KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF CROP AND SOIL SCIENCES

ESTIMATION OF GENETIC IMPROVEMENT OF MAIZE IN GHANA UNDER THREE LEVELS OF NITROGEN APPLICATION

BY

EVANS OWUSU BOATENG

(B.Sc. Agriculture Technology)

NOVEMBER, 2013.

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A THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE AGRONOMY (PLANT BREEDING)

NOVEMBER, 2013.

DECLARATION

This is to certify that this thesis is my own work and has not been submitted elsewhere for a degree to any other university. All source of information have been duly acknowledged.

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ABSTRACT

The Crop Research Institute of Ghana has released quality protein maize and hybrids into the Ghanaian market for full utilization by farmers and researchers to enhance food security in the country. The research was conducted to estimate the genetic improvement of maize in Ghana under three levels of nitrogen fertilizer application. The experiment was conducted in the 2011 major and minor seasons at Kwadaso and Fumesua. The genotypes comprised of 3 hybrids, 6 open- pollinated varieties (OPV's), 1 local variety and 4 inbred lines released from 1955 to 2010. The experimental design used was 3 × 14 factorial in a randomized complete block design in split-plot arrangement, with four replications in each environment. The nitrogen levels were 0, 45 and 90 kg N /ha randomized in the main plot and genotypes as the sub-plots. The analysis of variance showed that the effects due to environments, nitrogen levels, and genotypes were highly significant ($P<0.01$) for grain yield and other agronomic traits measured. The differences among genotypes were highly significant ($P< 0.01$) for grain yield and other agronomic traits. Genotype X Environment interactions were highly significant ($p < 0.01$) for grain yield, days to mid-silks, days to mid- anthesis, plant height, ear height, lodging, rust, blight, cob aspect, shelling percentage, 1000 seed weight and cob length. The response to nitrogen in terms of the genotypes ascertain that the hybrids out yielded the open- pollinated varieties and local variety at 0, 45, 90 kg N/ha respectively. Yields of hybrids responded positively over OPV's with an increased with nitrogen levels from 0 kg N/ha to 45 kg N/ha. Hybrids were also the most stable and highest yielding varieties under high nitrogen environments. It is recommended that farmers should be encouraged to buy and use hybrid seed to take advantage of their high yields under low N.

DEDICATION

This thesis is dedicated to the Almighty God and my parents, Mr. and Mrs. Boateng for their immense contribution towards this work.

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I deem it a great pleasure to render my profound thanks and appreciation, first to the Almighty God for granting me the guidance and protection throughout my education in spite of all predicaments. Glory be to His name.

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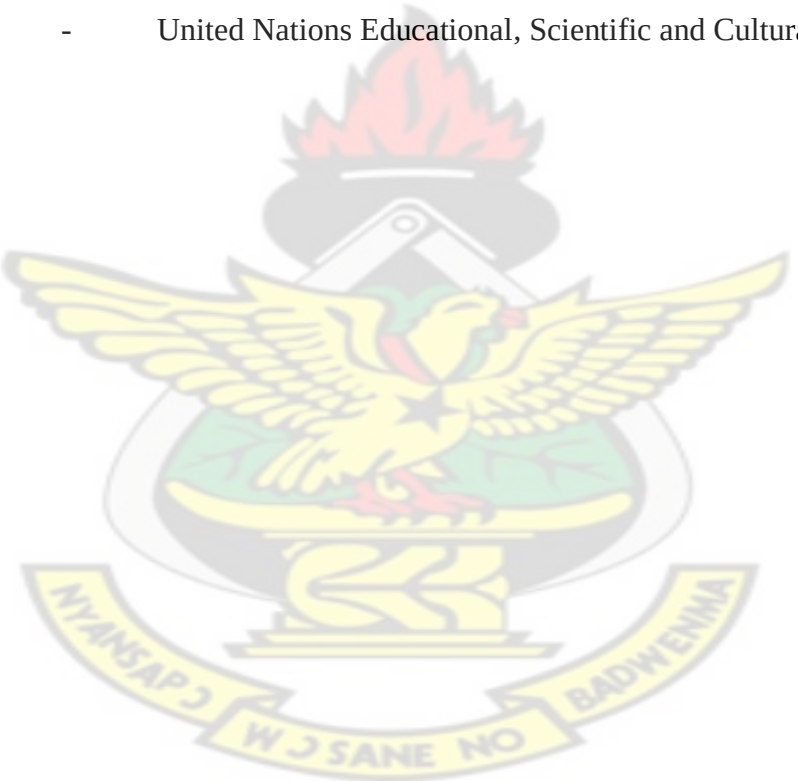
LIST OF ACRONYMS

IITA	-	International Institute of Tropical Agriculture
G x E	-	Genotype by Environment
USDA	-	United States Department of Agriculture
CIMMYT	-	International maize and wheat Improvement Center
FAO	-	Food and Agriculture Organization
PPMED	-	Policy, Planning, Monitoring and Evaluation Division
UNESCO	-	United Nations Educational, Scientific and Cultural Organization



CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Gramineae, sub-family Panicoideae and the tribe Andropogoneae (Norman *et al.*, 1995). Maize is the third most important cereal crop after wheat and rice in terms of production in the world (IITA, 2009). In Ghana, it is the most important cereal in terms of production and consumption (Breisinger *et al*., 2008). In Ghana, organized maize improvement started in the 1930's (GGDP, 1984; Sallah, 1986). From 1939 and1942, T .L.Williams improved several local germplasm, developed the variety C50 and introduced a yellow variety called Tsolo from South Africa (GGDP, 1984).

High yielding Mexican 17 was developed (Doku, 1961). Genetic gain estimates in breeding programmes are important to critically analyze efficiency and to plan new actions and strategies. Institutions working on annual crop breeding routinely conduct a series of trials to compare elite lines and to release new cultivars (Hoffmann and Vieira, 1987). Each year lines are replaced in the trials with the expectation that the new ones will be superior. The change in mean yield as a consequence of these substitutions may be considered an estimate of genetic gain. To evaluate maize breeding programmes in Brazil, Vencovsky *et al.* (1988) analyzed 20 years of trials. The gain was estimated for each pair of consecutive years as being the variation of annual means minus the variation of the means for the lines of the two years. Toledo *et al.* (1990) used the method of Vencovsky *et al.* (1988) to calculate genetic gain obtained by soybean (*Glycine max* Merr.) breeding in Paraná State. They calculated mean genetic gain by weighted least squares method to avoid cancellation of information obtained in intermediate years. This significant increase is attributed to adoption of improved

maize varieties and management practices in the country (Edmeades and Hallauer, 1992).

Notwithstanding the effort being made by breeders to improve productivity in maize production, farmers still rely on rain-fed agricultural system which limits maize production in Ghana (Ohemeng-Dapaah, 1994; Kasei *et al*., 1995; Obeng–Antwi*et al*., 1999).

Maize production zones in savannah regions are prone to drought stress because rainfall is unpredictable in terms of quantity and distribution during the growing season (Ohemeng -Dapaah, 1994; Kasei *et al.,* 1995) resulting in significant yield losses. As a typical example, total maize production in Ghana declined by 30% in 1982 as a result of drought stress throughout the country (GGDP, 1983). A significant proportion of yield increase in maize has been attributed to genetic improvement of the crop for tolerance to major environmental stresses (Edmeades *et al*., 1992).

Soil fertility is one of the predicament confronting farmers because they do not apply fertilizer at all or they apply at the wrong time or dosage. Comparatively, the cost of inorganic fertilizer is higher and is difficult for farmers to afford. This predicament is impeding productivity in terms of agriculture. Farmers also find it difficult to use organic manure because of its odour and the bulky nature (GGDP, 1984). It would be prudent to estimate genetic gains under three levels of nitrogen fertilizer application rate in different environments, in order to recommend appropriate genotypes for farmers.

1.2 Main objective

To evaluate the genetic improvement of maize in Ghana under three levels of nitrogen application.

1.2.1 Specific objectives were to;

I. ascertain the most stable genotype under low, medium and high nitrogen environment,

II. compare the relative yielding abilities of hybrids, 0pen-pollinated varieties and local variety under different levels of nitrogen application and

III. determine the minimum nitrogen level for optimum yield.

CHAPTER TWO

LITERATURE REVIEW

2.1 Maize production in Ghana and the world

Africa is a minor producer of maize, accounting for only 7% of global production. Maize yields in Ghana are quite low and average 1.7 t/ha in 2006 compared to the global average of about 5 t/ha (FARA, 2009). About 5.4 million tonnes of maize is produced annually from the land area under cultivation. The tremendous increase was achieved through expansion of maize production zones, development of early and extra high yielding varieties, better pricing, increasing demand by agro- allied companies and compatible technologies (Lafitte and Banziger, 1997). Despite the increase in total production, yield per hectare is relatively low. Some of the constraints are inadequate resources for farmers to purchase inputs and low fertility status of savannah soils. Low soil nitrogen is one of the most important abiotic factors limiting maize yields in the tropics(Lafitte and Banziger, 1997). Initially, resource-poor farmers relied on shifting cultivation or bush fallow for soil fertility maintenance. In recent years, it has become increasingly difficult to sustain this system because of increasing population pressure. As a result, nutrients and organic matter in the soil are depleted with corresponding decrease in yield. Increase in maize production can be achieved through increased levels of fertilizer application.

2.2 Botany of maize

The maize plant has profusely branched, fine root systems if root growth is not restricted, the root system of mature maize could extend approximately 1.5m laterally and downwards to about 2.0m or even deeper(ARC – Grain Crops Institute, 2003). The root system has adventitious roots developed in a crown of roots from nodes below the

soil surface. Normally, four to six adventitious roots are formed per band. After tasseling, roots develop into bands from the first two to three aerial nodes. These roots are comparatively thick, pigmented and covered with a waxy substance. The roots provide support to the plant and taking up nutrients to the plants for photosynthesis. Numerous root hairs occur on young plants which increase root surface area that is exposed to the soil, and play an important role in absorption of water and nutrients (ARC – Grain Crops Institute, 2003). The eight to 20 leaves that may form are arranged spirally on the stem, and they occur alternately in two opposite rows on the stem. The maize leaf is a typical grass leaf and consists of a sheath, ligules, auricles and a blade. The leaf blade is long, narrow, undulating towards the tip and it is glabrous to hairy. More stomata occur on the underside of the leaf than on the upper surface. On the upper surface, motor cells are present. The large wedge – shaped cells occur in rows, parallel and between the rows of the stomata. During moist conditions, these cells rapidly absorb water, become turgid and unfold the leaf. During warm, dry weather, the cells quickly lose their turgor resulting in leaves curl inwards exposing a smaller leaf surface to evaporation (ARC – Grain Crops Institute, 2003). Leaf rolling has a medium to low relationship with grain yield. Its impact on grain yield is usually significant at flowering (Banziger *et al*., 1997).

Improved maize in Ghana such as "Aburotia" Abeleehi" Laposta "Dobidi" and Okomosa" all trace their ancestry to the Tuxpeno- based germplasm from CIMMYT. The hybrids and OPVs were also developed from CIMMYT Populations 62 and 63 respectively (Sallah, 1986). Before the introduction of hybrid maize in Ghana, most farmers were growing the open- pollinated varieties (CIMMYT, 1990).

Most of the developing countries used open-pollinated varieties because they are cheaper as compared to hybrid seed (Akposoe, 1973). Farmers can use previous seeds

saved for planting without the hybrid seeds every season (Akposoe, 1973). Comparatively, hybrid maize yield is higher than the open pollinated maize (Carlone and Russell, 1987). The inherent genes in the hybrids are transferred onto fruiting to achieve good yields and to withstand all environmental conditions.

2.3 Importance of maize

Every part of the maize plant has economic value. The grain can be consumed as human food, fermented to produce a wide range of foods and beverages, fed to livestock, and used as an industrial input in the production of starch, oil, sugar, protein, cellulose and ethyl alcohol. The leaves, stalks, and tassels can be fed to livestock, either green (in the form of fodder or silage) or dried (in the form of stover). The roots can be used for mulching, incorporated into the soil to improve the physical structure or dried and burned as fuel (Morris, 2002).

2.4 Soil requirements for maize

The most suitable soil for maize is one with a good fertility level with physical properties, good internal drainage, and an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favorable specifically for maize production. Although large- scale maize production takes place on soil with a clay content of less than 10% (sandy soil) or in excess of 30% (clay and clay-loam soils), these texture classes have air and moisture regimes that are optimal for healthy maize production (IITA, 2009).

2.4.1 Temperature

Maize is cultivated from latitude 58ºN to latitude 40º S all through the temperate, subtropical, and tropical regions of the world (Hallaurer and Miranda, 1972). Maize is

a warm weather crop and is not grown in areas where the mean daily temperature is less than 19ºCor where the mean of the summer temperatures is less than 23ºC (Bradley, 2000). That is, the crop tolerates a wide range of environmental conditions, but grows well in warm sunny climates with adequate moisture (Purseglove, 1992). Although the minimum temperature for germination is 10ºC, germination is faster at soil temperature from 16ºCto 18ºC. At 20ºC, maize emerges within five to six days. The critical temperature detrimentally affecting yield is approximately 32ºC. In the temperate regions frost can damage maize at all growth stages and a frost-free period of 120 to 140 days is required to prevent damage whiles the growth point is below the soil surface, new leaves will form and frost damage will not be too serious. Leaves of mature plants are easily damaged by frost and grain filling can be adversely affected (IITA, 2009).

