] | 57.75 | 64.25 |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

Table 10: Effect of foliar applied N on maize performance under irrigation condition (1998)

| N rate | Performance Parameter: Maize height (cm) | | | |
|---|---|---|---|---|
| | | Foliar | | |
| | No. of Ears per plant. | Shelling percentage | Days to 50% tasseling | Days to 50% silking |
| $F_o$ | 1.000 | 82.6 | 80.5 | 92.7 |
| $F_1$ | 1.000 | 70.2 | 81.7 | 97.5 |
| $F_2$ | 1.000 | 71.2 | 77.7 | 91.7 |
| $F_3$ | 1.000 | 73.2 | 81.0 | 98.0 |
| $F_4$ | 1.000 | 71.2 | 82.0 | 96.7 |
| | | Soil | | |
| | No. of Ears per plant | Shelling percentage | Days to 50% tasseling | Days to 50% silking |
| $S_o$ | 0.975 | 73.2 | 80.5 | 89.2 |
| $S_{40}$ | 1.000 | 72.2 | 84.0 | 94.0 |
| $S_{80}$ | 1.050 | 79.8 | 85.2 | 93.7 |
| $S_{120}$ | 1.050 | 73.3 | 84.2 | 93.0 |
| $S_{160}$ | 0.975 | 72.5 | 88.2 | 95.5 |

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability.

### 4.2.15 Effect of N rates on 1000 grains weight (Rainfed)

The effect was highly significant (P/0.01) Fig. 2. The weights increased with incremental N rates from 0 to 4% N conc. $ha^{-1}$.

The effect was also highly significant with the soil applied trials and the weights increased with increased N rates from 0 - 120 $KgNha^{-1}$. There was a drop in weight at 160 $KgNha^{-1}$ but not statistically significant.

### 4.2.16 Effect of N levels on 1000 grains weight (Dry season)

The ffect was as earlier stated in 4.2.8 (Table 2) for the foliar trial. There was no clear trend as N conc. increased. Heaviest weight of 245.5g/1000 grains was obtained with 3% N conc. per ha. This was an increase of 0.7% above the control.

With soil applied N, the effect was not significant (Fig. 2). There was increased weight to a maximum of 247.3g/1000 grains with $160KgNha^{-1}$. This was an increase of 11% over the control.

The 1000 grains weights obtained by foliar applied N were better than those obtained from soil applied trials for both seasons works. This cannot be immediately explained.

