

**GROWTH AND YIELD RESPONSE OF MAIZE (*Zea mays* L.)
TO DIFFERENT LEVELS OF NITROGEN AND PHOSPHORUS IN HANDENI
DISTRICT, TANZANIA**



KWELI SAID

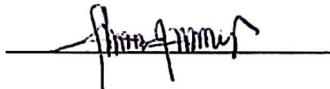
**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP
SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE,
MOROGORO. TANZANIA.**

ABSTRACT

The effects of sixteen levels of Nitrogen and Phosphorous fertilizers on growth and yield of maize (*Zea mays* L.) in Handeni District, Tanga Tanzania were studied between October 2012 and February 2013. The overall objective was to determine optimum rate of Nitrogen and Phosphorous recommendations for increased growth and productivity of maize in the district. The experiment was designed as split plot laid out in Randomized Complete Block Design (RCBD) with three replications and 16 treatments. Two maize varieties TMV1 and TAN250 were used; Nitrogen and Phosphorous fertilizers used in the experiment were Urea and TSP, respectively. Data collection started two weeks after treatments had been imposed in which grain yield components were recorded as follows; plant height, number of leaves, stem girth, leaf area, ear length, ear girth, number of grains per ear, weight of grains per ear, weight of grain per plot, weight of 100 grains and grain yield per ha. Cost of fertilizers per hectare and price of 1 tone of maize grain were determined. The data were analysed using analysis of variance (ANOVA) technique using GenStat statistical package. The treatment means were separated using the Duncan Multiple Range Test (DMRT) at 5% level of probability. The results showed that the application of 100 kgN/ha+40 kgP/ha significantly increased growth and yield of maize. These results also confirmed that, application of 80 kgN/ha + 40 kgP/ha can bring about an increase in growth and yield of maize but this will greatly benefit farmers in areas where the costs of Nitrogen and Phosphorus fertilizer is high. The experimental results revealed that application rate of 40 kgP/ha+100 kgN/ha would give the highest economic returns. These rates are recommended for growth and yield increases with better economical returns on maize production in Handeni District, Tanzania.

DECLARATION

I, Kweli Said, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.



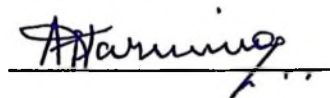
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Lastly, to those whom I cannot mention by names but in one way or another contributed to the success of this work, I convey my sincere thanks and appreciation to them.

DEDICATION

I dedicate this work to the ALMIGHTY GOD for keeping me healthier and strong enough to accomplish this study. Without forgetting my parents Mr. Said Hassan Mbelenje and Mrs. Zabibu Mbelenje for their full support towards my academic achievement.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ATP	Adenosine Triphosphate
Ca	Calcium
CEC	Cation Exchange Capacity
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
DMRT	Duncan Multiple Range Test
DNA	Deoxy-ribo nucleic acid
FAO	Food and Agriculture Organization of the United Nations
F-Prob	f- probability
FSD	Food Security Department
Ha	Hectare
K	Potassium
m.a.s.l	Meters above sea level
Mg	Magnesium
MRR	Marginal Rate of Return
N	Nitrogen
N ₂	Nitrogen gas
Na	Sodium
P	Phosphorus
pH	Negative Logarithm Of Hydrogen Ion Concentration
RCBD	Randomized Completely Block Design
SUA	Sokoine University of Agriculture
TAN250	Maize Variety
TMV1	Tanzania Maize Variety one

T-Prob	t-probability
Tsh	Tanzania Shillings
VCR	Value Cost Ratio
WAP	Weeks after Planting

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Maize (*Zea mays* L.) is the major cereal consumed in Tanzania. It is estimated that the annual per capita consumption of maize in Tanzania is 112.5 kg; national maize consumption is estimated to be three million tons per year. Maize contributes 60% of dietary calories to Tanzanian consumers (FSD, 1996). The cereal also contributes more than 50% of utilizable protein, while beans contribute 38% (Kamprath *et al.*, 1982).

Maize is grown in all the 30 regions of the mainland Tanzania. The crop is cultivated on an average of two million hectares equivalent to 45% of the cultivated area in Tanzania. However, most of the maize is produced in the Southern Highlands (46%), the Lake Zone, and the Northern Zone. Dar es Salaam, Lindi, Singida, Coast, Tanga and Mtwara are deficit regions (FSD, 1996). Maize is not only a staple crop in surplus regions; it is also a cash crop. For instance, in the Lake Zone, maize competes aggressively with cotton for land, labour, and farmers' cash. Realizing the importance of the maize crop to lives of Tanzanians, the government has been committing human and financial resources to develop the industry (FSD, 1996). Research and extension efforts in maize started in 1960s (Ashifaq *et al.*, 2004). In spite of the increase in area under maize cultivation, yield is still low due to declining soil fertility and insufficient use of fertilizers, which result in severe nutrients depletion of the soils (Nxumalo, 1993).

Maize requires adequate supply of nutrients particularly Nitrogen, Phosphorus and Potassium for good growth and high yield. Nitrogen and Phosphorus are very essential for good vegetative growth and grain development in maize production.

The quantity required for these nutrients, particularly Nitrogen, depends on the pre-clearing vegetation, organic matter content, tillage method and light intensity (Ashifaq *et al.*, 2004).

Plants are surrounded by the Nitrogen (N) in the atmosphere. Every ha of the earth's surface is covered by thousands of metric tonnes of this essential nutrient, but because atmospheric gaseous nitrogen is present as almost inert Nitrogen (N₂) molecules, this nitrogen is not directly available to the plants that need it for growth, develop and reproduction. Despite Nitrogen being the most abundant element in atmosphere, its deficiency is probably the most common nutritional problem affecting maize worldwide. Healthy maize plants often contain 3-4% Nitrogen in their aboveground tissues (Kamprath *et al.*, 1982). These are much higher concentrations than those of any other nutrient except carbon, hydrogen and oxygen.

Nitrogen is an important component of many important structural, genetic and metabolic compounds in plant cells (Stoskopf, 1995). It is a major component of chlorophyll, the compound by which plants use sunlight to produce sugars from water and carbon dioxide through the process called photosynthesis. According to Stoskopf (1995), it is also a major component of amino acids, the building blocks of proteins. Some proteins act as structural units in plant cells while others act as enzymes, making possible many of the biochemical reactions on which life is based (Stoskopf, 1995). Nitrogen is a component of energy-transfer compounds, such as ATP Adenosine Triphosphate (ATP), which allows cells to conserve and use the energy released in metabolism (Stoskopf, 1995). Also, Nitrogen is a significant component of nucleic acids such as DNA, the genetic material that allows cells (and eventually whole plants) to grow and reproduce. Nitrogen plays the same role in animals. Without nitrogen, there would be no life (Stoskopf, 1995).

Crop removal represents a loss of Nitrogen because it is part of the harvested portions of the crop or plant which is removed from the field completely. The Nitrogen in crop residues is recycled back into the system and is better thought of as immobilized rather than removed. Much of Nitrogen is eventually mineralized and may be reutilized by a crop (Bundy *et al.*, 1988). Plants absorb nitrogen from the soil as both NH_4^+ and NO_3^- ions, but because nitrification is so pervasive in agricultural soils, most of the nitrogen is taken up as nitrate. Nitrate moves freely toward plant roots as they absorb water. Once inside the plant NO_3^- is reduced to an NH_2 form and is assimilated to produce more complex compounds (Kamprath *et al.*, 1982). Because plants require very large quantities of nitrogen, an extensive root system is essential to allowing unrestricted uptake. Plants with roots restricted by compaction may show signs of nitrogen deficiency even when adequate nitrogen is present in the soil (Ashifaq *et al.*, 2004).

Phosphorus plays an important part in many physiological processes that occur within a developing and maturing plant. It is involved in enzymatic reactions in the plant. Phosphorus is essential for cell division because it is constituent element of nucleoproteins which are involved in the cell reproduction processes (Buresh *et al.*, 2005). It is also a component essential to the reactions of carbohydrates synthesis and degradation. It hastens the ripening of the fruits thus counteracting the effects of excess Nitrogen application to the soil. It helps to strengthen skeletal structure of the plant thereby preventing lodging (Nxumalo, 1993). However, the requirements and utilization of these nutrients (Nitrogen and Phosphorus) of maize depends on different factors including rainfall, varieties, soils etc. The response of maize plant to application of nitrogen and phosphorus fertilizers varies from variety to variety, location to location and also depends on the availability of the nutrients in the soil of particular area (Haque *et al.*, 2001).

1.2 Problem Statement

Low soil fertility has been identified as the major constraint in maize production in Handeni District. The problem is intensified by in-sufficient use of fertilizers, non-use of improved crop varieties, unpredictable weather conditions, use of poor agronomic practices such as wide or narrow plant spacing, weed management, and pest and disease control (Mangushi and Mathayo, 2006). The demand for food is increasing following population growth in this area, which necessitates increase in maize production.

1.3 Justification

The present agronomic practices practiced in Handeni District need to be improved to come up with options that will overcome the problems of crop growth and insufficient use of fertilizers (Mangushi and Mathayo, 2006). This will help to alleviate food insecurity and poverty in affected populations. Handeni District is comprised of a number of smallholder farmers situated in various small villages. Currently most of the small holder farmers in the area are not applying fertilizers in their farms, but even those few who are applying at the recommended rate of 23 kgN/ha and 10 kgP/ha (Mangushi and Mathayo, 2006) are still getting low yields. It is likely that the present fertilizer recommendations are no longer valid; thus, the new fertilizer recommendations which will be obtained in this study will be useful contribution which may lead to improved maize production and productivity.

1.4 Objectives

1.4.1 Overall objective

The overall objective of this study is to determine optimum rates of Nitrogen and Phosphorus fertilizers for increased growth and productivity of maize in Handeni District.

1.4.2 Specific objectives

- i. To evaluate growth and yield response of maize to varying rates of Nitrogen and Phosphorus; and,
- ii. To determine the economical application rates of Nitrogen and Phosphorus in maize fields.

CHAPTER TWO

2.0 LITERATURE REVIEW

Maize is a plant belonging to the family of grasses (*Poaceae*). It is cultivated globally as one of the most important cereal crops. Maize is not only an important source of food but also is a basic constituent of animal feed and raw material for the manufacture of many industrial products. The products include starch, maltodextrins, oil, syrups and other products of fermentation and distillation industries and recently used as bio fuel (Bundy and Carter, 1988).

Maize is a versatile crop grown over a range of agro climatic zones. In fact the suitability of maize to diverse environments is unmatched to any other crop (Nxumalo, 1993). It is grown from 58°N to 40°S; from below sea level to altitudes higher than 3000 m.a.s.l; and in areas with 250 mm to more than 5000 mm of rainfall per year and with a growing cycle ranging from 3 to 13 months (Nxumalo, 1993).

2.1 Taxonomy

Maize belongs to the tribe Maydeae of the grass family *Poaceae*. “Zea” (zela) was derived from an old Greek name for a food grass. The genus *Zea* consists of four species of which *Zea mays* L. is economically important. The other *Zea* sp., referred to as teosintes, is largely wild grasses native to Mexico and Central America (Nxumalo, 1993).

2.2 Reproductive Biology

2.2.1 Growth and development

Maize is a tall, determinate, monoecious, annual plant. It produces large, narrow, opposite leaves, borne alternatively along the length of stem. All maize varieties follow same general pattern of development, although specific time and interval between stages and

total number of leaves developed may vary between different hybrids, seasons, time of planting and location (Johnson, 1993). The various stages of maize growth are broadly divided into the vegetative and reproductive stages as follows:

2.2.1.1 Vegetative stages

Seedling/Sprouting stage comes about one week after sowing, and at this stage the plants have about 2-4 leaves. Grand growth stage also called knee height stage of plants arrives about 35-45 days after sowing. Tasselling/flowering initiation stage is the stage at which the tassels or male flowers appear. Generally, the maize plant would have attained its full height by this stage (Marschner, 1986).