2.4.2Water

In general, maize needs at least 500-700mm of well distributed rainfall during the growing season. This amount of rain may not be enough if the moisture cannot be stored in the soil because of run-off or shallow soil depth (ARC- Grain Crops Institute, 2003). Approximately 10 to 16kg of grains are produced for every millimetre of water used. A yield of 3152kg/ha requires between 350 to 450mm of rain per annum. At maturity, each plant will have used 250 liters of water in the absence of moisture (ARC – Grain Crops Institute, 2003).

2.5. Environment

The environment comprises of climate and physical factors that contribute to plant growth (Beets, 1982). It was indicated that genetic improvement of crop plants alone is not a remedy to predicaments in terms of food shortage in the world (Wood, 1983). To

achieve increase in crop productivity, high yielding varieties should be combined with improved agronomic practices such as appropriate planting distance, irrigation, pest and disease control, and fertilization (Russell *et al.,* 1970). Genetic improvement in traits of economic importance along with maintaining sufficient amount of variability is always the desired objective of maize breeding programmes (Hallauer, 1972).

Grzesiak (2001) observed considerable genotypic variability among various maize genotypes for different traits. Bylee (1997), Ihasan *et al*. (2005) also reported significant genetic differences for morphological parameter of maize genotypes. The variability is key to crop improvement (Welsh, 1981). For high yielding cultivars if high fertilizer doses are applied in successive vegetative growth occurs which corresponds to high lodging and less yield in terms of produce. Experience in a number of countries have shown that soil moisture and nutrient deficiency cause wilting for one – two days during tasseling can cause a reduction of yield of about 28% and six-eight days wilting can cause a reduction of yield of about 50%,which cannot be made up by later precipitation or irrigation (Tweneboa, 2000). Classman and Shaw (1970) indicated that stress imposed at 75% silking reduced yield by 6-8% per day but when this was combined with fertility stress, yield reduction was 13% per day with a large reduction in the number of developed kernels. Soil characteristics in terms of physical and chemical properties have bearing on the productivity of maize crop. A suitable environment for maize production cuts across a wide range of soils from sand, clay slightly acidic to alkaline soil (Olson and Sonder, 1988). At a very low pH soils are likely to be deficient in phosphorus due to typing up with active Aluminum components pH at high P levels, nutritional predicaments are often encounter with the elements phosphorus, zinc and iron. (Olson and Sonder, 1988).Hanway (1971) reported that NPK fertilizer is absorbed slowly during the seedling stage and rapidly during the

active growth and grain filling stages. The uptake of nitrogen and phosphorus continues until near maturity, but K absorption is largely completed by silking stage (Hanway, 1971).

The nitrogen and phosphorus are absorbed at the early stage and translocated into grain that would result in high yield. Veldkamp (1992) reported that application of fertilizer in their correct amount increases crop yield but plants needs nitrogen to make proteins net amino acids, P to convert energy from the sun into energy forms that the plant can use, and K for metabolism. The major abiotic challenge is low nitrogen and stress during critical stages of crop growth. Leaf chlorosis suggests poor nitrogen nutrition is prevalent on most farms at pre-anthesis and grain-filling stages of growth.

Poor N nutrition may be due to inadequate N fertilization or temporal mismatch between N availability in soil solution and crop uptake needs. Poor synchrony occurs when large pre-plant application of fertilizer N is available before the crop has sufficient root capacity for rapid uptake (Shanahan *et al*., 2008). Since yield is likely to be poor under nitrogen stress during silking coincide with nitrogen availability in soil solution and plant uptake demands is crucial to unlocking the potential of modern hybrids. Poor kernel formation, increased abortion and ultimately lower grain yield under nitrogen stress has been reported widely (Andrade *et al*., 2000). Maize obtains 35 – 55% of kernels nitrogen from post silking uptake between the 8 to10leaves (Ta and Weiland 1992; Lafitte, 1997). Silva *et al*. (2005) reported that nitrogen fertilization at booting and silking caused significant increments in grain yield and kernel crude protein content. Appropriate timing rate and time by split application in order to coincide nitrogen availability with crop needs is a best management practices that would result in better N use efficiency and yield(Robert, 2008).

Dennis (1983) reported that soils in Ghana have pH range of 5.6 – 6.5; organic matter and N are low in the savannah soils due to rampant burning, but high in forest soils due to recycling of leaf litter. It was observed that 60 - 80% of the fertilizer responses of maize are N, phosphorus is the second nutrient to which maize responds. Low pH, low organic matter, high iron, Aluminum and clay tend to reduce availability of phosphorus (Dennis, 1983).

Most soils in Ghana have low P- fixing capacity in 0 – 15cm depth and maize responds to P as low as 10 -20kg $P_2$05/ha.The optimum application rate of phosphorus is 40-80kg P_2O_5/ha (Dennis, 1983). The recommended rates of NPK fertilizers is in the range of 45 – 112kg N/ha, 19 – 67 kg P_2O_5 /ha and 0– 40kgk_2O/ha, depending on the type of soil (Dennis, 1983).

2.5.1 Gain Estimation

Predicting genetic gain enables plant breeders to determine breeding methods, which solidifies plant breeding as a science, consequentially, developing desirable selection strategies to enhance gains, has facilitated significant increases in crop yields (Duvick *et al.,* 2004). The response to selection is the change in the population mean due to selection and can be predicted as change y = [BXY (ΔX)] /t where change in y is the response to selection, BX is the regression coefficient between selection units X, response units' change in X or the selection differential and t is the number of years for cycle completion (Holland *et al.,* 1994).

Rodriques (1990) estimated the variances of annual gains and the covariance of consecutive gains from the number of treatments shared by each pair of years, to obtain a covariance matrix that was used in the generalized least squares method to obtain mean and variance estimates.Soares (1992) estimated genetic gain for rice (*Oryza*

sativa L.) breeding in the State of mines Gerais using, in addition to the method of Vencovsky *et al.* (1988) a method based on the behaviour of standard check.

2.6 Genotype by Environment Interaction

The primary aim of multi-location trial in plant breeding is to estimate yield of genotypes across diverse environments. Differential genotypic response to variable environmental conditions associated with changes in the ranking of the genotypes may limit accurate yield estimates and identification of high yielding, stable genotypes(Kempton, 1984). The conventional method of partitioning total variation into components due to varieties, environment and variety by environment interaction conveys little information on the individual patterns of response (Kempton, 1984). Regression analysis also has been used extensively to partition genotype by environment (GXE) interaction (Gauch, 1988). Multivariate analysis techniques such as principal component analysis are often used to simplify interpretation of GXE structure by representing complex relationships among locations or genotypes in a scatter plot (Westcott, 1987). Cluster analysis is used to group locations that discriminate among genotypes in a similar manner or to summarize the pattern of genotypic performance across environments (Crossa *et al.*, 1991).

Genotypes by environment interaction are the change in a cultivars relative performance over environments resulting from differential response of the cultivar to various edaphic, climatic and biotic factors (Dixon *et al*., 1994). The variety by location interaction could occur when the crop is tested throughout a region and this shows the region on different environment (Allard and Bradshaw, 1963).Genotype by environment interactions is a challenge to plant breeders because they cause difficulties in selecting genotypes evaluated in diverse environments. Genotype by environment

interaction is significant, its causes and implications must be carefully considered. Akposoe (1971) stated that differences in years, seasons, and locations may contribute to GXE interactions. He emphasizes that, minor season maize experiences low yield than the major season. Ansah (2001) reported that local maize germplasm in four environments were evaluated and noted that higher yields were experienced at the major season compared to the minor season. Akposoe (1975) evaluated three open-pollinated maize varieties at two plant population per hill and 15 fertilizer treatments in eight locations in Ghana and reported that variety by fertilizer interaction were significant at 5% in terms of yield at all the locations. Therefore GXE must be carefully assessed in plant breeding and selection programmes.

2.6.1Gains due to Genetic Improvement in maize

Statistical package have been used to estimate breeding progress in maize and other crops (Duvick, 1984). Varieties could be evaluated by direct comparison from different regimes in a common environment. It was suggested by Cox *et al*. (1988) that the evaluation of varieties from different regimes in common environment is the most direct of several methods used to estimate breeding progress. Duvick *et al.* (2004) reported that examination of data provides an estimate of 51% for the contribution of genetic, when trial yields are adjusted to the equivalent of average on farm yields for a period. They indicate that yield trial results can be categorized according to the average yield at each test site, and compared with the yield at different sites (Duvick, 2005).

A stability analysis of Ebechart and Russell (1996) can be used to compare yield responses of individual hybrids, or group of hybrids such as those released in a given decade. Mean yield of hybrid groups at each test site can be regressed on mean yield of all the varieties at each test site. Linear regression is a tool for estimating long- term

genetic gains (Casler *et al*., 2000). Failure to detect long term linear progress for yield in crop plants may be due to non- random sampling of the cultivars population, dilution of a few improved cultivars with unimproved cultivars, or lack of true genetic progress (Casler *et al*., 2000).

Evans and Fischer (1999) reported that linear regression is applied to yield versus year of release of the varieties. The slope indicates the annual rate of progress as kilogramme per hectare per year. Vencovsky *et al.* (1988) emphasized that gains can be estimated for each pair of consecutive year as being the variation of annual means minus the variation of the means for the lines common to the two years. Toledo *et al.* (1990) used the method of Vencovsky *et al*. (1988) to calculate the genetic gain obtained by soya bean (*Glycine max*merr.).Rodriques (1990) estimated the variance of annual gains and the covariance of consecutives gains from the number of treatments shared by each pair of year to obtained a covariance matrix that was used in the generalized least squares method to obtain mean and variance estimates. Soares (1992) estimate genetic gain for rice (*oryza sativa* L.) breeding in the State of Minas Gerais in addition to the method of Vencovsky *et al.* (1988).

The deviation between the mean for lines and the mean for the standard checks is calculated for each year. The estimation of the genetic progress is the linear regression coefficient of these deviations in relation to years (Duvick, 1977). The genetic gain obtained by breeding programmes to improve quantitative traits may be estimated by using data from regional trials. Evidence for the contribution of breeding increases in maize yield has reported in several studies (Russell, 1974, Duvick, 1977 and Meghji *et al*, 1984) .Genetic gains between 33-92 kg/ha/year were obtained using the hybrids and estimates using open- pollinated cultivars as the genetic improvement ranged from 56-89%.Evans and Fischer (1999) emphasized that indirect assessment could be used to

ascertain the gains in maize production. They indicated that results of well-managed yield trials, conducted at a number of locations over many years, could be used to compare new cultivars with several older standard ones. Such comparisons could be compiled serially to provide widely replicated estimates of the relative yield potential of long series of major cultivars when grown in the environment and with the agronomy to which they were adapted. However, it is important to restrict such comparisons to those trials that were disease-free (Evans and Fischer, 1999). Castleberry *et al*. (1984) compared maize cultivars from six decades (1930-1980) in low and high fertility conditions at one location for two years. The high fertility areas had received normal fertility application for 20 years whereas the low fertility areas had been in continuous production and unfertilized since 1958.The higher fertility area received approximately 200 kgN/ha, 90 kg of $P_2$05/ha and150 kg of $K_2$0/ha in the 2-years test. The low fertility area received no fertilizer. The yield response relative to decades was 87 kg/ha/year in the high fertility condition and 51 kg/ha/year under the low fertility condition, the newer hybrids were superior to the older cultivars in both fertility levels and the superiority was greater in the high fertility area than the low fertility area (Duvick, 1984).

2.7Physiological basis of Genetic gains

Grain yield is the product of accumulating dry matter (biomass) and allocating a portion of the total above ground biomass to the grain. The physiological basis for genetic gains is well established in most crops. Although yield potential in wheat improved steadily for over 30 years (Cavalieri and Smith, 1985). The physiological basis is only partially understood while the genetic basis remains largely unclear (Reynolds *et al*., 1998). Maize breeders during the hybrid era, 1939 to present, have been extremely successful in making continuous genetic improvement in commercial

grain yield. Maize development can be dissected into components whole-crop level physics and logical processes that occur during various development phases in the life cycle of the plant (Tollenaar and Lee, 2006). Physiological and morphological characteristics, such as osmotic adjustment, stomata behavior, chloroplast activity, leaf water potential, root volume, root weight, leaf area, and dry matter production, have been studied in several maize cultures grown in limited water supply (Sanchez – Diaz and Kramer, 1971). Stomata regulate leaf diffusive conductance, and thereby influence two of the most important processes in terrestrial plants, photosynthesis and transpiration. Terrestrial plants have to balance the uptake of CO_2 with the loss of water from the plant under various environmental conditions.

To obtain the optimal response to multi-factorial environmental changes, guard cells of stomata sense, many environmental factors, such as light (quantity and quality), temperature, humidity, intercellular CO_2 concentration, and drought - induced abscisic acid(ABA) (Raschke, 1975; Zeiger, 1983; Schroeder *et al*., 2001) and have the ability to integrate environmental and endogenous signals. Morphological and physiological traits associated with tolerance to high plant density and reported that density tolerate maize genotypes characterized by rapid completion of silk extrusion, pollen shed and rapid growth of the first ear and silk, reduced tassel size and efficient production of grain per unity leaf area. Increasing plant density is one method of maximizing interception of incoming solar energy in crop species. One of the major factors limiting conversion of light energy to grain in maize grown at high plant densities is barrenness, the failure of plants to produce ears (Buren, 1974; Stinson and Moss, 1960; Wolley *et al.*, 1962).