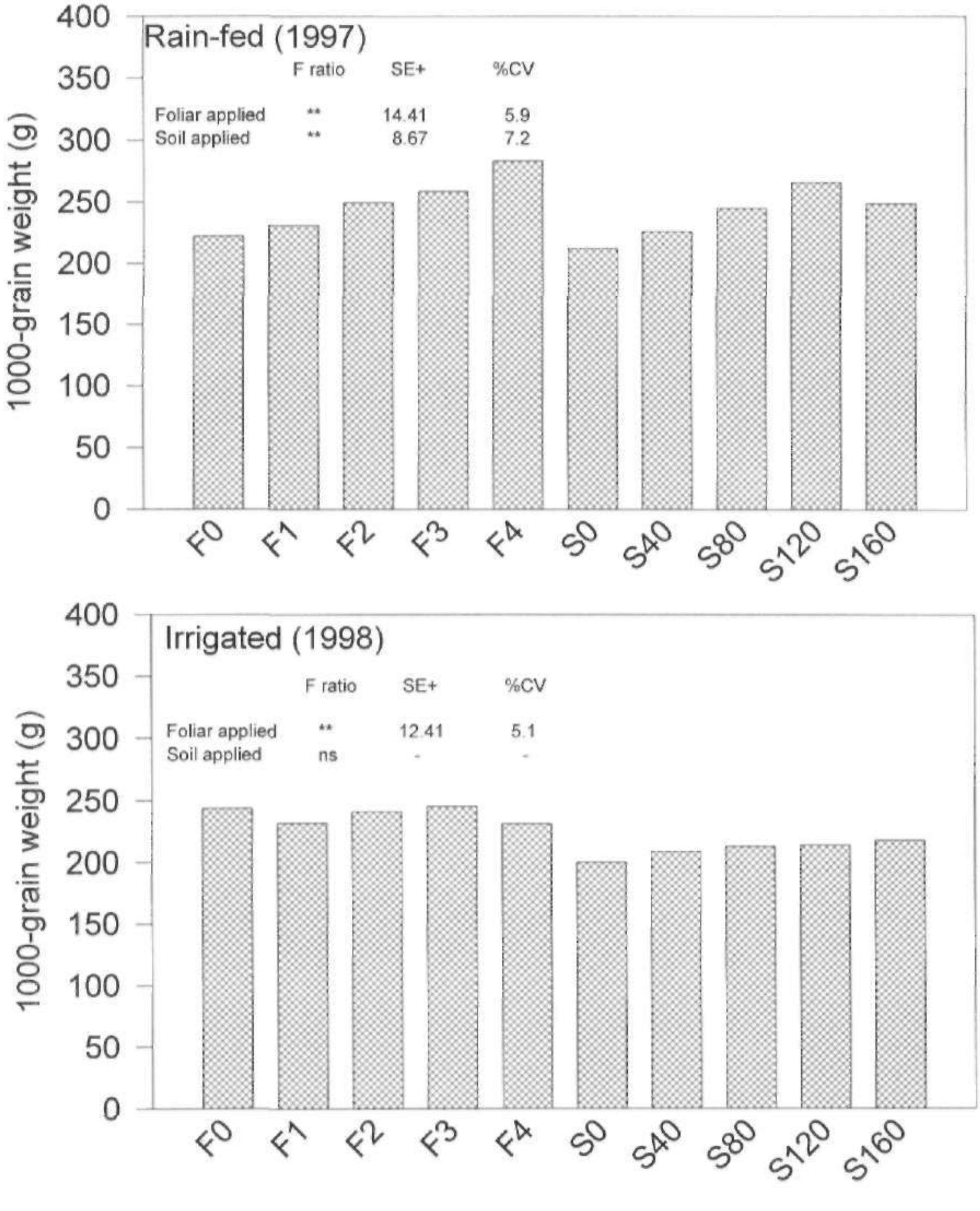



Fig.2: Effect of nitrogen rate and method of application on 1000-grain weight of maize under rain-fed and irrigated conditions

### 4.2.17 Effect of N rates on grains yield.

Nitrogen effect on grain yield was highly significant at 1%. There was increase in yield with increased N concentration. The highest grain yield of 3921 $Kgha^{-1}$ was obtained with 2% $Nha^{-1}$. With the increment of N concentration to 3% through to 4% there were 5 and 7.5% decreases in yields below the highest yield (Fig. 3).

Reduced yield was owing to reduction in leaf area resulting from scorching effect by the higher N concentrations. The scorch might have quicken leaf senescence. Leaf capacity to intercept light and carbon dioxide absorption were greatly hampered. Thus photosynthetic activities reduced.

Nitrogen effect on grain yield with soil applied N was as explained above. The grain yield increased with increased N level from 0 - 120 KgN $ha^{-1}$. The yield decreased with N rate above 120 $KgNha^{-1}$. Highest yield was 54/2$KgHa^{-1}$. with 120 $KgNha^{-1}$ (Fig. 3).

For methods of fertilization N effect on the leaf area was highly significant. The grain yield is usually determined by leaf area among other yield components. The increase in grain yield with increased N rates could be due to the positive effects of N application on leaf area. Balasubramanian et al. (1978) observed increase in grain yield with increase in N up to 120 $KgNha^{-1}$ at Samaru. There was a decrease in yield by increasing N level to 180 $KgNha^{-1}$. Ogunlela (1984) reported that optimum N rate for maize at Mokwa and Omu-Aran is between 100 and 150 $KgNha^{-1}$.

The grain yield from foliar fertilized trial was highly significant (P/0.01). Highest yield of 1197 $Kgha^{-1}$ was obtained with 2% N (Fig. 3).

