REDUCTION OF CHEMICAL FERTILIZER USE IN MAIZE BY NUTRISMART-AN ECO-FRIENDLY FERTILIZER

BY

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CERTIFICATE

This is to certify that the thesis entitled, **"REDUCTION OF CHEMICAL FERTILIZER USE IN MAIZE BY NUTRISMART-AN ECO-FRIENDLY FERTILIZER"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of bona fide research work carried out by **Fariza Nur**, Registration No. 03-01118 under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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Dedicated
To
My Beloved Mother

LIST OF ACRONYMS

AEZ	Agro-Ecological Zones
Anon.	Anonymous
Atm.	Atmospheric
BARI	Bangladesh Agricultural Research Institute
BJRI	Bangladesh Jute Research Institute
cm	Centi-meter
CV%	Percent Coefficient of Variation
DAS	Days after sowing
Df	Degrees of freedom
et al	And others
etc.	Etcetera
g	Grams
HI	Harvest index
IRRI	International Rice Research Institute
Kg	Kilogram
LAI	Leaf area index
LSD	Least Significant Differences
m^2	Meter square
mm	Milimeter
MP	Murate of Potash
N	Nitrogen
No.	Number
NS	Non significant
OM	Organic matter
PAR	Photo synthetically active radiation
ppm	Parts per million

SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
Var.	Variety
T ha^{-1}	Ton per hectare
°C	Degree Centrigrade
%	Percentage

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ABSTRACT

A field experiment was conducted during the Nov 2007-Dec 08 to find out the optimum combination of chemical fertilizer and Nutrismart (an eco-friendly fertilizer) and there by reducing the use of chemical fertilizer in two Maize variety- BARI hybrid bhutta-5 and Composite variety Khaibhutta with 5 combinations of fertilizer. The treatment were F_1 (100% Recommended Chemical fertilizer), F_2 (50% Chemical fertilizer+ 50% Nutrismart), F_3 (40% Chemical fertilizer + 60% Nutrismart), F_4 (25%Chemical fertilizer + 75% Nutrismart) and F_5 (100% Nutrismart). The data revealed that the variety BARI hybrid bhutta 5 gave higher LAI, cob diameter, cob length, weight of 1000 grains, shelling percentage, biological yield (t ha^{-1}) and harvest index. On the other hand, the plant height and the rest yield contributing parameters (no.of cobs $plant^{-1}$, no. of grain rows $plant^{-1}$, no. of grains cob^{-1}) were similar in Composite variety with that of BARI hybrid bhutta 5. Though both the varieties showed the statistically similar grain, stover and biological yield (t ha^{-1}) but numerically the grain and biological yield were higher found in the BARI hybrid bhutta 5 and comparatively higher stover yield in the composite variety. With the interaction of variety and fertilizer combination, V_1F_1 gave the highest result but the F_2 gave more or less similar response when it interact with the two varieties but in case of harvest index, the treatment V_1F_2 and V_1F_1 gave the superior result among all the interactions. The overall results indicated that in case of hybrid variety 50 to 60% chemical fertilizer could be replaced through Nutrismart by sacrificing only 10.18 to 17.10% yield but in case of composite variety similar yield was possible by 50% chemical fertilizer + 50% Nutrismart compared to that of 100% chemical fertilizer use.

Chapter 1

Introduction

CHAPTER 1
INTRODUCTION

Maize (*Zea mays)* is a highly versatile crop which has multiple uses causing annihilation in the food culture world wide. Agriculture is gradually moving towards maize cultivation in Bangladesh. Maize has been established as a potential crop in Bangladesh due to its diversified uses. Its cob is roasted and eaten; its corn is used in food processing industries. It is also used as good quality poultry feed and its stover is considered as a good quality fodder.

In the recent 50 years, the volume of chemical fertilizers used in agricultural production world wide has increased rapidly. In 2000, world wide fertilizer use reached 141 million tones, a ten –fold increase from the 14 million tones used in 1950 (Anon. , 2006). Today farmers are applying more and more chemical fertilizers to their farmland while the use of chemical fertilizer has greatly improved agricultural productivity. But the use of excess amount of chemical fertilizers have resulted in extensive environmental pollution through soil leaching and run-off into rivers, lakes and ground water. Moreover, overuse of chemical fertilizer has damaged the physical structure of soil. The physical properties of soil such as texture, structure, density, porosity, water content, consistency, etc are dominant factors affecting the use of a soil. These properties determine the availability of water into or through soils and the ease of root penetration (Donahue *et al.* 1983).

Eco-fertilizer is a new concept in fertilizer business which combines the benefit of microbial, organic and chemical fertilizers that plays an increasing role in the Integrated Plant Nutrient System (IPNS) and balanced fertilization. It has been emerged as a new trend in modern agriculture. Indeed there are many sound environmental and economic benefits in using these new fertilizers. Eco-friendly optimum fertilizer rates vary widely from one crop to another crop as well as from one field to another (Bundy and Andraski, 1995). Nutrismart comprises the four major natural ingredients: weathered coal (leonardite), phosphate rock, starch and microbe powder. The final product of Nutrismart is able to perform the key function like (1) nitrogen fixation- fix nitrogen from the air and convert it into a soluble form of nitrogen. (2) phosphate solubilization-solubilize unavailable phosphate into a soluble form of phosphate. (3) unlock potassium- unlock partial potassium in the soil into exchangeable potassium, thus increasing potassium efficiency. Due to its unique formulation, Nutrismart is able to supply the three major nutrients- NPK in soil to the crop. Nutrismart also contains humic substances, micro-nutrients and organic matter etc which improves the soil fertility.

Application of N fertilizer have been reported to have significant effect on grain yield and quality of maize (Tanaki *et al.*, 1988). But excess amount of chemical such as nitrate in soil, which may cause human health problem and makes crop vulnerable to insect and diseases. One of the principal reason for the poor efficiency of fertilizer use is that a proportion of applied N (80-89%) is lost via denitrification, volatilization and leaching losses from the soil-plant atmosphere system (Faruque, 2000).

Agricultural non-point source of environmental pollution have brought serious public concern since last decade. The N consumption in Bangladesh has increased from 19 thousand tones in 1960 to 943 thousand tones in 1996 (Faruque, 2000). Over dosages of chemical fertilizer application constantly in agriculture practice is one of the main reasons for fertilizer pollution. Excess amount of soluble N and P can easily go into ground water and /or surface water system through leaching or run-off. These have cause algae eruption in surface water system and the serious contamination in ground water system. The release of soluble NPK in the soil reaches very high levels immediately after chemical fertilizer application. Subsequently, however significant amounts of NPK will be leached out or surface loses through run-off/air evaporation or fixed in soil. This has resulted in insufficient nutrients remaining in the soil and repeated top dressing being required. Fluctuation in NPK levels in the soil not only cause serious pollution of N and P in natural environmental but also cause nutrient shortage to crop growth (Anon., 2006).

Nutrismart is an eco-friendly fertilizer that produced worldwide by CK Life Science (UK) has the ability to improve soil fertility and supply NPK nutrients by naturally adjusting the microbial population and indigenous soil enzyme activities based on available nutrients in soil, the nutrient uptake and use efficiency of the crops can be distinctly increased. The improved soil fertility further enhances the crop root system development and overall bioactivity in soil. The Integrated use of Nutrismart with organic and / or inorganic fertilizers allow the crop to uptake and use the NPK nutrients more efficiently and therefore reduces the amount of N and P being leached into the subsoil. Maximum water holding capacity with organic manure and balanced application of organic manures in combination with chemical fertilizers was important for maintaining soil health and productivity (Mathew and Nair, 1997). Nutrismart has the ability to improve the fertilizer use efficiency, also to improve the crop yield and quality, to reduce the adverse effect of wasteful fertilizers application and to maintain the sustainable agricultural system (FADINAP, 2000). So for the healthy existences, eco-friendly fertilizer has an enchanting power to sustain the agriculture that we need to pay our proper attention to this sector. No such work has yet been done in Bangladesh cereals crops like maize so the present investigation was under taken with the following objectives:

- to find out the possibility of reducing chemical fertilizer use in maize
- to determine the growth and yield performance of composite and hybrid maize with different fertilizer combinations
- to identify the optimum combination of chemical fertilizers and Nutrismart for getting maximum yields

Chapter 2

Review of literature

CHAPTER 2
REVIEW OF LITERATURE

Maize is one of the most important cereal crops in the world agricultural economy both as food for human and feed for animals. It has very high yield potential. It ranks 1st in respect of yield per unit area, 2nd in respect of total production and 3rd after wheat and rice in respect of acreage in cereal crops.

2.1 Effect of variety on yield

Palafox *et al.* (2006) reported that during spring and summer seasons of 2004, four experiments of 3-way quality protein maize (QPM) hybrids, were carried out in Camaron de Tejeda, Medellin de Bravo, Tlalixcoyan and San Andres Tuxtla, State of Veracruz, Mexico to characterize the yield and agronomic features of these hybrids, and identify those with best agronomic behaviour. Eleven QPM, 8 common hybrids and 2 checks were evaluated. Individual analysis for yield, days to tassel, days to silking, plant height and ear length, plant and ear aspect, and combined analysis for yield were conducted. The best hybrids in Medellin de Bravo were HC 1 and HC 2. In Camaron de Tejeda, HC 4 and HC 2 presented the best grain yield of 8-9 t ha^{-1}. HC 7 and HC 2 were the best hybrids in Tlalixcoyan with more than 6 t ha^{-1}. In San Andres Tuxtla, HC 1 and HC 4 registered the highest grain yield. Across the four locations, the best hybrids considering grain yield, adaptation, and plant and ear agronomic characteristics were HC 2, HC 4, and HC 1.

Sirisampan and Zoebisch (2005) reported that in northeast Thailand, maize (*Zea mays* L.) was mainly grown under rainfed conditions to identify and assess variety and cultivation-practice effects on the growth and yield of maize under temporary drought stress induced during the flowering stage. Under controlled soil-moisture conditions, three varieties (Suwan5 - open-pollinating; Big717 and Big949 - single-cross hybrids) and five cultivation practices (conventional (CT)); mungbean (*Vigna radiata* (L.) Wilzek) residue (Mn); spineless mimosa (*Mimosa invisa*) live mulch (Mi); manure (Ma); and plastic mulch (PI) were studied for two cropping seasons. The two hybrid varieties produced significantly higher grain yields than the open-pollinating variety, i.e., Big717 > Big949 > Suwan5. The effects of cultivation practices were less prominent and the highest average yields were produced by PI; the lowest by Ma.

Syed *et al.* (2002) conducted the field experiment during 2000 at Malakandher Research Farms, NWFP Agricultural University, Peshawar, Pakistan to study yield and yield components of different cultivars of maize as affected by various combinations of NP. Statistical analysis of the data revealed that days to 50% silking, 1000 grain weight, grain weight and biological yield were significantly affected by different varieties and fertilizer (NP) levels. Similarly, combination between varieties and NP had a significant effect on days to 50% tasselling, days to 50% silking, grain yield and biological yield. Maize variety Azam produced maximum 1000 grain weight, grain yield and biological yield when compared to other varieties. When the effect of different levels of NP was taken into account, it was revealed that plots treated with NP levels of 120:90 kg NP ha^{-1} produced maximum 1000 grain weight, grain yield and biological yield.

Olakojo and Iken (2001) evaluated nine improved open pollinated maize varieties and a local cultivar in five locations consisting of four agro-ecologies of Nigeria, for yield performance and stability estimates. The results showed that location (L), variety (V), and year (Y) were significant for yield. Similarly, location x variety (L x V) as well as location x variety x year (L x V x Y) interactions were significantly different in the tested genotypes at P=0.05. The improved maize varieties significantly out yielded the local check entry by between 10.3 and 30.3%, thus ranking TZB and Posa Rica 7843 as the highest yielding varieties. Stability estimates in the tested varieties showed that local variety was the most stable variety with Bi=1.0. Other varieties appeared to be stable in poor environment with stability estimates of <1.0. TZB and Posa Rica 7843 recorded the least (0.38 and 0.64) stability estimates.

Ogunbodede *et al.* (2001) evaluated seven early maturing open pollinated (OP) and five yellow hybrid maize varieties in 1996 in 22 locations representing the different agro ecologies of Nigeria. Significant location effects were observed for grain yield in the two sets of maize varieties tested. Grain yield was significantly higher in the northern/southern Guinea savanna agro ecologies when compared to the other agro ecologies. Highly significant varietals differences were found among the OPs and the yellow hybrids. The highest yielding OP variety was TZE Comp.4 DMR BC1 with an average grain yield of 2.43 t ha^{-1} while the best yellow hybrid was 8522-2 with a mean grain yield of 2.82 t ha^{-1}. Comparison of the results of the OPs and the hybrids showed that the hybrid had an average of 18.2% yield advantage over the OPs. The hybrid maize varieties and four of the seven OPs were stable in grain production across the locations.

Chaudhary *et al.* (2000) conducted a series of on-farm experiments involving 18 farmers during kharif season of 1993 to 1995 under mid-hill sub-humid agro-climate in Mandi district of Himachal Pradesh to assess the relative effect and impact of different technological inputs on maize (*Zea mays* L.) productivity. The treatments consisted of farmers' practices with local variety (control), farmers' practices with improved variety, farmers' practices with improved variety and recommended fertilizer and improved practices with improved variety and recommended fertilizer. The results indicated that the grain yield (3795 kg ha^{-1}) and net return (Rs. 8069 ha^{-1}) were significantly higher on adoption of improved practices along with improved variety and recommended fertilizer over other treatments and an additional gain in grain yield due to this practice was 1262 kg ha^{-1} with 49.8% increase against farmers' practices with local variety.

Tusuz and Balabanl (1997) conducted a study in the Antalya-Manavgat region during 1993-94, 8 hybrid maize varieties (P.3165, TTM813, TTM815, TTM81-19, ANT90, ANT-BEY, TUM82-6 and TUM82-7) were grown to determine changes in characters (50% silking date, plant height, ear height and moisture percentage at harvest) affecting grain yield. Over the two years of the experiment, heritability in the broad sense was highest for 50% silking (0.93), and low for plant height (0.12), ear height (0.31), harvest moisture percentage (0.03) and for yield (0.06). Yield was significantly correlated with 50% silking date ($r = 0.67$), plant height ($r = 0.50$), ear height ($r = 0.42$) and harvest moisture percentage ($r = 0.43$). Adaptation was very good for all of the tested varieties. Grain yield was highest for P.3165 (1343 kg da^{-1}) and ANT90 was the earliest variety. The yield potential of all of the varieties changed from year to year and a significant environmental effect was observed.

Babu *et al.* (1996) reported the performance of maize Ksheeramrutha, derived from South African maize, and its hybrids with Deccan 101, grown in the field at Karnataka during 1975-86. Ksheeramrutha was quick growing, leafy, tall and high yielding compared with the other genotypes tested. It produced good quality fodder, had high protein content and performed well in mixtures with black soya and cowpeas. It was released for cultivation in Karnataka in 1989.

An experiment was conducted at the Regional Agricultural Research Station, Jamalpur during the rabi season of 1995-96. The objective was to determine an optimum row spacing as well as nitrogen level of maize composite (synthetic) for maximum. Three row spacing viz. 60, 75 and 90 cm and three nitrogen levels viz. ,80, 120 and 160 kg ha^{-1}. The fertilizers 60-40-20-5 kg ha^{-1} P-K-S-Zn was used. The result reveled that different row spacing had no significant effect on yield while nitrogen level had the significant effect. In row spacing, the highest grain was recorded when maize sown in 75 cm spacing (5.74 ton ha^{-1}) and the lowest with 90 cm spacing (5.63 ton ha^{-1}). Nitrogen at the rate of

160 kg ha^{-1} produced the highest grain yield (6.34 ton ha^{-1}) which was statistically different from 80 and 120 kg ha^{-1}. (BARI, 1998).

Smale *et al.* (1995) reported that farmer adoption of seed/fertilizer technology could be characterized in terms of three simultaneous choices: whether to adopt the components of the recommended package; land allocation to new and old varieties; and the level of inputs such as fertilizer. Two distinctive features of maize technology adoption in Malawi are: land allocation to both traditional and hybrid maize varieties; and application of a modern input (fertilizer) to a traditional variety.

BARI (1985) conducted a field experiment at Joydebpur during kharif , 1985 and rabi 1986 with ten growth stages (i.e. collar of 4th, 8th and 12th leaf, tip tassel visible, silk visible, cob full size, kernel dough, kernal partially dented, kernal fully dented and maturity) in four maize varieties (viz. , Across7740, Sadaf, Amberpop and Pirsabak 8146). No variation in duration of growth stages was noticed upto 12th leaf stages among the varieties during kharif season. Their maturity period ranged from 78 days (Pirsabak 8146) to 93 days (Across 7740). Distinct differences was observed from 7th leaf stages during rabi season. The same varieties took 123 days (Pirsabak) to 138 days (Across 7740) to attain maturity in rabi season. The yield ranged from 1.94 to 2.84 ton ha^{-1} in kharif and 4.13 to 5.52 ton ha^{-1} in rabi. Variations in yield both in kharif and rabi might be due to seasonal variation. (BARI, 1988)

2.2 Effect of variety on dry matter production

Waes and Bockstaele (1997) tested approximately 150 varieties with a broad range for earliness over 4 years in different agricultural regions in Belgium. For corn maize, the consistency for earliness was in general good across locations and years, while yield was more influenced by location and year. Earliness of silage maize was also very consistent over locations. Dry matter yield was more influenced by location, but not as much as in corn maize. Digestibility and starch content were generally consistent over the years. Most corn and silage maize varieties had a moderate to good stability.

Akiyama and Takeda (1975) examined the effect of leaf photosynthetic rate on DM production in 4 maize cultivars, the rate being measured at 10 and 60 klx at various states of growth. The DM yield of each cultivar was measured at controlled LAI by varying the distance between pots. Leaf photosynthetic rates varied between cultivars; some attained a high capacity at high light intensity, while others were saturated at relatively low light intensities. Under these conditions cultivars which were adapted to low light intensity had the highest DM yields. Positive relationships were found between NAR and rate of leaf photosynthesis at all stages of growth. In particular, the photosynthetic rate of the youngest fully-expanded leaf at 60 klx was closely correlated with NAR at an early stage of growth, whereas the rate at 10 klx was highly correlated with NAR during active growth.