A recent study conducted in a high- yielding environment in Mexico revealed that leaf photosynthetic rate, leaf conductance and canopy temperature depression (CTD) were

all associated with yield progress in a set of eight spring bread wheat and maize lines, representing progress in yield potential between 1962 and 1988 (Fischer *et al*., 1998). One important implication of this work is that such traits can be measured reasonably simple in the field, suggesting a potential methodology for screening physiologically superior lines (Reynolds *et al.,* 1998). Additional physiological traits that may have implications on yield potential are translocation from the stems to grain of soluble carbohydrates (Stem reserve) and the ability to maintain green leaf area duration through grain filing (Jenner and Rathjan, 1975). Both traits would be more important where a crop assimilates waslimited, and physiological studies have indicated that higher yielding lines depend less on stem reserves than lower yielding ones (Stoy, 1965; Austin *et al*., 1980). Another area that has yet to be explored with respect to raising yield potential is the optimization of physical development. The relative length of the cardinal phonological stages is a function of the interaction of environmental cues with genes determining earliness per sensitivity to photoperiod (Slater and Rawson, 1994). The reproductive stage of development is pivotal in determining yield potential, and genetic variability for its duration relative to other phonological stages (Slater and Rawson, 1994). Edmeades *et al*. (1989) emphasized that, in order for an ear spikelet to produce a visible silk, it must achieve a threshold biomes within a given time interval relative to anthesis. Thus, where partitioning of assimilates to the ear is high, this resorts in rapid ear growth near anthesis and rapid silk extrusion. Any time partitioning is low, development of spikelet continues but becomes smaller, silk growth is slow and when such silk are pollinated, even with fresh pollen, after recipient plant has anthesised, the fertilized ovule may abort.

2.8 Common Maize Diseases that affect yield

There are many causes of low maize yield of which diseases play a significant role. Moreover seed – borne diseases cause enormous losses both in storage as well as in the field. A total of 112 diseases are known to occur on maize (USDA, 1960) of which 70 are seed-borne. Important seed-borne diseases of maize are leaf spot, leaf blight, collar rot, kernel rot, stalk rot, ear rot, scutellium rot, seeding blight and head smut (Richards, 1993). The kernel rots and black bundle diseases are caused by *Acremoniumstrictum* (Mathur and Kongsdal, 2003). The pathogen survives in the soil, plant debris and seed. The disease is favoured by post- flowering water stress; the disease kills the plant prematurely after flowering. Infected plant do not show symptoms until they reach the tasseling stage (CIMMYT, 2004), Wilting generally starts from the top leaves and become dull green, eventually lose colour and become dry (CIMMYT, 2004).

Another common disease of maize is southern leaf blight and it is caused by *Bipolarismaydis* (Mathur and Kongsdal, 2003). Leaves show greyish, and parallel straight-sided or diamond shaped 1- 4 cm long lesions with buff or brown borders or with prominent colour banding or irregular zonation (Ullstrup, 1985). Symptoms may be confined to leaves or may develop on sheaths, stalks, husks, ears and cobs. The lesions are longitudinally elongated typically limited to a single intravascular region, often coalescing to form more extensive dead portions (Ullstrup, 1985). Young lesions are small and diamond shaped as they mature, they elongate. Growth is limited by adjacent veins, so final lesion is rectangular 2-3cm long (CIMMTY, 2004).

Black kernel rot is caused by pathogen *Botryodiplodiatheo bromae* (Mathur and Kongsdal, 2003). The same fungi can produce stalk rot with conspicuous black discoloration in moist, hot environment (CIMMYT, 2004). Affected ears develop deep black shiny kernels and husk leaves can also turn black and be shredded (CIMMYT,

2004).It is obvious that, diseases that affect maize cause yields reduction and it reported that yields from developed countries are higher (7 t/ha) compared to 1-2 t/ha in the developing countries (CIMMYT, 1990).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Genotype

The evaluations involved fourteen maize genotypes. The genotypes comprised of three hybrid varieties, six open- pollinated varieties, one local variety and four inbred lines (Table 1).

3.2 Description of the experimental sites

The study was conducted in two phases during 2011 major and minor season at Kwadaso and Fumesua in the forest zone representing two growing environments. The environments were Kwadaso, major season and Fumesua minor season.Kwadaso and Fumesualie on latitude 6ºC42ºCN and longitude -1ºC 30ºCW. The soils were Ferric Acrisol, dark grey gritty loam to gritty clay loam. The soils at various locations were deep porous, well aerated, and properly drained (Adu, 1992).

3.3 Experimental design

The experimental design used was 3 x 14 factorial experiment arrange in randomized complete block design with four replications in each environment. The nitrogen levels were 0, 45 and 90 kgN/ha and varieties were randomized.

3. 4. Land Preparation

The weeds were slashed using a tractor mounted clasher and ploughed for effective planting. Two weeks to planting, a combination of Calliherb (2-4D) and Glyphosate was sprayed at a rate of 1.1kg ai/ha and 20.0 kgai/ha respectively to control the emergence of weeds.

Table 1. Characteristics of the maize genotypes used

Maize genotypes	Characteristic of the genotypes	Grain colour	Plant height (cm)	Days to 50% tasseling	Days to 50% silking	Maturity	Average yield t/ha
Mamaba	Open pollinated variety hybrid	White flint	128	54	56	105-110	7.5
Aburohemaa	Quality protein maize, Open pollinated variety	White flint	125	53	56	90-95	5.0
Akposoe	Quality protein maize	White	127	53	56	80-85	3.5
Omankwa	Quality protein maize, Open pollinated variety	White	125	53	57	90-95	5
Abontem	Quality protein maize	Yellow	125	53	57	80-85	4.7
Etubi	Quality protein maize hybrid	White	127	54	57	105-110	7.5
Golden Jubilee	Quality protein maize, Open pollinated variety	Yellow	127	54	57	105-110	5
Obatanpa	Quality protein maize, Open pollinated variety	White	127	52	55	105-110	5.5
Entry 5	Quality protein maize inbred	White	125	53	56	105-110	1.2
Entry 70	Quality protein maize inbred	White	132	53	57	105-110	1.3
Ohaw local	Normal maize Open pollinated variety	White	125	53	56	105-110	2.2
Entry 6	Quality protein maize inbred	White	127	53	56	105-110	1.1
GH 110	Quality protein maize hybrid	White	128	54	57	105-110	7.4
Entry 85	Quality protein maize inbred	White	127	53	56	105-110	1.3

Source: Crop Research Institute Kumasi, Ghana (2011).

Table 2. Rainfall distribution by agro-ecological zone in Ghana

Agro-ecological zone	Mean annual rainfall (mm)	Major Season (mm)	Minor Season (mm)
Rain Forest	2200	150-160	100
Deciduous	1500	150-160	90
Transitional	1300	200-220	60
Coastal	800	100-110	50
Guinea	1100	180-200	
Sudan Savannah	1000	150-160	

Source: Meteorological Service Department, Accra, Ghana(2011).

3.5 Soil Sample and analysis

Soil samples were collected at Kwadaso and Fumesua at a depth of 0-15, 15 – 30 and 30-45cm to ascertain the various chemical properties in order to recommend certain practices that would achieve optimum yield.

3.6 Planting

The varieties were planted on 21st July 2011 at Kwadaso in the Major season and 28th September 2011 at Fumesua in the minor season respectively. Each variety was planted in two- row plots to reduce variability or experimental error, because of the large number of treatments used in this experiment. Each plots measured 5m long with planting spacing of 75cm between rows and 22.5cm within rows to achieve a plant population of 59,260 plants per ha.

Four seeds were planted per hill and thinned to two plants to achieve the target population.

3.7 Fertilizer Application

All the treatments received a base application of phosphorus (P) as triple super phosphate at 60 kgP_2O_5/ha and Potassium (K) as Potassium chloride (KCl) at 30 kgK_2O/ha. Nitrogen was applied as sulphate of ammonia at 0, 45, and 90 kgN/ ha. Total nitrogen was applied at two equal doses, half at eight days after planting and the remainder at four weeks after planting.

3.8 Weed Control

Manual weeding with cutlass was used to clear the field at 4, 8 and 12 weeks, after planting to avoid competition for nutrients, water, and sunlight to achieve optimum yield at harvest.

3.9 Data Collected

1. Plant height

Plant height was measured in five plants of each genotype per two-row plot in centimeters (cm) from the base of the plant to flag leave and average height was determined.

2. Ear height

Ear height was measured in five plants of each genotype per two –row plot in centimeters from the base of the plant to the node bearing and the average height was determined.

3. Plant stand

The total number of plants per plot was counted after thinning and recorded.

4. Days to 50% tasseling

The number of days was counted from planting to the time when 50% of the plants had tassels shedding pollen.

5. Days to 50%silking

The number of days was counted from planting to the time when 50% of plants had silk.

6. Root Lodging

The number or percentage of plants that was root lodged were scored on the scale of 1-5 where 1 not lodged and 5 = heavily lodged.

7. Stalk lodging

The number or percentage of plants that were stalk-lodged were counted and recorded.

8. Ear rot

The total number of ears that were rotten was scored on the scale1-5, 1= little or no and 5 = most of the ears rotten.

9. Ear Harvest

The total number of ears harvested per plot were counted and recorded.

10. Ear aspect

Ear aspect was scored on a scale of 1-5 where 1= clean, uniform, large and well-filled ears and 5= rotten, variable, small and partially filled ears.

11. Disease

The diseases blight, streak, and rust were scored on the scale of 1-5 where, 1 means no disease and 5 severely affected.

Post - harvest data

1. Field weight of cobs

The weight of the cobs per plot was measured in kilogramme using an electronic balance and the values recorded.

2. Cob Length

Cob length was measured in five cobs in each genotype in centimeters with rule and the average was determined.

3. Cob diameter

Sample of five cobs were measured with a calliper and the average determined and recorded.

4. Grain moisture

The weight of the grain per plot was measured with electronic scale and the value recorded and oven dried, the difference divided by the initial weight and multiplied by one hundred.

5. 1000 seed weight

The weight (g) of 1000 seeds per plot in grammes was determined using electronic balance and the values recorded.

6. Shelling percentage

This was determined by dividing the grain weight of cobs by the field weight of cobs.

7. Grain yield

Grain yield per plot in kilogrammes were determined after shelling using an electronic balance and the values recorded.

8. Heterosis

The performance of a hybrid relative to its parent can be expressed as high parent heterosis, the comparison of the performance of the hybrid expressed as a percentage and computed as high-parent heterosis = (F1-Hp)x 100

Where F1 is performance of hybrid and Hp represents the performance of the best parent. The hybrids used for the experiment were GH110, Mamaba and Etubi. The inbred lines used to breed the genotype GH110 were Entry 6 and 70.

3.10 Cost -benefit analysis

Total cost was computed as:

TC = TFC + TVC

Where TC = Total cost, TFC = Total fixed cost, and TVC = Total Variable cost

Total Revenue was computed as:

TR = P X Q

Where TR = Total revenue, P = Profit and Q = quantity

Marginal Rate of Returns (MRR)was computed as:

MRR = Change in Profit divided by change in Total Variable cost multiplied by100.

3.11 Statistical Analysis

Data transformation was made on count variable to normalize them before statistical analysis. Genstat statistical package version 9 was used to analyze the data and Lsd (5%) was used to separate the means. Linear regression analysis was used to estimate yearly increase due to genetic improvement in yield and other traits.

CHAPTER FOUR

4.0 RESULTS

The analysis and results of soil chemicals for both Kwadaso (major season) and Fumesua (minor season) are presented in Tables 3 and 4.

Table 3 Soil chemical properties at Kwadaso site for 2011 major season.

	Soil Depth (cm)		
Soil properties	**0-15**	**15-30**	**30-45**
PH (1:1)	7.55	7.39	7.09
Organic Carbon (%)	0.52	0.43	0.36
Total Nitrogen (%)	0.05	0.04	0.03
Organic Matter (%)	0.9	0.74	0.62
Exchangeable Calcium (Me/100g)	9.35	7.48	4.54
Exchangeable Magnesium (Me/100g)	2.14	2.67	1.87
Exchangeable Potassium (Me/100g)	0.8	0.84	0.44
Exchangeable Sodium (Me/100g)	0.66	0.56	0.54
Total Exchangeable Base	12.95	11.55	7.39
Exchangeable Aluminum (Al+H)	0.05	0.05	0.08
CationExchange Capacity (Me/100gm)	13	11.6	7.47
Base Saturation (%)	99.6	99.5	98.9

Table 4. Soil chemical properties Fumesua site for the2011 minor season

Soil properties	Soil Depth (cm)		
	0-15	15-30	30-45
PH (1:1)	6.62	6.18	5.32
Organic Carbon (%)	1.20	0.71	0.57
Total Nitrogen (%)	0.12	0.07	0.05
Organic Matter (%)	2.07	1.22	0.98
Exchangeable Magnesium (Me/100g)	6.68	2.14	1.03
Exchangeable Calcium (Me/100g)	5.87	2.67	2.67
Exchangeable Potassium (Me/100g)	0.39	0.24	0.20
Exchangeable Sodium (Me/100g)	0.17	0.13	0.10
Total Exchangeable Base	13.11	5.18	4.00
Exchangeable Aluminum (Al+H)	0.10	0.12	0.60
Cation Exchange Capacity (Me/100gm)	13.21	5.30	4.60
Base Saturation (%)	99.20	97.70	86.90

4.1 MEAN SUM OF SQUARES OF COMBINED DATA FROM THE TWO ENVIRONMENTS

The combined analysis of variance for the major and minor seasons are presented in Table 5. The analysis indicated that the nitrogen levels, environment, variety, the variety by nitrogen interaction and the environment by nitrogen interaction were highly significant ($p < 0.01$) in terms of grain yield, and environment by nitrogen was also significant ($p < 0.05$). Variety by environment by nitrogen interaction was also significant ($p< 0.01$).Grain yield, 1000 seed weight, mid silking days, cob aspect, cob diameter, streak disease, open tip, stalk lodge and all the other agronomic parameters that were measured were significant($p< 0.01$)among the levels of nitrogen fertilizer.