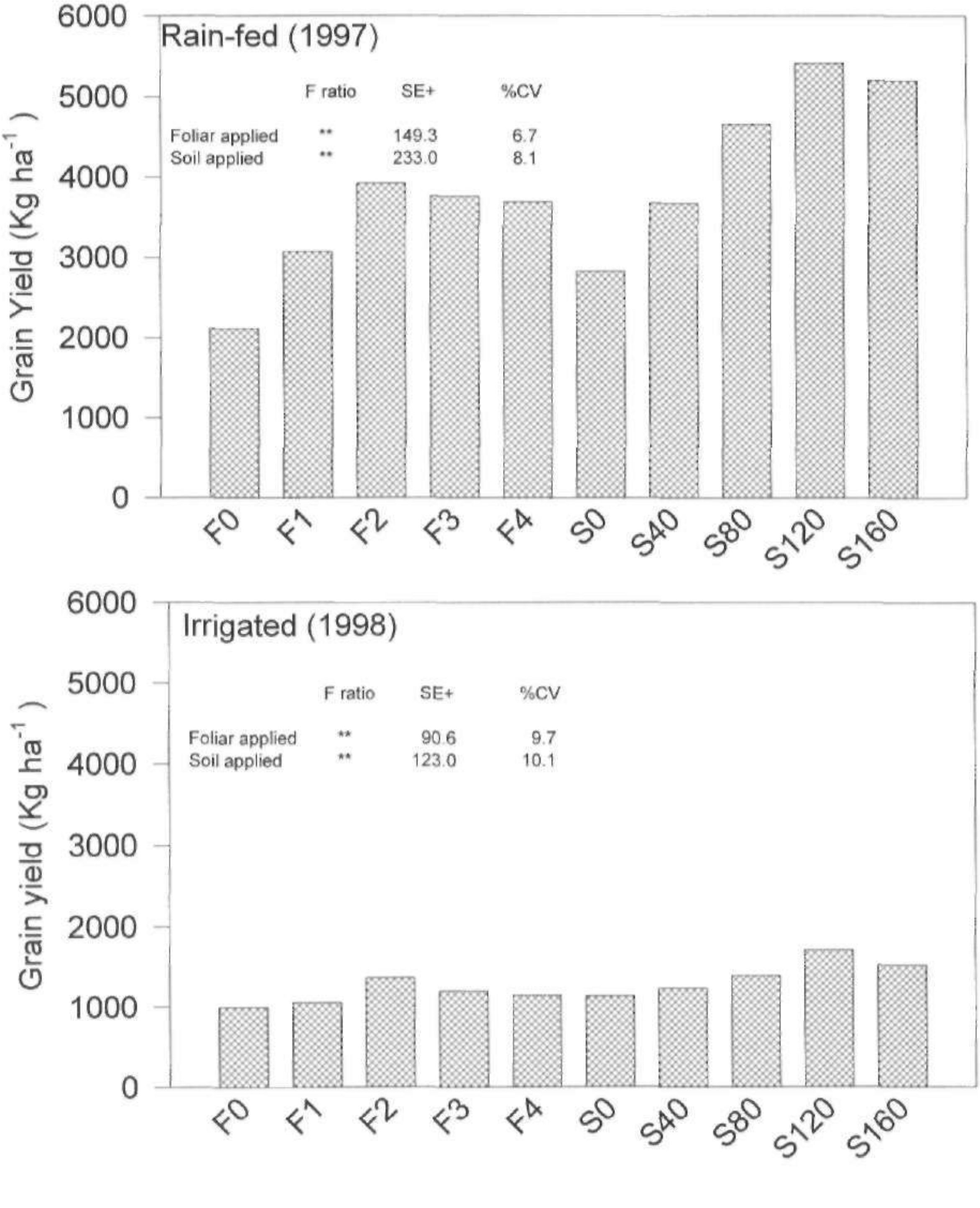



Fig.3: Effect of nitrogen rate and method of application on maize grain yield under rain-fed and irrigated conditions

The yield decreased with further N increment due to scorch effect on the foliage. The 4% N concentration has the highest destruction.

Soil applied N effect was similar to that of foliar described above. Highest yield was 1713 $Kgha^{-1}$ effect on yield was an earlier mentioned (Fig. 3).

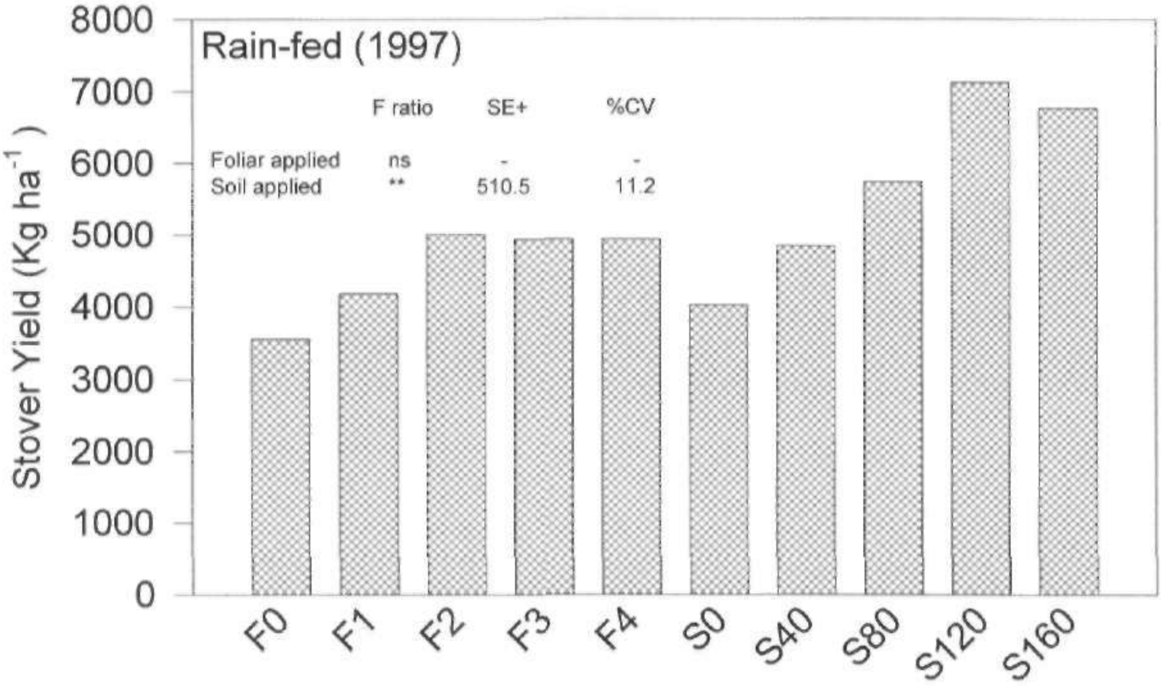
Grain yields from rainfed trials were higher than those from dry season trials. The discrepancy in yields was due to environmental effects. In the dry season, factors such as low temperatures delayed seeds germination and emergence. It took 14 days for the seeds to emerge. The cold weather hampered maize growth. The irrigation water was also very cold owing to low temperature and water supply schedule not kept due to pump problems.