2.2.1.2 Reproductive stages

Silking stage involving the formation of the female flowers or cobs is the first reproductive stage and occurs 2-3 days after tasselling stage. This stage begins when any silks are visible outside the husk. These are auxiliary flowers unlike tassels that are terminal ones (Marschner, 1986). Pollination occurs when these new moist silks catch the falling pollen grains. Soft-dough/Milky stage commences after pollination and fertilization is over. Grains start developing but they do not become hard (Zia *et al.*, 1991). This soft dough stage is noticed by the silks on the top of the cob which remain partially green at this stage. The covering of the cobs also remains green. Hard-dough/Maturity stage shows that the leaves get dried; silks get dried completely and become very brittle. Harvesting is done at this stage (Stoskopf, 1985).

2.2.2 Floral biology

Maize is a monoecious plant, that is, the sexes are partitioned into separate pistillate (ear), the female flower and staminate (tassel), the male flower. It has determinate growth habit and the shoot terminates into the inflorescences bearing staminate or pistillate flowers

(Haque *et al.*, 2001). The main shoot terminates in a staminate tassel. Maize is generally protandrous, that is, the male flower matures earlier than the female flower. Within each male flower spikelet, there are usually two functional florets, although development of the lower floret may be delayed slightly in comparison to the upper floret (Zig *et al.*, 1991).

Each floret contains a pair of thin scales i.e. lemma and palea, three anthers, two lodicules and rudimentary pistil. Pollen grains per anther have been reported to range from 2000 to 7500 (Zig *et al.*, 1991). Within an average of 7000 anthers per tassel and 2000 grains per anther, each tassel could produce 14×10^6 pollen grains. Bajwa (1991) estimated that 42 500 pollen grains are produced per square inch of cornfield. In terms of the ratio of pollen grains produced per ovules fertilized, it appears that since each ear requires about 1000 pollen grains for fertilization, there are about 20 000 pollen grains per kernel in excess of what is actually needed if pollination were 100% efficient. The pollen grains are very small, barely visible to the naked eye, light in weight, and easily carried by wind. The wind borne nature of the pollen and protandry lead to cross pollination, but there may be about 5% self-pollination (Stoskopf, 1995).

The female flower initially is smooth but protuberances soon form in rows. The basal protuberances are formed first and development advances towards the tip of the ears. The part above the attachment of the carpel develops a single sessile ovule, which consists of a nucleolus with two integuments or rudimentary seed coats (Zig *et al.*, 1991). The united carpel's, which will form the ovary wall or pericarp of the mature kernel, grow upward until they completely enclose the ovule. The anterior carpals, which face the ear tip form outgrowth, will develop into the style i.e. into long thread, known as silks. Silks are covered with numerous hairs, trichomes which form an angle with the silk where pollen grains are harboured. The base of the silk is unique, as it elongates continuously

until fertilization occurs. The cobs bear many rows of ovules that are always even in number (Stoskopf, 1995).

The female inflorescence or ear develops from one or more lateral branches (shanks) usually borne about half-way up the main stalk from axillary shoot buds. As the internodes of the shanks are condensed, the ear remains permanently enclosed in a mantle of many husk leaves. Thus the plant is unable to disperse its seeds in the manner of a wild plant and instead it depends upon human intervention for seed shelling and propagation (Stoskopf, 1985).

2.2.3 Pollination and fertilization

In maize, the pollen shed is not a continuous process and usually begins two to three days prior to silk emergence and continues for five to eight days. The silks are covered with fine, sticky hairs which serve to catch and anchor the pollen grains (Haque *et al.*, 2001). Pollen shed stops when the tassel is too wet or too dry and begins again when temperature conditions are favourable. Under favourable conditions, pollen grain remains viable for only 18 to 24 hours. Cool temperatures and high humidity favour pollen longevity. Under optimal conditions the interval between anthesis and silking is one to two days. Under any stress situation this interval increases (Kala, 1994). Fertilization occurs after the pollen grain is caught by the silk and germinates by growth of the pollen tube down the silk channel within minutes of coming in contact with a silk and the pollen tube grows the length of the silk and enters the embryo sac in 12 to 28 hours (Kala, 1994). Pollen is light and is often carried considerable distances by the wind. However, most of it settles within 6.09 to 15.24 m. Pollen of a given plant rarely fertilizes the silks of the same plant. Under field conditions 97% or more of the kernels produced by each plant are pollinated by other plants in the field. Fertilization of ovules begins about one third of the way up from the base of the ear (Kala, 1994).

2.2.4 Seed dispersal

Seed dispersal of individual kernels naturally does not occur because of the structure of the ears of maize. Maize, as a thoroughly domesticated plant, has lost all ability to disseminate its seeds and relies entirely on the aid of man for its distribution (Stoskopf, 1995). The kernels are tightly held on the cobs. In case ears fall to the ground, so many competing seedlings emerge that the likelihood that any will grow to maturity is extremely low.

2.2.5 Mating systems

Under natural conditions, maize reproduces only by seed production. Pollination occurs with the transfer of pollen from the tassels to the silks of the ear. About 95% of the ovules are cross pollinated and about 5% are self-pollinated (Zahir-ud –Din and Ismail, 1993), although plants are completely self-compatible. There is no asexually reproductive maize. Cell/tissue culture techniques can be used to propagate calli and reproduce tissues or plants asexually; however, with maize cells and tissues these techniques are difficult (Hoisington *et al.*, 1998).

2.2.6 Out crossing and gene flow

Gene flow from maize can occur by two means: pollen transfer and seed dispersal. Seed dispersal can be readily controlled in maize as domestication has all but eliminated any seed dispersal mechanisms that ancestral maize may have previously used (Purseglove, 1972). As mentioned earlier, the kernels are held tightly on the cobs and if the ear falls to the ground, competing seedlings limit growth to maturity (Gould, 1968).

Pollen movement is the only effective means of gene escape from maize plants. As maize is mainly cross pollinated, wind speed and direction affects pollen distribution. Maize pollen measuring about 0.1 mm in diameter and largest pollen among members of the

grass family, has been reported to be disseminated by wind from a comparatively low level of elevation. Further, due to its large size, maize pollen settles at a rate that is approximately 10 times faster than pollen from other wind-pollinated plants (Di-Giovanni *et al.*, 1995). Raynor *et al.* (1972) showed maize pollen is not transported as far by the wind as smaller pollen grain; does not disperse as widely horizontally or vertically; and settles to earth more quickly, much of it within the source itself.

Insects, such as bees, have been observed to collect pollen from maize tassels, but they do not play a significant role in cross-pollination as there is no incentive to visit the female flowers (Raynor *et al.*, 1972). However in the cultivation of commercial maize varieties, differences in flowering dates are small and thus cross-pollination between varieties may occur if grown in adjacent fields. The limited viability of maize pollen reduces the risk of cross-pollination, as a receptive host must be found within the 30 minutes that the pollen remains biologically active (Luna *et al.*, 2001). Cross-pollination is also affected by the concentration of maize pollen released; pollen produced by a maize crop will successfully compete with foreign pollen sources when present in higher concentrations (Raynor *et al.*, 1972).

Gene flow from maize to other species in the same genus (interspecific) and between genera (intergeneric) first requires the formation of a viable intermediate hybrid that is capable of producing fertile progeny that can survive into the next generation (Luna *et al.*, 2001). Assuming sexual compatibility exists, other factors also contribute to the likelihood of hybridization: proximity of the crop and related species to each other; environmental conditions; and overlapping flowering periods. The introgression of genes from maize to other plant species may require several generations of recurrent backcrossing (Kala, 1994).

2.3 Botanical Features

Maize is a tall, determinate annual C₄ plant varying in height from 1 to 4 metres producing large, narrow, opposing leaves (about a tenth as wide as they are long), borne alternately along the length of a solid stem (Zahir-Ud-Din and Ismail, 1993).

The botanical features of various plant parts are as follows:

Root: Normally maize plants have three types of roots, i) seminal roots - which develop from radical and persist for long period, ii) adventitious roots, fibrous roots developing from the lower nodes of stem below ground level which are the effective and active roots of plant and iii) brace or prop roots, produced by lower two nodes. The roots grow very rapidly and almost equally outwards and downwards. Favourable soils may allow maize root growth up to 60 cm laterally and in depth (Zahir-Ud-Din and Ismail, 1993).

Stem: The stem generally attains a thickness of three to four centimetres. The inter nodes are short and fairly thick at the base of the plant; become longer and thicker higher up the stem, and then taper again (Luna *et al.*, 2001). The ear bearing inter node is longitudinally grooved, to allow proper positioning of the ear head (cob). The upper leaves in maize are more responsible for light interception and are major contributors of photosynthates to the grain (Kala, 1994).

Flower: The apex of the stem ends in the tassel, an inflorescence of male flowers and the female inflorescences (cobs or ears) are borne at the apex of condensed, lateral branches known as shanks protruding from leaf axils (Bajwa *et al.*, 1991). The male (staminate) inflorescence, a loose panicle, produces pairs of free spikelets each enclosing a fertile and a sterile floret. The female (pistillate) inflorescence, a spike, produces pairs of spikelets on the surface of a highly condensed rachis (central axis, or "cob"). The female flower is

tightly covered over by several layers of leaves, and so closed in by them to the stem that they don't show themselves easily until emergence of the pale yellow silks from the leaf whorl at the end of the ear (Kala, 1994). The silks are the elongated stigmas that look like tufts of hair initially and later turn green or purple in colour. Each of the female spikelets encloses two fertile florets, one of whose ovaries will mature into a maize kernel once sexually fertilized by wind-blown pollen (Luna *et al.*, 2001).

Grain: The individual maize grain is botanically a caryopsis, a dry fruit containing a single seed fused to the inner tissues of the fruit case. The seed contains two sister structures, a germ which includes then plumule and radical from which a new plant will develop, and an endosperm which will provide nutrients for that germinating seedling until the seedling establishes sufficient leaf area to become autotrophy (Luna *et al.*, 2001). The germ is the source of maize "vegetable oil" (total oil content maize grain is 4% by weight). The endosperm occupies about two thirds of a maize kernel's volume and accounts for approximately 86% of its dry weight (Stoskopf, 1995). The endosperm of maize kernels can be yellow or white. The primary component of endosperm is starch, together with 10% bound protein (gluten), and this stored starch is the basis of the maize kernel's nutritional uses (Luna *et al.*, 2001).

2.4 Development of Maize Research

Studies carried out by Amani (2004); Skarstein (2005); Isinika *et al.* (2003); and Nyange and Wobst (2005), show that maize yield of smallholder farmers is low due to inadequate use of improved agronomic practices. The Poverty and Human Development Report of 1995 (FSD, 1996) showed that 87% of Tanzanian farmers interviewed by the research and analysis group under Tanzania's NSGRP said that they were not using chemical fertilizers; 77% were not using improved seeds; and 72% said that they were not using

pesticides, herbicides or insecticides (agrochemicals), due to high costs of agricultural inputs and services (Amani, 2004).

Before 1966, maize research in Tanzania was conducted at regional centers, each of which was responsible for a geographical area (Jones and Nyambo, 1982), but this system resulted in some duplication of effort. The National Maize Research Programme (NMRP) was established in the Lake Zone at Ukiriguru Research Center in 1966 to coordinate maize research and improve the utilization of research resources. The NMRP coordinates all phases of maize research, from varietal development and crop management research on the experiment station to verification trials in farmers' fields. In 1974, the NMRP was moved to Ilonga Research Center in the Eastern Zone. The NMRP has divided the country into three major agroecological zones for varietal recommendations: 1) the highlands (elevations >1,500 m.a.s.l), with a growing period of 6–8 months; 2) the intermediate (mid-altitude) zone (900–1,500 m.a.s.l), which is further divided into “wet” (>1,100 mm rainfall with a 4–5 month growing period) and “dry” subzones (<1,100 mm rainfall with a 3–4 month growing period); and, 3) the lowlands (0–900 m.a.s.l), with a 3–4 month growing period. The recommendations issued by regional and national research programs are related to improved varieties, optimum sowing dates, the use of fertilizer and/or farmyard manure (FYM), weed control, and disease and insect pest control (Moshi *et al.*, 1990).

Land preparation, planting time and method should start early enough so that planting can be done on time. Good tillage is important, as it allows free movement of water and air, which are vital for maize plant growth, and minimizes weed infestation at the early stages of maize growth (Nkonya, 1994).