The response of genotypes were highly significant ($p< 0.01$) for grain yield, shelling percentage, mid anthesis, mid silking, plant height, open tips, ear height, 1000 seed weight and other agronomic traits measured. The interactions of Genotype by Environment were significant ($p < 0.01$) for parameters such as grain yield, mid anthesis, cob length, cob diameter, streak, shelling percentage, rotten ears and stalk lodge. The interaction of Genotype X Nitrogen X Environment also showed a significant difference ($p < 0.01$) in terms of grain yield, days to 50% tasseling, plant height and other agronomic parameters measured.

Table 5 Mean sum of squares of combined analysis of Kwadaso and Fumesua

SOURCE	DF	Grain Yield (t/ha)	1000 Seed Weight (g)	Mid Anthesis (Days)	Mid Silking (Days)	ASI (Days)	Blight Disease (Score)	Cob Aspects (Score)
Rep	3	0.996	586.7 Ns	72.051 Ns	69.365 Ns	1.8284 Ns	0.4792 Ns	0.1220 Ns
Nitrogen Level	2	22.921**	1780.3*	24.664	30.110**	0.7500 Ns	0.5119 Ns	0.5625**
Environment (E)	1	2.252**	68.9 Ns	2601.860**	3132.964**	24.6458**	120.2411**	9.0030**
Variety (V)	13	39.471**	2749.1**	53.754**	47.971**	0.8693 Ns	0.8620*	0.9462**
Envt. X Nitrogen	2	0.237*	764.7 Ns	27.521**	13.687 Ns	7.0476**	1.000 Ns	0.7351**
Variety X Nitrogen	26	0.5016**	258.4 Ns	48.963**	2.514 Ns	0.8397 Ns	0.4863 Ns	0.2869 Ns
Envt. X Nitrogen	13	0.178**	333.9 Ns	3.324	43.669**	0.8253 Ns	0.600 Ns	0.2594 Ns

SOURCE	DF	Cob Diameter (cm)	Plant Height (cm)	Cob Length (cm)	Ears Per Plant	Ear height (cm)	Streak (Score)	Open Tip (cm)
Rep	3	1.235 Ns	11825.2 NS	0.995 Ns	0.23076 Ns	6617.9 Ns	0.31347 Ns	340.9 Ns
Nitrogen Level	2	1.0257**	543.8 Ns	1.845 Ns	0.06891 Ns	54.2 Ns	0.17044**	1677.0**
Environment (E)	1	43.0789**	243262.1**	376.597**	7.53162**	24018.3**	1.31803**	2.64439.9**
Variety (V)	13	1.3244**	3123.0**	10.158**	0.04161 Ns	1745.5**	0.06098 Ns	417.0**
Envt. X Nitrogen	2	0.1521 Ns	7667.1**	3.392 Ns	0.05299 Ns	3851.7**	0.17044**	300.6 Ns
Variety X Nitrogen	26	0.1897 Ns	363.2 Ns	3.056 Ns	0.03416 Ns	201.1 Ns	0.02215 Ns	326.4 Ns
Envt. X Nitrogen	13	0.5170**	944.4 Ns	8.441**	0.03038 Ns	383.2 Ns	0.11336**	299.3 Ns

Significant at 1%, * Significant at 5%, Ns Not Significant

CON'T Table 5 Mean sum of squares of combined analysis of Kwadaso and Fumesua

SOURCE	DF	Shelling Percentage (%)	Rotten Ears (cm)	Root Lodge (cm)	Stalk Lodge (cm)
Rep	3	101.3 Ns	189.00 Ns	675.04 Ns	5985.1 Ns
Nit. Level	2	213.0 Ns	8.90 Ns	60.31 Ns	2808.0**
Envt. (E)	1	27353.6**	427.91**	5097.46**	21773.3**
Variety (V)	13	3550.5**	141.58**	95.86**	370.1 Ns
Envt X Nit.	2	1079.5**	10.93 Ns	103.81*	381.7 Ns
Vty X Nit	26	520.6**	49.98 Ns	45.44 Ns	258.2 Ns
Envt X Nit	13	568.5**	143.85**	44.88 Ns	794.1**

** Significant at 1%, * Significant at 5%, Ns Not Significant

4.2 Grain Yield

The response of the grain yield of the 14 genotypes to nitrogen application rate is presented in Table 6 and figure 1. The genotypes responded positively in terms of increased in nitrogen levels. The response of the genotypes to that of the yields increased orderly from 90 kgN/ha > 45 kgN/ha > 0 kgN/ha.

The response of the nitrogen fertilizer was highly effective to hybrids, open -pollinated varieties, local variety and the inbred lines based on grain yield. The mean grain yield of hybrid, open pollinated, local varieties and inbred lines are presented in the graph (Fig. 1). The mean difference of hybrid, open pollinated variety, local and inbred lines are 4.24 t/ha, 3.6 t/ha, 3.2 t/ha and 1.13 t/ha respectively.

Comparatively, the difference between the hybrids and local variety was encouraging. The hybrid performed better in terms of yield by 13.5% and the open pollinated varieties by 8% hybrid to inbred lines also yielded 58.3% difference.

Again, comparative yields in terms of fertilizer application rate also proved to be significant. Mean of 90 kgN/ha was 3.5 t/ha, 45 kgN/ha was 3 t/ha and that of 0 kgN/ha was 2.5 kgN/ha. This implies that the varieties responded positively to fertilizer application.

Table 6. Mean grain yield of 14 genotypes evaluated at Fumesua and Kwadaso in 2011

		Fumesua (Minor season)			Kwadaso(major season)			
Genotype	**Variety**	**0KgN/ha**	**45KgN/ha**	**90KgN/ha**	**0KgN/ha**	**45KgN/ha**	**90KgN/ha**	**Means**
Mamaba	Hybrid	3.94	4.34	5.04	3.98	5.08	5.65	4.67
GH 110	Hybrid	3.46	3.61	4.28	3.64	3.91	4.43	3.88
Etubi	Hybrid	3.47	3.75	4.53	3.91	4.35	5.06	4.17
Abontem	OPV	3.07	3.27	4.33	3.19	3.63	4.55	3.67
Aburohemaa	OPV	3.05	3.37	4.25	3.08	3.62	4.49	3.64
Akposoe	OPV	3.10	3.55	4.35	3.32	3.60	4.55	3.74
Obatanpa	OPV	2.99	3.21	4.13	3.00	3.60	4.39	3.55
Golden J	OPV	3.04	3.30	4.10	3.11	3.41	4.12	3.51
Omankwa	OPV	2.94	3.29	4.17	3.07	3.45	4.49	3.56
Ohaw Local	Local	2.78	3.28	3.60	2.86	3.39	3.61	3.25
Entry 5	Inbred	0.98	1.05	1.20	1.15	1.17	1.22	1.12
Entry 6	Inbred	0.99	1.11	1.17	1.03	1.14	1.23	1.11
Entry 70	Inbred	0.94	1.09	1.09	1.08	1.13	1.72	1.18
Entry 85	Inbred	0.89	1.08	1.14	1.05	1.20	1.24	1.10
Means		2.54	2.80	3.38	2.67	3.04	3.63	3.01
Lsd (5%)	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.062
CV (%)	7.8							

Comparison of N treatment means.

Table 7. Mean grain yield (t/ha) of the 14 maize genotypes evaluated under three levels of nitrogen in two environments of the year 2011.

Genotypes	Year of release	0 KgN/ha	45KgN/ha	90KgN/ha	Mean
Ohaw local	1955	2.82	3.43	3.60	3.28
Obatanpa	1992	2.99	3.41	4.26	3.55
Mamaba	1996	3.96	4.71	5.34	4.67
GH 110	1997	3.55	3.76	4.36	3.89
Entry 5	1997	1.07	1.13	1.21	1.13
Entry 6	1997	1.01	1.11	1.20	1.08
Entry 70	1997	1.01	1.11	1.40	1.17
Golden Jubilee	2007	3.07	3.35	4.11	3.51
Etubi	2007	3.69	4.05	4.75	4.16
Akposoe	2007	3.21	3.58	4.45	3.74
Omankwa	2007	3.01	3.37	4.33	3.57
Entry 85	2007	0.97	1.14	1.19	1.10
Aburohemaa	2010	3.07	3.49	4.34	3.63
Abontem	2010	3.13	3.14	4.44	3.25
Mean		2.61	2.83	3.20	3.00
LSD (0.05)		0.062	0.062	0.062	0.062
CV	3.6				

Table 8.High parent heterosis value of three hybrids

Hybrids	Mean performance (t/ha)	High parent Heterosis value (%)
GH110	3.89	232.5
Mamaba	4.67	299.1
Etubi	4.16	255.2

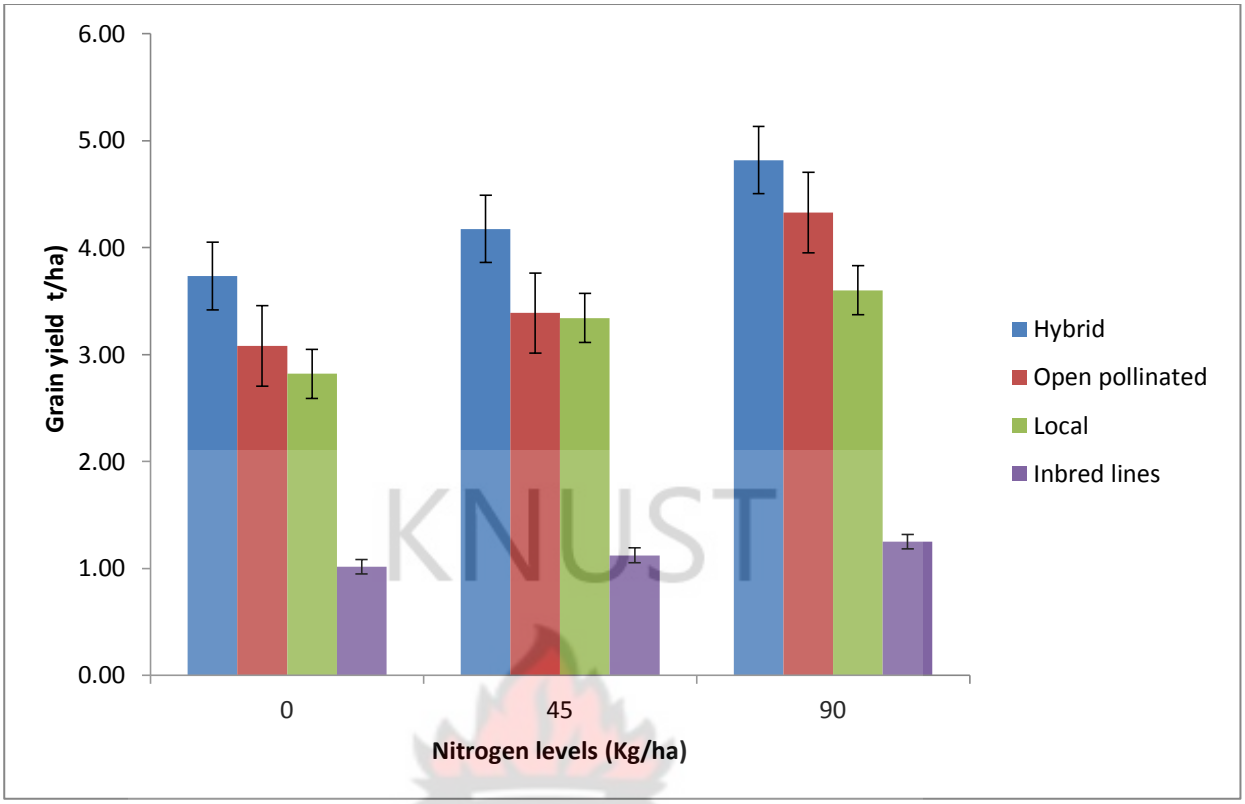


Figure 1. Mean grain yield of inbred lines, local variety, open pollinated varieties and hybrids evaluated under three levels of nitrogen at Fumesua and Kwadaso in 2011.

4.3 Shelling Percentage

The comparative response of 14 genotypes of nitrogen application is shown in Table 9. All the genotypes showed consistent pattern for the nitrogen response in terms of hybrid, OPV's, local variety and inbred lines. Comparatively, the response was positive in all the genotypes with respect to nitrogen levels of 0 kgN/ha, 45 kgN/ha and 90 kgN/ha.The mean shelling percentage of the genotypes showed tremendous increased of 44.9 at 0 kgN/ha, 47.70 at 45kg/ha and 54.17 percent at 90 kgN/ha in terms of performance of the hybrid.

The OPV's also showed significant difference from 34.4 at 0 kgN/ha, 42.07 at 45 kgN/ha and 45.27 at 90 kgN/ha. In all, there was an absolute increase in shelling

percentage in terms of hybrid, OPVs, local variety and inbred lines at all levels of nitrogen application.