The weather was windy and dusty. The wind has average monthly speed of 114.6$kmdy^{-1}$ which prevented carbon oxide ($Co_2$) concentration around the trial fields. This affected $Co_2$ uptake for photosynthesis. The winds also increasesd the rate of transpiration as the monthly average relative humidity was 13.6%.

The foliage of the maize were covered with dust which decreased urea absorption because the stomata were covered with the dust.

### 4.2.18 Effect of N rates on stover yield (Rainfed)

Stover yield due to foliar application was not significant (P/0.05) (Fig. 4). There was, though not significant, increase in stover yield with increase N concentration from to 2% $Nha^{-1}$ and decreased with application of higher concentrations 3 arid 4%.



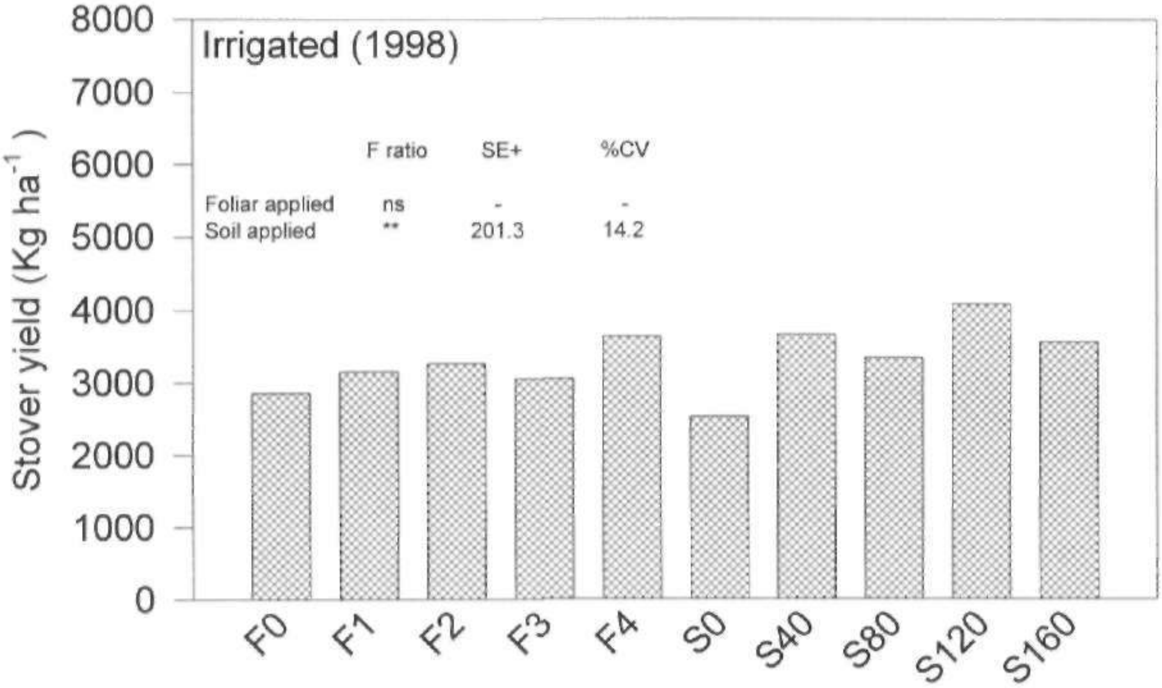




Fig. 4: Effect of nitrogen rate and method of application method on maize stover yield under rain-fed and irrigated conditions

The decreased stover yield was due to destruction of some of the stover components mostly the foliage due to scorch.