The maize plant has a relatively high demand for nutrients, particularly nitrogen (N) and phosphorus (P) (Amani, 2004). These nutrients may be obtained through the application of farmyard manure (FYM) or inorganic fertilizers. Farmyard manure is applied at a rate of 5–10 t/ha by spreading 15 kg of FYM after every five steps or 4–5 m (Moshi *et al.*, 1990). The manure is spread in rows before ridges are made to cover it or is spread on the field before the land is cultivated (Njoroge *et al.*, 1998).

Nitrogen is a major limiting nutrient and is needed in large amounts for increased maize yield. An adequate supply of N is needed throughout the growing season and is one of the most important factors for improved soil management practices (Moshi *et al.*, 1990). In the intermediate and high rainfall areas, where moisture is reliable, the use of N fertilizers results in greater economic returns (Jones and Nyambo, 1982). In medium and low rainfall areas, response to N fertilizers is unreliable or poor (Njoroge *et al.*, 1998).

The recommended rate of N fertilizer is 60 kg N/ha applied as a top dressing (Mowo *et al.*, 1993). According to those authors, nitrogen applications may be split by applying about 50% of the total amount at planting and the remainder just before tasselling. Calcium ammonium nitrate (CAN) or nitrochalk is the preferred type of fertilizer (Mowo *et al.*, 1993). Sulphate of ammonium (SA) is not recommended because it rapidly acidifies the soil. Nitrogen fertilization is not recommended for the heavy mbuga soils (Nkonya *et al.*, 1997).

Phosphorus is also essential for plant growth, as it is involved in the transfer of energy within the plant and has a structural role in a number of compounds. Farmers are presently advised to apply 16 kg P/ha as basal fertilizer. Phosphorus should be applied in a single dose at planting (Njoroge *et al.*, 1998).

Fertilizer is normally placed 5 cm below the depth of the seed and about 5–8 cm to the side. This is accomplished by digging a single hole beside each seed, placing the fertilizer in the hole, and covering it with soil (Nkonya *et al.*, 1997). Alternatively a continuous furrow is made along the length of the planting row. Fertilizer is placed in the furrow and covered with soil. The seed is planted on top of this soil and covered properly (Ahmed *et al.*, 1990).

Weeding time, frequency, and method Weeds seriously affect maize yield and can cause major yield reductions by competing with the maize crop for water, light, and nutrients. Some weeds may also harbor insect pests and diseases that directly infest the plants, also causing yield losses (Nkonya *et al.*, 1997). Two weeding times are recommended for maize production using hand hoes. The first weeding should be done two weeks after germination and the second before tasselling (Mowo *et al.*, 1993). The introduction of the ox-cultivator has reduced the labor requirement for weeding if the crop is sown in rows. For large-scale maize production, the use of herbicide in combination with other cultural practices is an economical method of weeding if labor is a constraint (Asfaw *et al.*, 1997).

Between the years 1961-65 and 1985-95 the rate of growth of maize production in Tanzania was estimated to be 4.6%, of which 2.4% and 2.2% per year were due to increase in area under cultivation and productivity, respectively. Despite this growth in yield, the national average is less than 1.5 t/ha. However, grain yields are moderately higher in high potential areas such as the Southern Highlands (Moshi *et al.*, 1990).

Most maize growing areas in Tanzania are divided into three agro ecological zones: the low altitude zone (less than 900 m.a.s.l); the medium altitude zone (900-1500 m.a.s.l); and the high altitude zone (above 1500 m.a.s.l). Maize production recommendations were

developed to suit those agro ecological zones (Mowo *et al.*, 1993). Different research results have shown that maize cultivars differ markedly in grain yield response to Nitrogen fertilizers (Bundy *et al.*, 1988). Previous research findings indicated that the increase in maize grain yield after Nitrogen application is largely due to an increase in the number of ears per plant, increase in total dry matter distributed to grain and increase in average ear weight (Buresh *et al.*, 2005). Other studies indicated that maize cultivars differ in grain yield response to Nitrogen application (Kamprath *et al.*, 1982). The results of various experiment carried out in Tanzania showed that highbred maize varieties were to require high fertilizer rates for optimum yield. Research reports also indicated that maize responded better in savannah than forest soils. The difference between the two zones was attributed to the presence of higher insulation in the savannah (Ashifaq *et al.*, 2004).

Most plants take up Nitrogen from the soil continuously throughout their life and nitrogen demand usually increases as plant size increases. A plant supplied with adequate Nitrogen grows rapidly and produces large amounts of succulent, green foliage (Mowo *et al.*, 1993). Providing adequate Nitrogen allows an annual crop, such as maize, to grow to full maturity, rather than delaying it. A Nitrogen-deficient plant is generally small and develops slowly because it lacks the Nitrogen necessary to manufacture adequate structural and genetic materials (Mowo *et al.*, 1993). It is usually pale green or yellowish, because it lacks adequate chlorophyll. Older leaves often become necrotic and die as the plant moves Nitrogen from less important older tissues to more important younger ones (Hoisington *et al.*, 1998).

On the other hand, some plants may grow rapidly when supplied with excessive Nitrogen that they develop protoplasm faster than they can build sufficient supporting material in

cell walls. Such plants are often rather weak and may be prone to mechanical injury. Development of weak straw and lodging of small grains is an example of such an effect (Kamprath *et al.*, 1982).

Nitrogen is a vital plant nutrient and major yield determining factor required for maize production (Kamprath *et al.*, 1982). It is very essential for plant growth and makes up 1-4% of dry matter of the plant (Paradkar *et al.*, 1993.) Nitrogen is a component of protein and nucleic acid and when it is sub optimal protein is reduced (Haque *et al.*, 2001). Its availability in sufficient quality throughout the growing season is essential for optimum maize growth. It is also an integral component of many other compounds essential for plant growth processes including chlorophyll and many enzymes. It also mediates the utilization of Phosphorus, Potassium and other elements in plants (Bajwa *et al.*, 1991). The optimal amount of these elements in the soil cannot be utilized efficiently if nitrogen is deficient in plants. Therefore Nitrogen deficiency or excess can result in reduces maize yields (Mowo *et al.*, 1993).

It is impossible to recommend a single level of Nitrogen without considering the variations in locations, soil types and other factors. Thus, researchers have found optimum maize yields at varying levels of Nitrogen, for example, A-kais and Yin (2003) in Islamabad Pakistan found optimum maize yields at 140 to 250kgNha⁻¹. (Bajwa *et al.* (1991) reported that at Nakuru Region in Kenya a split application of 185kgNha⁻¹ was sufficient to achieve maximum maize yield and in most instances 125kgNha⁻¹ was sufficient. Kang (1981) found that in Southern Highlands Tanzania grain yield increased significantly with fertilizer rates of up to 120kgNha⁻¹. Timing of fertilizer N application is an important management tool in this effort (Kamprath *et al.*, 1982).

The total Phosphorus content of most surface soils is low, averaging only 0.6% available Phosphorus. This compares to an average soil content of 0.14% Nitrogen and 0.83% Potassium. Many factors influence the content of soil Phosphorus. Among these are: (1) type of parent material from which the soil is derived; (2) degree of weathering; and (3) climatic conditions. In addition, soil phosphorus levels are affected by erosion, crop removal and Phosphorus application (Haque *et al.*, 2001).

Soil Phosphorus is classified in two broad groups, organic and inorganic. Organic Phosphorus is found in plant residues, manures, and microbial tissues. Soils low in organic matter may contain only 3% of their total phosphorus in the organic form, but high organic matter soils may contain 50% or more of their total Phosphorus content in the organic form (Mangushi and Mathayo, 2006).

Inorganic forms of soil phosphorus consist of apatite (the original source of all Phosphorus), complexes of iron and aluminium Phosphates, and phosphorus absorbed on clay particles. The solubility of these Phosphorus compounds, as well as organic Phosphorus is extremely low and only very small amounts of soil phosphorus are in solution at any one time (Kamprath *et al.*, 1982). Most soils contain less than a 0.5kg per acre of soluble phosphorus, with some soils containing considerably less. Through adequate Phosphorus fertilization and good crop/soil management, soil solution Phosphorus can be replaced rapidly enough for optimum crop production (Haque *et al.*, 2001).

Phosphorus is another essential nutrient required for increasing maize yield. Consequently, the lack of Phosphorus is as important as the lack of Nitrogen in limiting maize performance. Phosphorus is an essential nutrient both as a part of several key plant

structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants (Paradkar *et al.*, 1993). Phosphorus is noted especially for its role in capturing and converting the sun's energy into useful plant compounds. The two examples that follow illustrate how vital phosphorus nutrition is to normal plant development and production. Phosphorus is a vital component of DNA, the genetic "memory unit" of all living things. It is also a component of RNA, the compound that reads the DNA genetic code to build proteins and other compounds essential for plant structure, seed yield, and genetic transfer (Mowo *et al.*, 1993). The structures of both DNA and RNA are linked together by phosphorus bonds. Phosphorus is a vital component of ATP, the "energy unit" of plants. ATP forms during photosynthesis, has phosphorus in its structure, and processes from the beginning of seedling growth through to the formation of grain and maturity (Bajwa *et al.*, 1991).

Thus phosphorus is essential for the general health and vigour of all plants. Some specific growth factors that have been associated with phosphorus are: stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of legumes, improvements in crop quality, and increased resistance to plant diseases. Phosphorus deficiency is more difficult to diagnose than a deficiency of nitrogen or potassium (Hoisington *et al.*, 1998). Crops usually display no obvious symptoms of phosphorus deficiency, other than a general stunting of the plant during early growth, and by the time a visual deficiency is recognized it may be too late to correct in annual crops. Some crops, such as maize, tend to show an abnormal discoloration when phosphorus is deficient. The plants are usually dark bluish-green in colour with leaves and stem becoming purplish (Haque *et al.*, 2001). The degree of purple is influenced by the genetic makeup of the plant, some hybrids showing much greater discoloration than others.

The purplish colour is due to accumulation of sugars which favours the synthesis of anthocyanin (a purplish colored pigment) that occurs in the leaves of the plant (Bajwa *et al.*, 1991).

With regard to P, some earlier studies carried out with phosphorus fertilizers indicated positive response of maize to low rates of the element (Haque *et al.*, 2001). Positive response of maize to low phosphorus application in the Savannah zones of Nigeria has been reported by Adediran and Banjoko (1995). Application by 17.6 kgP/ha appeared to be optimum since at higher rates the yield was depressed. However there was steady increase in grain yield up to 26.4 KgP/ha at Mokwa southern guinea savannah. The yield at this rate was significantly higher than applying 8.8 kgP/ha but not different from 17.6 kgP/ha. Application of higher rate was reported to be capable of causing nutrients imbalance and consequently yield depression of western yellow maize (Haque *et al.*, 2001). Various factors could be responsible for phosphorus availability to crop plant. These includes the form of native soil phosphorus, the type of phosphorus applied to the soil and soil reaction. It has been reported that total phosphorus was higher in forest soils than in Savannah (Kamprath *et al.*, 1982).

It has been reported that maize crop responds very well to variable rates of nitrogen and phosphorus fertilizers and thus increase grain yield and protein content. In an experiment carried out in southern highlands of Tanzania, it was estimated that a crop that produces 5-6 tones/ha will have removed 100-150 kg of nitrogen and 40-60 kg of phosphorus ha⁻¹ from the soil at harvest (Haque *et al.*, 2001). The study showed the increase in plant height and number of grains per ear with increasing nitrogen levels when 50 100, and 150 kgN/ha together with 26.4 kgPha (Singh and Dukey, 1991). Further increase in nitrogen rates decreased plant height and grains per ear. Average grains yield was highest



with 100 kgN+60 kgP ha^{-1} . Maximum yield of about 3.0 t ha^{-1} have been reported in maize when 92 kgN and 40 kgP were applied per ha (Singh and Dukey, 1991).

The first concern of a farmer who wishes to use fertilizer is to determine what type to use and how much to apply. Since he needs to know how much he can expect to gain if he spends money on fertilizer, the primary economic test is an estimation of the increase in crop production and its value that will result from the application of a given quantity of plant nutrient (Mowo *et al.*, 1993). The cost of the fertilizer must be weighed against either the increased value of the crop or even against alternative uses of the money, possibly with a greater potential rate of return. Because of the law of diminishing returns the aim of the farmer should be to use fertilizer at the most profitable or economic optimum rate (Haque *et al.*, 2001).