2.3 Effect of variety on grain quality

Wu *et al.* (2004) conducted a field experiment with a high-protein (Zhongdan 9409), a high-oil (Jiyou No. 1) and a common (Simi 25) maize variety in Changchun, Jilin, China. The kernel yields of the high-protein maize (HPM) and the high-oil maize (HOM) were 24.91 and 12.49% lower, the protein yield/ha of HPM was 13.5% higher, and the fat yield ha^{-1} of the HOM was 30.84% higher, as compared with those of the common maize (CM), respectively. Moreover, the kernel volume weights and the water content in kernels of the HPM and the HOM were lower and higher than those of the CM, respectively. The biggest kernel volume and the highest dry matter accumulation were recorded in the HPM, followed by the CM.

Paulsen *et al.* (2003) reported that Maize starch yield was affected by variety, environmental growing conditions, and drying conditions. One-hundred gram starch yield tests that predict actual wet milling starch yield were used as a reference method for developing an extractable starch calibration on a NIR

Systems Model 6500 spectrophotometer. A maize starch yield calibration was developed from 940 samples and used to predict a validation set of 304 samples. It had a standard error of prediction (SEP) of 1.06, a coefficient of determination r2 of 0.77 and a ratio of performance to deviations (rpd) of 2.1. This indicates about 95% of similar samples could have starch yield predicted by near-infrared reflectance within about +or-2.1%. The calibration should be successful in segregating maize lots for high and low starch yield percentages.

Almeida *et al.* (1999) conducted 19 maize cultivars for lodging, breaking and yield, and 9 were selected for further study. There were no significant differences among these 9 cultivars for dry matter yield, ear percentage, contents of neutral detergent fibre (NDF) and acid detergent fibre (ADF), or in vitro dry matter digestibility (IVDMD), while crude protein (CP) and soluble carbohydrate contents varied slightly. In silage produced from these cultivars, NDF, ADF, ammonium-N and IVDMD varied between cultivars, while CP and lactic acid contents and pH did not.

2.4 Effect of variety on soil

Huang *et al.* (2006) grown a reported that a high-oil maize variety Gaoyou HE-2 in 1 x 1 x 1 m cement pits without bottoms. The cement pits were filled with 3 kinds of soil (clay soil, loam soil and sandy soil). The effects of different types of soil on kernel quality and yield were determined. Significant differences in the dynamics of kernel dry matter accumulation after 35 days of silking were recorded among the 3 soils, but the dynamics of kernel dry matter accumulation were similar before 35 days of silking among the soils. The content of oil and protein in kernel in the loam soil treatment was 8.92 and 10.23% higher than those in the clay soil and sandy soil treatments, respectively. The highest kernel yield/ear (176.5 g) was noted in the clay soil treatment and was 16.77 and 52.63% higher than those in the loam soil treatment and in the sandy soil treatment. The oil yield, protein yield, starch yield and kernel yield were ranked as clay soil>loam soil>sandy soil.

Therefore, in order to obtain higher economic benefits, high oil maize should be grown on clay soil followed by loam soil.

Belay *et al.* (2002) conducted a long-term field experiment initiated in 1939 at the University of Pretoria, South Africa, to assess the long-term effect of direct N and K and residual P fertilizers on chemical and microbial properties of soil and grain yield of maize in rotation with field pea. Long-term fertilizer application resulted in decreased total organic C (TOC) and basic cation contents, and had an acidifying effect on soil. The decrease in TOC was higher in simple fertilizer treatments (N, P, or K) whereas basic cation contents and pH declined more in balanced fertilizer treatments (NPK). Levels of total N were higher in the balanced than in simple fertilizer treatments. Soil microbial biomass and numbers of bacteria, actinomycetes and fungi were influenced by, and exhibited qualitative changes in response to, long-term fertilizer application.

Tahir *et al.* (2002) conducted a pot experiment to evaluate the growth response of 2 maize cultivars (Magic and Golden) to compaction in sandy loam, sandy clay loam soils during spring 2001. Results revealed that soil compaction had an adverse effect on fresh weight of shoot; P concentration and N and P uptake in shoot, while soil texture has significant effect on plant height, fresh shoot weight and concentration and its uptake. Interaction between soil texture and compaction was significant for fresh weight of maize fodder as well as P and K concentration and their uptake in shoot. Varietal response under compacted and non-compacted conditions was also found statistically significant in some areas, but interaction between soil texture and variety and their combined effect was non-significant for all the growth parameters.

Andreotti *et al.* (1999) conducted a greenhouse experiment to study soil fertility changes and dry matter yield of maize (hybrid 'Zeneca 8392') grown in pots with 3 types of soil (Quartzpsamment and two alic dark red latosol -

Haplorthox soils) as a function of potassium fertilizer application (0, 2.17, 4.34, and 8.68 g K_2O pot^{-1}) and base saturation (40 and 70%) on soil. Potassium content in the soil was adjusted by applying 0 (control), 3.62, 7.24 or 14.48 g KCl pot^{-1}. Phosphorus (200 mg kg^{-1}) and zinc (5 mg kg^{-1}) were applied to all treatments at sowing time. Nitrogen was applied at sowing time (83.7 mg kg^{-1}) as well as top dressing, 25 and 40 days after seedling emergence, a total of 200 mg kg^{-1}.Result revealed that the soil buffering capacity decreased the effect of elevation base saturation of soil on exchange and residual acidity. The increase in base saturation allowed elevation of Ca and Mg levels, base saturation and CEC values independently of soil texture. The effect of elevation of base saturation in the increase of pH was larger in clayey soils.

2.5 Effect of fertilizer on yield

Eltelib *et al.* (2006) studied the effect of nitrogen and phosphorus application on growth, forage yield and quality of fodder maize growing in Sudan. The variety used was Giza 2. Nitrogen was applied at the rates of (0, 40 and 80 kg N ha^{-1}), while phosphorus levels were (0, 50 and 100 kg P2O5 ha^{-1}). Parameters studied were plant height, number of leaves per plant, stem diameter and leaf area index (LAI), days to 50% tasseling, dry matter yield, crude protein and crude fibre contents were studied. Results showed that addition of nitrogen fertilizer significantly increased plant height, stem diameter and LAI, forage dry matter yield and protein content. Phosphorus fertilizer application had no significant effect on growth, days to 50% tasseling, dry matter yield and crude protein content. Neither nitrogen nor phosphorus had a significant effect on the crude fibre content.

Malik *et al.* (2004) conducted an experiment during 1998 and 1999 to determine the optimum and economic NP fertilizer level in on-farm maize trials under prevailing agroclimatic conditions at 5 different locations (Golra, Rawat, Thandapani, Sihala and Bharakahu) of Islamabad Capital Territory, Pakistan. The treatments on the improved open-pollinated variety (OPV)

Gauher included 6 NP levels (40:00, 40:30, 40:60, 80:00, 80:30 and 80:60 kg ha^{-1}). Soil analyses for NPK contents were conducted for each location. Result revealed that fertilizer treatments did not significantly affect the number of plants and ears at harvest at all locations but had significant effects on grain and stalk yields at 3 locations. At Bharakahu, both of these traits exhibited non-significant differences, while grain yield at Sihala and stalk yield at Rawat were not significantly affected by treatments. At all other locations, the grain and stalk yields were significantly increased by increasing the amount of N and P fertilizers

Devi (2002) conducted an experiment at the College of Agriculture, Vellayani, Kerala, India, under the All India Co-ordinated Research Project on Forage Crops, to investigate the forage yield of maize as influenced by nitrogen (N) levels and biofertilizers. Eighteen treatment combinations comprising six levels of N (0, 25, 50, 75, 100 and 125 kg N ha^{-1}) and three levels of biofertilizers (no biofertilizer, seed inoculation with Azotobacter and Azospirillum). Results showed that the fodder maize variety 'African Tall' produced significantly higher green forage and dry matter yields at higher dose of N. Green forage yield increased significantly up to 125 kg N ha^{-1}, while 75 and 100 kg N ha^{-1} also produced significant yield difference compared to 0, 25 and 50 kg N ha$^{-1.}$ The biofertilizers showed no significant effect on forage yields.

Agba *et al.* (2005) conducted two field experiments to determine the efficacy of Nitrogen fertilizer on the growth and yield of improved maize variety in the teaching and research farm department of Agronomy Obubra, Cross River University of Technology, Nigeria, during the 2003/2004 cropping seasons. The experiment comprised seven rates of urea (46% N) fertilizer at 0, 50, 90, 130, 170, 210 and 250 kg ha^{-1} with three replications. Urea application significantly increased plant height, number of leaves and ear weight, ear length and ear diameter per plant. The use of 210 kg N ha^{-1} produced the best maize grain yield of 2.43 and 2.96 ton ha $^{-1}$ in 2003 and 2004, respectively.

Yusuf *et al.* (2005) reported that the response of maize variety TZSR-Y1 grown on soils (mainly Alfisols and Entisols) collected from 30 different locations in northern Nigeria to applied zinc fertilizer application was examined in two screenhouse pot experiments. The Mehlich 1 extractable soil zinc (Zn) ranged from 0.6 to 4.1 mg kg-1 with a mean of 2.00 mg kg-1. Due to the wide variations observed in the initial Mehlich 1 extractable Zn and the large sample soils involved, two fertilizer rates (0 and 10 mg kg^{-1}) were used to determine maize response to applied Zn. In many of the soils, yield was increased by the addition of Zn and there were large differences in response pattern. Dry matter production was higher in the first crop, making 55% of the total against 45% from the second crop. This was attributed to the mineralization and subsequent utilization of Zn reserve in the organic complexes of the soil.

Niu *et al.* (2005) conducted a field test with a fodder maize variety Baimaya in 2002 in Xuanhua, Hebei, China, to investigate the effects of different amounts of N fertilizer applied as a top dressing (0 as control, 34.5, 69.0, 103.5, 138.0, 172.5 and 207.0 kg N ha^{-1}) on crop yield and quality. The top dressing of N fertilizer significantly enhanced the yield of fodder maize and the contents of crude protein, true protein and amino acids in stalks. The highest fresh (45 089.9 kg ha^{-1}) and dry yields (9 378.7 kg ha^{-1}) were noted at 138.0 kg N ha^{-1}. The highest contents of crude protein (7.84%), true protein (1.97%) and amino acids (0.28%) in stalks were also noted at 138.0 kg N ha^{-1}. Therefore, the optimum amount of N fertilizer applied as a top dressing in the northwest arid land in Hebei province was 138.0 kg N ha^{-1}.

Wakene *et al.* (2005) initiated an experiment in 1997 cropping season to study the effect of supplementing low rates of NP fertilizers with farmyard manure (FYM) in the maize based farming systems of western Oromia, Ethiopia. The treatments used were 0/0, 20/20, 40/25 and 60/30 kg N/P ha-1 and 0, 4, 8, and 12 metric tonnes (t) of FYM ha^{-1} in factorial combination. The residual effects of FYM were investigated for Laga Kalla, Walda and Shoboka during the 1998 cropping season. The result revealed that the main effects of N/P fertilizers and FYM significantly increased maize grain yields in all locations except for Walda in case of N/P fertilizers and except for Harato in case of FYM in 1997. In the same year, the interaction effects of the FYM and the low rates of NP fertilizers on grain yield were significant at all locations except for Shoboka. The interaction of the residual effects of the FYM and the low rates of NP fertilizers on grain yield were significant at Shoboka and Laga Kalla sites during the 1998 season. Therefore, the integrated use of properly handled FYM and low rates NP fertilizers could be used for improved maize production in the areas under consideration.

Dong *et al.* (2005) studied the nitrogen transformation in maize soil after application of different organic manure to investigate the nitrogen mineralization on the surface soil, NO_3--N dynamics and distribution in the soil profile, and N_2O emission. The study was conducted at Yucheng Comprehensive Experimental Station in North China Plain. The experiment was laid out in 24 plots in random plot design with 8 treatments, each with 3 replicates: maize plantation without fertilizer (CK1), bare soil without maize plantation and fertilizer application (CK2), swine manure (S1, S2), poultry manure (P1, P2), and cattle manure (C1, C2). The result revealed that the emissions of N_2O were affected by the application of organic manures in the order of P2 > S2 > C2 > P1 > S1 > C1 > CK1 > CK2. All these results showed that organic manure applications significantly affect nitrogen transformation and distribution in maize soil.

Presterl *et al.* (2004) reported that for the analysis of nitrogen (N) efficiency, field experiments with different reduced N levels were imperative. Results of tests with 49 maize lines in Germany were shown. Yields were measured at various N levels. QTL's (quantitative trait loci) were mapped within a population of 720 double haploid lines in southern and eastern Germany. The tendency of higher yield stability of these varieties is also of interest under conventional farming conditions with higher nitrogen levels. The causality of the identified genes and the nitrogen efficiency traits need further research to be fully established. Marker-assisted selection should then be possible. The trait nitrogen efficiency should become important for variety listing because, N sensitive areas and low input farming or organic are expected to increase in importance. Further testing could also establish if there was a link between N efficiency and drought tolerance.

Sanjeev *et al.* (2004) conducted a field experiment during the 1999 summer season in Chhattisgarh, India, the treatments comprised of 3 maize cultivars (Mahyco-1765, ProAgro-3436 and Nutan-581); 3 sowing dates (22 April, 2 May, and May 12) and 3 levels of integrated nutrient management i.e. recommended dose of 120:60:40 kg N, P_2O_5, K_2O ha^{-1} (F100), 90 kg N ha^{-1} + 6 t FYM ha^{-1} + 45 kg P_2O_5 + 10 kg K_2O ha^{-1} (F75O25) and 60 kg ha^{-1} + 12 t FYM ha^{-1} + 30 kg P_2O_5 ha-1 (F50O50). ProAgro-3436 recorded the tallest plant and more girth and it was significantly higher than Mahyco-1765 and Nutan-581 both at 60 days after sowing and at harvest. Dry matter production on the 40th day was significantly higher in Nutan-581 followed by ProAgro-3436 and Mahyco-1765. Mahyco-1765 gave significantly higher cob yield and yield attributes compared to ProAgro-3436 and Nutan-581.

Jin *et al.* (2004) grown a high-starch maize variety (ZD21) in a field experiment with a common variety (SM25) as the control. Urea was applied at 0, 150, 195 and 240 kg N ha^{-1}. As compared with SM25, ZD21 had greater maximum N uptake rate, which occurred at an earlier date, and higher total N uptake at maturity, though its grain yield was lower. The nitrogen in its grain largely originated from the nitrogen absorbed by the roots rather than from the transfer of N from the vegetative organs. It had higher total starch and amylopectin and lower amylose/amylopectin ratio than SM25. It had higher total crude proteins, albumin, globin and glutelins and lower prolamins. Its total fatty acids were relatively low. however, the content of unsaturated fatty acids were fairly high. In both varieties, the responses of amylopectin, prolamins, palmitic acid, oleic acid and linoleic acid to N application were similar to those of the contents of starch, crude protein and fatty acids, and increased with N rate if N application was not excessive. Nitrogen application had no significant effect on the contents of amylose, albumin, globin and glutelins and of stearic acid, arachidic acid and linolenic acid.

Kogbe and Adediran (2003) tested the effects of five rates each of N, P and K application on three hybrid and two open-pollinated maize varieties in three separate experiments on an Arenic haplustalf (USDA) at Ilora in the derived savanna and Typic paleustalf (USDA) at Mokwa in the southern guinea savanna of Nigeria. The hybrid maize varieties planted were 8516-12, 8321-18 and 8329-15 and were compared with the open-pollinated maize, TZSR-Y and TZSR-W. Nitrogen was applied at rates 0-200 kg ha-1 in the first trial, while P and K were supplied as basal nutrients. In the second trial, P was applied at rates 0-80 kg P_2O_5 ha^{-1} using basal N and K fertilizers. In another trial, K was applied at rates 0-120 kg ha^{-1} with blanket application of N and P. The hybrid maize gave higher yields and used N and P more efficiently than the open pollinated at both trial locations. The 8516-12 showed higher N and P use efficiency than other varieties. Consequently, planting such variety could be advantageous, using minimal dose of fertilizer most especially, where farmers have less access to fertilizer.

El-Nagar (2003) conducted six field experiments in Egypt in 2001 and 2002, to study maize growth, grain yield and yield attributes under five nitrogen fertilizer rates: 70, 100, 130, 160, and 190 kg N $feddan^{-1}$, with or without Azospirillum brasilense inoculation and three irrigation regime treatments.. Growth traits, grain yield and yield attributes, protein content and recovered nitrogen were positively related to bacterial inoculation. Increasing the nitrogen rate to 130 kg $feddan^{-1}$ significantly increased growth, grain yield and yield attributes. Application of 130 kg N feddan produced 105.29% of the calculated maximum grain yield and was likely the most cost-effective rate. The interaction between inoculation and nitrogen fertilizer significantly increased N recovery. [1 feddan=0.42 ha].

Wang *et al.* (2003) reported that in China, the average rate of N application for rice production is high and fertilizer-N use efficiency was low compared with other major rice growing countries. Environmental pollution by nitrogen leaching or runoff from rice fields had become a serious concern. In cooperation with IRRI scientists, they developed a new site-specific nutrient management (SSNM) approach for double-rice growth area of Jinhua. The agronomic performance of SSNM was tested against the farmer's fertilizer practice (FFP) in the cropping seasons of past five years (1998-2002). Compared with FFP, when SSNM was adopted, average grain yield increased by 0.4 t hm-^{2} and nitrogen use efficiency increased significantly. About 30% of fertilizer N used in current rice production could be reduced through adoption of SSNM, which could effectively cut off the non-point pollution resource of N from rice fields.

Maeda *et al.* (2003) studied the Nitrate (NO_3) leaching in an Andisol treated with four N fertilizers (SC: swine compost, CU: coated urea, AN: ammonium N, or NF: no fertilizer) for 7 years. Sweet corn *(Zea mays* L.) was grown in summer, followed by Chinese cabbage (*Brassica rapa* L. var. amplexicaulis) or cabbage (*Brassica oleracea* L. var. capitata) in autumn each year. The potential NO_3-N concentrations by an N and water balance equation satisfactorily predicted NO_3-N concentration in the AN and CU plots, but substantially overestimated that in the SC plot, presumably because a large portion of N from SC first accumulated in soil in the organic form. Their results indicated that, under the Japanese climate (Asian monsoon), excessive N from chemical fertilizers applied to Andisols could caused substantial NO_3 leaching, while compost application was promising to establish high yields and low N leaching during a few years but caused the same level of NO_3 leaching as in chemically fertilized plots over longer periods.