Soil applied urea significantly affected maize stover yield. The yield increased with increased N rates from 0 to 120 $KgNha^{-1}$ and decreased with further increase of N level to 160 $KgNha^{-1}$.

Jones (1973) and Hamissa et al. (1979) independently observed increase in dry matter yield in response to increase N fertilization. Alson et al, (1964) found significant increase in stover yield with increased N application.

### 4.2.19 Effect of N rates on stover yield (Dry season)

The effect of foliar applied N on stover was as of foliar effect explained for rainfed foliar trial (Fig. IV).

With the soil applied N, the effect was highly significant (P/0.01) (Fig. IV). With increased N to 160 $KgNha^{-1}$ stover yield decreased.

Stover yield from rainfed trials were higher than those from dry season trials because of the reasons already advanced in the grains yield (Section 4.4.0).

### 4.3.0 Effect of N rate on uptake of N, P and K in maize grain and stover for the two season trials.

### 4.3.1 Effect of N rates on uptake of N in maize grain and stover for the two seasons.

Foliar applied N effect on the uptake of N is highly significant (P/0.01) in grains for both season and methods of fertilization (Fig. 5).

Uptake of N in the stover is also highly significant in the rainfed trial fertilized by foliar application, but not significant in irrigated trials.

With the soil applied fertilization method, N. uptake is significant (P/0.05) in the rainfed season and highly significant with soil applied method. (Fig. 5).

### 4.3.2 Effect of N rates on phosphorus (P.) uptake in maize grain and stover for the two seasons

Phosphorus uptake in the grains in significant (P/0.05) in both seasons and methods of fertilization (Fig. 6).

In the stover, P uptake is highly significant (P/0.01) with rainfed trials and both fertilization methods. But with irrigated trials P. uptake is significant (P/0.05) regardless of fertilization method (Fig. 6).

### 4.3.3 Effect of N rates on potassium (K) uptake in maize grain and stover for the two seasons

In the grain N uptake is highly significant (P/0.01) in both seasons and fertilizer application method (Fig. 7).

Uptake of K in the stover for the rainfed foliar fertilized trial is highly significant and only significant (P/0.05) with soil applied N trial. With the dry season trials, K uptake is significant with foliar fertilization but highly significant with soil applied fertilization (Fig. 7).