Since the economics of fertilizer use is a broad subject, only a brief description is given here of the concepts commonly used in measuring the economic returns or benefits from fertilizer. It is essential however, that extension workers and planners of fertilizer use development should have a thorough understanding of what each economic concept means, and under what conditions they apply (Mowo *et al.*, 1993).

Net return

As indicated above the farmer must compare the expected value of the additional yield obtained by the application of fertilizer with the cost of the fertilizer responsible for the added crop production. The farmer estimates the additional value by multiplying the additional amount of crop expected to be harvested by the price they might reasonably expect to receive for his crop (Mowo *et al.*, 1993). The cost of the fertilizer is simply the product of the amount of fertilizer applied to the crop and the unit price paid for the

fertilizer. The difference between the added value of the crop and the cost of fertilizer is known as the net return. In practice, because of the element of risk, a relatively large net return is usually needed to convince farmers to use fertilizers (Hassan *et al.*, 1998).

Marginal analysis show the level of net return from each successive unit of fertilizer applied increases in relation to the cost of the fertilizer. The marginal net return is the increases in net return which can be obtained from a given increment of fertilizer. It depends on the value of the crop response to the increment of fertilizer and the cost of that increment, i.e. the marginal cost of fertilizer (Hassan *et al.*, 1998). The marginal rate of return (MRR) to a given increment of fertilizer is the marginal net return divided by the marginal cost of fertilizer. As a general rule, farmers do not want to use fertilizer beyond the point at which the MRR is at least 40% in one crop season, since at a lower MRR the value of the additional yield might not cover the cost of the additional fertilizer applied. This percentage assumes that there would be very little cost of capital in the form of interest for borrowed money. The economic optimum rate which gives the highest net return however is where the marginal rate of return is nil, i.e. where the value of the last crop yield increment exactly equals the cost of the last increment of fertilizer required to obtain that additional yield (Bundy *et al.*, 1988).

Value-cost ratio

Another commonly used indicator of profitability of fertilizer use is the value-cost ratio (VCR) – the quotient obtained from devising the expected value of the yield increase by the cost of fertilizer applied to bring about the increased yield (Bundy *et al.*, 1988).

It is an average and is calculated as follows:

$$VCR = \left(\frac{\text{Value of the yield increase}}{\text{Cost of fertilizer applied}} \right) \dots\dots\dots(1)$$

If the VCR is more than 1, it means that a profit is to be expected. However, because of the risk element, most farmers in the developing countries would not use fertilizer unless the expected VCR is at least 2. This is equivalent to a 100% return on the cash spent on the fertilizer (Hassan *et al.*, 1998). As a general rule, because of the nature of the typical response curve showing diminishing marginal returns, VCRs are higher on the lower and steeper part of the curve, where the marginal net return is also higher. A farmer should aim for a higher VCR he intends to apply fertilizer at a rate lower than the recommended optimum Bundy *et al.* (1988) explains that, in practice, farmers use less than recommended rates. This is because the amount of fertilizer which farmers will use depends on the anticipated yield response, crop prices expected, fertilizer availability and cost, level of financial resources and credit availability, fertilizer availability and cost, level of financial resources and credit availability, tenure consideration, the degree of risk and uncertainty and the farmer's ability to bear them. At the time the farmer buys his fertilizer, only one of these, the cost of fertilizer, is accurately known (Bundy *et al.*, 1988).

An average number, based on experimental or farm trials, or the farmer's own experience, is used to estimate the probable increases in yield, but the actual response varies with the weather, and in turn affects the cost of harvesting and marketing (Hassan *et al.*, 1998). The price of the crop when it is harvested some months later may also be an estimate, unless a fixed support price is effectively implemented. The price may be substantially reduced on a free market if favourable weather or the widespread use of fertilizers leads to a sharp rise in yields and total output (Singh and Dukey, 1991). A farmer thus has not been cautious and allows what he considers a fair safety margin when deciding how much fertilizer to use on his crops (FSD, 1996).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

The study was conducted at Mgambo National Service Farm located in Handeni District in Tanga Region. The area is located at an altitude of 153 m above sea level, latitude 05° 09'S and longitude 38° 27'E, temperature range is 15°-33°C, and rainfall pattern is bimodal amounting to 800-1200 mm per year.

3.2 Materials Used

Nitrogen fertilizer (urea) and phosphorus fertilizer (TSP) were used with two maize varieties (TMV1 and TAN 250) obtained from local agro-dealers in Korogwe town. These varieties were selected because they are early maturing, high yielding and tolerance to drought. The fertilisers were selected because; urea has high residual N activity, which may last for 4 to 6 weeks thus continued availability for plant growth. On the other hand, TSP has high solubility with high P content and it is rapidly available for plant uptake.

3.3 Soil Analysis

Composite soil samples exhumed to a depth of 20 cm was taken from the experimental site using a soil auger prior to sowing the crop. Soil analysis was carried out at the Soil Science laboratory, Sokoine University of Agriculture. The collected samples were air-dried and ground to pass through 2 mm sieve to remove large particles, debris and stones. The sieved samples were analyzed for Soil organic matter, soil pH in 1:2.5 soil to water ratio using the Coleman's pH meter, was determined using the Wakley and Black procedure (Nelson *et al.*, 1992). Total Nitrogen was determined by the micro Kjeldahl method (Bremner, 1965), available Phosphorus was extracted by Bray's P1 method (Bray and Kurtz, 1945) and soil texture was analyzed by hydrometer method.

3.4 Experimental Design and Treatments

The experiment was a split plot laid out in randomized complete block design (RCBD) with three replications and 16 treatments. The net plot size was 2m x 3m, with a path of 50 cm between the plots and 1m between replications. The total land area was 40 m x 22.5 m = 900 m².

3.5 Crop Husbandry

The seeds were planted in October 28 at a spacing of 75x25 cm. Two seeds were sown per hole and seedlings were thinned seven days after emergence to one plant per hill. The treatments (Phosphorus and Nitrogen fertilizers at different levels) were applied during planting and two weeks after emergence, respectively. All other cultural practices such as three times weeding and plant protection measures were kept at optimum level for the crop in plots.

3.6 Data Collection

Data collection started two weeks after the treatments had been applied. Growth and yield parameters were recorded at different stages of crop growth and development as follows: plant height, number of leaves, stem girth, leaf area, ear length, ear girth, number of grains per ear, weight of grains per ear, weight of grain per plot, weight of 100-grains and grain yield. Grain yield/ha, cost of fertilizers/ha and price of 1 tone of maize grain was determined. These parameters were determined in the following ways:

3.7 Objective 1: To Evaluate Growth and Yield Response of Maize to Varying Rates of Nitrogen and Phosphorus

Data collected

Plant height (cm): This was taken from a sample of six randomly selected maize plants excluding guard rows marked within each plot. A tape measure was used for measuring the height from the ground level to the top-most leaf. The mean from the six maize plants was then determined.

Number of leaves: Visual counting of leaves from the six randomly selected plants excluding guard rows was made and the number was recorded for each plant. The mean value was calculated for each plot.

Stem girth (mm): The girth of the six selected maize plants was measured with a venire calliper for each plot and the value was averaged.

Leaf area (cm²): The leaf area was determined by the non destructive method; length x width (Saxena *et al.*, 1965) using the relation: Leaf area = 0.75 (length x width), where 0.75 is a constant. Six leaves were measured with a tape measure for each plot and the leaf area determined.

Ear length (cm): The length of six dehusked maize ear per plot was measured using a tape measure and the mean value was calculated.

Ear girth (mm): This was also taken from a sample of six ears per plot with the use of venire calliper and the values were recorded and averaged.

Number of grains per ear: The number of grains in six ears from each plot was counted after drying and shelling and was divided by the number of ears to determine the mean.

Weight of grains per ear (g): The grains of the same six ears mentioned above were weighed separately and then averaged for each plot.

Weight of grains per plot (g): The weight of the six ears from each (treatment) plot was added to obtain the weight of grains per plot.

100-grain weight (g): One hundred grains were counted from each plot and weighed.

Grain yield (tone): All cobs including sub- sample were threshed mechanically to estimate grain yield/plot which was then converted into yield per ha.

3.8 Data Analysis

All data were subjected to the analysis of variance (ANOVA) technique using GenStat statistical package. The treatment means were separated using the Duncan Multiple Range Test (DMRT) at 5% level of probability. Mean difference was declared significant at $P < 0.05$.

3.9 Objective 2: To Determine the Economical Application Rates of Nitrogen and Phosphorus in Maize

Data collected

Economic analysis was done using prevailing market prices for inputs at planting and for output at harvesting. Grain yield/ha, cost of fertilizers/ha, cost of production /ha, price of 1 tone of maize grain was collected, and finally calculated by the formula:

$$VCR = \left(\frac{\text{Value of the yield increase}}{\text{Cost of fertilizer applied}} \right) \dots\dots\dots (2)$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

In this study the nutrients, Phosphorus and Nitrogen, were considered as limiting factors to increased growth and yield of maize. The results of two varieties of maize, TMV1 and TAN250 are detailed in the following sections.

4.1 Soil Analysis

The soil pH as determined in 1:2.5 soil: H₂O suspension was 6.51. Landon (1991) categorized pH values as follows; very high (>8.5); high (7.5-8.5); medium (5.5-7.0) and low (>5.5). According to the above categorisation the pH of the sand clay was rated as medium (Table 1) i.e. the soil has medium acidic reaction. One of the characteristics of acid soils is the risk of aluminium toxicity. Acid solutions cause the breakdown of clay minerals releasing aluminium and these ions are adsorbed onto the surface of the remaining clay particles where it is available to plants as a toxic element. The physiology of aluminium in soil solution is complex; very few plants appear to require it (apart from the tea plant), some plants are stimulated by Al in low concentrations but in general Al in solution retards the growth of roots and prevents or inhibits the uptake of phosphorus and its translocation to the rest of the plant (Fleming, 1980). Manganese is also found in excess in acid soils. It accumulates in all tissues and interferes with the metabolism of the plant. This problem is best diagnosed by plant analysis. Foy and Brown (1999) reported Mn toxicity symptoms in Lucerne at Mn level of 1000 ppm in the plant. To be available to plants, Mn must be in a divalent state. For this reason, the toxicity of Mn is affected by the oxidation state of the soil. Generally toxicity from Al and Mn occur together and both are ameliorated by liming. *Nitrogen:* - Soil pH affects the supply of available nitrogen from sources in the soil and from added manures and fertilizers (Curtin and Smilie, 1986).

Table 1: Physical and chemical properties of soil in the experimental site

Soil properties	Unit	Remark (s)
pH 1:1(H ₂ O)	6.51	medium
Organic C (%)	2.08	Moderate
Soil organic matter (%)	3.97	Moderate
Total N (%)	0.19	Low
P(extractable)Bray method	3.4	Low
Exchangeable cation(cmol(+)/kg soil)		
Ca	2.45	Low
Mg	2.10	Medium
Na	0.47	Low
K	0.31	Medium
Particle size (%)		
Sand	48	
Silt	14	Sandy clay
Clay	38	

Nitrogen from organic matter, either from applied organic nitrogenous manures or from plant residues, is converted into forms available to plants by the activities of micro-organisms. The organisms responsible for the conversion of organic N to ammonium show a marked tolerance to acidity. On the other hand, the bacteria responsible for the conversion of ammonium to nitrates cannot work efficiently in acid soils, and ammonium salts applied as mineral fertilizers remain near the surface and are only slowly converted to nitrates. The most favorable reaction range for nitrification lies between pH 6 and 8 (Goulding and Annis 1998). A pH of about 6.3-6.5 is generally considered most favorable for nitrogen. Phosphorus availability to plants is strongly influenced by soil pH, and its availability is maximized when pH is between 5.5 and 7.5. Acid soil conditions (pH < 5.5), cause dissolution of aluminum and iron minerals which precipitates with P effectively "tying" it up. Basic soil conditions (pH > 7.5) cause excessive calcium to be present in soil solution, which can precipitate with P, ultimately decreasing its availability. The optimum pH range for maize production is 6 to 7 (Purseglove, 1972), but maize can be generally grown in soils with pH outside the 6-7 range if proper management practices are implemented.