Rameshwar and Totawat (2002) conducted a field experiment during the kharif season of 1999 in Rajasthan, India, to determine the effect of using biogas slurry and Azotobacter as supplement of N fertilizer on maize cv. Navjot performance. Treatments were: chemical urea at 100% (90 kg N ha^{-1}), and 50 and 75%; organic biogas slurry at 100% (90 kg N ha^{-1}), and 50 and 75%, with or without Azotobacter; and combination of chemical and organic fertilizer at 1:1 ratio. All treatments significantly increased maize grain and stover yield, yield attributes and nutrient uptake. The available nutrient status of the soil after maize harvest was highest in the organic treatment, followed by the integrated chemical+organic fertilizer treatment.

Latha *et al.* (2002) studied the residual effect of organic manures (farmyard manure, poultry manure, coir pith, and biogas slurry) solely or in combination with zinc at 0.0, 12.5, and 25.0 kg zinc sulfate ha^{-1} on sunflower (hybrid MSFH-17) grown after maize in Coimbatore, Tamil Nadu, India. The application of manure with zinc significantly increased seed and stalk yields. Seed yield was increased by 15% due to the residual effect of 25 kg zinc sulfate ha^{-1} and by 12% due to the application of manures, with that of poultry being the most effective. Zinc use efficiency decreased with the increase in zinc sulfate rate. Zinc sulfate + manure gave higher zinc use efficiency than zinc sulfate alone. The results indicated that the recommended 25 kg zinc sulfate ha^{-1} could be replaced with 12.5 kg zinc sulfate ha^{-1} if applied with manures.

Nanda *et al.* (2002) conducted an experiment concurrently for 3 years (1998-99, 1999-2000 and 2000-01) to study the effect of inorganic and organic combinations of nitrogen (N) in forage maize-wheat sequence. The experiment consisted of 9 treatments: T1, 100% N from inorganic fertilizer; T2, 50% N from fertilizer + 50% N from farmyard manure (FYM); T3, 50% N from fertilizer + 50% N from poultry manure; T4, 50% N from fertilizer + 50% N from goat manure; T5, 50% N from fertilizer + 50% N from subabul [*Leucaena leucocephala]* leaves; T6, 75% N from fertilizer + 25% N from FYM; T7, 75% N from fertilizer + 25% N from poultry manure; T8, 75% N from fertilizer + 25% N from goat manure; and T9, 75% from fertilizer + 25% N from subabul leaves. The use of T9 showed a significantly higher green forage yield at 19.22 t ha^{-1}, dry forage yield (5.00 t ha^{-1}) and crude protein yield (3.59 q ha^{-1}) in fodder maize and a net return of Rs 14 124.00 ha^{-1} in maize-wheat sequence. The succeeding wheat crop recorded significantly higher grain yield (2.15 t ha^{-1}) due to T5. The soil fertility after kharif maize improved and subsequently depleted after rabi wheat.

Sridhar *et al.* (2002) reported that the use of compost or manure in agriculture as an organic source of nutrients which was low in nitrogen content. Farmers commonly used chemical N fertilizers such as urea, calcium ammonium nitrate (CAN), and NPK formulations. These chemical supplements might have a negative impact on the environment through nitrate leaching into water, leading to eutrophication of surface waters that could affect public health. *Gliricidia sepium,* a fast-growing, tropical, perennial hedge plant was tested as a source of N in organo-mineral fertilizer formulations. Average nutrient content of Gliricidia is 3.8% N, 0.32% P, 1.8% K, 0.8% Ca, and 0.2% Mg. Using a sand culture and Amaranthus caudatus as a test crop, it was shown that amending commercial composts with 30% Gliricidia prunings would benefit many small-scale farmers and control environmental pollution.

Baquerol and Rojas (2001) conducted an experiment in Colombia to study the effects of some interactions resulting from the addition of organic materials (cowpea residues and chicken manure) and two levels of lime, (0 and 1500 kg ha^{-1} dolomite lime) on the grain yield and nutrient acquisition of three maize cultivars. Grain yield increased in treatments that received either 5 t ha^{-1} cowpea, residues 5 t ha^{-1} chicken manure, or 1500 kg ha^{-1} dolomite lime. Yield improvement was higher in the Al-sensitive cultivar, (ICA-V 109) than in the Al-tolerant variety, (Sikuani-V110). Treatments that received only chicken manure had grain yield slightly higher than treatments with 1500 kg ha^{-1} of lime. There was a positive effect on grain yield and nutrient acquisition in treatments both, organic materials and dolomite lime. The results indicated that the cultivars which were more efficient in nutrient uptake under aluminium stress had a good chance to grow well in acid soils low in nutrients.

Huang *et al.* (2001) reported that in a field experiment with 7 varieties of maize, the plants were supplied with N at 0, 75 and 150 kg ha^{-1} and in a pot trial the plants were supplied with N at 0, 200 and 400 mg kg^{-1} soil. Information on seed yield per day, nitrogen use efficiency (NUE), root morphology, leaf nitrate reductase activity (NAR) and photosynthetic parameters (photosynthesis rate, leaf relative moisture and stomatal resistance) were recorded. Significant differences were observed among the 7 varieties in their (daily) seed yield, which appeared correlated with the duration of growth period. NUE was correlated with root dry weight, root length, root surface area, leaf NRA, net photosynthetic rate and stomatal resistance. Adequate N supply increased net photosynthetic rate, stomatal resistance, leaf NR content, dry matter accumulation and seed yield, and the extent of increase varied with variety.

Pursushottam and Puri (2001) conducted a field experiment in Salooni, Himachal Pradesh, India, during the rainy seasons of 1996 and 1997 to study the response of maize cultivars (Early Composite, Parvati, and Salooni Local) to farmyard manure (0 and 15 t ha^{-1}) and N (0, 45, and 90 kg ha^{-1}) application. Among the cultivars, Salooni Local gave the tallest plant and longest cobs as well as the highest number of cobs, 1000grain weight stover yield and grain yield . The application of 90 kg N and 15 t farmyard manure ha^{-1} gave the tallest plants, cob length, number of grains per cob, 100-seed weight, grain and stover yields, and harvest index. The highest agronomic efficiency was obtained with 45 kg N and 15 t farmyard manure ha^{-1}. Grain yield was also highest with 90 kg N+15 t farmyard manure ha^{-1}. Without farmyard manure, the yield obtained with 90 kg N ha^{-1} was equal to that obtained with 45 kg N+15 t farmyard manure ha$^{-1.}$

Vadivel *et al.* (2001) conducted a field experiment in Coimbatoire, Tamil Nadu, India, during winter of 1995-96 and 1996-97 to study the effects of organic N sources and N rate (0, 20, 40, and 60 kg ha^{-1}) on the growth and yield of maize cv. Co 1. The organic N sources were composted coir pith (6.25 t ha^{-1}) and enriched farmyard manure (750 kg ha^{-1}) applied as basal and Azospirillum inoculated on seeds and soil. Enriched farmyard manure and 60 kg N ha^{-1} gave the tallest plants and the highest leaf area index; cob length, girth, and weight; 1000-grain weight; dry matter production; and grain and straw yields in both years.

Rout *et al.* (2001) conducted a study during the kharif seasons in Orissa, India, to assess the effects of biofertilizers on nitrogen (N) fertilizer economics and maize (cv. Ganga 5) yield. Treatments comprised: four N rates (60, 80, 100 and 120 kg ha^{-1}) and/or four biofertilizer rates (no biofertilizer, Azotobacter, Azospirillum and Azotobacter + Azospirillum inoculations). The biofertilizer effects decreased as the nitrogen rates increased. Biofertilizers had beneficial effects on yield. The beneficial effects were higher than the biofertilizer cost. The benefits were more pronounced at the lower (60 and 80 kg ha^{-1}) than the higher N rates (100 and 120 kg ha^{-1}). It is concluded that biofertilizers in combination with inorganic N fertilizers can substitute up to 20% nitrogenous fertilizers and increase maize yield.

Rusu *et al.* (2000) studied the influence of a variety of complex leaf fertilizers, synthetic amino acids and liquid nitrogen compounds on maize (hybrid PI 110) in a field experiment conducted on chernozem (Trifesti) and dark luvisol (Lespezi) soils found in Iasi, Romania, during 1993-97. Yield increased were significantly higher on chernozem soils. The efficiency of leaf fertilization in maize was higher in less favourable years, when the differences among the variants had a tendency to equalize.

Tripathi and Shrestha (2000) conducted field experiments in 3 systems: rice (cultivars Makawanpur-1 and Ekie) wheat (cultivars Rohini and Annapurna-4) in bunded terraces (Chambas and Pakuwa), upland rice(cv. Tauii) blackgram (cv. Mash) in rainfed ancient terraces (Dordor Tar) and maize (cv. Manakamana-1) fingermillet (cv.Okhle) in rainfed upland (Dordor Gaun) in Nepal from 1997 to 2000 to determine the response of different levels of N-based farmyard manure (FYM) and chemical fertilizers, alone or in combinations, on rice-wheat, upland rice-blackgram, and maize-fingermillet cropping systems. Full dose of nutrients through chemical fertilizers were better than 50% FYM + 50% chemical fertilizers for high yield of rice-wheat and maize-fingermillet crops. Rice blackgram yields were at par with 50% FYM or chemical fertilizer treatments. At Dordor Tar, full dose of FYM in upland rice increased organic C and full dose of chemical fertilizers increased available P. Soil pH and exchangeable K decreased in all the treatments. At Dordor Gaun, full dose of chemical fetilizer sustaine organic C but decreased soil pH, total N ans exchangeable K while 50% FYM + 50% chemical fertilizers sustained available P.

Andreotti *et al.* (1999) conducted the residual effects of zinc application (0.70, 5, 10 mg/dm3) and liming (15, 20 and 70% base saturation) on the dry matter yield and nutrient levels in maize (triple hybrid XL 370) at 57 days after emergence under greenhouse conditions. Increasing zinc levels increased the dry matter and zinc level in maize. The dry matter yield was not affected by zinc application but was affected by base saturation. The zinc levels in the stems and leaves were reduced with increasing base saturation.

Maliki *et al.* (1998) reported that *Senna siamea* [formerly *Cassia siamea*], *Chromolaena odorata* and *Imperata cylindrica* were applied at a rate of 5 t ha^{-1} dry matter (DM) sole and in combination with 600 kg ha^{-1} NPK 15-15-15 in order to evaluate their impact on maize production on a degraded Acrisol in southern Benin. The experiment was conducted on a farmer's field. Despite the physical and chemical differences, no significant yield difference between the three types of green manure was observed. The effect of green manure was not only due to the nutrient release but also due to the soil covering effect that favoured weed suppression, root development and soil moisture. The association of mineral fertilizer and green manure increased and stabilized yields.

Davidescu *et al.* (1998) reported that the use of chemical fertilizers, manure and chemical substances for plant protection could influenced the quality of fodder plant and the environment. Chemical fertilizers with nitrogen as nitrate have a high solubility and can be leached by irrigation water or precipitation through soil in phreatic water. Lead could be accumulated in fodder plants and could be absorbed from polluted soil or from polluted environment by industries. The accumulation of nitrates in fodder plants was accelerated in variant where lead was applied. The content of total nitrogen and protein corresponds to their normal contents in fodder plants as 2-3.5% total nitrogen and 8-22% protein. Increasing nitrogen doses and the lead added in soil determined increases in yield and protein content in fodder plants.

Sanjeev and Bangarwa (1997) conducted a field experiment on winter maize at CCS HAU, Hisar farm during rabi season. In the experiment three levels of plant density (83000, 110000 and 145000 plants ha^{-1}) and 5 nitrogen levels (0, 60, 120, 180 and 240 kg ha^{-1}) replicated four times. The soil of the experimental field was sandy loam low in nitrogen, medium in phosphorus and high in potash. Grain yield at 110000 plants ha^{-1} was 14.88 and 12.20% higher than at 145000 and 83000 plants/ha, respectively. Plant height and dry matter g msuperscript^{-2} were affected significantly up to 110000 plants ha^{-1}, while stover yield increased with increase in plant density. Number of effective ears plant^{-1}, number of grains ear^{-1}, 100-seed weight, grain weight ear^{-1}, percentage ear filling and grain yield plant^{-1} decreased with higher plant density. Grain and stover yield increased significantly up to 240 kg N ha^{-1}. Number of grains ear^{-1}, 1000 seed weight, grain weight ear^{-1} increased significantly up to 180 kg N ha^{-1} and grain yield plant^{-1} up to 240 kg N ha^{-1}. Highest grain yield (5845 kg ha^{-1}) was obtained at 110000 plants ha^{-1} given 240 kg N ha$^{-1.}$

Suri and Puri (1997) conducted a field experiment in the low-hill submontane zone of Himachal Pradesh during 1990-91 to evaluate the direct, residual and cumulative effects of farmyard manure (0 or 10 t ha^{-1}) and phosphorus (0, 13 or 26 kg ha^{-1}) application in a maize cv. Local/wheat cv. VL 616/maize cropping sequence. Farmyard manure and P showed significant direct and residual effects on the 3 sequential crops The residual farmyard manure increased the grain yield of the next maize crop by 235 kg ha^{-1}. Application of 26 kg P ha^{-1} to the preceding wheat increased the grain yield of second maize crop by 300 kg ha^{-1}. A fresh P application of 13 kg ha^{-1} to the second crop increased its grain yield by 357 kg ha^{-1}. All the interactions were significant.

Videva and Koteva (1997) carried out a long-term stationary fertilizer experiment in Bulgaria within the range of the 8th rotation of the crop sequence, a study was conducted to establish the effect of the complex mineral fertilization on the nutritive value of grain, stems and cobs of maize of the variety Knezha 53. It was found that under unirrigated conditions with increasing rates of mineral fertilizers, the crude protein content of maize increased up to 11.83% in the stems and up to 5.65% in the cobs. The content of the nitrogen free extracts decreased in all organs. Indices concerning the energetic nutrition of maize feed, such as gross energy, digestible energy, and net energy, showed insignificant changes under the effect of fertilization. The amount of intestine-digestible protein increased under the effect of fertilization from 124.79 g kg^{-1} dry matter in the grain of the unfertilized plants to 141.53 g kg^{-1} dry matter in the plants fertilized with N15P8K8.

Kamalakumari and Singaram (1996) reported that in long term field trials over 20 years initiated in 1972 on a Typic Ustochrept clay loam soil at Coimbatore, Tamil Nadu, maize cv. Co.1 was given various rates of N, P and K, 0 or 25 kg $ZnSO_4$, 0 or 10 t farmyard manure (FYM) and hand weeding or no weeding. Available P and K in soil increased with rate of NPK fertilizer and with FYM application. Grain yield and uptake of N, P and K were highest with 135 kg N + 67.5 kg P_2O_5 + 35 kg K_2O + 10 t FYM ha^{-1}. Continuous application of N only resulted in depletion of Olsen-P in soil.

Ramamurthy and Shivashankar (1996) conducted a field study at Hebbal, Bangalore, during 1990-92 on a sandy loam soil to determine the response of maize cv. Deccan 101 sown in the rainy seasons, to the residual organic matter and phosphorus fertilizers present from application to previous soyabean crops. Organic fertilizers were applied to the soyabeans at 0, 5 or 10 t ha^{-1} (1:1 farmyard manure and rice straw) and inorganic P was applied at 37.5 or 56.25 kg P_2O_5 ha^{-1}. The residual effect of 10 t ha^{-1} organic fertilizer resulted in a significant increase in dry matter production, grain yield, protein content and the uptake of nutrients by maize. An increase in grain yield of 8% was observed due to a residual response to 56.25 kg P_2O_5 ha^{-1} compared with 37.5 kg P_2O_5 ha^{-1} application.

The experiment was conducted during the rabi season of 1996-97 at the Central Research Station BARI farm, Joydebpur, RARS, Jamalpur and Jessore to find put the optimum dose and time of application of nitrogen for maximum yield of hybrid maize. The treatments were three nitrogen levels : (200, 250 and 300 kg N ha^{-1}) and four time of N- application :1) ½ basal + ½ at 35 DAE. 2) 1/3 basal + 1/3 N at 35 DAE + 1/3 at 65 DAE. 3) 1/3 N basal + 1/3 N at 35 DAE +1/3 N at 85 DAE and 4) 1/3 N basal+1/3 N at 45 DAE +1/3 N at 85 DAE.The hybrid maize (Pacific 11) was used having 75 cm row spacing and 25 cm between plant. The result showed that nitrogen application may be splited 1/3 N as basal, 1/3 N as 35 DAE and 1/3 at 60 DAE with 200 kg N ha^{-1} for higher grain yield of hybrid maize for Joydebpur condition and for Jessore condition 250 kg ha^{-1}. For Jamalpur area 300kg ha^{-1} may be applied at ½ as basal and a half at 35 DAE. (BARI, 1998).

Nanda *et al.* (1995) reported that In a field trial in kharif [monsoon] 1993 at Bhubaneswar, Orissa, fodder maize cv. African Tall was given 0-75 kg N ha^{-1} with or without seed inoculation with Azotobacter or Azospirillum. Green fodder yield and benefit:cost ratio were highest with a combination of 75 kg N/ha and seed inoculation with Azospirillum (22.0 t ha^{-1} and 1.37) and lowest in the control (7.6 t ha^{-1} and 0.07). Application of 50 kg N ha^{-1} alone gave a similar green fodder yield to application of 25 kg N + seed inoculation with Azospirillum. Protein yield was highest with 75 kg N ha$^{-1.}$

An experiment was conducted at Joydebpur farm during rabi season of 1989-90 to evaluate the effect of fertilizer placement and timing of nitrogen application on the yield of maize. The trial was setup with methods of placement pf fertilizer (broadcast and furrow) and time of nitrogen application (full dose of N at basal, ½ N basal + ½ N 45 DAE, ½ N at 45 DAE + ½ N at 75 DAE, 1/3 basal + 1/3 25 DAE +1/3 at 45 DAE and 1/3 basal + 1/3 at 45 DAE + 1/3 at 75 DAE) in maize. Broadcasting of fertilizer produced maximum yield of maize followed by furrow method. Highest grain yield was obtained when full dose of nitrogen was applied at sowing but this was at for 50% N used at basal + 5 % N at 45 days after emergence of the crop (DAE). Lowest grain yield was obtained when N- fertilizer was not given at sowing. (BARI, 1998).