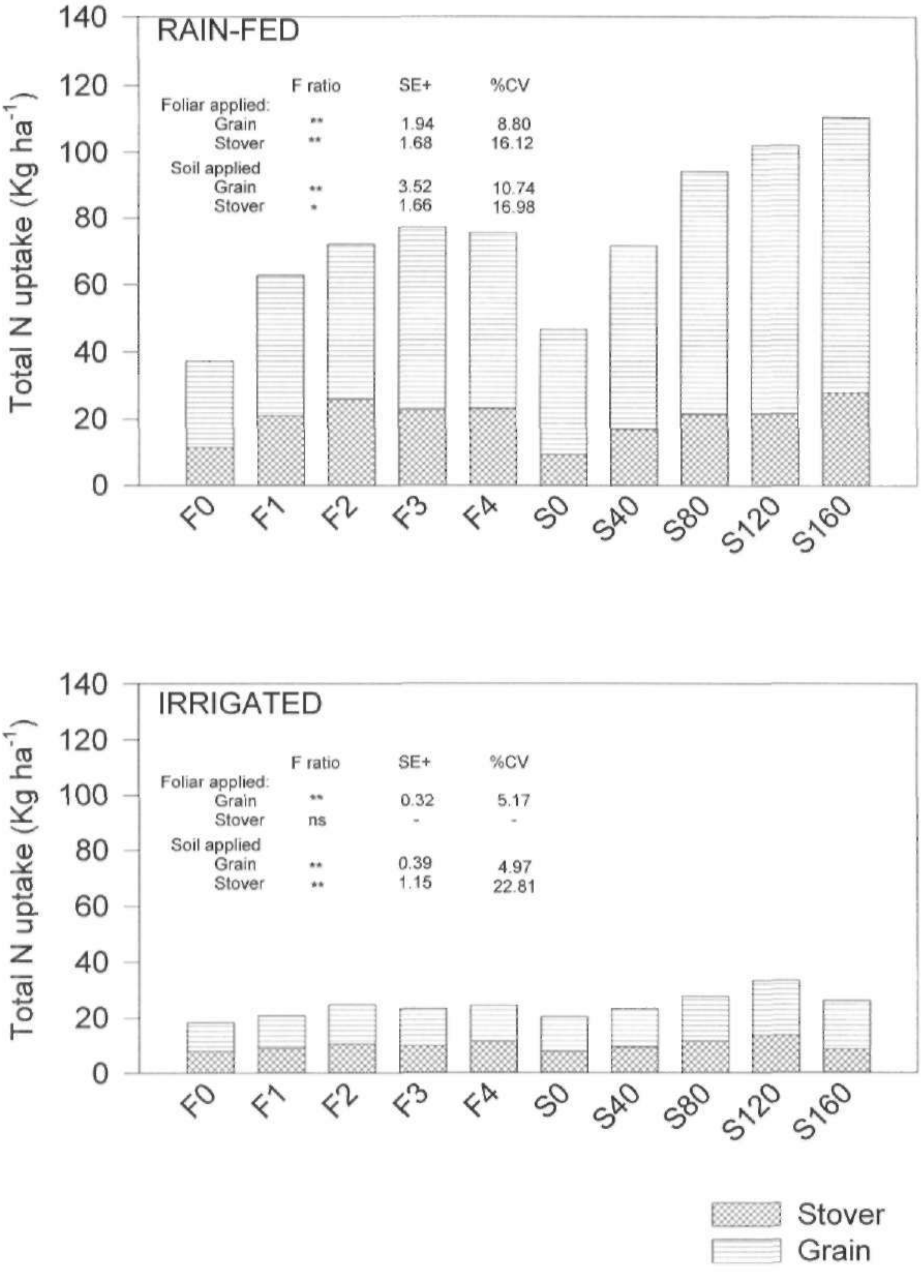



Fig. 5: Effect of nitrogen rate and method of application on total nitrogen uptake by maize under rain-fed and irrigated conditions