The $\text{NH}_4\text{F-HCL}$ extractable P (Bray-1-P) of the soil was found to be 3.4 mg/kg soils (Table 1). According to the categorization by Landon (1991), Bray-1-P < 15 mg/kg soil is rated as low and is likely to give response when P fertilizers are applied. The low level of Bray -1-P in sandy clay could probably be due to low level of P in the soils parent material and conversion of P into forms not extractable by the Bray -1-P reagent because of the strongly acidic nature of the soil (Landon (1991). This is further supported by the observation that phosphorus is deficient in most agricultural soil (Ashifaq *et al.*, 2004) due to continuous P uptake by plants without returning it back as fertilizers. A critical level of P concentrations for maize production is 25 cmol kg⁻¹ soil (Singh *et al.*, 1977). Therefore basing on the above critical P level, the sand clay requires supplemental P from other sources like in organic fertilizers and manure for maize production.

Total Nitrogen for the sand clay was 0.19% (Table 1) and rated as low according to the rating by Landon (1991). This is apparently due to low organic matter content in the soil and the fast transformation of organic matter, which takes place in tropical soils. According to Kaaya *et al.* (1994) total N > 0.2% is highly suitable for maize production. The organic carbon (2.08%) and organic matter (2.97%) in the sand clay were ranked as moderate according to Landon (1991). Kaaya *et al.* (1994) observed that organic carbon in the range 1.0-2.0 was moderately adequate for maize production.

The exchangeable Ca, Mg, K and Na values were 2.45, 2.10, 0.47 and 0.31 cmol (+)/kg soil, respectively. The values of exchangeable Ca and Na were rated as low while those of Mg and K were rated as medium based on ratings by Landon (1991). The low values for exchangeable Ca and Na and medium values for exchangeable Mg and K could be attributed to the Ca, Mg, K and Na contents in the parent materials from which the soil was formed and to the pH of the soil (Kaaya *et al.*, 1994).

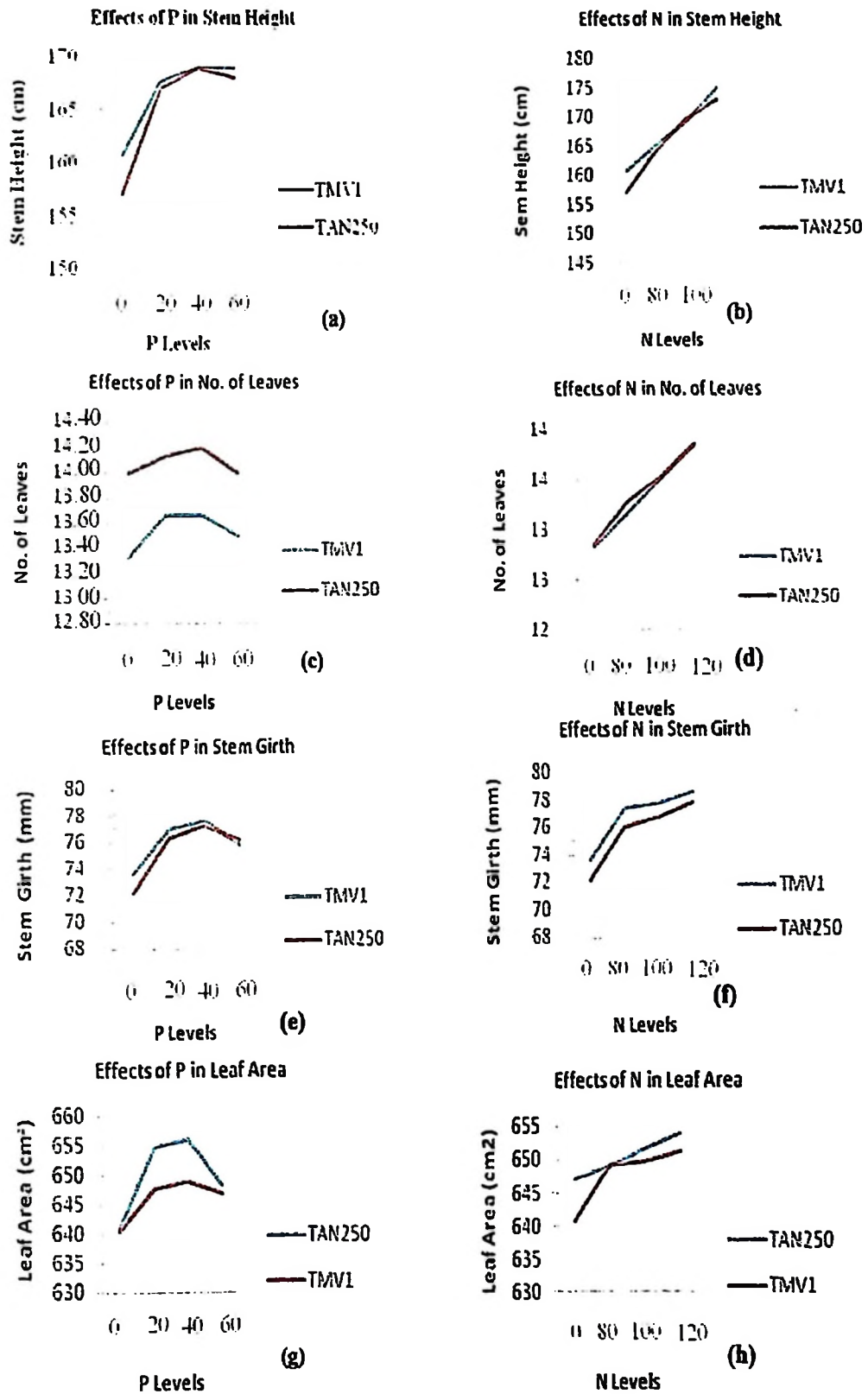


Figure 1: Effects of N and P on some vegetative growth characteristics of two maize varieties

Promotion effect of high P level on plant height was probably due to better development of root system and nutrient absorption (Aldrich *et al.*, 1975; A-kais *et al.*, 2003; Adams, 2004). Ashifaq *et al.* (2004) reported that plant height of maize increased with increase in P application. The results are in agreement to the findings of Singh *et al.* (1989) who reported that plant height of maize plants increased with increasing Phosphorus levels.

4.2.1.2 Number of leaves per plant

The effect of different levels of P on number of leaves per plant was not significant (Fig.1c). However, number of leaves per plant increased to maximum (14.13) in plots with P applied at the rate of 40 kg ha⁻¹ and decreased to minimum (12.79) in plots with P applied at the rate of 0 kg ha⁻¹ (Fig.1c). This indicates that P at the rate of 40 kg ha⁻¹ might be optimum for increasing the number of leaves per plant, which ultimately has a direct effect on grain yield. Therefore, further increase in P above 40 kg ha⁻¹ did not have a linear effect on the number of leaves per plant. It is observed from plots with P application at the rate of 60 kg ha⁻¹ that had less number of leaves per plant even though both treatments were statistically not significant. Increase in number of leaves per plant at higher P levels might be due to the increase in P availability to maize plants that had positive impacts on plant growth which resulted in increase in number of leaves per plant. Haque *et al.* (2001) reported that number of leaves in maize increased with application of P than control, and that the increase in leaf area was more with application of SSP (single super phosphate) as compared to DAP (diammonium phosphate) and NP (nitrophos).

4.2.1.3 Stem girth

The effect of P application on stem girth is shown in Fig. 2e. P application significantly increased stem girth. Stem girth was increased with successive increments of P application rate up to 40 kgP ha⁻¹ (156 mm). Maize plants were more gigantic in those

that received 40 kgP ha^{-1} than those that received lower or more than that (148 mm) and (154 mm), respectively.

This observation is in agreement with the findings of Ashifaq *et al.* (2004) who reported that increasing P levels in the maize plants increased growth and yield of maize crop. The untreated plants were almost stunted in growth as they had to rely on the native soil fertility which, from the result of chemical analysis was deficient in these nutrients (Table 1). The colossal of plant is an important growth character directly linked to the productive potential of plants in terms of grains. An optimum stem girth is claimed to be positively correlated with productivity of plant (Ashifaq *et al.*, 2004).

4.2.1.4 Leaf area

Leaf area per plant was significantly affected by phosphorus application (Fig.1g). The phosphorus at 40 kg ha^{-1} led to highest leaf area per plant (655 cm 2) followed by 20 kg P ha^{-1} (653 cm 2) (Fig.1g). The lowest leaf area per plant (640 cm 2) was observed without Phosphorus application.

Results clearly showed that TMV1 gained maximum leaf area over TAN250 (Fig.1h). This might be due to faster growth rate of TMV1 as compared to TAN250. These results are in conformity with those of Haque *et al.* (2001) and Ashifaq *et al.* (2004) who reported that leaf area increased in maize as a result of Phosphorous application.

4.2.2 Effect of nitrogen

4.2.2.1 Stem height

Results showed that increase in Nitrogen application rate increased plant height with the highest rate of 120 kg N ha^{-1} producing the tallest plants (178.2 cm); while the shortest plants were recorded in 0 kg N ha^{-1} (155.8 cm) (Fig.1b). TMV1 showed higher response to Nitrogen levels compared to TAN250. These results are in close conformity with those

obtained by Singh (1991) who found out that plant height in maize increases with increases in N rates. However, Haque *et al.*, (2001) reported that increase in N rates had no significant effects on plant height. The discrepancy in the results obtained in this study and that of Haque *et al.* (2001) might be due to the differences in the range of plant stands, native soil fertility status and the varieties used.

4.2.2.2 Number of leaves

The effect of different levels of N on number of leaves per plant was significant. However, number of leaves per plant increased to a maximum (14.50) in plots with N applied at the rate of 120 kg ha⁻¹ and decreased to a minimum (13.44) in plots with N applied at the rate of 0 kg ha⁻¹ (Fig.1d). Therefore, further increase in N above 120 kg ha⁻¹ may have a linear effect on the number of leaves per plant in maize, which is obvious from the plots with N application at the rate below 120 kg ha⁻¹ that had less number of leaves per plant. Increase in number of leaves per plant at higher N levels might be due to the increases in N availability to maize plants that had positive impacts on plant growth which resulted in increase in number of leaves per plant.

High levels of nitrogen promote vegetative growth in maize which leads to even absorption of plant nutrients by the roots and enhanced cell division and formation of more tissues, resulting in luxurious vegetative growth and thereby increasing number of leaves. This agrees with Singh (1991) who reported that plant growth increases with increased Nitrogen levels.

4.2.2.3 Stem girth

Results regarding stem girth (Fig.1f) indicated that the different levels of Nitrogen had a significant effect on maize stem girth. Application of N at the rate of 120 kg ha⁻¹ resulted in bigger stem girth (80 mm), followed by N applied at the rate of 100 kg ha⁻¹ (78 mm).

Therefore, further increase in N above 120 kg ha⁻¹ may have a directly proportional effect on the stem girth of maize, which is obvious from the trend showed by the results. The thinner stem girth (72 mm) was observed with 0 kg ha⁻¹. Nitrogen improves vegetative growth, which has a great effect on the overall plant growth performance; therefore the regimes of N at the rate of 0 kg ha⁻¹ resulted in lowest stem girth. This observation is in agreement with the findings of Ashifaq *et al.* (2004) who reported that increasing levels of N increases growth and yield of maize.

4.2.2.4 Leaf area

Leaf area per plant was significantly affected by Nitrogen application. The Nitrogen at 120 kg ha⁻¹ produced the highest leaf area per plant (655 cm²) followed by the minimum leaf area per plant (640 cm²) which was observed without nitrogen application (Fig.1g). Results clearly showed that TAN250 had greater leaf area than TMV1. This might be due to faster growth rate of TAN250 as compare to TMV1 (Mangushi and Mathayo, 2006). These results are in conformity with those of Jayakumar *et al.* (2008) and Buresh *et al.* (2005) who reported that leaf area increased in maize as a result of Nitrogen application.