Table 9. Mean shelling percentage for 14 genotypes evaluated under three levels of nitrogen in 2011

Genotypes	Year of release	0 kgN/ha	45 kgN/ha	90 kgN/ha	Mean
Ohaw local	1955	21.2	12.9	17.2	17.1
Obatanpa	1992	38.9	47.5	48.9	45.10
Mamaba	1997	39.0	41.9	57.1	46.0
GH 110	1997	48.7	53.9	55.2	52.6
Entry 5	1997	22.0	20.3	21.7	21.3
Entry 6	1997	17.1	9.30	8.50	11.63
Entry 70	1997	21.9	22.1	22.5	22.16
Golden Jubilee	2007	37.2	39.2	43.8	40.06
Etubi	2007	47.0	47.3	50.2	48.16
Akposoe	2007	35.6	44.5	46.2	42.10
Entry 85	2007	20.1	20.4	11.8	17.43
Omankwa	2007	24.0	33.7	40.7	32.80
Aburohemaa	2010	32.4	48.5	49.5	43.46
Abontem	2010	38.3	39.0	42.5	39.9
Mean		31.67	34.32	66.48	34.27
LSD (0.05)		4.04	4.04	4.04	8.73
CV 3.1(%)					

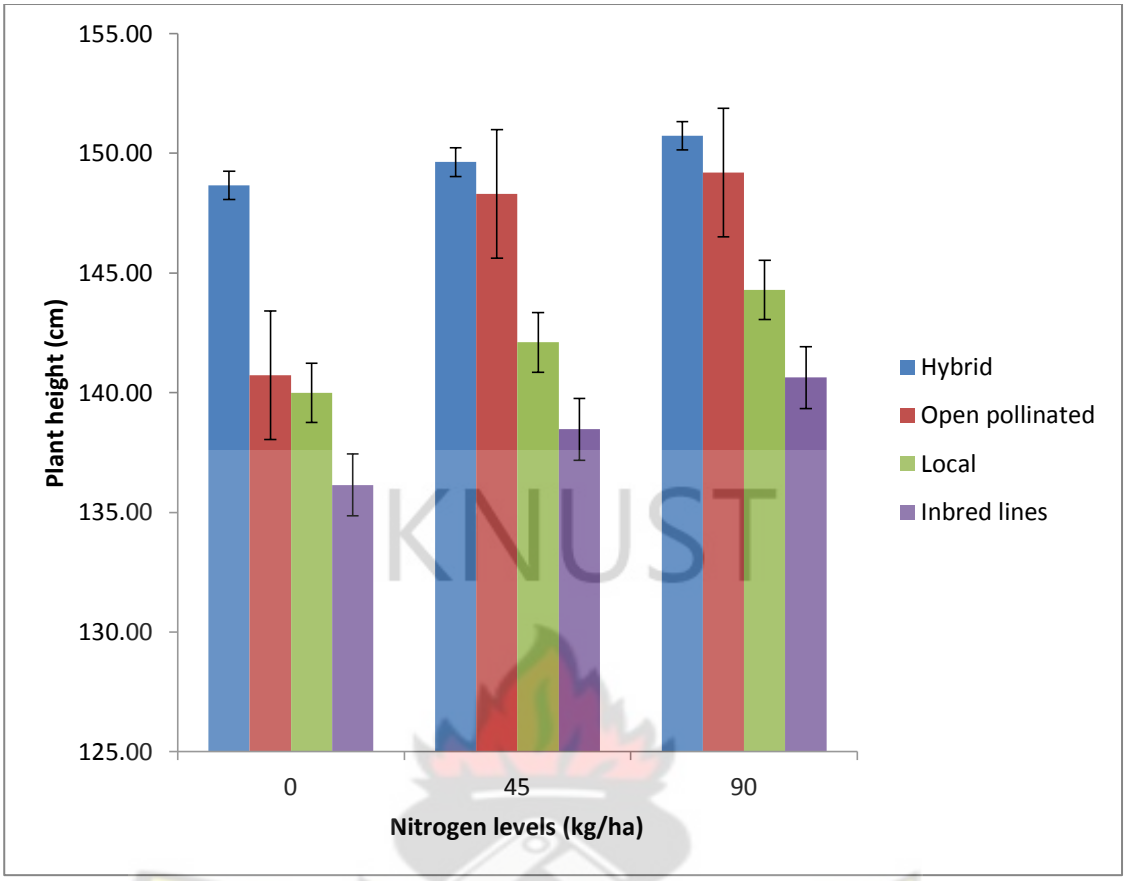


Figure 2. Mean plant height of inbred lines, local variety, OPVs and hybrids evaluated under three levels of nitrogen at Kwadaso and Fumesua in 2011

4.4 Cob Diameter

The response of cob diameter to nitrogen application is presented in Table 10 and figure 2. The nitrogen application rate was effective in increasing the cob diameters of the varieties in terms of nitrogen application rate of 90 kgN/ha > 45 kgN/ha > 0 kg N/ha. The mean cob diameter (cm) of local variety, OPV's and hybrids improved tremendously in order of 3.25, 3.47 and 3.80 cm respectively. At zero nitrogen application, significant differences were observed specifically, the inbred lines observed 3.12 cm, local variety 3.4 cm, OPV's 3.41 cm and hybrids 3.69 cm. This indicated that if the right application rate of fertilizer is adhered to or applied, it increased the cob diameters tremendously. At 45 kgN/ha, the genotypes responded

positively in order of means 3.27, 3.48, 3.55 and 3.82 cm respectively. At 90 kgN/ha the varieties were highly significant in order of 3.43, 3.52, 3.64 and 3.91cm respectively.

Table 10. Mean cob diameter for 14 genotypes evaluated under three levels of nitrogen with year of release

Genotypes	Year of release	0 kgN/ha	45 kgN/ha	90 kgN/ha	Mean
Ohaw local	1955	3.48	3.40	3.52	3.47
Obatanpa	1992	3.13	3.42	3.59	3.38
Mamaba	1997	3.72	3.83	3.92	3.82
GH 110	1997	3.72	3.86	3.95	3.84
Entry 5	1997	3.07	3.12	3.13	3.09
Entry 6	1997	3.08	3.33	3.88	3.43
Entry 70	1997	3.23	3.25	3.31	3.26
Golden jubilee	2007	3.20	3.44	3.50	3.38
Akposoe	2007	3.64	3.71	3.87	3.74
Etubi	2007	3.38	3.48	3.52	3.46
Entry 85	2007	3.64	3.79	3.85	2.65
Omankwa	2010	3.66	3.76	3.83	3.75
Aburohemaa	2010	3.42	3.48	3.49	3.46
Abontem	2010	3.15	3.39	3.393	3.31
Mean		3.38	3.51	3.62	3.22
LSD (0.05)		0.12	0.12	0.119	0.285
CV 3.3 (%)					

Comparison of N levels and year of release

Rotten Ears

The response of the 14 genotypes to nitrogen application with respect to rotten ears is presented in Table 11. The nitrogen application rate shown clearly the reduction of ear rots between zero and 90 kgN/ha. The mean number of rotten ears in terms of nitrogen application rate at 0 kgN/ha, 45 kgN/ha and 90kgN/ha were 7.18, 6.78 and 6.64 respectively. The difference between zero application and 45 kgN/ha was 0.4 and that of zero to 90 kgN/ha was 0.54.

Table 11. Mean rotten ears of 14 genotypes evaluated under three levels of nitrogen application in the year 2011.

Genotypes	Year of release	0 kgN/ha	45 kgN/ha	90 kgN/ha	Mean
Ohaw local	1955	3.21	2.41	3.61	4.73
Obatanpa	1992	7.60	3.82	2.14	4.52
Mamba	1997	4.97	3.66	1.04	3.22
GH 110	1997	4.90	2.66	2.29	3.28
Entry 5	1997	11.25	8.71	7.07	9.01
Entry 6	1997	10.57	7.8	7.32	8.56
Entry 70	1997	8.21	6.84	4.64	6.56
Golden Jubilee	2007	9.86	7.89	3.79	7.17
Akposoe	2007	11.03	9.74	7.4	9.39
Etubi	2007	4.83	4.15	1.32	3.43
Entry 85	2007	9.03	8.18	6.74	8.19
Abontem	2010	11.6	10.1	4.04	8.58
Aburohemaa	2010	13.84	9.76	8.44	10.68
Omankwa	2010	8.84	3.76	3.65	7.41
Mean		7.18	6.78	6.64	6.76
Lsd		2.51	2.51	2.51	5.43
CV	21.8				

4.5 Incidence of blight disease

The response of the 14 genotypes to nitrogen application with respect to blight disease is indicated in Table 12. There were no significant differences in terms of the response observed in blight infections. The mean blight scores observed at 0 kgN/ha were higher than 90 kgN/ha. The higher blight scores were observed at the inbred lines, local variety, OPV's and hybrids, respectively.

Table 12 Mean blight disease of 14 genotypes evaluated under three levels of nitrogen application in year 2011.

Genotypes	Year of release	0kgN/ha	45kgN/ha	90kgN/ha	Mean
Ohaw local	1955	30	2.7	2.7	3.0
Obatanpa	1992	3.0	3.6	2.3	3.0
Mamba	1997	2.8	2.7	2.2	2.6
GH 110	1997	2.8	2.6	2.2	2.5
Entry 5	1997	2.2	2.2	2.1	2.3
Entry 6	1997	2.8	2.7	2.7	2.7
Entry 70	1997	3.2	2.75	3.1	3.0
Golden Jubilee	2007	3.1	3.1	2.8	3.0
Akposoe	2007	2.7	2.6	2.5	2.6
Etubi	2007	2.8	2.8	2.5	2.7
Entry 85	2007	3.0	2.7	3.0	2.9
Abontem	2010	2.8	2.6	2.7	2.7
Aburohemaa	2010	2.6	3.0	2.6	2.7
Omankwa	2010	3.0	2.6	2.3	2.6
Mean		2.9	2.7	2.5	2.7
Lsd		0.179	0.179	0.179	0.389
CV (%)	2.7				

Comparison of N treatment means

4.6 Genetic gain for grain yield

The linear regression analysis is presented in Figure 3. The linear regression indicated a positive linear estimate for grain yield. The gains were 0.0025, 0.0149 and 0.0132 at 0, 45 and 90 kgN/ha, respectively. This signified that there was much gain in terms of grain yield at 0, 45 and 90 kgN/ha.

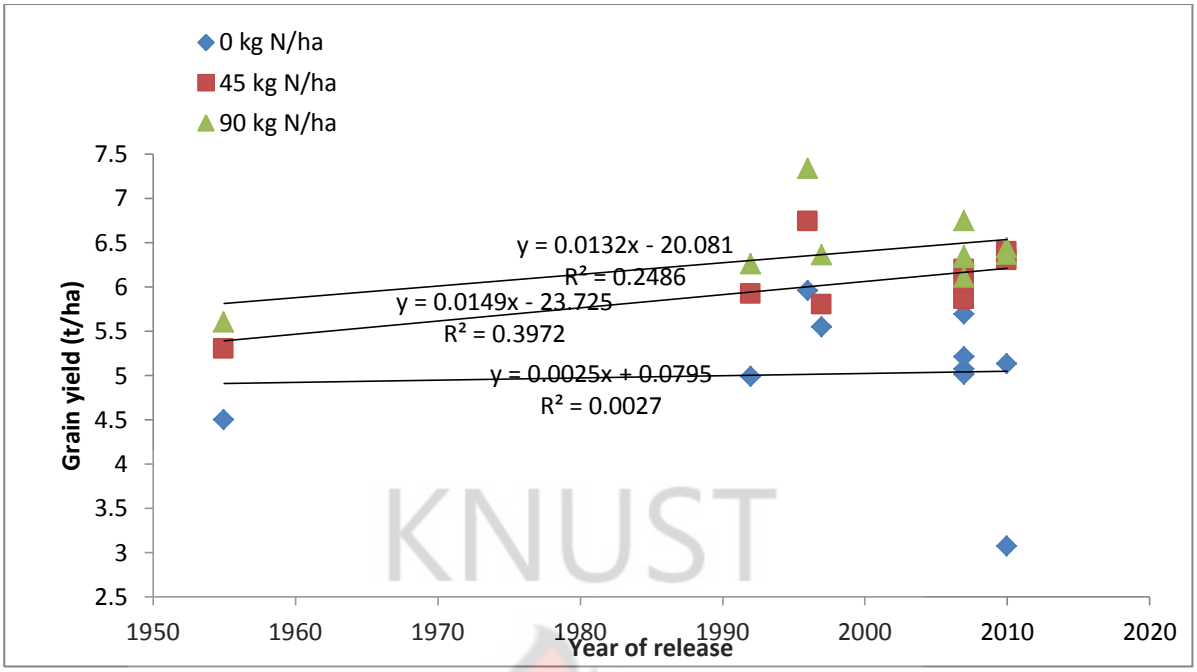


Figure 3. Genetic gain between grain yield and year of release.