Akiyama *et al.* (1986) reported that maize and rice were grown in succession in the dry and wet season and rice straw, rice husks, maize stalks and sawdust were applied at 2 levels or FYM or synthetic soil conditioner applied. Total and available N content increased with organic materials, and soil reduction and Fe2+ content were higher on application of rice straw or maize stalks at the higher level than with other materials. Injurious effects of decomposition on rice plants were negligible. In all years maize yield was higher with FYM than other materials, which gave poor growth and yields when applied at higher levels due to N deficiency and undecomposed OM. Treatment effects were greater on maize than on rice.

El-Attar *et al.* (1982) reported that the application of 10 tons/acre of farmyard manure increased the maize yield by 13% in the clay loam soil of Abis, and by 19% in the calcareous sandy clay loam of Nubaria. In addition the farmyard manure improved the response of maize to ZnO and $ZnSO_4$. Zinc application increased the leaf content of zinc, but reduced both copper and manganese, and had an uncertain effect on iron. A larger response to organic matter and zinc was found in Abis than in Nubaria showing the effect of carbonates on micronutrient availability and uptake.

Capurro and Voss (1981) reported that relative N efficiency index (EN), defined as the nutrient efficiency at 99% of max. yield, was obtained from quadratic regressions of maize yield on fertilizer N rates for each of 33 experiments conducted on well, moderately well and poorly drained soils in Iowa. EN was closely related to the square root of the quadratic coeff. Values of EN ranged from 2.5 to 9.3, and max. yields varied from 3600 to 10 200 kg grains ha^{-1}. Nutrient efficiencies were calculated from given values of EN and relative yield, and this gave efficiencies in kg grain/kg N of 14 for EN of 2 and 42 for EN of 6 at a relative yield of 50%. The required increase in N rate for economic opt. yield was calculated from given values of EN, relative yield, max. yield and the N:maize price ratio.

Bedi and Sekhon (1977) reported that in a glasshouse experiment, fertilizer potassium and magnesium were applied in various amounts to 20 soils differing in the proportion of exchangeable potassium to the sum of the three exchangeable cations, potassium, calcium and magnesium. Maize, cv. Ganga-5, was grown as the test crop. In soils where this ratio exceeded 0.05, potassium fertilizer reduced yields. An optimum ratio of exchangeable calcium, magnesium and potassium appears more important than their absolute amount. Magnesium application to high-potassium soils improved the cation equivalent ratio within the plant and the dry-matter yield.

2.6 Effect of chemical fertilizer on environment

Obilo and Ogunyemi (2005) reported that a field experiments were conducted in the early rainy season and mid rainy season in the year 2000 at Umunarukwu village in Oguta to investigate the effects of crude oil pollution, gas flaring and exhaust fumes of tankers on the growth and performance of three different varieties of maize, namely, DMR ESR.W (V1), DMR ESR.Y (V2) and Oguta Local (V3), the local variety. These maize varieties were also chemically analyzed for their absorption of heavy metals along with the soil samples collected before and after planting. The amounts of lead (Pb) and Cadmium (Cd) absorbed by the local variety were significantly Pb=9.83 ppm, and Cd=0.93 ppm. This local variety also exhibited an appreciable increase in plant height (in P1) despite the high accumulation of cadmium and lead in its tissue.

Choudhury and Kennedy (2005) reported that Nitrogen (N) requirements of rice crop were met from both the soil and fertilizers. Because of acute N deficiency in most rice soils, fertilizer N must be applied to meet the crop demand. N fertilizer applied to rice crops was partially lost through different mechanisms, including ammonia volatilization, denitrification, and leaching. These losses might cause environmental problems such as polluting the atmosphere, aquatic systems, and groundwater. These problems could not be alleviated completely. However, they can be reduced a considerable extent by various techniques.

Su *et al.* (2005) reported that dry farming and slow-release or controlled-release compound fertilizer application to rice could not only improve the use efficiency of water and fertilizer but also abate the environmental pollution. Under the condition of applying the same inorganic slow-release compound fertilizer (ISF), a field experiment was conducted in cold and flooded paddy field in China to investigate the effects of three different paddy surface managements, i.e., conventional flooding (CF), dryland covered with plastic film (DF) and dryland covered with straw (DS) on the growth characteristics and yield of rice, nitrogen forms in leaf, fertilizer-N use efficiency, contents of amino acid and protein in rice. The apparent recovery rate and agronomic efficiency and physiological efficiency of nitrogen for rice were in the order of DF>CF>DS. It was clearly indicated that the nitrogen nutrition in rice leaf at tillering stage affected the contents of amino acids and protein, and dryland covered with plastic film could improve the quality of rice.

Pathak *et al.* (2004) reported that environmental problems such as groundwater pollution, eutrophication, methaemoglobinaemia, acid rain, ozone depletion and waterborne diseases, are associated with underuse, overuse and incorrect use of fertilizers. Improvement of fertilizer use efficiency was necessary to increase crop productivity and reduce environmental pollution. The nutrient use efficiency might be improved by regulating the supply from the fertilizer material, enhancing the uptake and utilization efficiencies by the plant and reducing the nutrient concentration in the harvested produce. These technologies were: new forms of fertilizer, precision farming, integrated nutrient management, site-specific nutrient management, demand-driven N application, conservation agriculture, fertigation, and computer-based decision support systems.

Ma *et al.* (2003) reported that relying less on fertilizer N and more on crop residual and biological N2 fixation by legume crops had been suggested as an effective way to meet the challenge of maximizing economic return while minimizing environmental pollution. A field study was conducted on a Brandon loam soil (Orthic Humic Gleysol) to determine the effects of crop rotation and N amendments on grain yield, crop growth, N uptake and use efficiency (NUE) of maize (*Zea mays* L.) and fertilizer replacement values of legume. The rotations included maize in annual rotation with soybean [*Glycine max* (L.) Merrill], alfalfa (*Medicago sativa* L.) or continuous maize. Their results indicated that maize in annual rotation with legume crops could increase the maize yields by as much as 20% and reduce the amount of chemical fertilizer N by as much as 180 kg N ha^{-1}. The effect of legume preceding crop on maize dry matter production and N uptake is expressed mostly in the later stages of crop growth in this mid- to short-growing-season region.

Carroll *et al.* (2003) reported that regular applications of ammonium nitrate (35-140 kg N ha^{-1} year^{-1}) and ammonium sulphate (140 kg N ha^{-1} year^{-1}) to areas of acidic and calcareous grassland in the Derbyshire Peak District over a period of 6 years, had resulted in significant losses in both overall plant cover, and the abundance of individual species, associated with clear and dose-related increases in shoot nitrogen content. No overall growth response to nitrogen treatment was seen at any stage in the experiment. Phosphorus additions to the calcareous plots did however lead to significant increases in plant cover and total biomass, indicative of phosphorus limitation in this system. Clear and dose-related increases in soil nitrogen mineralization rates were also obtained, consistent with marked effects of the nitrogen additions on soil processes. High nitrification rates were seen on the calcareous plots, and this process was associated with significant acidification of the 140 kg N ha^{-1} year^{-1} treatments.

Tamminga (2003) reported that differences in soil, climate and socioeconomic conditions caused animal production to vary widely between European regions, notably in animal density and percentage landless farming. Nutrients causing environmental concern are those containing excessive phosphorus (P), potassium (K) and nitrate (NO_3), contaminating soil and water and those losing the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) into the air. Successful and feasible interventions are to intensify, to reduce external inputs and to optimize. The recommended measures required legal and mental interventions, the success of which will largely depend on the quality of legislation and the acceptability of its implementation.

Cai *et al.* (2002) investigated ammonia volatilization, denitrification loss and total nitrogen (N) loss (unaccounted-for N) from N fertilizer applied to a calcareous sandy loam fluvo-aquic soil at Fengqiu in the North China Plain. Denitrification (its major gas products are N_2 and N_2O) usually was not a significant pathway of N loss from N fertilizer applied to maize and wheat. The amount of N_2O emission (N_2O is an intermediate product from both nitrification and denitrification) was comparable to denitrification loss for maize and wheat, and it was not significant in the economy of fertilizer N in agronomical terms, but it was of great concern for the environment.

Zhu and Chen (2002) reported that China is a big country with a huge population and limited farmland area per capita. To produce enough food for feeding the population is of vital importance for the county. A huge achievement in food production since 1949 had been made. The regression analysis in each period of 10 years showd that there is a significant positive linear correlation between the annual food production and annual chemical fertilizer N (CF-N) consumption throughout 1949-1998. However, the regression coefficient, b, in each period of 10 years since 1949 had been declining rapidly. Meanwhile, environmental pollution was becoming a serious issue. In last 20 years, N concentrations in surface and ground water had been increasing, 'Alga blooms' in lakes and 'red tides' in estuaries occur frequently, and the emissions of N_2O and NH_3 from farmlands rise.

Pathak *et al.* (2002) presented a review on NPK consumption trend in India vis-a-vis some developed countries, environmental consequences of NPK fertilizer use, and strategies to increase fertilizer use efficiency and minimize environmental pollution. The major environmental consequences related to fertilizer use included nitrate pollution of groundwater, eutrophication, ammonia volatilization, acid rain, greenhouse effect, damage to crops and soil organisms, and trace element and heavy metals contamination. The nutrient balance approach and site specific nutrient management could be used to increase fertilizer consumption without degrading environmental quality.

Wu *et al.* (2001) reported that plastic film mulching cultivation was a promising alternative technology for the conventional continuous flooded cultivation system of rice (*Oryza sativa*). The objective of this study, conducted at 2 locations in China, was to establish a better rice film mulching cultivation system and to improve the nitrogen (N) use efficiency in this system. The average N use efficiency for this higher yield treatment was about 43.0%, compared to 30.3% for the flooded-cultivation with the farmer's fertilizer rate in 1999 and 2000. For the Japonica cultivar 9454, plastic film mulching was a better cultivation technology, coupled with direct dibble sowing, for high yield and N use efficiency. Higher grain yield of 8842 kg ha^{-1} was obtained in the mulching plot with direct sowing in 1998. The N use efficiency with film mulching (48.6%) was also higher than in the flooded-cultivation system with direct sowing in 1999.

Mishima (2001) reported that the excessive use of chemical fertilizers and manure in intensive agriculture sometimes caused environmental problems, including water pollution. Although it was speculated that surplus nitrogen (N) from Japanese agriculture may have had a strong impact on the environment, few quantitative assessments were available. Therefore, the sum of the amount of residual N on farmland and non-utilized livestock wastes was not the lowest during the period and the sum of both was 141, 163, 158, and 148 kg N ha^{-1} in 1980, 1985, 1990, and 1997, respectively. To decrease these levels as well as the environmental risk associated with agricultural production, reduced input of chemical fertilizers for vegetables and industrial crops, and effective and active use of livestock wastes are important.

Faruque (2000) reported that over 470 thousand tones of nitrogen were used for crop production annually in Bangladesh. The application of N for various purposes was increasing without its adverse effect on the environment being realized. One of the principal reasons for the poor efficiency of fertilizer use was that a proportion of applied N (80-89%) was lost via denitrification, volatilization and leaching losses from the soil plant atmosphere system. The effect of N on the environmental pollution and the various measures for environmental protection were also discussed. Proper management of N fertilizer requires a stepwise process for determining the N rate required. Appropriate accounting for N relative to yield goal of various crops and contributions from residual soil nitrate, mineralization, and immobilization, legume credits, and manure credits.

Tang *et al.* (2000) developed a model of sustainable agriculture of 'high output, low input and less pollution' (HLL model) in paddy fields of China. Approx. 10-13 t ha^{-1} of rice and 3-4 t ha^{-1} of fish was harvested. The amount of chemical fertilizer and pesticide decreased ~50%, therefore reducing environmental pollution, and simultaneously decreasing the methane emission. It was concluded that the comprehensive techniques for this model should be popularized.

Hasler (1998) reported that environmental policy measures aimed at reducing nitrogen leaching from the root zone were analyzed using farm-level models representing typical Danish crop farms and livestock holdings, the objective being to indicate the cost-effectiveness of the measures compared to a baseline scenario (1995). The cost-effectiveness of the measures was expressed as costs (i.e. changes in producers surplus) per kg reduction in N leaching, and the reductions in N leaching levels from the measures were compared with the official targets of 49% reductions. Levies will also entail the risk of unintended and adverse effects as crop selection can be influenced. These negative effects could be reduced by supplementing levies with a requirement to under sow catch crops in spring-sown cereals and legumes.

Ghosh and Ravi (1998) reported that when applied for rice under flooded conditions, nitrogen was prone to different types of losses, reaching as high as 60%. With the increase in area under modern rice cultivars in different countries, the usage of chemical fertilizers had increased to as much as 150 kg N $ha^{-1.}$ About 10% of the total N fertilizers used globally were applied to rice. Chemical fertilizers supply N in ammonia, nitrate or amide forms. Among the N-fertilizers, ~80% of the demand were met by urea, which is highly water soluble and prone to losses. Studies had shown that N applied in the form of ammonium sulfate was more lethal than urea. About 50% of the fish, Catla catla (common carp), were killed when ammonia concentration reached 29.4 $mgNH_3$-N $litre^{-1}$. Fish growth was higher under organic- than inorganic-based N fertilizers. The number of phytoplankton species (fish food) was less when chemical fertilizers were used as a N source. Leached NO_3-N might also pollute groundwater.

Davidescu *et al.* (1998) reported that the use of chemical fertilizers, manure and chemical substances for plant protection could influence the quality of fodder plant and the environment. Chemical fertilizers with nitrogen as nitrate had a high solubility and can be leached by irrigation water or precipitation through soil in phreatic water. Lead could be accumulated in fodder plants and could be absorbed from polluted environment by industries. The accumulation of nitrates in fodder plants was accelerated in variant where lead was applied. The content of total nitrogen and protein corresponds to their normal contents in fodder plants as 2-3.5% total nitrogen and 8-22% protein. Increasing nitrogen doses and the lead added in soil determined increases in yield and protein content in fodder plants.

Oenema *et al.* (1998) discussed the effects of a series of policies and measures launched by the Dutch government from 1986 onwards to decrease nitrogen losses to acceptable levels. The main focus was on the nitrogen and phosphorus accounting system MINAS, implemented from 1998 onwards. Possible effect of the MINAS policy and measure on the nitrate contamination of ground water examined via whole farm analysis and simulation models, with a focus on nitrate leaky sandy soil and dairy farming system. Results indicated that MINAS was effective, and that additional measures were needed for agricultural land on dry sandy soils.

Pleijel *et al.* (1998) measured the Soil emissions of nitrous oxide (N_2O) using static field chambers, which were installed in a wheat field. The treatments were: open-top chambers with ambient CO_2 concentrations (OTC350), open-top chambers with 700 ppm CO_2 (OTC700) and ambient air plots without open-top chambers (AA). Measurements of N_2O emissions were made weekly starting at anthesis. It was suggest that a competition for soil nitrogen exists between plants and the microbial community. The AA plots emitted less N_2O during the green canopy period compared with the chamber treatments. After harvest, the emissions from AA increased up to the same magnitude as the chamber treatments. The lower emissions of the ambient air plots during the pre-harvest period could be explained partly by lower ambient temperatures and drier soil.

Lang (1996) given a historical survey of the changes in the concept of sustainable development was given. Clarification of the interrelations between food security strategy and sustainability in agriculture were outlined and the possible role of nitrogen, phosphorus and potassium in environmental pollution examined. Conclusions as to the more important steps to be taken towards realizing sustainable agriculture were drawn.

El-Fouly and Fawzi (1996) reported that nitrogen use per unit area in Egyptian agriculture was >300 kg ha^{-1}. An annual average increase of ~2% to the year 2000 was estimated. Fertilizer use is characterized by excessive N application, moderate P use and neglect of K and micronutrients. Use of micronutrient foliar fertilizers leads to increases in root growth and higher uptake of macronutrients. Use of relatively high rates of fertilizers is essential, but should be optimized to obtain the highest possible efficiency. Making crop and location specific fertilizer recommendations available to farmers helps in increasing high quality yields, which results in high economic benefits, keeping agricultural production sustainable and decreasing pollution.

Benbi and Biswas (1996) reported that in field trials in 1971/72-1992/93 at Ludhiana, Punjab, India, rotations of maize cv. Ganga-5 (1971-83) or Pratap (1983-93), wheat cv. Kalyansona (1971-78), WL 711 (1978-89) or HD 2329 (1989-90) and fodder cowpeas cv. FS 1 (1971-78) or FS 68 (1979-93) were given no fertilizer, 100% recommended N, 100% NP, 50% NPK, 100% NPK + herbicide, 150% NPK, 100% NPK + Zn or 100% NPK + farmyard manure. For maize, wheat and cowpeas, 100% NPK respectively represented 150 kg N + 32.7 kg P + 62.2 kg K ha^{-1}; 150 kg N + 32.7 kg P + 31.1 kg K ha^{-1}; and 20 kg N + 17.5 kg P + 16.6 kg K ha^{-1}. Results showed that N removal and apparent N recovery by both maize and wheat was directly related to the balanced application of N, P and K fertilizers. It was concluded that balanced and judicious use of N, P and K fertilizers coupled with the addition of any deficient element (e.g. Zn) help in minimizing N losses and environmental pollution.

Diez *et al.* (1994) reported that the effects of applying different commercial, controlled release fertilizers (CRF) as a means of controlling NO_3 pollution of groundwater in an irrigated maize crop were tested. The polluting effects of two sources of irrigation water with different NO_3 content were also evaluated. Results showed that conventional agricultural practices are one of the main causes of NO_3 aquifer pollution.

Decau *et al.* (1993) reported that the effect of incorporating crop residues on nitrate leaching was studied in lysimeter experiments with irrigated maize in monoculture. Up to 40% of the free nitrogen remaining in the soil after harvest was fixed by the added crop residues (11.6 t ha^{-1}, C/N ratio 63), resulting in a marked reduction in the nitrate content of drainage waters.