4.3 Effects of N and P on Reproductive Growth Characteristics

Reproductive growth parameters were recorded at hard dough maturity stage when the leaves had and silks had dried. Nitrogen and Phosphorus effects were determined in number of ears per plant, ear length, ear girth, number of rows per ear and number of grain per ear.

4.3.1 Effects of phosphorus

Phosphorus effects were determined in the reproductive growth parameters. The following parameters were used for the evaluation.

4.3.1.1 Number of ears per plant

Data regarding number of ears per plant were significantly affected ($P \leq 0.05$) by the different levels of phosphorus (Fig. 2a). Mean values indicated that maximum number of ears per plant (1.25) was recorded in plots with P applied at the rate of 40 kg ha⁻¹ followed by P applied at the rate of 60 kg ha⁻¹ (1.02). Phosphorus at the rate of 40-60 kg ha⁻¹ might be an optimum rate for best results in number of ears per plant. Thus increasing P levels up to 40 Kgha⁻¹ had a directly proportional effect on the number of ears per plant in maize.

This effect can be clearly understood from the control plots i.e. P application at the rate of 0 kg ha⁻¹. This could be the reason for the observed low number of ears per plant (0.80) recorded in the control plots. It may also be due to the fact that optimum availability of P has been associated with increased growth, thus those plots which received optimum P produced more ears per plant as compared to the control. Ashifaq *et al.* (2004) reported that the number of ears per plant in maize increases with increase in P application. They argued that less number of ears per plant in the control plots resulted in less number of grains per plant that finally resulted in minimum grain yield.

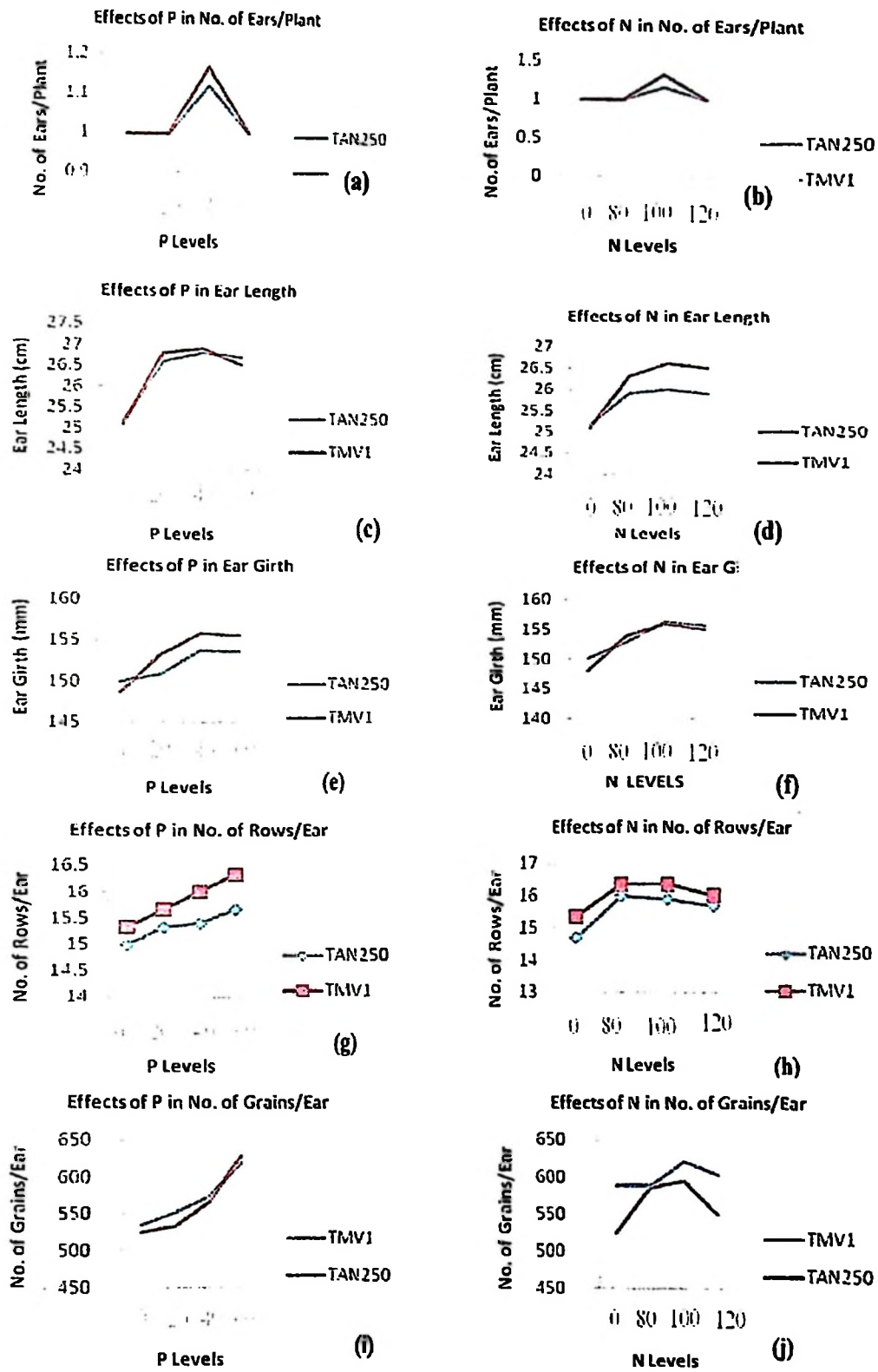


Figure 2: Effects of N and P on some reproductive growth characteristics of two maize varieties

4.3.1.2 Ear length

Ear length is an important yield component of the maize crop. The result from this experiment reveals that Phosphorous levels had significant effect on ear length. The maximum ear length (27.36 cm) was obtained in those plots where 40 kgP ha⁻¹ was applied (Fig. 2c). However the plots where 60 kgP ha⁻¹ was applied, gave lower ear length. The lowest ear length (25.4 cm) was obtained in control. Both TMV1 and TAN250 showed similar trends in ear length response to P levels. These results are also in conformity with those of Bundy *et al.* (1988) who reported that ear length increased with optimum level of Phosphorous.

4.3.1.3 Ear girth

Ear girth is significantly and positively correlated with, 100 grain weight, number of grain per cob and yield (Table 2). The results showed that phosphorous levels had non-significant effect on ear girth. The maximum ear girth (15.5 cm²) was observed in those plots where 40 kgP ha⁻¹ was applied. However the plots with 60 kgP ha⁻¹ gave similar results. The minimum ear girth (14.9 cm²) was observed in those plots where no phosphorous was applied. The results related to ear girth in maize as affected by different levels of P are shown in Fig. 2e, which clearly show that P had non-significant effect on ear girth in maize while TMV1 gave greater ear girth than TAN250. An increase in ear girth with optimum Phosphorus application has also been reported by Jayakumar *et al.* (2008) and Rayor *et al.* (1972).

4.3.1.4 Number of rows /ear

The maximum grain rows per ear leads to the maximum grain yield of maize crop which ultimately affect the final grain yield. The results reveal that different Phosphorous levels had significant effects on number of grain rows per ear. The maximum grain rows per ear

(16.05) were observed from plots with 60 kgP ha⁻¹ was applied. However the plots with 40 kgP ha⁻¹ gave less number of grains rows per ear. The lowest grain rows per ear (15) were observed from control.

Lowest number of grain rows per cob was recorded in plots without P application. This was possibly due to less availability of nutrients per unit area that resulted less partitioning of photosynthates to the cob (Bundy *et al.*, 1988). Similar results were reported by Jayakumar *et al.* (2008). Also Rayor *et al.* (1972) reported that the number of grains rows per cob was significantly affected by Phosphorus level.

4.3.1.5 Number of grains per ear

The results showed that different levels of phosphorus had a significant effect ($P \leq 0.05$) on number of grain per ear in maize (Table 2). The application of P at the rate of 40 kg ha⁻¹ resulted in higher number of grains per ear (582), which was at par with all the other P treatments except the control (540). Thus, further increases in P levels above 40 kg ha⁻¹ did not show any a linear effect with regard to the number of grains per ear in maize, as noted in plots with 60 kgP ha⁻¹ which gave fewer number of grains per ear even though both treatments were statistically similar.

As P is responsible for good root growth which directly affects the overall plant performance, the regimes of P at the rate of 0 kg ha⁻¹ resulted in the least number of grains per ear. The results are in accordance with those of Bundy *et al.* (1988) who reported that Phosphorous fertilizer applications significantly affected the number of grains per ear. The results are also similar with those of Rayor *et al.* (1972) who reported that numbers of grains per ear were influenced significantly by P application. Kumar *et al.* (1998) observed that the number of grains per ear in maize increased with increases in P levels.

Table 2: Effects of different levels of nitrogen and phosphorus on, Ear length, Ear girth, No. rows/ear and No. grain/ear

Treatment	Varieties	Ear length	Ear girth (mm)	No. rows/ear	No. grain/ear
0 kgP +0 kgN	TAN250	5.167 de	50.08 fg	15 abcd	602.8 a
0 kgP +80 kgN	TAN250	5.867 abcde	53.89 bcdef	14.67 d	635.8 ab
0 kgP +100 kgN	TAN250	6.717 abc	54.99 abcde	15.33 abcd	631.8 ab
0 kgP +120 kgN	TAN250	6.183 abcde	55.83 abcd	15.67 abcd	629.5 ab
20 kgP +0 kgN	TAN250	6.667 abc	50.97 efg	15.33 abcd	626.7 ab
20 kgP +80 kgN	TAN250	5.55 bcde	55.28 abcde	14 cd	620.7 ab
20 kgP + 100 kgN	TAN250	6.417 abcde	53.44 bcdef	15.67 abcd	618.7 ab
20 kgP + 120 kgN	TAN250	6.667 abc	55.69 abcd	14.67 bcd	617.2 ab
40 kgP + 0 kgN	TAN250	6.8 abc	53.7 bcdef	15 abcd	617.2 ab
40 kgP + 80 kgN	TAN250	6.65 abc	54 bcdef	15 cd	614.3 ab
40 kgP + 100 kgN	TAN250	6.863 ab	56.29 abc	15 cd	682.8 a
40 kgP + 120 kgN	TAN250	6.2 abcde	52.92 cdef	16.43 ab	587.7 abcd
60 kgP + 0 kgN	TAN250	6.717 abc	53.61 bcdef	15.67 abcd	587.2 abcd
60 kgP + 80 kgN	TAN250	6.1 abcde	54.43 bcdef	15.67 abcd	581.2 abcd
60 kgP + 100 kgN	TAN250	6.833 ab	54.98 abcde	16.33 ab	572.3 abcde
60 kgP + 120 kgN	TAN250	5.483 cde	53.79 bcdef	14.33 bcd	567.5 abcde
0 kgP + 0 kgN	TMV1	5.1 e	48.07 g	15.33 abcd	524.3 bcde
0 kgP + 80 kgN	TMV1	6.3 abcde	52.76 cdef	16.33 ab	560.5 bcde
0 kgP +100 kgN	TMV1	6.6 abc	56.1 abcd	16.33 ab	559.8 bcde
0 kgP +120 kgN	TMV1	6.683 abc	55.53 abcd	15.33 abcd	558.3 bcde
20 kgP +0 kgN	TMV1	6.917 a	55.82 abcd	15.67 bcd	550.7 bcde
20 kgP +80 kgN	TMV1	6.667 abc	57.89 ab	17 a	544 bcde
20 kgP + 100 kgN	TMV1	6.133 abcde	55.41 abcde	16.33 ab	541.7 bcde
20 kgP + 120 kgN	TMV1	6.433 abcd	56.35 abc	16.33 ab	541.7 bcde
40 kgP + 0 kgN	TMV1	5.867 abcde	53.3 bcdef	16 abc	535 bcde
40 kgP + 80 kgN	TMV1	6.95 a	56.4 abc	15.67 bcd	529.7 bcde
40 kgP + 100 kgN	TMV1	7.167 a	59.14 a	16.33 ab	563.3 bcde
40 kgP + 120 kgN	TMV1	6.367 abcde	55.78 abcd	15.67 abcd	521 bcde
60 kgP + 0 kgN	TMV1	6.567 abc	55.67 abcd	16.33 ab	517.5 bcde
60 kgP + 80 kgN	TMV1	7.083 a	55.97 abcd	16 abc	485.2 cde
60 kgP + 100 kgN	TMV1	6.083 abcde	51.65 defg	15.67 bcd	478.8 de
60 kgP + 120 kgN	TMV1	6.333 abcde	56.99 abc	15 abcd	460.2 e
	MEAN	6.38	54.59	15.41	570.78
	CV%	10.5	4.2	7	10.5
	LSD	1.09	3.74	1.77	98
	F Prob	**	***	ns	**

4.3.2 Effects of nitrogen

In this study reproductive growth parameters were resolute to know how they have been affected by Nitrogen levels as follows:

4.3.2.1 Number of ears per plant

The results regarding the number of ears per plant are presented in Fig. 2b, which indicated that application of nitrogen partly affected the number of ears per plant. It seems that number of ears per plant is basically a genetic character and not too much influenced by crop nutrition (Bundy *et al.*, 1988).