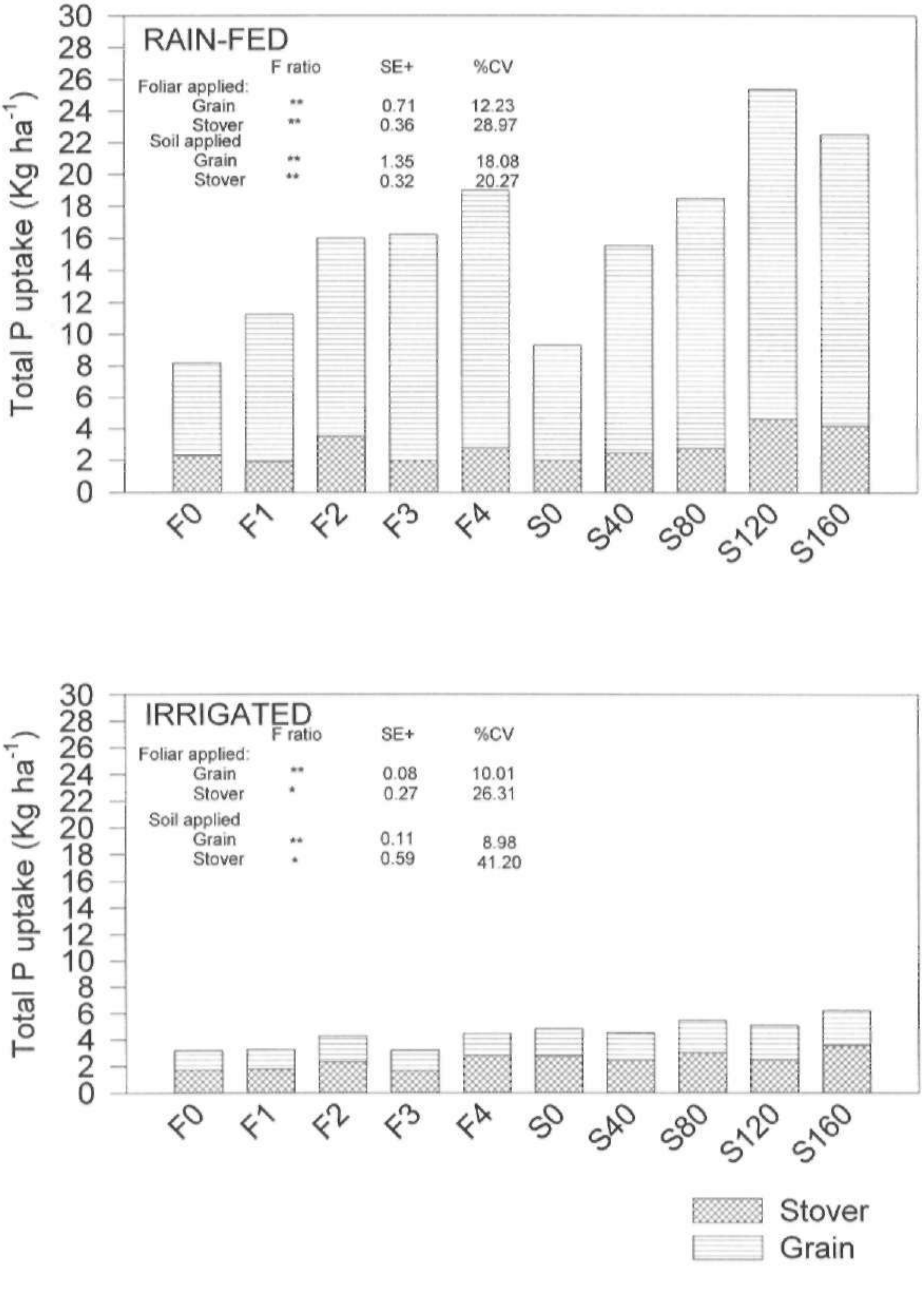



Fig. 6: Effect of nitrogen rate and method of application on total phosphorus uptake by maize under rain-fed and irrigated conditions

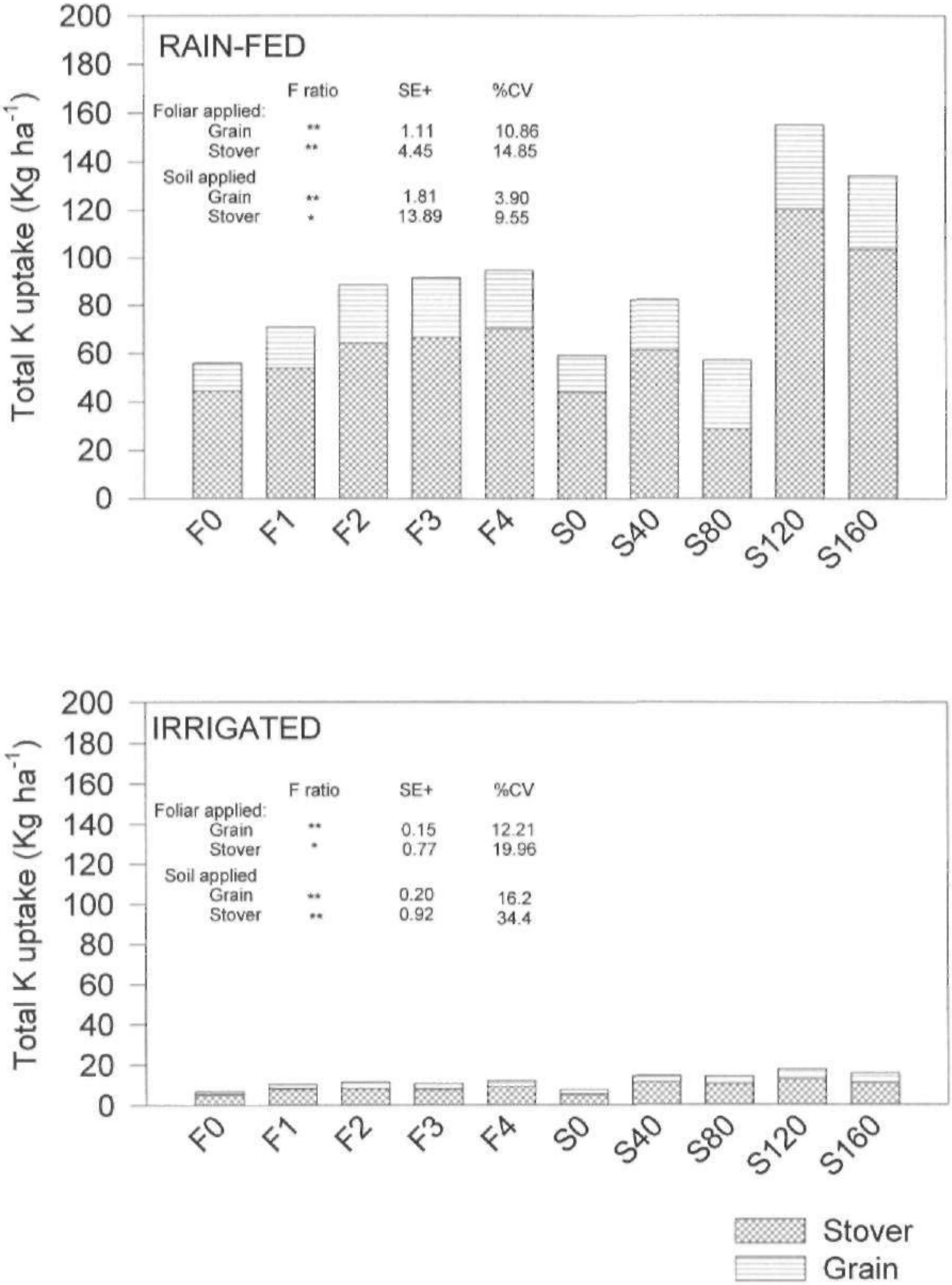



Fig. 7: Effect of nitrogen rate and method of application on total potassium uptake by maize under rain-fed and irrigated conditions