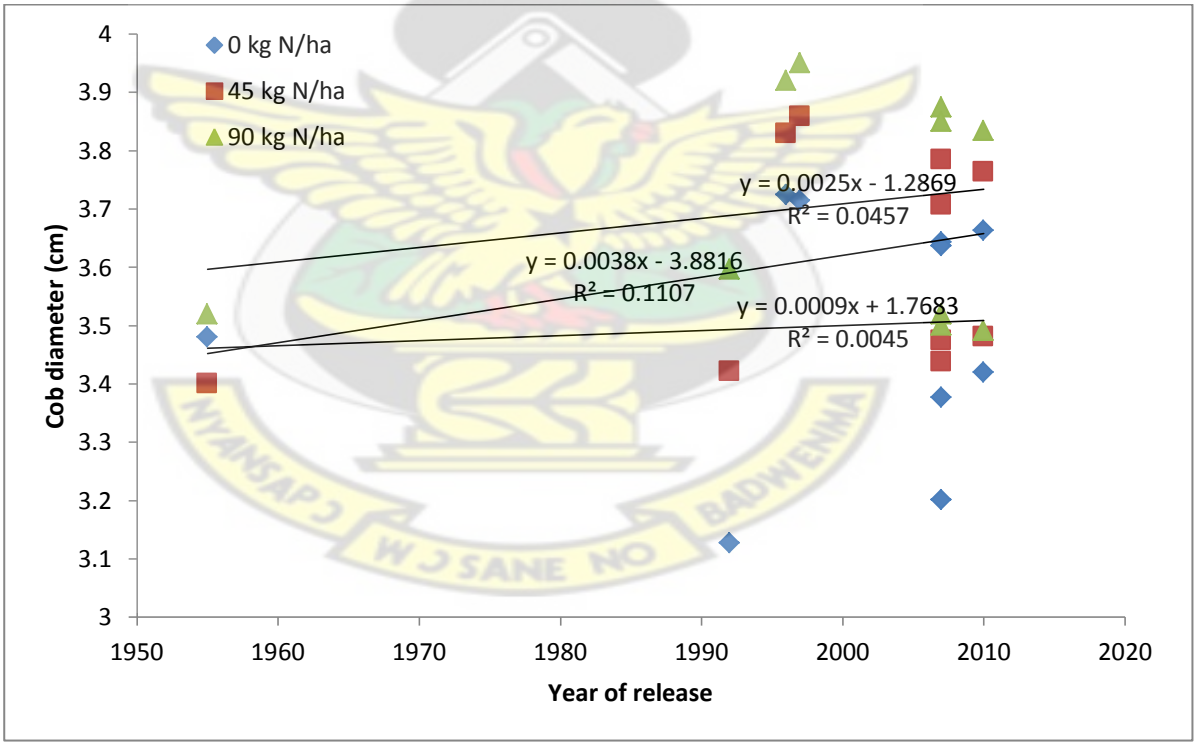


Figure 4. Genetic gains between cob diameter and year of release.

4.7 Genetic gain for shelling percentage

The linear regression analysis for shelling percentage is presented in Figure 5. The linear regression analysis showed positive linear estimate for the shelling percentage. The gains were 0.213 per year at zero fertilizer N and 0.469 per year at 45 kgN/ha and 0.415 at 90 kgN/ha. The corresponding R^2 values associated with the linear regression were 0.082, 0.205 and 0.121 at 0, 45 and 90 kg N/ha respectively.

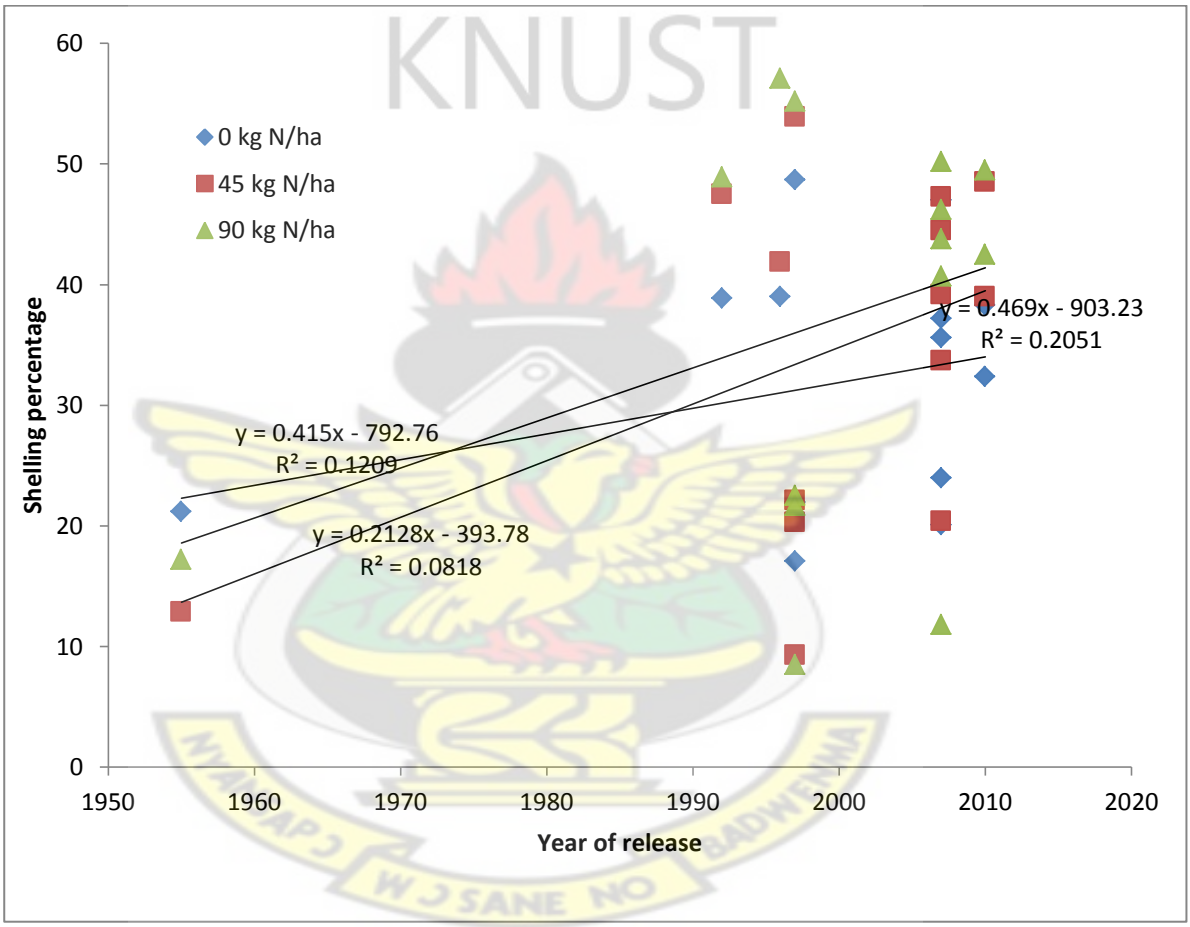


Figure 5. Genetic gains between shelling percentage and year of release.

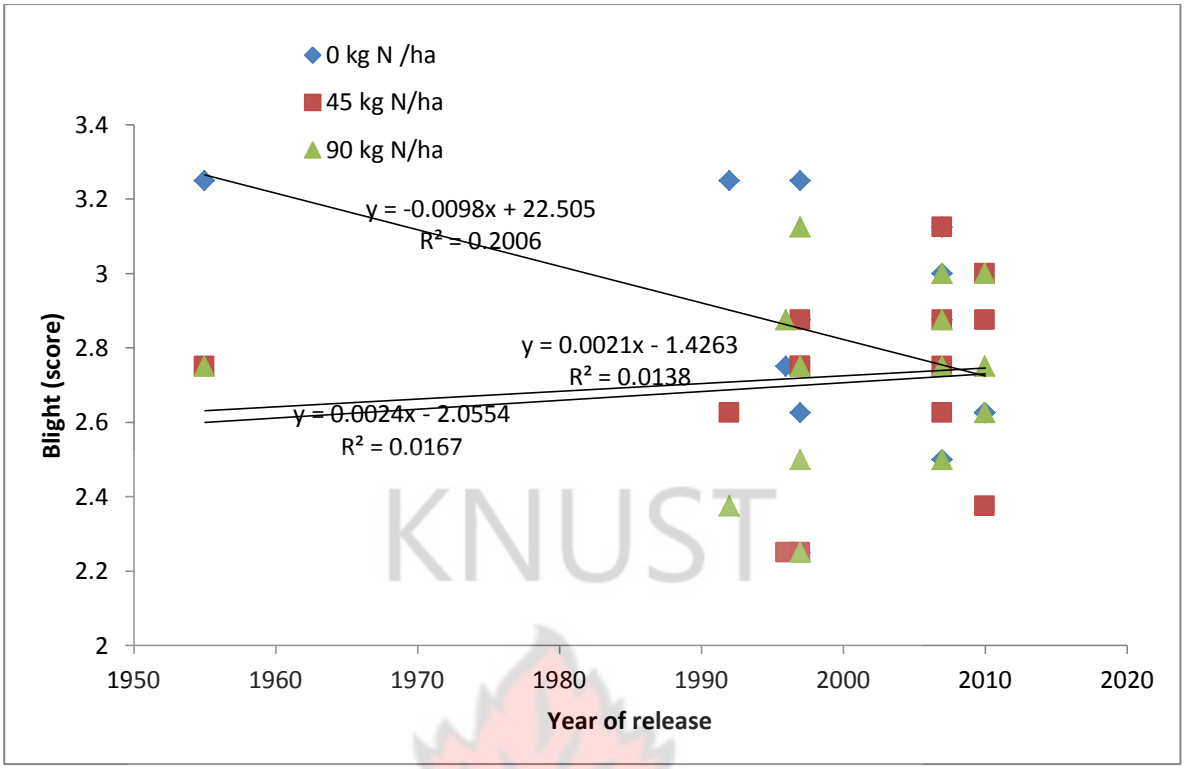


Figure 6. Genetic gain between blight disease (Score) and year of release.

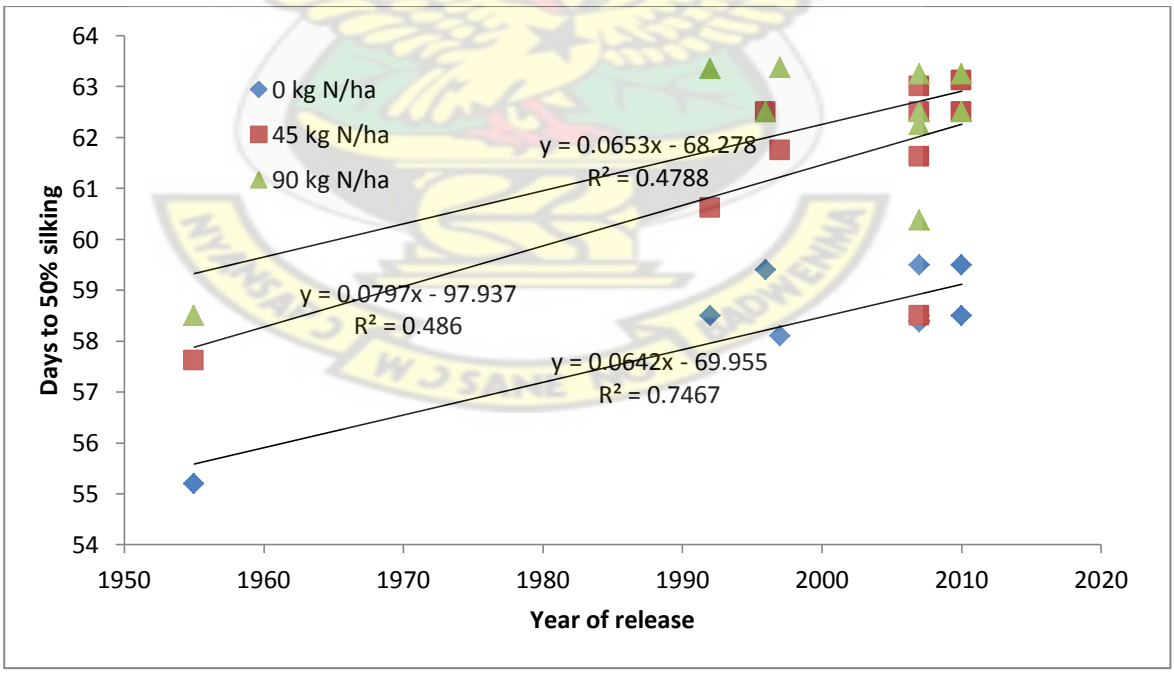


Figure 7. Genetic gains between 50% silking and year of release.