Jambert *et al.* (1993) reported that in the maize-pine cropping system practiced in the Landes de Gascogne, France, on mainly sandy soils with a high water table, fertilization of irrigated maize with urea or anhydrous ammonia caused important emissions of gaseous nitrogen compounds (NH_3, NO_2, N_2O). Fluxes of 8.5 x 10-6 g N msuperscript^{-1} 2 per hr were recorded even in winter, with a marked increase just after fertilization. In most agro systems excess nitrogen leads to water pollution, in this case the N compounds were released mainly to the atmosphere, with very little pollution of the groundwater.

Chapter 3

Materials and Methods

CHAPTER 3
MATERIALS AND METHODS

The experiment was under taken during Nov 2007 to Dec 2008 to come across the optimum combination of chemical fertilizer and Nutrismart aiming reduction of usage of chemical fertilizer in both two Maize variety-BARI hybrid bhutta 5 and composite variety khaibhutta with 5 combination of fertilizer.

3.1 Experimental Site

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU). It was situated at 23°41′ North latitude and 90°22′ East longitude. The land was 8.6 m above the sea level. It was belongs to Madhupur Tract (AEZ 28). For better understanding about experimental site are shown in the Map of AEZ of Bangladesh in Appendix I.

3.2 Climate

The climate of the experimental site was characterized by moderate temperature, high humidity and moderate rainfall .The weather data during the study period of experimentation is shown in Appendix-II.

3.3 Soil

The field belongs to the general soil type which was characterized by shallow red brown terrace soil. The land was above flood level. There was available sunshine during the experimental period. Soil sample was collected from 15cm depth of the experimental site and was sent to SRDI, Dhaka for analysis. The result of analysis was given in Appendix-III.

3.4 Materials

(a) Seeds- BARI hybrid bhutta 5 and Khaibhutta ware collected from Bangladesh Agricultural Research Institute (BARI).

(b) Fertilizers- Urea, TSP, MP, Gypsum, $ZnSO_4$, Boric Acid, Cowdung and Nutrismart. Nutrismart was collected from CK Life Science, Hong kong and the rest fertilizers were collected from the farm of SAU.

3.5 Description of the varieties and Nutrismart

3.5.1 BARI hybrid bhutta 5

This hybrid variety of maize has high quality protein rich grains. It is single cross hybrid variety. It was invented in 2004 by National Seed Board (NSB). The average height of this variety is about 210-250cm and 150-200cm in Rabi and Kharif season respectively. The color of grain is orange yellow and the weight of 1000 grains is about 325-350 g and yield is about 6-7 ton ha^{-1}.

3.5.2 Composite variety (Khaibhutta)

It was approved for getting khai in 1986. The grain size are quite small than that of hybrid variety. The weight of 1000 grains is about 140-200 g. In Rabi and Kharif season this variety was harvested between 125-130 and 90-100 days respectively. The yield is about 3-5 ton and 2.5-3.30 ton in Rabi and Kharif season respectively. About 90-95% khai can be obtained from this kind of variety. It is delicious in taste.

3.5.3 Nutrismart

Nutrismart is an eco-friendly fertilizer that comprises four major natural ingredients:weathered coal, phosphate rock, starch and microbe powder. The final product of Nutrismart is able to perform the following key functions:

(1) Nitrogen fixation- fix nitrogen from the air and convert it into a soluble form of nitrogen.

(2) Phosphate solubilization- solobilize unavailable phosphate into a soluble form of phosphate.

(3) Unlock potassium- unlock partial potassium in the soil into exchangeable potassium, thus increasing potassium efficiency.

3.6 Layout of the experiment

The experiment was laid out on 23 November according to the experimental design (split plot). The field was divided into 3 blocks to represent 3 replication. Each block was divided into 2 main plots to accommodate the variety and each main plot into 5 sub plot to accommodate the fertilizer combinations. The length and breadth of the experimental site was 32 and 19 meter respectively. There were 30 plots in the experimental site and the size of each plot was 4.5×3 meter. The spacing was 75×25 cm (Appendix-III).

3.7 Experimental treatments

(a) Main plot: Variety (2)

1) BARI hybrid bhutta 5 -V_1

2) Khaibhutta -V_2

b) Sub plot: Fertilizer combinations (5)

1) Recommended 100% chemical fertilizer (control) - F_1

2) 50% chemical fertilizer + 50% Nutrismart - F_2

3) 40% chemical fertilizer + 60% Nutrismart - F_3

4) 25% chemical fertilizer + 75% Nutrismart - F_4

5) 100% Nutrismart - F_5

3.8 Detail of experimental preparation

3.8.1 Land preparation

Land was prepared by ploughing and then cross ploughing and levelled on 22 November, 2007.

3.8.2 Seed sowing:

Seeds of both the varieties were sown on that day 24 November, 2007.

3.8.3 Fertilization

The recommended fertilizer dose used for composite variety was 222-222-144-150-10-5-400 kg ha^{-1} of Urea, TSP, MP, Gypsum, $ZnSO_4$, Boric acid and Nutrismart respectively and for hybrid variety was 500-250-200-250-10-5-600 kg ha^{-1} of Urea, TSP, MP, Gypsum, $ZnSO_4$, Boric acid and Nutrismart respectively. Fertilization (basal dose) was completed on 24 November, 2007. One third of urea along with full amount of other fertilizers as per treatment was applied during final land preparation as basal dose and the rest urea as per treatment was applied in two equal installments as side dressing. The second dose of fertilizer was given on 29 December, 2007 and third dose of fertilizer was given on 3 February, 2008.

3. 9 Intercultural operations

3. 9 .1 Irrigation

First irrigation was given on 6 December, 2007 which was at 10 days after sowing. Second irrigation was given on 25 December, 2007 which was 31 days after sowing. Third irrigation was given on 19 January, 2008 which was 56 days after sowing.

3. 9. 2 Thinning and weeding

During plant growth period one thinning and one hand wedding was done, thinning was done on 18 December, 2007 which was 24 days after sowing and the hand weeding was done on 19 December, 2007 which was 25 days after sowing.

3. 9. 3 Earthing up

Earthing up was done on 29 December, 2007 which was 35 days after sowing. It was done to protect the plant from lodging and for better nutrition uptake.

3. 9. 4 Plant protection measures

Insecticides (Diazinon) were sprayed on 4 February, 2008 to protect the crop from insects.

3. 9. 5 Harvesting

For Khaibhutta, harvesting was done on 9 April, 2008 and for BARI hybrid bhutta 5 it was done on 15 April, 2008.

3. 9. 6 Drying

The harvested products were taken on the threshing floor and it was dried for about 2-3 days.

3. 10 Data collection

It was done on the basis of following parameter

3. 10. 1. Plant height at different DAS (30, 60, 90, and at harvest)

At different stages of crop growth, the height of ten randomly selected plants per plot was measured from ground level to the tip of the plant portion and the mean value of plant height was recorded in cm.

3. 10. 2. Leaf area index (LAI)

Leaf area index were estimated manually by counting the total number of leaves per plant and measuring the length and average width of leaf and multiplying by a factor of 0.70 (Kluen and Wolf, 1986). It was done at 30. 60, 90 days after sowing (DAS) and at harvest.

Leaf area index (LAI):

$$\mathbf{LAI} = \frac{\text{Surface area of leaf sample}\,(\mathrm{m}^{-2})}{\text{Ground area from where the leaves were collected}} \times \text{correction factor}$$

3. 10. 3. Dry matter production at different DAS (30, 60, 90 and at harvest)

From each plot 2 plants were uprooted randomly. Then the leaves stem and roots were separated and these were oven dried to get the dry weight of the collected samples. It was performed at 30, 60, 90 DAS and at harvest.

3. 10. 4. Numbers of cobs plant^{-1}

The number of cobs plant^{-1} were counted from randomly sampled plants. It was done by counting the total number of cobs plot^{-1} and divided by the total number of sampled plants.

3. 10. 5. Number of grain rows cob^{-1}

Ten cobs from each plot were selected randomly and the number of rows was counted and then the average result was recorded.

3. 10. 6. Diameter of cob (cm)

Ten cobs were randomly selected per plot and the diameter was taken from 3 portion of each cob (upper, middle and lower portion). Then average result was recorded in cm.

3. 10. 7. Length of cob (cm)

Ten randomly selected cobs were taken from each plot to measure the length. The average result was recorded in cm

3. 10. 8. Number of grains cob^{-1}

The numbers of grains per cob was collected from ten randomly selected cobs of each plot and finally averaged.

3. 10. 9. Weight of 1000 grains

From the seed stock of each plot 1000 seeds were counted and the weight was measured by an electrical balance. It was recorded in gram.

3. 10. 10. Shelling percentage

Weight of shell was taken then it was divided by the weight of shell and the weight of grains. Then it was multiplying by 100. It was done by taking 10 randomly selected cobs plot^{-1}. Then the average result was obtained.

3. 10. 11. Grain yield (t ha^{-1})

Grain yield was determined from the central 3 m length of all 3 inner rows of the plot (leaving two boarder rows and one row for dry matter calculation) and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3. 10. 12. Stover yield (t ha^{-1})

Stover yield was determined from the central 3 m length of all 3 inner rows of the each plot. After threshing, the sub sample was oven dried to a constant weight and finally converted to t ha^{-1}.

3. 10. 13. Biological yield (t ha^{-1})

It was the total yield including both the economic and stover yield.

3. 10. 14. Harvest index (HI)

Harvest index is the ratio of economic (grain) yield and biological yield. It was calculated by dividing the economic grain yield from the harvested area by the biological yield of the same area (Donald, 1963) and multiplying by 100.

$$\text{Harvest Index (\%)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.11 Statistical analysis

The collected data were analyzed with the computer based software IRRISTAT 4.0 and the mean values were separated using least significant difference (LSD) test at 5% level of significance.

Chapter 4

Results and Discussions

Chapter 4

Results and Discussions

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Crop growth characters

4. 1 .1 Plant height at different days after sowing (DAS)

Plant height is an important morphological character that acts as a potent indicator of availability of growth resources in its vicinity.

4.1.1.2 Effect of variety

The plant height of maize was significantly influenced by variety at 30, 60 and 90 days after sowing (DAS) and at harvest (Appendix V and Table 1). At 30 days after sowing (DAS), the variety Khaibhutta showed significantly higher plant height (42.62 cm) compared to BARI hybrid bhutta 5 (38.24 cm). The composite variety Khaibhutta gave 11.45% higher plant height than the BARI hybrid bhutta-5. Similar significant higher plant height of composite variety was also found at 60 and 90 DAS. The trend of higher plant height of composite variety over hybrid variety at the later period was decreasing and it was 6.23 and 3.267% at 60 and 90 DAS respectively (Table 1).

4.1.1.2 Effect of fertilizer combination

The plant height of maize was significantly influenced by fertilizer combination at 30, 60 and 90 DAS and at harvest (Table 1). At 30 DAS, the recommended chemical fertilizer (F_1) showed the highest plant height (48.76 cm) compared to other fertilizer combinations. The F_1 gave 8.651% higher plant height than F_2. The trend of decreasing plant height was 17.86, 26.74 and 32.83% for applying the fertilizer combination of F_3, F_4 and F_5 respectively. The similar trend was observed at 60 DAS but here the fertilizer combination of F_1 and F_2 were statistically similar. The F_2 gave 4.82% lower plant height than F_1 where as it was 8.65% lower than F_1 at 30 DAS. The trend of decreasing plant height of Nutrismart treated plots were 14.27, 23.02 and 34.54% in F_3, F_4 and F_5 over F_1 respectively (Appendix V and Table 1). At 90

DAS, the trend of decreasing plant height showed the similarities like 30 DAS. Here F_1 showed significantly the tallest plants (212.72 cm) that decreased 4.84, 10.11, 17.4 and 27.59% in F_2, F_3, F_4 and F_5 respectively. At harvest, the plants of F_1 showed higher plant height that was similar to F_2 and F_3. The shortest plant height was revealed in F_5 and it was similar to F_4. The trend of decreasing plant height of F_2, F_3, F_4 and F_5 over F_1 was 3.62, 8.54, 18.28 and 21.59% respectively. The variation of plant height due to different fertilizer use was also reported by Eltelib *et al* (2006).

Table 1. Effect of variety, fertilizer combination and their interaction on plant height (cm) at different days after sowing (DAS).

Treatments	Days after sowing(DAS)			
	30	60	90	At harvest
Variety (V)				
V_1	38.24 b	114.89 b	184.35 b	228.17
V_2	42.62 a	122.05 a	190.37 a	219.40
LSD (0.05)	1.14	4.39	5.40	15.63 NS
Fertilizer combination (F)				
F_1	48.76 a	139.85 a	212.72 a	249.78 a
F_2	44.88 b	133.41 ab	202.42 b	240.73 ab
F_3	40.05 c	119.89 c	191.22 c	228.45 abc
F_4	35.72 d	107.65 d	176.40 d	204.12 cd
F_5	32.75 e	91.54 e	154.04 e	195.86 d
LSD (0.05)	1.81	6.92	8.54	24.72
Interactions (V×F)				
V_1F_1	46.81 b	139.21 ab	211.40 ab	257.90 a
V_1F_2	43.22 c	132.08 abcd	198.50 cd	250.53 ab
V_1F_3	38.84 de	113.79 e	189.44de	238.50 abcd
V_1F_4	32.90 g	103.34 fg	176.81g	196.76 efghi
V_1F_5	29.43 h	86.02 h	145.60 j	197.16 efgh
V_2F_1	50.70 a	140.50 a	214.04 a	241.67 abc
V_2F_2	46.53 b	134.74 abc	206.36 abc	230.93 abcde
V_2F_3	41.27 cd	125.98 cd	193.00 de	218.40 bcdef
V_2F_4	38.54 ef	111.95 ef	176.00 gh	211.49 cdefg
V_2F_5	36.07 f	97.07 g	162.49 i	194.55 fghi
LSD (0.05)	2.562	9.796	12.07	34.96
CV (%)	3.66	4.77	3.72	9.02

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100%Chemical fertilizer, F_2=50%Chemical fertilizer + 50% Nutrismart ,F_3=40%Chemical fertilizer + 60%Nutrismart, F_4=25%Chemical fertilizer + 75%Nutrismart and F_5=100%Nutrismart.

4.1.1. 3 Interaction effects of variety and fertilizer combinations

The interaction effect of variety and fertilizer combination was found significant in different growth stages of the crop (Appendix V and Table 1).

At 30 DAS, the highest plant height (50.70 cm) was given by the variety Khaibhutta with recommended dose of chemical fertilizers. The second highest plant height (46.81 cm) was found in the hybrid variety BARI hybrid bhutta 5 that similar with V_2F_2. The lowest plant height (29.43 cm) was found in V_1F_5 (BARI hybrid bhutta-5 with Nutrismart). Treatment V_2F_1 showed 72.27% higher plant height compared to V_1F_5.

At 60 DAS, V_2F_2 showed the highest plant height (140.50 cm) that was similar to V_1F_1, V_2F_2 and V_1F_2. The other treatments showed intermediate plant height. Almost similar trend of plant height was also shown at 90 DAS.

At harvest, the highest plant height was recorded in V_1F_1 that was similar with V_1F_2, V_2F_1, V_1F_3 and V_2F_2 (Table 1). The lowest plant height was shown by V_2F_5 (194.55 cm) that was similar to V_1F_5, V_1F_4, V_2F_4 and V_2F_3.

4.1.2 Leaf area index (LAI) at different days after sowing

Leaf area index (LAI) expresses the ratio of leaf surface area to the ground area. It is one of the important determinants of dry matter (DM) production. Crop production practically means the efficient interception of photo synthetically active radiation (PAR) and its conversion into food and other useable materials. Efficient interaction of PAR by a crop canopy requires adequate leaf area expansion. Leaf area is made up of the total green lamina of emerged leaves (Kerting and Carberry, 1993). According to Gay and Bloc (1992), LAI values above 5.0 under typical conditions in Europe are suggestive of a high yield potential of maize. On the other hand, Gardner *et al.* (1985) reported that in general, photosynthesis increase until nearly all incident solar radiation is intercepted by photosynthetic surfaces and any further increase in leaf area only increase shading of the lower leaves with little benefit to the plant.

4. 1. 2. 1 Effect of variety

LAI of maize was not significantly affected by variety at 30DAS but it was significantly influenced by variety at 60, 90 DAS and at harvest. At 30 DAS (Table 2) the hybrid and composite variety showed the similar LAI. At 60 DAS, the hybrid variety showed the superior result (2.081) than the composite variety (1.75) and the hybrid variety gave 18.52% higher LAI than the composite variety. This kind of similarities was also observed at 90 DAS and at harvest where the hybrid variety gave 3.56 and 8.02% higher LAI respectively than the composite variety Khaibhutta. (Appendix VI and Table 2).

4. 1. 2. 2 Effect of fertilizer combination

At 30 DAS, the different fertilizer combination showed the significant response where the F_1 gave the higher LAI (0.288) than the other fertilizer combinations. The variation of LAI due to using different fertilizer was also reported by Eltelib *et al* (2006). The F_1 gave 22.4% higher LAI than F_2 at 30 DAS. The similar trend was also observed at 60, 90 DAS and at harvest. The F_1 gave 10.83, 3.60 and 8.53% higher LAI than F_2 at 60, 90 DAS and at harvest respectively. At 90 DAS it was 3.46, 13.61, 25.52 and 42.46% higher compared to F_2, F_3, F_4 and F_5 respectively.

Table 2. Effect of variety, fertilizer combination and their interaction on leaf area index (LAI) at different days after sowing (DAS).

Treatments	Days after sowing(DAS)			
	30	60	90	At harvest
Variety (V)				
V_1	0.183	2.080 a	3.17 a	1.91 a
V_2	0.180	1.75 b	3.06 b	1.78 b
LSD (0.05)	NS	0.020	0.054	0.043
Fertilizer combination (F)				
F_1	0.28 a	2.660 a	3.59 a	2.35 a
F_2	0.23 b	2.400 b	3.47 b	2.17 b
F_3	0.16 c	1.84 c	3.16 c	1.87 c
F_4	0.13 d	1.45 d	2.86 d	1.57 d
F_5	0.11 e	1.24 e	2.52 e	1.27 e
LSD (0.05)	0.018	0.032	0.084	0.068
Interactions V×F				
V_1F_1	0.303 a	2.867 a	3.683 a	2.387 a
V_1F_2	0.240 c	2.690 b	3.520 b	2.263 bc
V_1F_3	0.160 ef	2.090 de	3.187 e	1.943 e
V_1F_4	0.117 hi	10447 g	2.927 g	1.687 g
V_1F_5	0.097 j	1.300 i	2.540 i	1.283 i
V_2F_1	0.253 b	2.453 c	3.503 bc	2.320 ab
V_2F_2	0.213 d	2.110 d	3.410 bcd	2.073 d
V_2F_3	0.163 e	1.597 f	3.123 ef	1.793 f
V_2F_4	0.147 g	1.443 gh	2.783 h	1.443 h
V_2F_5	0.127 h	1.170 j	2.40 j	1.253 j
LSD (0.05)	0.026	0.045	0.120	0.096
CV (%)	8.157	1.370	2.223	3.019

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100%Chemical fertilizer, F_2=50%Chemical fertilizer + 50% Nutrismart ,F_3=40%Chemical fertilizer + 60%Nutrismart, F_4=25%Chemical fertilizer + 75%Nutrismart and F_5=100%Nutrismart.