## 4.4.0 ECONOMIC ANALYSIS

Economic analysis of producing one hectare of maize using the via soil and spray methods of fertilization of maize crop was carried out (Table 11). It was clear that producing one hectare of maize under rainfed conditions using the necessary inputs as indicated in the table 11, gave a return of N56,897 by soil fertilization. Maize produced by foliar fertilization the return was N34,170. Therefore it is economical to produce one hectare of maize in the wet season using either method of fertilization. This was so because it was 1,951 $KgNha^{-1}$ of maize that need to be produced to cover the cost of via soil fertilization method was used and 1,824 Kg maize/ha if foliar fertilization method was used.

With the dry season trials, using soil fertilization method a negative return of N5,263.25 was obtained and it was also a loss of N13,539.25 incurred using foliar fertilization.

To recover the cost of producing one hectare of maize using soil fertilization method one need to have produced 1,678 $Kgha^{-1}$ and 1,792 $Kgha^{-1}$ using foliar fertilization method.

It is not economical to produce one hectare of maize using either soil or foliar fertilization method in the dry season based on the information so far obtained.

Table 11: Cost and returns for producing one hectare of maize using foliar and soil methods of N fertilization.

| | Rainfed | | Irrigated | |
|---|---|---|---|---|
| | Soil | Foliar | Soil | Foliar |
| Output (Kg/ha) | 4353 | 3310 | 1399 | 1153 |
| Gross Revenue (₦/ha.)<br>Labour cost (₦/ha.) | 100119 | 76130 | 32173 | 26515 |
| Other costs (₦/ha. | 18280 | 2000 | 16000 | 18000 |
| Seed | | | | |
| Water<br>Fertilizer | 625 | 625 | 625 | 625 |
| SSP | - | - | 1250 | 1250 |
| MOP | | | | |
| Urea | | | | |
| Total Cost (₦/ha.) | 13360 | 13360 | 13360 | 13360 |
| Return (₦/ha.) | 4000 | 4000 | 4000 | 4000 |
| Return/Man.hr (₦/ha.)<br>Yield needed to cover cost (Kg/ha.) | 6957 | 3975 | 6957 | 3975 |
| | 43222 | 41960 | 38592 | 41210 |
| | 56897 | 34170 | -6419 | -14695 |
| | 124.50 | 68.34 | -16.05 | -32.65 |
| | 1951 | 1824 | 1678 | 1792 |

Maize grain valued at ₦23 $kg^{-1}$

Maize seed valued at ₦25 $kg^{-1}$

SSP valued at ₦40 $kg^{-1}$

MOP valued at ₦40 $kg^{-1}$

Urea valued at ₦40 $kg^{-1}$

Labour valued at ₦40 man hour

Water used valued at ₦1250/ha/season (From Hadejia-Jam'are River Basin Development Authority, Kano, 1997).

# CHAPTER FIVE

## 5.0 SUMMARY AND CONCLUSION

In the two seasons trials carried out in 1997 and 1998 under rainfed and irrigation conditions respectively, at the Institute for Agricultural Research Experimental Farm, Samaru, it was observed that morphologically, soil urea fertilized maize showed higher N response than foliar urea fertilized maize because the former was visually greener than the latter.

Maize supplied with urea via the soil produced higher leaf area in both seasons than foliar treated maize. This led to higher grain and stover yields, higher 1000 grains weight.

It was observed that 2% N concentration $ha^{-1}$ was the optimum while 3 and 4% N concentrations $ha^{-1}$ were toxic in foliar application while 120 KgN $ha^{-1}$ was the optimum under soil applied N.

Nutrient uptake was improved with increased N rates for both methods.

Economic analysis of producing one hectare of maize from each method of fertilization, has shown that it pays more to produce maize via using the conventional method of soil application.

Information so obtained from this work is not adequate to advise farmers to adopt the technology. More work needs to be done on foliar technology to ascertain the best N concentration devoid of scorching crops foliage, increased yield to match or to exceed that of soil fertilization.

Possible areas for further work includes more spray frequency, appropriate time for spraying, crop growth stage at which application of N spray can be of greatest benefit to the crops

The use of ultra low volume (ULV) sprayers instead of using coarse knapsack sprayer should be seriously considered. The use of Ultra Low volume (ULV) will eliminate the use of water which is needed in large quantity. ULV will give very good coverage of the leaves since the fertilizer solution will be atomized and come out as fine mist unto the foliage.

The surfactant need to be studied. Good surfactant will allow the fertilizer solution remains on the surface of leaves for better absorption.

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