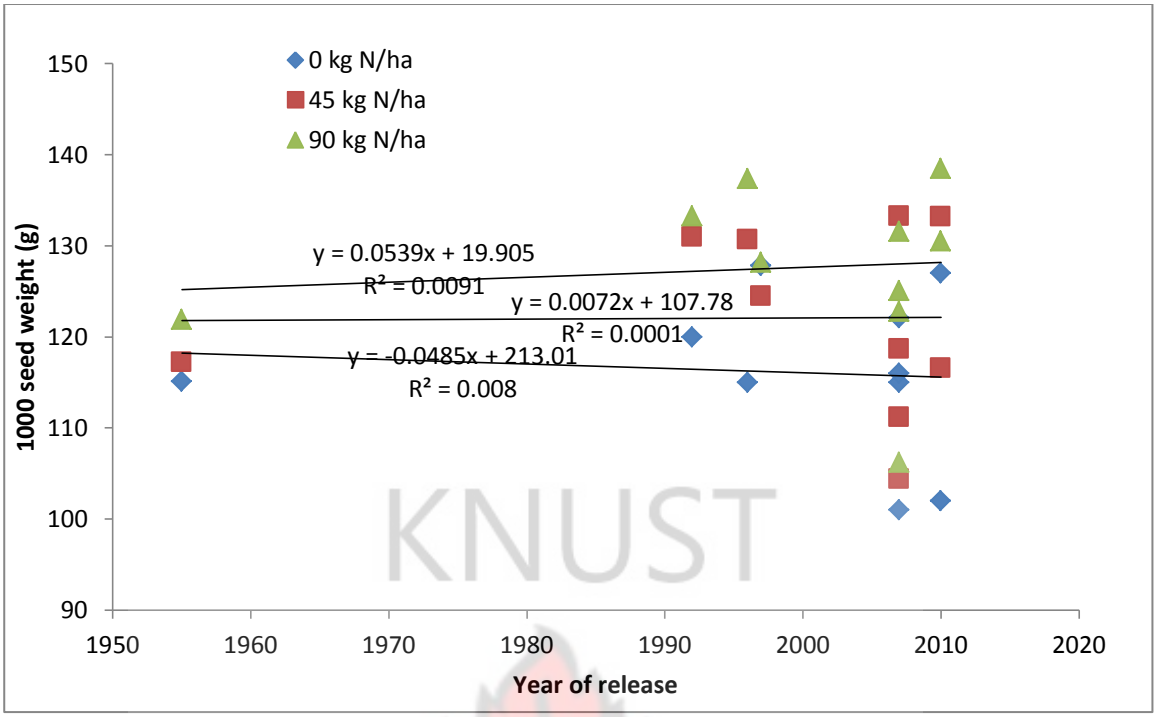


Figure 8. Genetic gain between 1000 seed weight and year of release

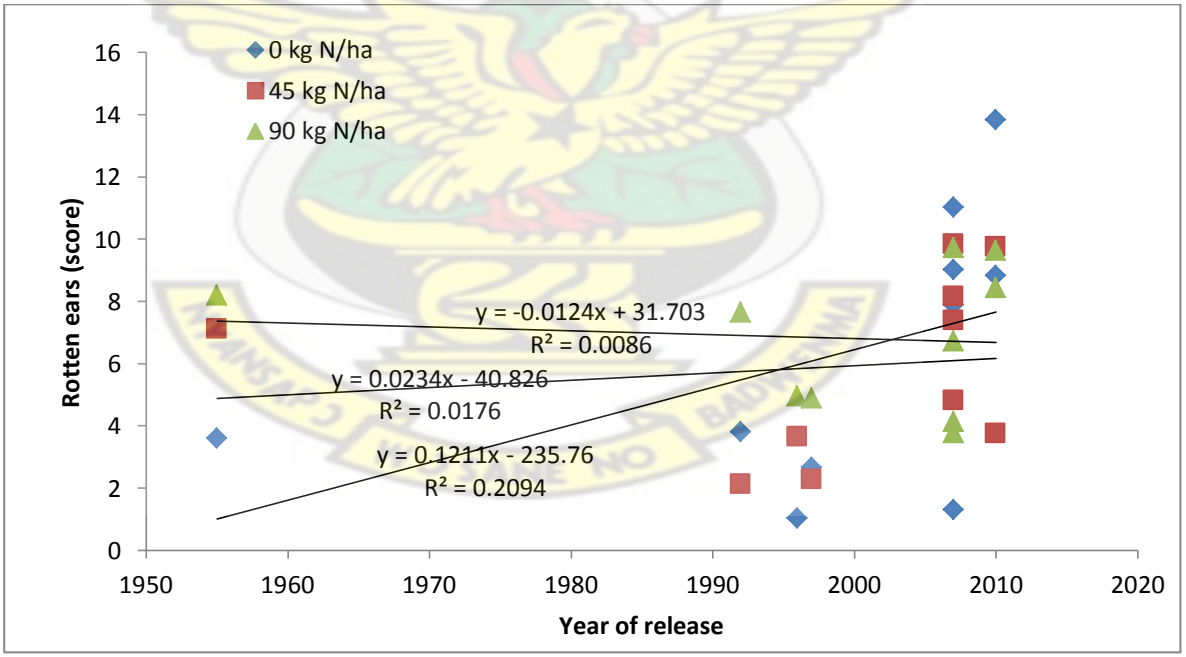


Figure 9. Genetic gain between rotten ears and year of release

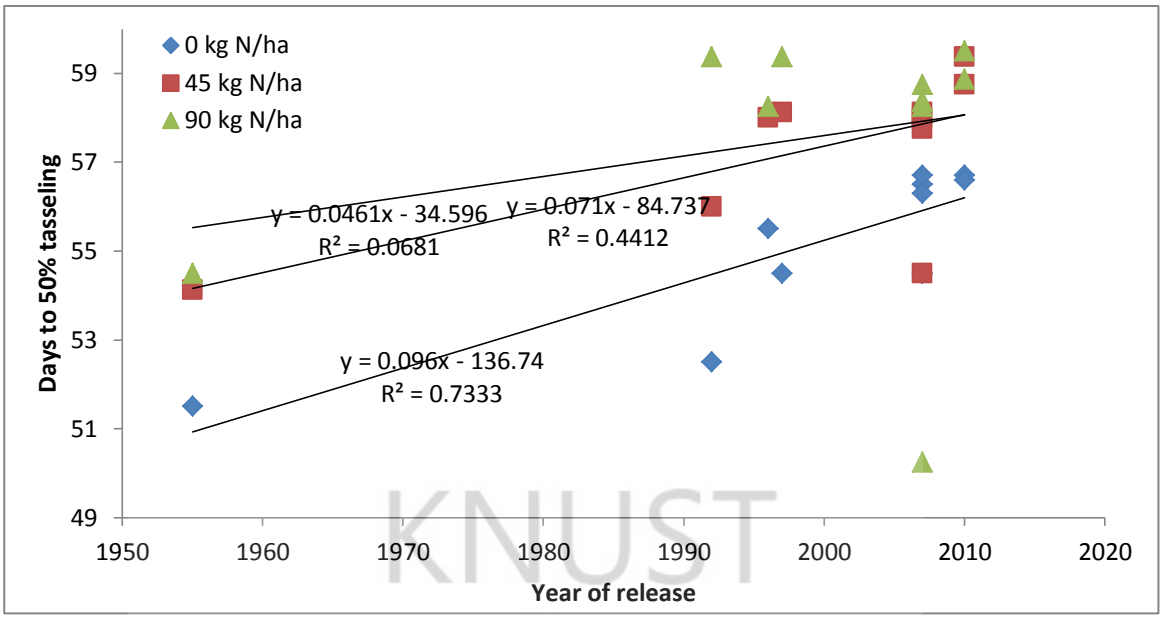


Figure 10. Genetic gain between days to 50% tasseling and year of release

4.8 Economic analysis of net benefit

The economic analysis for the net benefit is presented in Table 13. The results indicated that; if the right nitrogen application rate were applied correspond to the required grain yield. The marginal rate of returns depict that changing from local variety to hybrids has 125%. This implies that if farmers use hybrids without applying fertilizer, because of not been affordable they are likely to get higher returns. The marginal rate of returns of 100% achieved in changing from OPV's to hybrids is tremendous. In a situation where affordability of the fertilizer is a predicament, farmers should resort to hybrids to obtained higher returns. This shows clearly that if farmers are advised to apply nitrogen properly to their crops they would maximize profit.

Table 13: Economic analysis of net benefit

	Local Variety			OPV's			Hybrids		
Nitrogen Levels	0	45	90	0	45	90	0	45	90
Grain Yield (t/ha)	2.90	3.30	3.90	3.40	3.95	4.30	3.80	4.50	5.80
Gross (G) Benefit	29.00	33.00	39.00	34.00	39.50	43.00	38.00	45.00	58.00
Variable cost (Gh)	8.00	8.00	8.00	10.00	10.00	10.00	12.00	12.00	12.00
Fertilizer application rate	0	10.00	20.00	0	10.00	20.00	0	10.00	20.00
Total variable cost (TVC)	8.00	18.00	28.00	10.00	20.00	30.00	12.00	22.00	32.00
(GB-TVC)	21.00	15.00	11.00	24.00	19.5	10.00	26.00	23.00	26.00

Table 14: Dominance analysis

VARIETIES	TOTAL VARIABLE COST	NET BENEFIT
0kgN/ha Local vars.	8.00	21.00
0PVs	10.00	24.00
Hybrids	12.00	26.00
45 kgN/ha		
Local Vars.	18.00	15.00
OPVs	20.00	19.00
Hybrids	22.00	23.00
90kgN / ha		
Local variety	28.00	11.00
OPVs	30.00	10.00
Hybrid	32.00	26.00

Marginal rate of returns (MRR)

MRR = Hybrid – Local variety (0kgN)

$$= \frac{26.00-21.00}{12.00-8.00} \times 100 \quad = \quad \frac{5.00}{4.00} \times 100 \quad = \underline{125\%}$$

Hybrid (0KgN) – OPV's = $\frac{26.00-24.00}{12.00-10.00} \times 100 = \quad \frac{2.00}{2.00} \times 100 \quad = \underline{100\%}$

Table 15: Maize prices between 1955 to2010

Year	1955	1992	1996	1997	2007	2010
Maize price per 100 kg (Gh)	5	10.48	35.00	64.32	74.35	100

Source: SRID(2001)

CHAPTER FIVE

5.0 DISCUSSION

The genetic improvement of maize in Ghana was investigated under three levels of nitrogen in two environments in order to ascertain the genetic progress made in maize varieties released from 1955 to 2010

5.1 Genotypes

Clearly significant difference was observed among the genotypes. This indicated that the genotypes were from different parental or population and have different maturity dates as well as yielding ability as reported by (Menkin *et al*., 2000). The genotypes investigated were inbred lines, local variety, open- pollinated varieties and hybrids. Comparatively terms, the hybrid yielded higher followed by OPVs, local variety and inbred lines. The results show clearly that hybrids yielded higher as a result of certain genes that have been accumulated in the hybrids to withstand condition in terms of nutrients level in the soil.

5.2 Environment

There was a significant difference among the environments in which the experiment was conducted. The yields realized at the major season were higher than that of the minor season, because of the rainfall distribution in the major season which corresponds to higher yield than that the minor season. The results ascertained Ansah (2001) findings that yields were higher in the major season than in the minor season in southern Ghana due to better rainfall pattern.

5.3 Genotype X Environment interaction

Genotype and Environment interaction was significant ($p<0.01$) for grain yield and most of the agronomic traits or parameters measured. Romagosa and Fox (1993) have reported that the proportion of sums of squares due to differences among sites in most yield trials range from 80-90% and variation due to G by E interaction is usually larger than genotype variation. Similar results have been consistently reported for maize in West and Central Africa and the results confirm the earlier studies (Badu-Apraku *et al.,* 1997, Fakorede *et al*., 1989). Genotype by environment interaction may be as a result of differences in soil, varieties release and rainfall distribution. The study revealed that the genotypes responded differently in terms of major and minor season. This suggests that, breeders should be encouraged to release varieties that can be adapted to minor and major season (Akposoe, 1971).However, Ansah (2001) reported that G by E interaction was as results of location differences.

5.4 Response of genotype to nitrogen application

The genotype by nitrogen interaction were significant ($p<0.001$) for grain yield, plant height, shelling percentage, cob diameter, days to 50% tasseling and days to 50% silking. The plant aspect rating showed that at 45 and 90 kg N/ha the plants had better appearance than plants that received 0kgN/ha during 8-10 weeks after planting. The plants from plots that did not receive nitrogen were severely yellowish and stunted. For all the varieties evaluated, increasing the amount of N per hectare resulted in appreciable increase in grain yield. Sallah *et al*. (1998) reported that significant increase in grain yield is due to increase in nitrogen levels. Significant differences were observed in the grain yield between inbred lines and local variety at various nitrogen levels. The OPV's and the hybrids also observed a significant difference with respect to

nitrogen application but in all OPV's and hybrids have more response to fertilizer and have better results (Castleberry *et al.,* 1984, Sallah *et al.,* 1998 and Twumasi-Afriyie, 1999). This experiment ascertained, the yield response to N application was higher in hybrids than the OPVs, locals and inbred lines as suggested by the GGDP (1996) report that hybrids out performed more than the OPVs in response to nitrogen application in the Guinea savannah zone.

The results revealed that higher nitrogen levels also reduced the number of rotten ears and shelling percentage. This can be attributed to grain weight to ear weight was lower with increasing nitrogen application. This as a result of partitioning of more assimilates to the cobs at the expense of the grain production in response to increasing in N level.

This significant increase in cob diameter with increase in N levels, specifically hybrid varieties was efficient in response to physiological activities in terms of growth rate and dry matter accumulation.

5.5 Genetic gain for grain yield

The genetic gain in this experiment for grain yield revealed that yield was between 0.0025 to 0.0149 t/ha. This implies that the yield were low compare to 70 kg/ha/yr obtained in the US Corn Belt and 69 kg/ha/yr obtained in north America (Russell, 1974 and Castleberry *et al.,* 1984).This differences can be attributed to differences in genotype as well as environment (Sallah *et al.,* 1998).The gain in terms of yield comparatively was one third of what was achieved by Sallah (1998) when compared open pollinated varieties with higher nitrogen level and the results obtained ascertain that there has been an improvement in all the nitrogen levels applied with respect to genotypes. This implies that if breeding programmes focus on breeding of hybrids or high yielding varieties higher yield will be achieved.

5.6 Genetic gain for shelling percentage

The regression analysis for shelling percentage was significant at 45 kgN/ha. At 45kgN/ha the correlation was 0.45 against the shelling percentage. This specified that breeder's effort was not effective in improving the shelling percentage but rather their major objective was improving high yield, quality and quantity maize, resistance to pest, disease, and drought (Obeng-Antwi and Sallah, 1999).

5.7 Genetic gain for cob diameter

The results indicated that the gain in terms of improving the cob diameter which corresponds to the yield was observed at 45kgN/ha. At 45kgN/ha the correlation was 0.22 against the cob diameter. Increasing the cob diameter of maize varieties was not the optimum objective of breeders but rather focused on yield and other trait.