4.1. 2. 3 Interaction effect of variety and fertilizer combination

At 30 DAS, the interaction was significant where V_1F_1 gave the highest result (0.303) and it was 26.25% higher than V_1F_2. Treatment V_1F_5 gave the lowest result (0.97) and it was 212.37% lower than V_1F_1. The similar highest results were also observed at 30 and 60 DAS. But the treatment V_1F_2 gave the 2nd highest result (2.690) at 60 DAS and it was 6.57% lower than V_1F_1. Treatment V_2F_5 gave the lowest LAI and it was 145.04% lower than V_1F_1. At 90 DAS, statistically similarities observed among the treatment of V_1F_2, V_2F_1 and V_2F_2. But V_2F_1 gave 2.72% higher LAI than V_2F_2. Treatment V_1F_1 gave the highest result (3.68) and it was 4.6% higher than V_1F_2. At harvest, treatment V_1F_1 and V_2F_1 were statistically similar but V_1F_1 gave the highest result than V_2F_1. Treatment V_1F_1 gave 5.47% higher LAI than V_1F_2 (Table 2).

4.1.3 Dry matter production (Leaf)

Dry matter production of crop plants was directly related to the utilization of solar radiation. It was observed that the effect of canopy was a major determinant of photosynthetic efficiency and growth (Donald, 1963 and Williams *et al.* 1968).

4.1. 3. 1 Effect of variety

The variety showed significant variation of dry matter production at 30 and 60 DAS but insignificant at 90 DAS and at harvest. It was observed that Khaibhutta gave 58.8% higher dry matter (leaves) than BARI hybrid bhutta 5 and it was changed at 60 DAS where BARI hybrid bhutta 5 gave 13.46% higher dry matter than Khaibhutta. But in the later stage at 90 DAS and at harvest it showed the insignificant variation for dry matter production of leaves. (Table 3).

4. 1. 3. 2 Effect of fertilizer combination

The fertilizer combination showed significant variation of leaf dry weight at 30, 60 and 90 DAS and at harvest (Table 3) but the trend was not similar for all growth durations. At 30 DAS, significantly the highest leaves dry weight (2.25 g plant^{-1}) was given by control treatment that was similar to F_2 (50% chemical + 50% Nutrismart). The lowest leaves dry weight (1.75g plant^{-1}) was found in F_5 (100% Nutrismart application) that was similar to F_3 and F_4. Almost similar trend of leaves dry weight was also observed at 60 and 90 DAS. But at harvest, F_2 showed the highest leaves dry weight that was similar to F_1, F_3 and F_4 but F_5 showed the lowest leaves dry weight (35.85 g plant^{-1}).

Table 3. Effect of variety, fertilizer combination and their interaction on leaf dry matter production (g plant^{-1}) at different days after sowing

Treatments	Dry weight of leaves at different growth durations (DAS)			
	30	60	90	At harvest
Variety (V)				
V_1	1.57 b	25.55 a	33.92	43.512
V_2	2.50 a	22.52 b	34.49	41.02
LSD (0.05)	0.131	1.593	NS	NS
Fertilizer combination (F)				
F_1	2.25 a	27.45 ab	37.53 a	43.98 abc
F_2	2.44 ab	27.73 a	33.47 bcd	44.733 a
F_3	1.84 cd	23.50 c	35.783 ab	44.27 ab
F_4	1.90 c	23.17 cd	34.32 bc	42.50 abcd
F_5	1.75 cd	18.31 e	29.93 e	35.85 e
LSD (0.05)	0.208	2.520	3.067	4.379
Interactions (V×F)				
V_1F_1	2.01 ef	30.70 a	38.150 a	45.433 abc
V_1F_2	1.74 fg	30.70 a	32.943 bcdefgh	43.77 abcdef
V_1F_3	1.21 gh	23.47 bcdef	36.17 abc	43.833 abcde
V_1F_4	1.55 hi	24.033 bcd	33.17 bcdefg	46.36 a
V_1F_5	1.36 hi	18.83 gh	29.17 ghi	38.173 efghi
V_2F_1	2.49 b	24.20 bc	36.90 ab	42.523 abcdefg
V_2F_2	3.15 a	24.77 b	34.00 abcdef	45.70 ab
V_2F_3	2.47 bc	23.53 bcde	35.40 abcde	44.400 abcd
V_2F_4	2.25 bcd	22.30 bcdefg	35.47 abcd	38.633 defgh
V_2F_5	2.15 de	17.80 h	30.70 fghi	33.533 hi
LSD (0.05)	0.294	3.564	4.34	6.192
CV (%)	8.343	8.567	7.328	8.466

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100%Chemical fertilizer, F_2=50%Chemical fertilizer + 50% Nutrismart ,F_3=40%Chemical fertilizer + 60%Nutrismart,F_4=25%Chemical fertilizer + 75%Nutrismart and F_5=100%Nutrismart.

4.1. 3. 3 Interaction effect of variety and fertilizer combination

The leaves dry matter production of maize was significantly affected by the interaction of variety and fertilizer combinations for all the studied durations (Appendix VII and Table 3) but the trend was not similar.

At 30 DAS, the highest dry matter of leaves was given by the composite variety with 50% chemical fertilizer + 50% Nutrismart application, in respect of fertilizer combination the hybrid variety resulted lower leaves dry matter at 30 DAS compared to the composite variety. The scenario of dry matter production was changed at the advancement of growth stages and hence the hybrid variety showed higher leaves dry weight compared to the composite variety at 60 and 90 DAS. At harvest the treatment combinations of V_1F_1, V_1F_2, V_1F_3, V_1F_4, V_2F_1, V_2F_2 and V_2F_3 showed similar leaves dry weight and the lowest dry weight of leaves were (33.53g plant^{-1}) at V_2F_5.

4.1.4 Dry matter production (stem)

4.1.4.1 Effect of variety

The varietals effect of stem dry weight was significant at 30, 60, 90 DAS and at harvest. It was observed that hybrid variety gave 24.53, 42.48, 11.66 and 22.15% higher dry matter than the composite variety at 30, 60, 90 DAS and at harvest (Table 4).

4.1.4. Effect of fertilizer combination

At 30 DAS, the highest stem dry matter was resulted in plots of 100% chemical fertilizer application that was similar to 50% chemical fertilizer + 50% Nutrismart treatment. With the increment of Nutrismart dose, the stem dry matter production was decreased and hence the lowest dry matter (0.098 g plant^{-1}) was given by the 100% Nutrismart treatment that was similar to 25% chemical fertilizer + 75% Nutrismart treatment. Similar higher stem dry weight was also produced by the higher chemical fertilizer treated plots at 60 and 90

DAS and at harvest. There were no statistical variation of stem dry weight was found among F_1, F_2 and F_3 treatments at harvest but the lowest dry matter was resulted in higher Nutrismart treated plants (Table-4).

Table 4. Effect of variety, fertilizer combination and their interaction on stem dry matter (g plant^{-1}) at different days after sowing

Treatments	Dry weight of stem at different growth durations (DAS)			
	30	60	90	At harvest
Variety (V)				
V_1	0.2005a	13.29 a	42.90 a	136.59 a
V_2	0.1613b	9.32 b	38.42 b	111.83 b
LSD (0.05)	0.027	1.036	1.904	9.280
Fertilizer combination(F)				
F_1	0.261 a	11.95 ab	47.08 a	138.32 a
F_2	0.221 ab	12.98 a	42.65 b	128.70 ab
F_3	0.20 bc	11.26 bc	40.68 bc	126.55 abc
F_4	0.13 d	11.08 bcd	37.05 d	120.85 bcd
F_5	0.10 d	9.25 e	35.83 de	106.64 d
LSD (0.05)	0.041	1.639	3.010	14.672
Interaction(V×F)				
V_1F_1	0.29 a	14.83 a	50.33 a	152.13 a
V_1F_2	0.25 b	14.67 ab	47.17 ab	141.90 ab
V_1F_3	0.210 bcd	11.90 cd	40.73 cd	140.43 abc
V_1F_4	0.17 defg	13.33 abc	37.53 defgh	128.50 bcd
V_1F_5	0.094 hi	11.70 cde	38.73 def	120.00 cdef
V_2F_1	0.237 abc	9.067 fgh	43.83 bc	124.50 bcde
V_2F_2	0.20 bcde	11.30 cdef	38.13 defg	115.50 defg
V_2F_3	0.180 cdef	10.62 defg	40.63 cde	112.67 defghi
V_2F_4	0.090 hi	8.83 ghi	36.57 defghi	113.20 defgh
V_2F_5	0.103 h	6.80 ghi	32.93 i	93.28 hi
LSD (0.05)	0.060	2.317	4.258	20.750
CV (%)	18.924	11.840	6.050	9.651

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100%Chemical fertilizer, F_2=50%Chemical fertilizer + 50% Nutrismart ,F_3=40%Chemical fertilizer + 60%Nutrismart, F_4=25%Chemical fertilizer + 75%Nutrismart and F_5=100%Nutrismart.

4.1.4.3 Interaction effect of variety and fertilizer combination

The interaction effect of variety and fertilizer combination showed significant variation of stem dry weight of maize at all the studied durations (Appendix VIII and Table 4)

At 30 DAS the highest stem dry weight (0.286 g plant^{-1}) was found in chemical fertilizer applied treatments of hybrid variety that was similar to the another variety with same fertilizer dose. The lowest weight (0.090 g plant^{-1}) was given by the composite variety with 25% chemical fertilizer + 75% Nutrismart application that was similar to the both variety with 100% Nutrismart application (Table 4). Irrespective of fertilizer combination, the higher stem dry weight was recorded in hybrid variety compared to the composite variety. The highest weight at harvest was found in V_1F_1 that was similar to V_1F_2 and V_1F_2 and the lowest weight was in V_2F_5 that was similar to V_2F_4 and V_2F_3.

4.1.5 Dry matter production (Root)

4.1.5.1 Effect of variety

Varietals effect was significant on the root dry matter production. At 30 DAS, composite variety gave superior result (0.488 g plant^{-1}) than the hybrid variety (0.260) and it was 87.6% higher than the hybrid variety. But the trend was just opposite at 30, 60 DAS and at harvest, the hybrid variety gave 30.38, 14.32 and 21.79% higher root dry weight than composite variety (Table 5).

4.1.5.2 Effect of fertilizer combination

At 30 DAS, different fertilizer combinations showed dissimilar root dry weight where 100% chemical fertilizer and 100% Nutrismart treatments revealed higher root dry weight of maize. The treatment combination of F_3 and F_4 showed lower root dry weight (Table 5). At 60 DAS, the treatment combinations of F_1, F_5 and F4 gave higher root dry weight and the lowest root dry weight (1.57 g plant^{-1}) was showed by F_2 (50% chemical fertilizer + 50%

Nutrismart). Similar trend of higher root dry weight at 90 DAS and at harvest was also given by F_1 and F_5.

Table 5. Effect of variety, fertilizer combination and their interaction on root dry matter (g plant^{-1}) at different days after sowing

Treatments	Dry weight of root at different growth durations (DAS)			
	30	60	90	At harvest
Variety (V)				
V_1	0.260 b	2.210 a	20.933 a	28.569 a
V_2	0.488 a	1.695 b	18.367 b	23.455 b
LSD (0.05)	0.033	1.090	1.993	2.648
Fertilizer combination (F)				
F_1	0.463 a	2.298 a	22.471 a	28.660 a
F_2	0.390 bc	1.570 d	18.473 bcd	25.01 abcd
F_3	0.288 d	1.837 bcd	19.750 abc	26.30 abc
F_4	0.303 d	2.008 abc	17.067 cd	22.77 cd
F_5	0.427 ab	2.050 ab	20.638 ab	27.32 ab
LSD (0.05)	0.052	0.350	3.152	4.187
Interactions (V×F)				
V_1F_1	0.336 e	2.433 ab	25.867 a	34.72 a
V_1F_2	0.293 efg	1.687 defg	21.867 ab	31.00 ab
V_1F_3	0.250 gh	2.340 abc	18.83 bcdefg	26.40 bcde
V_1F_4	0.187 hi	2.626 a	18.43 bcdefgh	23.92 cdefg
V_1F_5	0.237 ghi	1.963 bcdef	19.96 bcde	26.80 bcd
V_2F_1	0.590 ab	2.163 abcd	19.07 bcdef	22.60 cdefgh
V_2F_2	0.487 c	1.453 gh	15.08 fghi	19.02 ghi
V_2F_3	0.327 ef	1.333 hi	20.67 bcd	26.20 bcdef
V_2F_4	0.420 cd	1.390 hi	15.70 efghi	21.617 defghi
V_2F_5	0.617 a	2.317 abcde	21.310 bc	27.840 bc
LSD (0.05)	0.074	0.495	4.459	5.921
CV (%)	11.531	14.660	13.09	13.151

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100%Chemical fertilizer, F_2=50%Chemical fertilizer + 50% Nutrismart ,F_3=40%Chemical fertilizer + 60%Nutrismart, F_4=25%Chemical fertilizer + 75%Nutrismart and F_5=100%Nutrismart.

4.1.5.3 Interaction effect of variety and fertilizer combination

The interaction effect of variety and fertilizer combinations on root dry weight was significant for all the studied durations. At 30 DAS, irrespective of fertilizer combinations, the composite variety Khaibhutta showed higher dry weight compared to the hybrid variety and the 100% chemical fertilizer and 100% Nutrismart treatments of Khaibhutta resulted higher root dry weight. With the advancement of growth stages, the hybrid variety gradually increased root dry weight at 60 and 90 DAS. At harvest, F_1 and F_2 of hybrid variety gave higher root dry weight that followed by F_5 of Khaibhutta. The lowest root dry weight was found in V_2F_2 (50% Chemical fertilizer + 50% Nutrismart) in Khaibhutta (Appendix IX and Table 5).

4.2 Yield contributing characters

4.2.1 Cob diameter (cm)

4.2.1.1 Effect of variety

The varietal effect was significant and the hybrid variety gave higher cob diameter (13.91 cm) than the composite variety (10.39 cm). The cob diameter of hybrid variety was 33.87% higher than that of composite variety (Table 6).

4.2.1.2 Effect of fertilizer combination

The cob diameter was varied for different fertilizer combinations. The highest cob diameter (13.11 cm) was given by the recommended chemical fertilizer application. Agba *et al.* (2005) also reported that the similar higher cob diameter was found due to the nitrogen fertilizer application. Reduction of normal chemical fertilizer dose also reduced the cob diameter of maize. The reduction of chemical fertilizer and the addition of Nutrismart showed second highest similar cob diameter (Appendix X and Table 6). With the reduction of chemical fertilizer dose the cob diameter also reduced and the lowest cob diameter (911.10 cm) was found in 100% Nutrismart application.

4.2.1.3 Interaction effect of variety and fertilizer combination

Application of recommended dose of chemical fertilizer in hybrid variety (V_1F_5) showed the highest cob diameter (14.86 cm) that was similar with the diameter of (14.40 cm) of V_1F_2 (50% Chemical fertilizer + 50% Nutrismart) treatment (Figure1). The reduction of chemical fertilizer also reduced the cob diameter irrespective of variety and the trend was almost similar. (Figure1). The hybrid variety showed its lowest cob diameter (12.80 cm) in 100% Nutrismart application that was similar to V_1F_4 (13.30 cm). The lowest cob diameter (9.40 cm) was found in V_2F_5 (Composite variety with 100% Nutrismart application) and it was similar to V_2F_4 (9.97 cm).

Table 6. Effect of variety and fertilizer combination on cob diameter, cob length, no. of cobs plant^{-1} and no. of grain rows cob^{-1}

Treatments	Cob diameter (cm)	Cob length (cm)	No. of cobs plant^{-1}	No. of rows cob^{-1}
Variety (V)				
V_1	13.91a	17.71a	1.88	14.22
V_2	10.39b	16.29b	1.81	13.86
LSD (0.05)	0.276	0.742	NS	NS
Fertilizer combination (F)				
F_1	13.11a	18.58a	2.20a	15.18a
F_2	12.62b	17.98ab	2.06ab	14.56ab
F_3	12.30bc	17.22bc	1.93ab	13.88bc
F_4	11.63d	15.99de	1.700ab	13.50cd
F_5	11.10e	15.22de	1.33b	13.40d
LSD (0.05)	0.437	1.173	0.862	0.764
CV (%)	2.937	5.639	38.276	4.448

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100% Chemical fertilizer, F_2=50% Chemical fertilizer + 50% Nutrismart ,F_3=40% Chemical fertilizer + 60% Nutrismart, F_4=25% Chemical fertilizer + 75% Nutrismart and F_5=100% Nutrismart.