The difference in number of ears per plant in all fertilizer treatments were statistically similar, but significantly higher number of ears (1.26) per plant was recorded with 100 kg ha⁻¹, than the control, which produced 1.03 ears per plant, but did not differ with other treatments. These results are in line with those reported by of (Ashifaq *et al.*, 2004).

4.3.2.2 Ear length

The maximum ear length (26.76 cm) was obtained with 100 kgNha⁻¹. However, the plots with 120 kgN ha⁻¹ gave shorter ears. The minimum ear length (25.4 cm) was obtained in control.

Both TMV1 and TAN250 cultivars showed similar results in case of ear length (Fig. 2d). A faster growth under higher levels of Nitrogen might have played a significant role in reducing competition for photosynthates and nutrients with other plants resulting in healthier plants. This increase in availability of photosynthates might have enhanced number of flowers and fertilization which resulted in higher values of yield components (Ashifaq *et al.*, 2004). Further, in most of cereals, the reduction of long ears length

beyond 100 kgNha^{-1} can be explained to be due higher assimilation surface at reproductive development which results in reduced green cob formation because of adequate production of metabolites and their translocation vegetative parts.

The results of the present study which indicated positive responses of various yield attributes to optimum Nitrogen fertilization corroborates with the findings of several researchers (Singh and Dukey, 1991; Raja *et al.*, 2006; Luna and Ban, 2001). The higher green cob yield realization with application of higher levels of Nitrogen could be ascribed to its profound influence on vegetative and reproductive growth of the crop (Stoskopf, 1995). These results are in accordance with the findings of Raja *et al.* (2006), Paradkar and Olso *et al.* (1988) and Kumar *et al.* (1998).

4.3.2.3 Ear girth

Nitrogen levels appreciably affected ear girth. Ear girth increased with increasing Nitrogen rates. The thickest ears were obtained with 100 kg N /ha (15.5 cm) and the thinnest ears (14.63 cm) were obtained with 0 kg N /ha (Fig. 2f). Singh *et al.* (2000) reported effects Nitrogen levels on ear girth and thinner ears were obtained with high Nitrogen level.

Increase in ear girth with nitrogen levels of up to 100 kg ha^{-1} has also been reported by Olso *et al.* (1988) and Padkar *et al.* (2003). These results contradicted the findings of Oslo *et al.* (1988) and Luna *et al.* (2001). These contradictory results might have been due to variation in the fertility status of soil or variation in genetic traits of the crop plant (Stoskopf, 1995).

4.3.2.4 Number of rows per ear

Nitrogen did not significantly affect the number of rows per ear (Fig. 2h). The maximum number of rows per ear (16.5) was recorded with 80 and 100 kgNha⁻¹ followed by 120 kg N ha⁻¹. The other N levels gave less number of grains per ear. This is in agreement with Di-Gioavanni *et al.* (1995) who reported maximum number of rows per ear in plants applied with 100% of recommended N level (120 kgNha⁻¹).

4.3.2.5 Number of grains per ear

The response of number of grain per ear was significantly affected by nitrogen (Fig. 2j). The number of grains per ear ranged between 652.9 and 548.8. Maximum number of grains per ear (652.9) was recorded with 100 kg Nha⁻¹ while the minimum (548.8) was recorded without N application.

On the other hand, the number of grains per ear increased with increasing Nitrogen levels up to 100 kgNha⁻¹. The results concur partly with observations made by Olso *et al.* (1988) who reported that grain number increased with increasing Nitrogen levels. Similar results have been reported by Hussain *et al.* (2006). Increase in grains per ear at higher Nitrogen levels might be due to lower competition for nutrients that allowed the plants to accumulate more biomass with higher capacity to convert more photosynthates into sink, resulting in more grains per ear. These results are also in agreement with Kamparath (1982) who concluded that grain number per ear was higher at optimum Nitrogen levels.

4.4 Effects of N and P on Grain Yield and Yield Components

Grain yield and yield component parameters were taken and recorded after harvesting. Nitrogen and Phosphorus effects were determined in the following parameters; weight of grains per ear, weight of 100 grains, weight of grains per plot and grains yield t ha⁻¹.

4.4.1 Effects of Phosphorus

4.4.1.1 Weight of grains per ear

It is an important parameter that dictates the final grain yield of a crop. Results reveal that different Phosphorous levels had statistically significant effect on grain weight. The maximum grain weight per ear (97.03 g) was observed with 40 kgPha⁻¹ (Fig.3a). However, plots with 60 kgPha⁻¹ gave similar results. The minimum grain weight per ear (45.6 g) was observed in plots without Phosphorous. Both TMV1 and TAN250 showed similar trends in response to P levels with regard to grain weight per ear.

The maximum grain weight per ear was recorded with 40 kgP ha⁻¹, which might be due to increases in leaf area and leaves per plant. The other reason might be due to the availability of optimum nutrients levels for the maize plant. This observation is in agreement with the findings of Ashifaq *et al.* (2004) who reported that optimum level of P increased growth and grains weight of the crop.

4.4.1.2 Weight of 100 grains

The effect of different levels of P on 100 grain weight was not significant. However, a highest 100 grains weight of 14.8 g was recorded with 40 kgP ha⁻¹. The 100 grain weight is an important yield component that contributes significantly to grain yield estimate. The treatment with 40 kgP ha⁻¹ seems to be the most economical and yield enhancing in the maize crop since none of the other P levels positively affected the 100 grain weight. P levels above 40 kg ha⁻¹ had no effect on crop performance (Fig. 3c). The lowest 100 grain weight (6.3 g) was observed with the control. Hussain *et al.* (2006) observed an increase in 100 grain weight with high in N and P levels. Phosphorus being responsible for good root growth, directly affected the 100 grain weight because P at the rate of 0 kg ha⁻¹ (control plots) resulted in the least thousand grain weight (Hussain *et al.*, 2006).

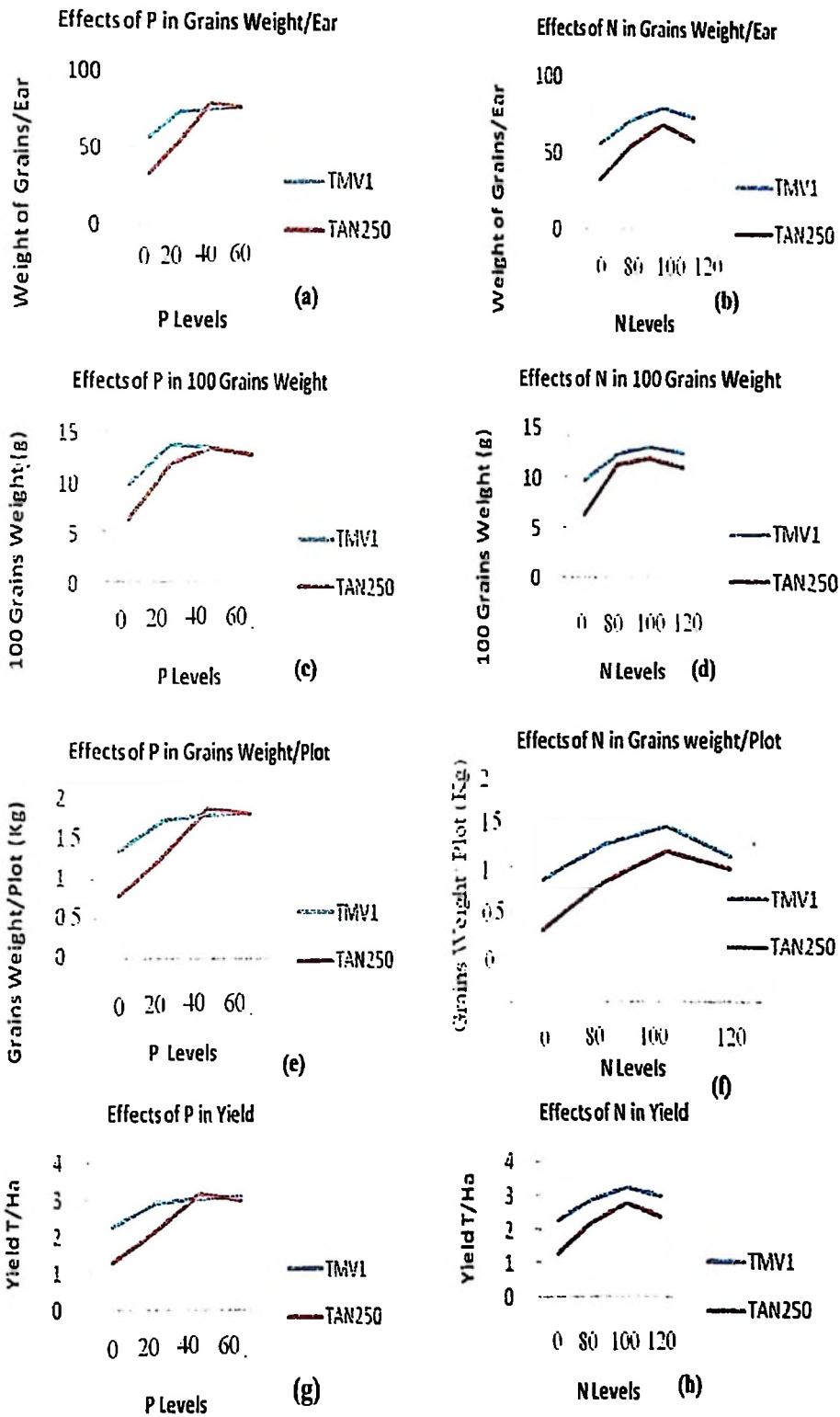


Figure 3: Effects of N and P on yield and yield components of two maize varieties

4.4.1.3 Grain yield

Grain yield was significantly affected by the different levels of Phosphorous. Mean values of the data showed that maximum grain yield (3.72 t ha^{-1}) was produced with 40 kgP ha^{-1} , followed by 60 kg P ha^{-1} (3.33 t ha^{-1}). The control plots resulted in minimum grain yield (1.305 kg ha^{-1}).

Phosphorus application at the rate of 40 kg P ha^{-1} resulted in taller plants, more number of ears per plant and number of grains per ear, which resulted in greater grain yield as compared to the other P levels (Fig. 3g).

Phosphorus is present in seeds and fruits in large quantities and is essential for seed formation (Olso *et al.*, 1988). The increase in grain yield due to P application was also reported by (Kamprath *et al.*, 1982). Ashifaq *et al.* (2004) reported that grain yield of maize increased with increase in P application. Similar results were also reported by Hussain *et al.* (2006) who found that grain yield increased with Phosphorus application and plots receiving 90 kgP ha^{-1} gave maximum grain yield as compared to those applied with lower and higher P levels.

4.4.2 Effects of nitrogen

4.4.2.1 Weight of grain per ear

Results revealed that different nitrogen levels statistically effected grain weight per ear. The maximum grain weight per ear (97.10 g) was observed with 100 kgNha^{-1} (Fig. 3d). However, the plots with 120 kgNha^{-1} gave statistically similar results. The minimum grain weight per ear (46.4 g) was observed without nitrogen. Both TMV1 and TAN250 showed similar trends in case of grain weight per ear. It also indicated that increasing N above 100 kg ha^{-1} did not significantly improve crop performance in terms of grains weight per ear.