5.8 Genetic gain of blight disease

The incidence of blight disease at the study period was not significant ($p > 0.05$) since the disease was not severe. The blight reduction was -0.01 to 0.02 per year. The correlation between the year of release and the disease was between 11% to 44% which implies that varieties that were release between the years of 2000-2010 have genes that are able to resist disease infection.

5.9 Genetic gain of Days to 50% silking

The regression analysis of days to 50% silking was significant ($P<0.05$) in terms of performance which ranged from 0.064 to 0.079 which represents 64% and 79% respectively. However the gain was low but there were significant improvement in all levels of nitrogen application rate. The correlation between year of release and days to 50% silking was 0.74, 0.48, 0.47or 56% at 0, 45 and 90 kgN/ha respectively.

5.10 Conclusions

In all, the fourteen genotypes involving three hybrids, six open pollinated varieties, one local variety and four inbred lines released from 1955 to 2010 were evaluated at three nitrogen levels in two environments. The study revealed that yields of hybrid out-performed the OPVs, local variety and inbred lines under low nitrogen application. Yields of hybrid responded positively over open-pollinated varieties with an increased with nitrogen level from 0 kgN/ha to 45 kgN/ha and at 90 kgN/ha. Hybrids were also the most stable and highest yielding genotypes under low and high nitrogen environment. The results revealed that when one could not buy or purchase fertilizer the best option was to go for hybrids rather than the cultivation of local variety because of its yielding ability. A lot of progress has been made in genetic improvement of maize varieties in Ghana since 1950s.

Breeding activities were effective in improving yield potentials and other traits under low levels of nitrogen in the soil. The results also confirmed that breeding resulted in genotype improvement of traits including days to mid silk, ear height, and plant height and l000 seed weight.

5.11 Recommendation

Farmers should be encouraged to purchase and use hybrid seed, to take advantage of their high yields under low nitrogen. Large quantities of hybrid seeds should be produced by the Crop Research Institute (CRI) and private seed companies to bring down the unit price of hybrid seed to make it affordable to farmers.

Farmers should be taught the recommended nitrogen application rate to achieve optimum yields.

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APPENDICES

Appendix 1: Analysis of grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	2.99012	0.99671	17.91	
Rep.*Units* stratum					
Nitrogen_level	2	45.84334	22.92167	411.78	<.001
Location	1	2.25236	2.25236	40.46	<.001
Variety	13	513.13585	39.47199	709.11	<.001
Nitrogen_level.Location	2	0.47536	0.23768	4.27	0.015
Nitrogen_level.Variety	26	13.04228	0.50163	9.01	<.001
Location.Variety	13	2.32693	0.17899	3.22	<.001
Nitrogen_level.Location.Variety	26	1.40155	0.05391	0.97	0.512
Residual	249	13.86043	0.05566		
Total	335	595.32822			

Appendix 2: Analysis of shelling percentage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	303.8	101.3	0.43	
Rep.*Units* stratum					
Nitrogen_level	2	426.0	213.0	0.90	0.407
Location	1	27353.6	27353.6	116.00	<.001
Variety	13	46155.9	3550.5	15.06	<.001
Nitrogen_level.Location	2	2158.9	1079.5	4.58	0.011
Nitrogen_level.Variety	26	13534.5	520.6	2.21	<.001
Location.Variety	13	7390.7	568.5	2.41	0.004
Nitrogen_level.Location.Variety	26	4173.3	160.5	0.68	0.879
Residual	249	58714.2	235.8		
Total	335	160211.0			

Appendix 3: Analysis of variance of days to 50% tasseling

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	216.152	72.051	9.58	
Rep.*Units* stratum					
Location	1	2601.860	2601.860	345.97	<.001
Nitrogen_level	2	49.327	24.664	3.28	0.039
Variety	13	698.801	53.754	7.15	<.001
Location.Nitrogen_level	2	55.042	27.521	3.66	0.027
Location.Variety	13	636.515	48.963	6.51	<.001
Nitrogen_level.Variety	26	86.423	3.324	0.44	0.992
Location.Nitrogen_level.Variety	26	99.208	3.816	0.51	0.979
Residual	249	1872.598	7.520		
Total	335	6315.926			

Appendix 4: Analysis of variance of days to 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	208.095	69.365	9.81	
Rep.*Units* stratum					
Location	1	3132.964	3132.964	443.27	<.001
Nitrogen_level	2	60.220	30.110	4.26	0.015
Variety	13	623.619	47.971	6.79	<.001
Location.Nitrogen_level	2	27.375	13.687	1.94	0.146
Location.Variety	13	567.702	43.669	6.18	<.001
Nitrogen_level.Variety	26	65.363	2.514	0.36	0.999
Location.Nitrogen_level.Variety	26	91.708	3.527	0.50	0.982
Residual	249	1759.905	7.068		
Total	335	6536.952			

Appendix 5: Analysis of variance ASI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	5.4851	1.8284	2.82	
Rep.*Units* stratum					
Location	1	24.6458	24.6458	38.05	<.001
Nitrogen_level	2	1.5000	0.7500	1.16	0.316
Variety	13	11.3006	0.8693	1.34	0.189
Location.Nitrogen_level	2	14.0952	7.0476	10.88	<.001
Location.Variety	13	10.7292	0.8253	1.27	0.229
Nitrogen_level.Variety	26	21.8333	0.8397	1.30	0.159
Location.Nitrogen_level.Variety	26	11.4048	0.4386	0.68	0.882
Residual	249	161.2649	0.6477		
Total	335	262.2589			

Appendix 6: Analysis of variance of plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	35475.5	11825.2	16.29	
Rep.*Units* stratum					
Location	1	243262.1	243262.1	335.03	<.001
Nitrogen_level	2	1087.5	543.8	0.75	0.474
Variety	13	40599.4	3123.0	4.30	<.001
Location.Nitrogen_level	2	15334.1	7667.1	10.56	<.001
Location.Variety	13	12276.7	944.4	1.30	0.213
Nitrogen_level.Variety	26	9443.7	363.2	0.50	0.981
Location.Nitrogen_level.Variety	26	6326.6	243.3	0.34	0.999
Residual	249	180795.8	726.1		
Total	335	544601.4			

Appendix 7: Analysis of variance of ear height

Source of variation	d .f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	19853.8	6617.9	18.37	
Rep.*Units* stratum					
Location	1	24018.3	24018.3	66.66	<.001
Nitrogen_level	2	108.3	54.2	0.15	0.860
Variety	13	22691.1	1745.5	4.84	<.001
Location.Nitrogen_level	2	7703.5	3851.7	10.69	<.001
Location.Variety	13	4981.6	383.2	1.06	0.392
Nitrogen_level.Variety	26	5227.4	201.1	0.56	0.961
Location.Nitrogen_level.Variety	26	2827.6	108.8	0.30	1.000
Residual	249	89713.2	360.3		
Total	335	177124.7			

Appendix 8: Analysis of variance of root lodge

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	2025.13	675.04	16.25	
Rep.*Units* stratum					
Location	1	5097.46	5097.46	122.71	<.001
Nitrogen_level	2	120.61	60.31	1.45	0.236
Variety	13	1246.20	95.86	2.31	0.007
Location.Nitrogen_level	2	207.61	103.81	2.50	0.084
Location.Variety	13	583.38	44.88	1.08	0.377
Nitrogen_level.Variety	26	1181.38	45.44	1.09	0.349
Location.Nitrogen_level.Variety	26	1334.77	51.34	1.24	0.205
Residual	249	10343.57	41.54		
Total	335	22140.10			

Appendix 9: Analysis of variance of stalk lodge

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	17955.2	5985.1	19.04	
Rep.*Units* stratum					
Location	1	21773.3	21773.3	69.27	<.001
Nitrogen_level	2	5616.1	2808.0	8.93	<.001
Variety	13	4810.7	370.1	1.18	0.296
Location.Nitrogen_level	2	763.5	381.7	1.21	0.299
Location.Variety	13	10323.7	794.1	2.53	0.003
Nitrogen_level.Variety	26	6714.3	258.2	0.82	0.718
Location.Nitrogen_level.Variety	26	4664.5	179.4	0.57	0.955
Residual	2 49	78268.6	314.3		
Total	335	150889.9			

Appendix 10: Analysis of variance of cob diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	3.3704	1.1235	5.43	
Rep.*Units* stratum					
Location	1	43.0789	43.0789	208.37	<.001
Nitrogen_level	2	2.0514	1.0257	4.96	0.008
Variety	13	17.2168	1.3244	6.41	<.001
Location.Nitrogen_level	2	0.3043	0.1521	0.74	0.480
Location.Variety	13	6.7208	0.5170	2.50	0.003
Nitrogen_level.Variety	26	4.9322	0.1897	0.92	0.584
Location.Nitrogen_level.Variety	26	5.0012	0.1924	0.93	0.566
Residual	249	51.4794	0.2067		
Total	335	134.1554			

Appendix 11: Analysis of variance of cob length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	2.986	0.995	0.35	
Rep.*Units* stratum					
Location	1	376.597	376.597	131.87	<.001
Nitrogen_level	2	3.689	1.845	0.65	0.525
Variety	13	132.060	10.158	3.56	<.001
Location.Nitrogen_level	2	6.785	3.392	1.19	0.307
Location.Variety	13	109.735	8.441	2.96	<.001
Nitrogen_level.Variety	26	79.458	3.056	1.07	0.377
Location.Nitrogen_level.Variety	26	40.431	1.555	0.54	0.967
Residual	249	711.105	2.856		
Total	335	1462.847			

Appendix 12: Analysis of variance of open tips

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1022.7	340.9	1.67	
Rep.*Units* stratum					
Location	1	264439.9	264439.9	1296.62	<.001
Nitrogen_level	2	3354.0	1677.0	8.22	<.001
Variety	13	5421.6	417.0	2.04	0.018
Location.Nitrogen_level	2	601.2	300.6	1.47	0.231
Location.Variety	13	3890.6	299.3	1.47	0.130
Nitrogen_level.Variety	26	8486.0	326.4	1.60	0.037
Location.Nitrogen_level.Variety	26	5755.5	221.4	1.09	0.359
Residual	249	50782.3	203.9		
Total	335	343753.7			

Appendix 12: Analysis of variance of ears per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.69229	0.23076	5.76	
Rep.*Units* stratum					
Location	1	7.53162	7.53162	188.03	<.001
Nitrogen_level	2	0.13783	0.06891	1.72	0.181
Variety	13	0.54099	0.04161	1.04	0.414
Location.Nitrogen_level	2	0.10599	0.05299	1.32	0.268
Location.Variety	13	0.39488	0.03038	0.76	0.704
Nitrogen_level.Variety	26	0.88824	0.03416	0.85	0.675
Location.Nitrogen_level.Variety	26	1.31433	0.05055	1.26	0.184
Residual	249	9.97379	0.04006		
Total	335	21.57996			

Appendix 13 analysis of ears aspect

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.3661	0.1220	0.53	
Rep.*Units* stratum					
Location	1	9.0030	9.0030	39.41	<.001
Nitrogen_level	2	1.1250	0.5625	2.46	0.087
Variety	13	12.3006	0.9462	4.14	<.001
Location.Nitrogen_level	2	1.4702	0.7351	3.22	0.042
Location.Variety	13	3.3720	0.2594	1.14	0.330
Nitrogen_level.Variety	26	7.4583	0.2869	1.26	0.189
Location.Nitrogen_level.Variety	26	3.7798	0.1454	0.64	0.916
Residual	249	56.8839	0.2284		
Total	335	95.7589			

Appendix 14: Analysis of variance of rotten ears

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	567.00	189.00	2.07	
Rep.*Units* stratum					
Location	1	427.91	427.91	4.69	0.031
Nitrogen_level	2	17.80	8.90	0.10	0.907
Variety	13	1840.58	141.58	1.55	0.099
Location.Nitrogen_level	2	21.86	10.93	0.12	0.887
Location.Variety	13	1870.10	143.85	1.58	0.092
Nitrogen_level.Variety	26	1299.49	49.98	0.55	0.966
Location.Nitrogen_level.Variety	26	1499.05	57.66	0.63	0.919
Residual	249	22705.56	91.19		
Total	335	30249.35			

Appendix 15: Analysis of variance of blight diseases

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.4375	0.4792	1.03	
Rep.*Units* stratum					
Location	1	120.2411	120.2411	257.41	<.001
Nitrogen_level	2	1.0238	0.5119	1.10	0.336
Variety	13	11.2054	0.8620	1.85	0.037
Location.Nitrogen_level	2	2.0000	1.0000	2.14	0.120
Location.Variety	13	7.8006	0.6000	1.28	0.222
Nitrogen_level.Variety	26	12.6429	0.4863	1.04	0.414
Location.Nitrogen_level.Variety	26	11.8333	0.4551	0.97	0.504
Residual	249	116.3125	0.4671		
Total	335	284.4970			

Appendix 16: Analysis of variance of 1000 seed weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1760.2	586.7	1.08	
Rep.*Units* stratum					
Location	1	68.9	68.9	0.13	0.722
Nitrogen_level	2	3560.6	1780.3	3.29	0.039
Variety	13	35737.7	2749.1	5.07	<.001
Location.Nitrogen_level	2	1529.4	764.7	1.41	0.246
Location.Variety	13	4405.6	338.9	0.63	0.832
Nitrogen_level.Variety	26	6718.2	258.4	0.48	0.987
Location.Nitrogen_level.Variety	26	11233.2	432.0	0.80	0.749
Residual	249	134882.2	541.7		
Total	335	199895.8			