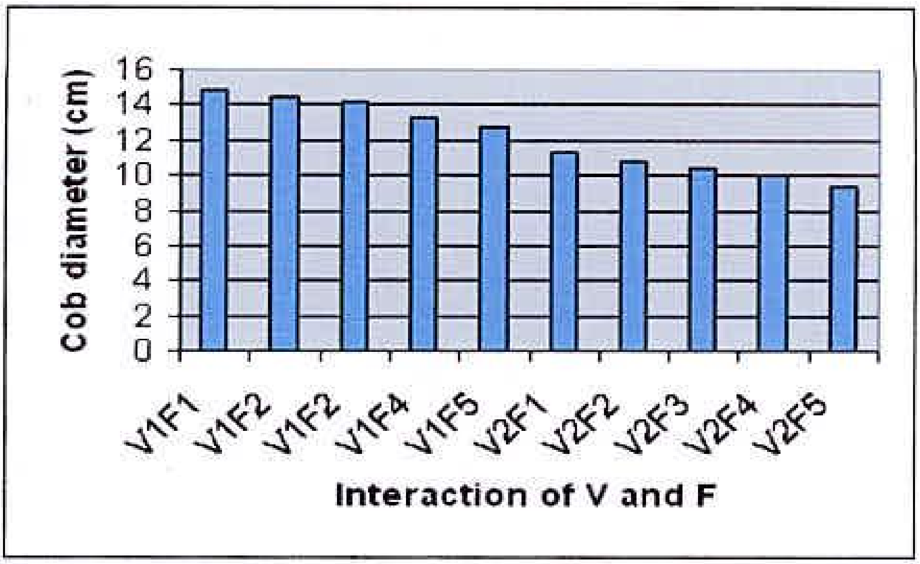

Figure1. Interaction effect of variety and fertilizer combination on cob (cm) diameter (LSD $_{0.05}$ = 0.618).

4.2.2 Cob length (cm)

4.2.2.1 Effect of variety

The varietals effects was significant and the hybrid variety gave the higher cob length (17.71 cm) compared to the composite variety (16.29 cm). The cob length of hybrid variety was 8.71% higher than that of composite variety (Appendix X and Table 6).

4.2.2.2 Effect of fertilizer combination

The highest cob length was (18.58 cm) obtained by the application of recommended chemical fertilizer. The result was in agreement with those stated by Agba *et al.* (2005) who observed the similar result. With the reduction of chemical fertilizer, the cob length was also reduced and the lowest cob length (15.22 cm) was found when 100% Nutrismart was applied. With the application of F_2 (50% chemical fertilizer + 50% Nutrismart), the cob length was (17.98 cm) and it was only 3.22% lower (Table 6) than that of F_1 (recommended chemical fertilizer).

4.2.2.3 Interaction effect of variety and fertilizer combination

Application of 100% chemical fertilizer in hybrid variety (V_1F_1) gave the highest cob length (19.39 cm) and it was similar with V_1F_2 (50% chemical fertilizer + 50% Nutrismart in that of hybrid variety) and V_1F_3 (40% Chemical fertilizer + 60% Nutrismart). The reduction of chemical fertilizer also reduced the cob length and it was observed that the lowest cob length was obtained from V_1F_5 (15.58 cm) when 100% Nutrismart was used and it was 18.26% lower than the application of recommended chemical fertilizer. This trend was almost similar in case of the composite variety Khaibhutta (Table 6). Where 100% chemical fertilizer gave the highest cob length (17.78 cm) and the lowest cob length was obtained when 100% Nutrismart was used and it was 17.89% lower than that of recommended dose of chemical fertilizer. With the application of 50% chemical fertilizer + 50% Nutrismart, this composite variety gave the second highest cob length (17.31 cm) and it was only 2.64% lower than that of recommended chemical fertilizer (Figure 2) of the same variety.

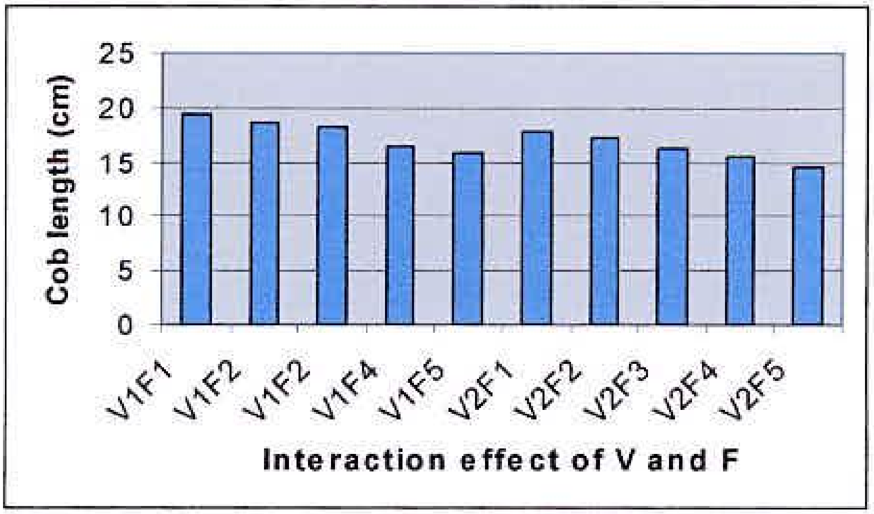

Figure 2. Interaction effect of variety and fertilizer combination on cob (cm) length (LDS $_{0.05}$ = 1.660)

4.2.3 No. of cobs plant^{-1}

4.2.3.1 Effect of variety

The varietal effects were not significant where the hybrid variety gave numerically maximum (1.88) number of cobs plant^{-1} than that of composite variety (1.81). The hybrid variety gave 3.86% higher no. of cobs plant^{-1} compared to the composite variety (Table 6). This might due to the varietal characteristics of those two varieties.

4.2.3.2 Effect of fertilizer combination

The highest number of cobs plant^{-1} (2.20) was obtained in F_1 (recommended chemical fertilizer) that was similar to F_2 (2.06), F_3 (1.96) and F_4 (1.70). The lowest number of cobs plant^{-1} (1.33) was revealed in F_5. There were no significant variations found among F_2, F_3, F_4 and F_5 for number of cobs plant^{-1}. Reduction of chemical fertilizer from recommended dose also reduced cob number and it was 6.36, 12.27, 22.37 and 39.55% lower in F_2, F_3, F_4 and F_5 respectively compared to F_1(Table 6).

4.2.3.3 Interaction effect of variety and fertilizer combination

The highest number of cobs plant^{-1} was obtained from F_1 (100% Chemical fertilizer) in hybrid variety. With the application of F_2 (50% Chemical fertilizer + 50% Nutrismart) in hybrid variety, the response was also similar to that of F_1 and it was only 8.99% lower than the application of recommended dose of chemical fertilizer. The trend of decreased in the number of cobs plant^{-1} was found in that of hybrid variety and the lowest number of cobs plant^{-1} was obtained with that of F_5 (100% Nutrismart) in hybrid variety that was 44.05% lower than F_1 of the same variety. With the application of different fertilizer combination in the composite variety, the trend was also similar as in that of hybrid variety. The highest (2.13) and lowest number of cobs plant^{-1} (1.40) which were obtained from F_1 and F_5 respectively (Table 6). But with the application of F_2 (50% Chemical fertilizer + 50% Nutrismart), the composite variety Khaibhutta gave the second highest number of cobs plant^{-1} which was only 3.29% lower compared to F_1 (Figure 3) that with the same variety.

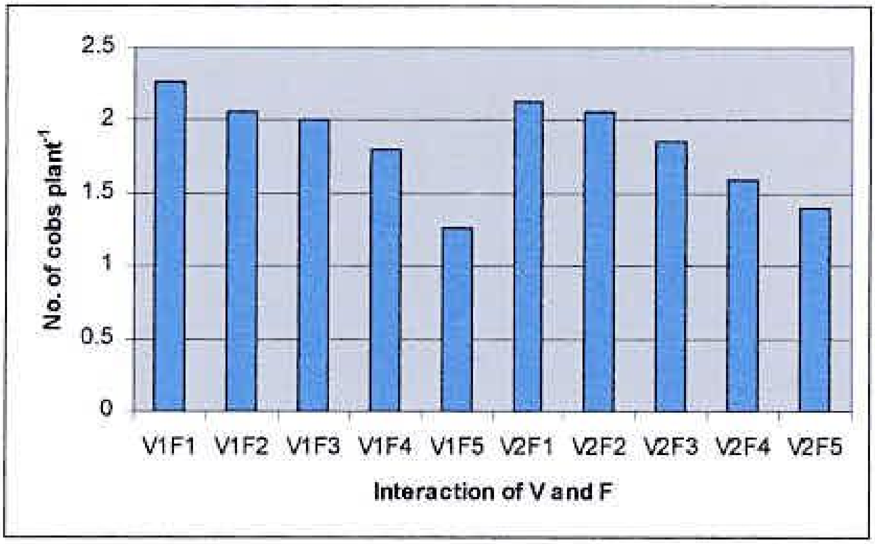

Figure 3. Interaction effect of variety and fertilizer combination on number of cobs plant^{-1} (LSD $_{0.05}$ = 1.219).

4.2.4. No. of grain rows cob^{-1}

4.2.4.1 Effect of variety

The varietals effect was not significant though the hybrid variety gave the maximum (14.22) number of grain rows cob^{-1} compared to the composite variety (13.86). The number of grain rows was 2.60% higher in the hybrid variety than that of composite variety (Table 6).

4.2.4.2 Effect of fertilities combination

The higher no. of grain rows cob^{-1} (15.18) was obtained when 100% Chemical fertilizer was applied (15.18) and it was only 4.26% higher than the F_2 (14.56) with the application of 50% Chemical fertilizer + 50% Nutrismart. With the reduction of recommended chemical fertilizer, the no. of grain rows cob^{-1} was also reduced and the lowest (13.40) no. of grain rows cob^{-1} was obtained in F_5 (100% Nutrismart) and it was 11.72% lower than the recommended dose of chemical fertilizer (Appendix IX and Table 6).

4.2.4.3 Interaction effect of variety and fertilizer combination

The highest number of grain rows cob^{-1} was found when 100% Chemical fertilizer was used in both the variety- hybrid and composite. The hybrid variety with F_1 (100% recommended chemical fertilizer) gave the highest number of grain rows/cob (15.73) and it was only 3.64% higher than that of F_2 (50% Chemical fertilizer + 50% Nutrismart) treatment. With the reduction of recommended chemical fertilizer, the number of grain rows cob^{-1} was also reduced in the hybrid variety and the lowest no. of grain rows cob^{-1} was obtained from V_1F_5 (hybrid variety with 100% Nutrismart). This trend was almost similar when F_1 was used in the composite variety and the highest number of grain rows cob^{-1} was obtained from V_2F_1. The F_2 gave (14.30) number of grain rows cob^{-1} compared to that of F_1 (14.63) in the composite variety Khaibhutta and it was only 2.26% higher than the application of 100% chemical fertilizer (Figure 4).

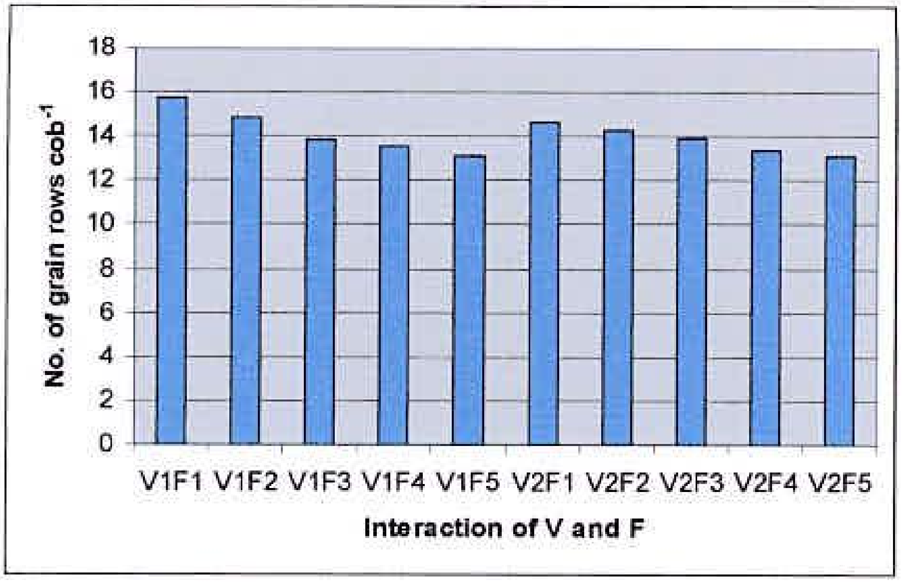

Figure 4. Interaction effect of variety and fertilizer combination on number of grain rows cob^{-1} (LSD $_{0.05}$ = 1.080).

4.2.5 Number of grains cob^{-1}

4.2.5.1 Effect of variety

Number of grains cob^{-1} is an important yield contributing character. The varietals effect was not significant. The composite variety Khaibhutta gave the numerically superior (458.97) number of grains cob^{-1} compared to the hybrid variety (458.88). The number of grains cob^{-1} was only 0.02% higher in composite variety than that of hybrid variety (Appendix X and Table 7).

4.2.5.2 Effect of fertilizer combination

The highest number of grains cob^{-1} was obtained when F_1 (100% recommended chemical fertilizer) was used. It was only 2.163% higher than F_2 (50% Chemical fertilizer + 50% Nutrismart) treatment which gave the second highest number of grains cob^{-1}. With the increase of Nutrismart application, the number of grains cob^{-1} was decreased and the lowest number grains cob^{-1} was found in F_5 (100% Nutrismart) that was 413.81 and it was 20% lower than that of F_1 (Table 7).

4.2.5.3 Interaction effect of variety and fertilizer combination

Application of 100% recommended chemical fertilizer in composite variety (V_2F_1) gave the highest number of grains cob^{-1} and it was similar with that of V_2F_2 and V_1F_1. Fertilizer combination F_2 (50% chemical fertilizer + 50% Nutrismart) in composite variety Khaibhutta gave the second highest number of grains cob^{-1} which was only 1.926% lower than the V_2F_1. With the application of 100% recommended chemical fertilizer in hybrid variety, it gave the higher no. of grains/cob which was only 2.37% higher than F_2 (50% Chemical fertilizer + 50% Nutrismart) treatment (Figure 5). Among all the treatments, V_2F_5 (100% Nutrismart with composite variety) gave the lowest number of grains cob^{-1} (400.83) and it was 20.47% lower than that of V_2F_1 (503.97). With the reduction of recommended chemical fertilizer, the number of grains cob was also reduced from V_2F_1 to V_2F_5. V_1F_5 gave 13.213% lower no. of grains cob^{-1} than the V_1F_1.

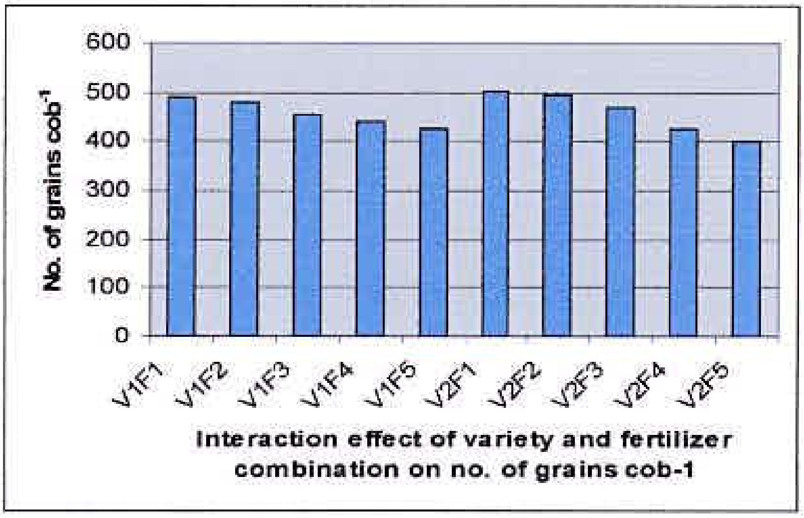

Figure 5. Interaction effect of variety and fertilizer combination on number of grains cob^{-1} (LSD $_{0.05}$ = 16.281)

Table 7. Effect of variety and fertilizer combination on number of grains cob^{-1}, weight of 1000 grains and shelling percentage

Treatments	No. of grains cob^{-1}	1000 grain weight(g)	Shelling percentage
Variety (V)			
V_1	458.88	291.85a	12.01a
V_2	458.973	180.53b	10.81b
LSD (0.05)	NS	8.765	0.321
Fertilizer combination (F)			
F_1	497.87a	270.60a	14.65a
F_2	487.33ab	256.39b	12.90b
F_3	462.22c	234.42c	11.56c
F_4	433.39d	222.04d	9.95d
F_5	413.81e	197.45e	7.99e
LSD (0.05)	11.512	13.859	0.508
CV (%)	2.049	4.794	3.634

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100% Chemical fertilizer, F_2=50% Chemical fertilizer + 50% Nutrismart ,F_3=40% Chemical fertilizer + 60% Nutrismart, F_4=25% Chemical fertilizer + 75% Nutrismart and F_5=100% Nutrismart.

4.2.6 Weight of 1000 grains

4.2.6.1 Effect of variety

The varietals effect was significant and the hybrid variety gave the higher (291.85) weight of 1000 grains than that of composite variety (180.53). The weight of 1000 grains was 38.14% higher in hybrid variety than the composite variety (Appendix X and Table 7). The variation of grain weight among different maize varieties was also reported by Syed *et al.* (2002).

4.2.6.2 Effect of fertilizer combination

With the application of recommended dose of chemical fertilizer, the weight of 1000 grains was the highest (270.60) compared to that of other fertilizer combinations and it gave 5.54%, 15.43%, 21.87% and 32.02% higher weight of 1000 grains compared to the fertilizer combination of F_2 (50% Chemical fertilizer + 50% Nutrismart), F_3 (40% Chemical fertilizer + 60% Nutrismart), and F_4 (25% Chemical fertilizer + 75% Nutrismart) application respectively. So the effect was significant due to the application of different fertilizer combination (Table 7).

4.2.6.3 Interaction effect of variety and fertilizer combination

The hybrid variety when treated with F_1 (100% Chemical fertilizer) gave the highest weight of 1000 grains and it was numerically similar with F_2 (50% Chemical fertilizer + 50% Nutrismart) in that of hybrid variety. There was no significant differences between V_1F_1 (324.93) and V_1F_2 (317.16). The weight of 1000 grains was only 2.448% higher in V_1F_1 compared to the V_1F_2. With the increasing application of Nutrismart, the weight of 1000 grains were decreased both in hybrid and composite varieties and the lowest weight of 1000 grains was found in V_2F_5 (145.96) and it was 55.07% lower than that of the V_1F_1 (324.930) which gave the highest weight of 1000 grains. It also revealed from the figure 60 that the lowest 1000 grain obtained from the treatment combination of V_1F_5 was higher than the highest 1000 grain weight obtained from the combination of composite variety with the F_1 fertilizer (V_2F_1). In the composite variety with F_1 gave the highest weight of 1000 grains (216.26) and the F_2 gave (195.61) and it was only 10.56% higher compared to that of F_1 treatment in composite variety (Table 7).