The maximum grain weight per ear observed with 100 kgN ha⁻¹ might be due to increased leaf area and greater number of leaves per plant. The other reason might be due to the availability of optimum nutrients levels for the maize plant. This observation is in agreement with the findings of Ashifaq *et al.* (2004) who reported that optimum level of N application increased growth and grains weight of crops.

4.4.2.2 Weight of 100 grains

Nitrogen had significant effect on 100 grain weight (Fig. 3d). In both varieties, control plots (0 kgN ha⁻¹) had significantly lower 100 grain weight of 5.2 g than where N was applied. The maximum 100 grain weight (14.3 g) was recorded with 100 kgN ha⁻¹. These results are in line with Bundy and Carter (1988) who reported maximum 1000 grain weight (248 g) with 200 kg ha⁻¹ N. Significantly lighter 1000 grain weight (219.8 g) was recorded with 0 kgNha⁻¹ which may be due to weaker seedling and unproductive plants produced thereof, which may have resulted in low grain weight.

4.4.2.3 Grain yield

Grain yield was significantly affected by different levels of Nitrogen. Mean values of the data showed that maximum grain yield (3.72 tones ha⁻¹) was produced in treatments with 100 kg N ha⁻¹, followed by 120 kg N ha⁻¹ (3.33 tones ha⁻¹). The control plots gave minimum grain yield of 1.31 tones ha⁻¹. Nitrogen application at rate of 100 kg N ha⁻¹ resulted in taller plants, more number of ears per plant and number of grains per ear, which resulted in higher grain yield as compared to other N levels. (Fig. 3h).

The increase in grain yield due to N application was also reported by Jayakumar *et al.* (2008) and Buresh *et al.* (2005). Purselove (1972) reported that grain yield of maize increased with increase in N application. Similar results were also reported by Hussain *et al.* (2006) who found that grain yield increased with optimum Nitrogen

application and plots receiving 90 kg N ha⁻¹ gave maximum grain yield as compared to lower and upper levels of N.

4.5 Correlation between Variables

It has been suggested that yield and growth components have either a direct or indirect effect on grain yield or both. Therefore it was essential to determine the effects of growth and yield components on grain yield. Correlation analysis is the most common statistical method used for this purpose. Correlation analysis is a reliable statistical technique which provide to quality the inter relationships of different yield components and indicate whether the influence is directly reflected in the yield (Kumar *et al.*, 1998). Purseglove (1972) have commonly used correlation analysis to explain clearly the relationship among yield components.

4.5.1 Vegetative growths

The relationship between stem height and grain yield is shown in Table 3. There was a weak negative and significant relationship between grain yield and number of leaves and grain yield and leaf area (Table 3). Therefore knowing the value of leaf area and number of leaves can give the information about the grain yield of the maize. This is supported by Purseglove (1972) who reported high vegetative growth i.e. high number of leaves and high leaf area over stimulate tillering which locks carbohydrates in structural parts of the plant and finally reduces grain yield.

Table 3: Correlation of vegetative growth characteristics

Variables	Plant height	Number of leaves	Leaf area	Stem girth	Grain yield
1 Plant height (cm)	1				
2 Number of leaves	0.512ns	1			
3 Leaf area (cm ²)	0.103ns	-0.06ns	1		
4 Stem girth (mm)	-0.08ns	-0.16ns	0.273ns	1	
5 Grain yield (tones ha ⁻¹)	-0.82ns	-0.05*	-0.035*	0.441ns	1

Key: **= highly significant, *= significant and ns = not significant (P≤ 0.05)

4.5.2 Reproductive growth

Strong positive and highly significant correlation was observed between grain yield and grains per ear (Table 4). The results prove the above evidence that more number of grains per ear means high grain yield in maize. Therefore knowing the number of grains per ear gives strong information about the grain yield in the maize. Also there were weak positive and high correlations between number of ears per plant and grain yield (Table 4). The result from the experiment confirms that more number of ears per plant would results in high grain yield.

Table 4: Correlation of yield and reproductive growth characteristics

Variables	Ear length	Number of cars/ Plant	Number of grains/ ear	Number of rows/ car	Ear girth (mm)	Grain yield
1 Ear length	1					
2 number of cars/plant	0.475ns	1				
3 number of grains /ear	0.009ns	0.095ns	1			
4 number of rows/ear	0.323ns	0.341ns	0.373ns	1		
5 ear girth (mm)	0.597ns	0.323ns	0.099ns	0.14ns	1	
6 Grain yield (tones ha ⁻¹)	0.265ns	0.005**	0.05*	0.29ns	0.468ns	1

Key: Key: ** =highly significant, * = significant and ns = not significant (P≤ 0.05).

4.5.3 Grain yield and yield components

Significant positive correlation existed between grain yield and weight of grains per ear, and grain yield and between weight of grains per m² (Table 5). Therefore knowing the value of grains per ear and weight of grains per m² can give strong information about grain yield of maize. However, the results indicate that more weight of grains per ear and more weight of grains per m² mean more grain yield of maize. This implies that as grain weight per ear and plot increase grain yield similarly increased. Similar observation was reported by (Purseglove, 1972).

Table 5: Correlation of yield and yield components

	Variables	100 grains weight (gm)	Grains weight/car	Grains weight/m ²	Grain yield
1	100 grains weight (gm)	1			
2	weight of grains/car (gm)	0.87	1		
3	weight of grains/m ² (kg)	0.873	0.999	1	
4	Grain yield (tones ha ⁻¹)	0.872	0.048*	0.018*	1

Key: Key: **= highly significant, *= significant and ns = not significant ($P \leq 0.05$).

4.6 Economic Analysis

In order to identify a suitable treatment combination, economic evaluation of different treatment combinations was done through partial budgeting. Economic analysis presented in (Table 5) reveals that highest gross margin for TMV1 and TAN250 were TZS 2 022 000 ha⁻¹ and TZS 1 962 000 respectively, were obtained from the treatment (40 kgP/ha+100kgN/ha) with a variable fertilizers cost of TZS 210 000 ha⁻¹. Lowest gross margin for TAN250 and TMV1 were TZS 787 800/ha and TZS 1 116 000, respectively ha⁻¹. With respect to lowest gross margins, fertilizers costs were at TZS 0 ha⁻¹ for TAN250 and TZS 0 ha⁻¹ for TMV1.

Different scholars have used the same technique in profitability analysis: Gabagambi (1998) used the model in profitability analysis for smallholder production process in paddy and cotton production and Mutayoba (2005) used the technique in vanilla, coffee, tea, banana and maize to establish the relative economic profitability of various smallholders' in Bukoba District. Gross margin was therefore used to estimate income from coffee production. From the above, it may be concluded that 40 kgP/ha⁻¹ of Phosphorous and 100 kgN/ha⁻¹ of nitrogen with respect to TMV1 gave the highest profit margin and hence treatment 40 kgP+100 kgN is the best combination for the farm worthiest.

Table 6: Effects of different rates of nitrogen and phosphorus on agronomic, economic and value-cost ratio (VCR) of two maize varieties

Nutrients level P + N	Variety	Agronomic fertilizer effects			Economic fertilizer effects		VCR
		Average yield increase ton ha ⁻¹	Price of maize at harvest/100 Kg Tsh	Value of yield increase Tsh	Fertilizer cost Tsh	Profit due to fertilizer	
0 kgP+0 kgN	TAN250	1.313	60000	787800	0	787800	0
0 kgP+80 kgN	TAN250	2.22	60000	1332000	120000	1212000	11.1
0 kgP+100 kgN	TAN250	2.777	60000	1666200	150000	1516200	11.1
0 kgP+120 kgN	TAN250	2.5	60000	1500000	180000	1320000	8.3
20 kgP+0 kgN	TAN250	1.9	60000	1140000	30000	1110000	38.0
20 kgP+80 kgN	TAN250	2.443	60000	1465800	150000	1315800	9.8
20 kgP+100 kgN	TAN250	2.277	60000	1366200	180000	1186200	7.6
20 kgP+120 kgN	TAN250	3.333	60000	1999800	210000	1789800	9.5
40 kgP+0 kgN	TAN250	3.17	60000	1902000	60000	1842000	31.7
40 kgP+80 kgN	TAN250	2.16	60000	1296000	180000	1116000	7.2
40 kgP+100 kgN	TAN250	3.62	60000	2172000	210000	1962000	10.3
40 kgP+120 kgN	TAN250	2.65	60000	1590000	240000	1350000	6.62
60 kgP+0 kgN	TAN250	2.01	60000	1206000	90000	1116000	13.4
60 kgP+80 kgN	TAN250	2.28	60000	1366200	210000	1156200	6.51
60 kgP+100 kgN	TAN250	2.66	60000	1597800	240000	1357800	6.65
60 kgP+120 kgN	TAN250	2.54	60000	1524000	270000	1254000	5.64
0 kgP+0 kgN	TMV1	2.28	60000	1366200	0	1366200	0
0 kgP+80 kgN	TMV1	2.89	60000	1734000	120000	1614000	14.45
0 kgP+100 kgN	TMV1	3.21	60000	1926000	150000	1776000	12.84
0 kgP+120 kgN	TMV1	3.53	60000	2118000	180000	1938000	12.41
20 kgP+0 kgN	TMV1	1.97	60000	1182000	30000	1152000	39.4
20 kgP+80 kgN	TMV1	2.28	60000	1368000	150000	1218000	9.12
20 kgP+100 kgN	TMV1	3.39	60000	2034000	180000	1854000	11.3
20 kgP+120 kgN	TMV1	3.39	60000	2032200	210000	1822200	9.67
40 kgP+0 kgN	TMV1	3.05	60000	1831800	60000	1771800	30.53
40 kgP+80 kgN	TMV1	3.61	60000	2166000	180000	1986000	12.03
40 kgP+100 kgN	TMV1	3.72	60000	2232000	210000	2022000	10.62
40 kgP+120 kgN	TMV1	3.22	60000	1932000	240000	1692000	8.05
60 kgP+0 kgN	TMV1	2.01	60000	1206000	90000	1116000	13.4
60 kgP+80 kgN	TMV1	3.33	60000	1998000	210000	1788000	9.51
60 kgP+100 kgN	TMV1	2.5	60000	1500000	240000	1260000	6.95
60 kgP+120 kgN	TMV1	3.12	60000	1872000	270000	1602000	6.23

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study revealed that, Phosphorous and Nitrogen deficiency affect growth and yield response of maize particularly in the study area. Based on data generated following conclusions were drawn.

Maize growth responded favorably to N application from 0 kgN to 120 kgNha⁻¹ on the other hand maize yield responded absolutely with 0 kgN to 100 kgNha⁻¹.

Maize showed the increase in growth due to Phosphorous at 0 kgP to 40 kgP and maize yield responded well at 40 kgP to 60 kgP. Interaction between Nitrogen and Phosphorous significantly enhanced growth and yield. Treatment with 100 kgNha⁻¹+ 40 kgP ha⁻¹ gave superior results compared to all other treatments.

Though the varieties were different, they similarly responded to N and P fertilizers. The maize variety TMV1 however, was more responsive to inorganic fertilizer by producing higher grain yield than TAN250.

Economic evaluations indicated that application of 40 kgP and 100 kgN gave higher returns on investment.

Overall, Phosphorus and Nitrogen levels of 40 kgP/ha +100 kgN/ha can be recommended for growth, yield responses and economical development of maize farmers in Handeni District.

5.2 Recommendations

- i. Since the trial was conducted for one season using only two varieties, it is suggested that this study be carried out for at least two more seasons in different locations for further verification of the results obtained.
- ii. The application of inorganic fertilizer increased grain yield considerably; to improve the rate of fertilizer adoption, the government could subsidize the cost of fertilizer in order to make it affordable for farmers to purchase. Government policies should ensure that terms for bank credits are flexible to enhance farmers' access to affordable credits, which will increase their ability to boost crop production and productivity, enhance flexibility to change crop and soil management strategies in response to climate change.
- iii. Efforts should be done to encourage people in the study area to use nitrogen and phosphorus fertilizer for better economical return

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