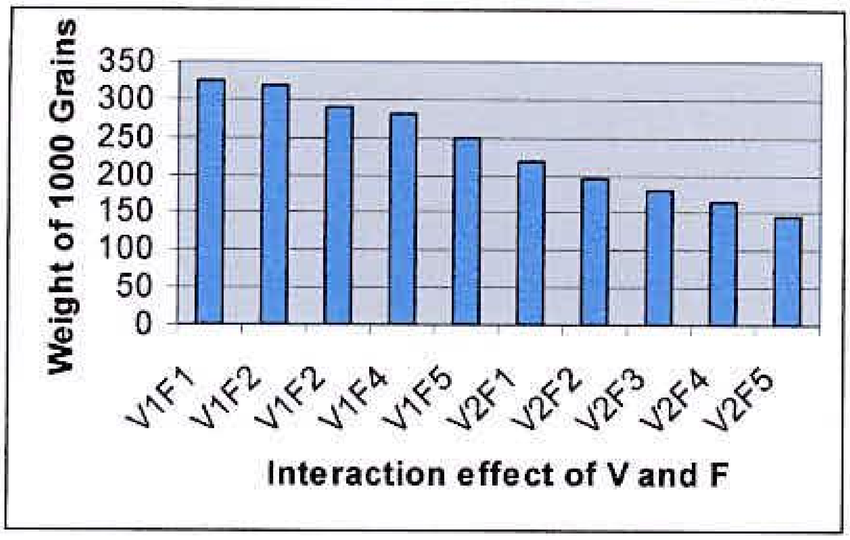

Figure 6. Interaction effect of Variety and Fertilizer combination on 1000 grains weight (LSD $_{0.05}$ = 19.599)

4.2.7 Shelling percentage

4.2.7.1 Effect of variety

The varietals effect was significant and the higher shelling percentage was obtained from the hybrid variety (12.01) compared to the composite variety (10.81). The shelling percentage was 9.99% lower in composite variety than that of hybrid variety (Appendix XI and Table 7).

4.2.7.2 Effect of fertilizer combination

The effect was significant due to the application of different fertilizer combination. Among all the fertilizer combinations, the highest shelling percentages was obtained from F_1 (14.65) with the application of recommended chemical fertilizer dose compared to other fertilizer combinations. With the application of F_2 (50% Chemical fertilizer + 50% Nutrismart), it gave the second highest shelling percentage (12.90) which was only 11.93% lower than that of F_1. With the reduction of recommended chemical fertilizer, the shelling percentage was also reduced and the lowest shelling percentage was obtained from F_5 (100% Nutrismart) application which gave 45.47% and 38.08% lower shelling percentage compared to F_1 and F_2 respectively (Table 7).

4.2.7.3 Interaction effect of variety and fertilizer combination

The highest shelling percentage was found from V_1F_1 (when hybrid variety was treated with 100% chemical fertilizer) and it was similar with V_2F_1 (when the composite variety was treated with recommended dose of chemical fertilizer) but with the reduction of chemical fertilizer, the shelling percentage was also reduced. The lowest shelling percentages was found in V_1F_5 (8.74) and it was 41.07% lower than V_1F_1 (14.83). The V_1F_2 (when the hybrid variety treated with 50% chemical fertilizer + 50% Nutrismart) gave only 12.74% lower shelling percentage compared to V_1F_1 (Table 7). On the other hand, V_2F_1 gave only 12.49% higher shelling percentage than V_2F_2 (when the composite variety treated with 50% Chemical fertilizer + 50% Nutrismart). From the figure it revealed that the lowest shelling percentage was found in V_2F_5.

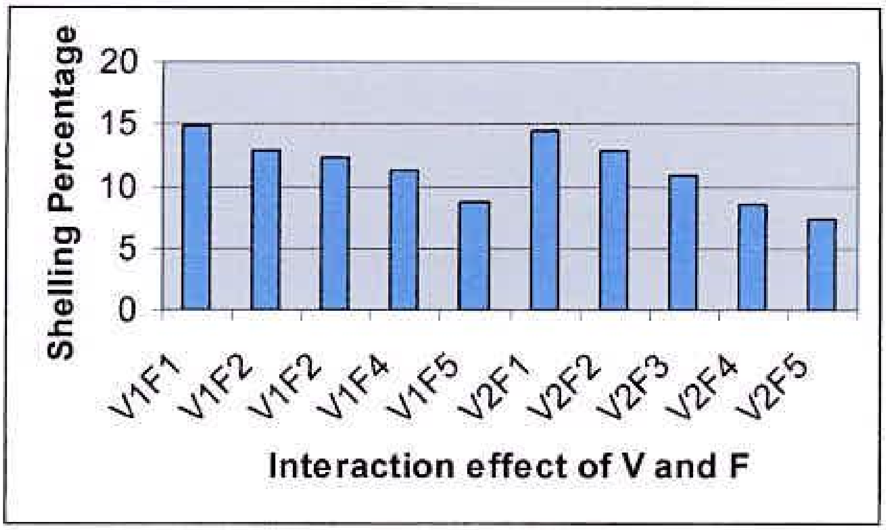

Figure 7. Interaction effect of variety and fertilizer combination on shelling Percentage (LSD $_{0.05}$ = 0.718).

4.3.1 Grain yield (t ha^{-1})

4.3.1.1 Effect of variety

The hybrid variety showed numerically superior grain yield (5.65 t ha^{-1}) though there was no significant differences between the two studied varieties (Table 8). The grain yield of hybrid variety was 23.09% higher compared to the composite variety Khaibhutta. The similar higher yield of hybrid variety was also reported by Sirisampan and Zoebisch (2005) and Ogunbodede *et al.* (2001)

4.3.1 .2 Effect of fertilizer combination

Recommended dose of chemical fertilizer (F_1) resulted in the highest grain yield of maize (6.54 t ha^{-1}). The similar results were also reported by Chaudhary *et al.* (2000) and El Nagar (2003). The second highest yield (5.94 t ha^{-1}) was found in F_2 (50% Chemical fertilizer + 50% Nutrismart) treatment. The lowest yield (3.76 t ha^{-1}) was given by F_5 (100% Nutrismart) that was similar to the F_4 (25% Chemical fertilizer + 75% Nutrismart). The yield reduction of F_2, F_3, F_4 and F_5 compared to F_1 was 9.17, 19.11, 37.77 and 42.51% respectively (Appendix XI and Table 8). It means that the reduction of

50% chemical fertilizer from the recommended dose, the yield reduction was only 600kg ha^{-1}.

4.3.1.3 Interaction effect of variety and fertilizer combination

The interaction effect of variety and fertilizer combination showed the significant variations for grain yield of maize (Appendix-X and Table-8). The higher grain yield (7.37 t ha^{-1}) was found in V_1F_1 (hybrid variety with the recommended dose of chemical fertilizer).Similar result was reported by Kogbe and Adediran (2003). The second highest yield was given by V_1F_2 (6.62 t ha^{-1}) that was similar to V_1F_3 (6.12 t ha^{-1}). In case of the composite variety Khaibhutta, F_1 and F_2 revealed the similar grain yield (Figure 8). The lowest yield for both the varieties was found in F^4 (25% Chemical + 60% Nutrismart) and F_5 (100% Nutrismart).

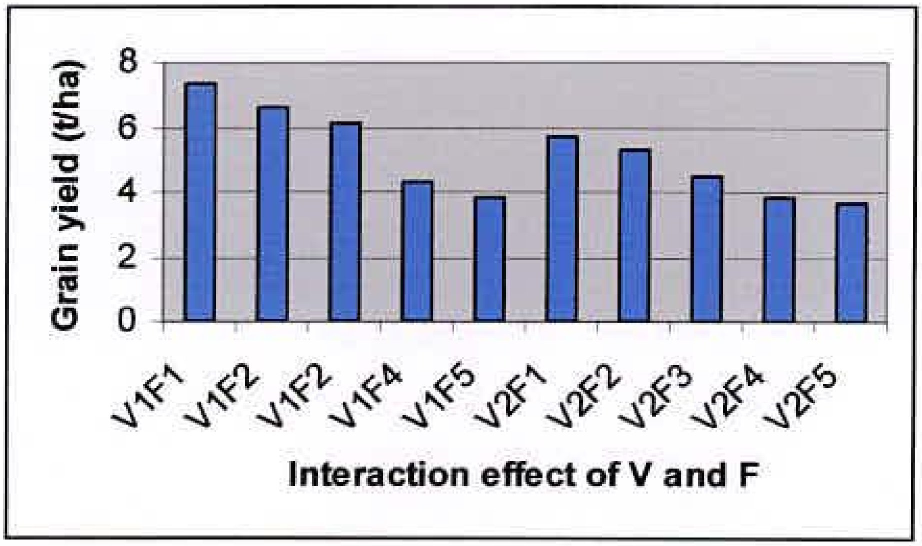

Figure 8. Interaction effect of variety and fertilizer combination on grain yield (t ha^{-1}) (LSD $_{0.05}$ = 0.575).

Table- 8. Effect of variety , fertilizer combination and their interaction on Grain yield, stover yield, biological yield and harvest index

Treatments	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Variety (V)				
V_1	5.65	10.47	16.21a	34.86a
V_2	4.59	10.59	15.19b	30.22b
LSD (0.05)	NS	NS	0.787	1.50
Fertilizer combination (F)				
F_1	6.54a	12.64a	19.18a	34.10 a
F_2	5.94b	10.93b	16.88b	.35.19 a
F_3	5.29c	10.59bc	15.88bc	33.31 a
F_4	4.07d	9.86bc	13.93d	29.22 b
F_5	3.76d	8.63d	12.40e	30.32 b
LSD (0.05)	0.406	1.132	1.245	2.40
CV (%)	6.480	8.785	6.498	6.25

V_1= BARI hybrid Bhutta 5, V_2= Khaibhutta, F_1=100% Chemical fertilizer, F_2=50% Chemical fertilizer + 50% Nutrismart ,F_3=40% Chemical fertilizer + 60% Nutrismart, F_4=25% Chemical fertilizer + 75% Nutrismart and F_5=100% Nutrismart.

4.3.2 Stover yield ($t\ ha^{-1}$)

4.3.2.1 Effect of variety

Though there was no significant differences between the two variety-hybrid and composite but the composite variety gave numerically higher stover yield (10.59 $t\ ha^{-1}$) compared to that of the hybrid variety (10.47 $t\ ha^{-1}$). The stover yield of composite variety was only 1.15% higher than that of hybrid variety (Appendix XI and Table 8).

4.3.2.2 Effect of fertilizer combination

The recommended dose of chemical fertilizer gave the highest (12.64) stover yield compared to other fertilizer combinations. With the application of F_2 (50% Chemical fertilizer + 50% Nutrismart) application, it gave the second highest Stover yield (10.93 t ha^{-1}) which was 13.52% lower than the F_1 (100% recommended chemical fertilizer). The fertilizer combination of F_3 (40% Chemical fertilizer + 60% Nutrismart) and F_4 (25% Chemacal fertilizer + 75% Nutrismart) were numerically similar with F_2. But the lowest stover yield was obtained from F_5 (8.63) t ha^{-1} when 100% Nutrismart was applied and it gave 31.72% lower stover yield than F_1 (Table 8).

4.3.2.3 Interaction effect of variety and fertilizer combination

The interaction effect of variety and fertilizer combination showed the significant variations for the stover yield of maize (Appendix X and Figure 9). The highest stover yield was (12.70 t ha^{-1}) in V_1F_1 (hybrid variety with recommended dose of chemical fertilizer) which was similar with V_2F_1 (composite variety with recommended dose of chemical fertilizer). The hybrid variety when treated with F_2 (50% Chemical fertilizer + 50% Nutrismart) gave the stover yield (10.70 t ha^{-1}) which was 15.74% lower than the V_1F_1 (12.70 t ha^{-1}). Among all the interactions, the lowest stover yield was obtained from V_1F_5 (hybrid variety with 100% Nutrismart) and V_2F_5 (Composite variety with 100% Nutrismart) and these were statistically similar. The V_2F_2 (11.17 t ha^{-1}) gave 11.20% lower stover yield than V_2F_1 (12.58 t ha^{-1}).

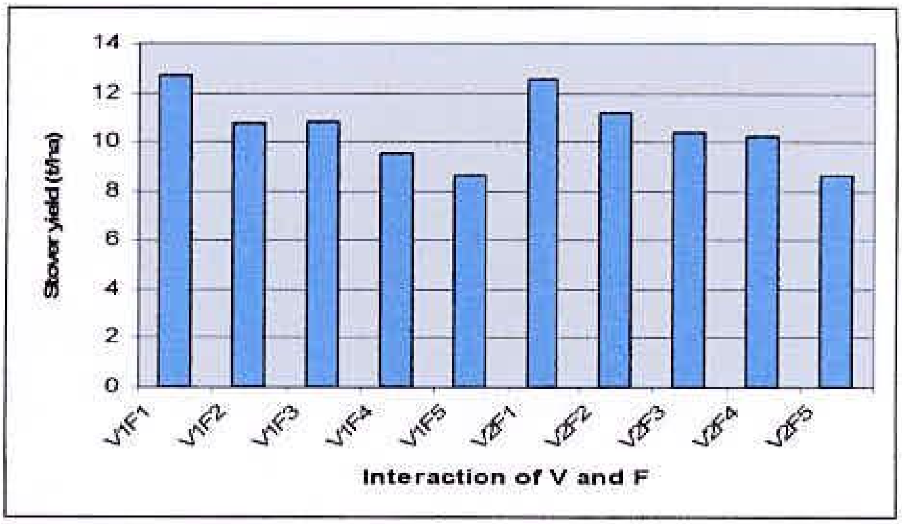

Figure 9. Interaction effect of variety and fertilizer combination on stover yield (t ha^{-1}) (LSD $_{0.05}$ = 1.601).

4.3.3 Biological yield (t ha^{-1})

4.3.3 1 Effect of variety

The highest biological yield was obtained from the hybrid variety (16.21 t ha^{-1}) compared to the composite variety (15.19 t ha^{-1}) and the varietal effect was significant. The hybrid variety gave 6.71% higher biological yield than that of composite variety (Appendix XI and Table 8).

4.3.3. 2 Effect of fertilizer combination

The effect due to different fertilizer combination was significant. With the application of recommended chemical fertilizer, the highest biological yield was found in F_1 (100% Chemical fertilizer). The fertilizer combination of F_2 (50%Chemical fertilizer + 50% Nutrismart) statistically was similar with F_3 (40% Chemical fertilizer + 60% Nutrismart) application. The F_2 (16.88 t ha^{-1}) and F_3 (15.88 t ha^{-1}) gave 11.99% and 17.20% lower biological yield than the F_1 (19.18 t ha^{-1}). F_4 (25% Chemical + 75% Nutrismart) and F_5 (100% Nutrismart) gave 27.37 and 35.34% lower biological yield compared to F_1. The lowest biological yield was found in the fertilizer combination where 100% Nutrismart was used.

4.3.3. 3 Interaction effect of variety and fertilizer combination

Significant effect was found due to the interaction of variety and fertilizer combination. With the application of recommended chemical fertilizer in hybrid variety, the highest biological yield (20.07 t ha^{-1}) was found in V_1F_1 which gave 15.87% higher biological yield than V_1F_2 (hybrid variety with recommended chemical fertilizer). The V_2F_1 (composite variety with recommended fertilizer) was statistically similar with V_1F_2 and V_1F_3. On the other hand, V_2F_2 (composite variety with 50% chemical fertilizer + 50% Nutrismart) gave 10.114% lower biological yield compared to V_2F_1. Among all the treatments both V_1F_5 and V_2F_5 gave the lowest biological yield and these are statistically similar (Table 8)

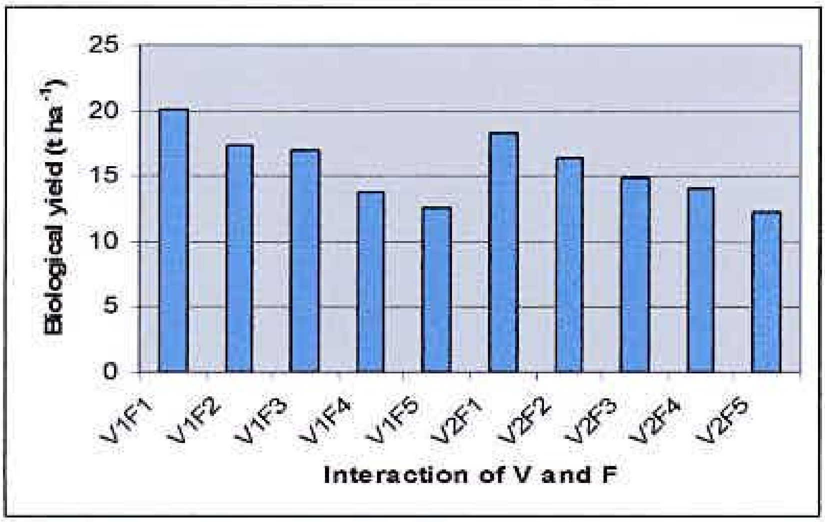

Figure 10. Interaction effect of Variety and Fertilizer combination on biological yield (t ha^{-1}) (LSD $_{0.05}$ = 1.761).

4. 4 Harvest index (HI)

4. 4. 1 Effect of variety

The varietals effect was significant where the hybrid variety gave the higher harvest index (34.86%) compared to that of composite variety (30.22%) and it was 15.35% higher than the composite variety.

4. 4. 2 Effect of fertililizer combination

The effects due to the application of different fertilizer combination were significant. The F_2 (50% Chemical fertilizer + 50% Nutrismart) gave the highest harvest index (35.19%) but it was similar with F_1 (100% Chemical fertilizer) and F_3 (40% Chemical fertilizer + 60% Nutrismart). The F_1 and F_3 gave 1.09 and 1.88 % lower harvest index compared to that of F_2. On the other hand, both the fertilizer combination of F_4 (25% Chemical fertilizer + 75% Nutrismart) and F_5 (100% Nutrismart) are similar but among all the fertilizer combinations F_4 (29.22%) gave the lowest result which gave 5.97% lower harvest index compared to F_2 (Appendix XI and Table 8).

4. 4. 3 Interaction effect of variety and fertilizer combination

The interaction effect of variety and fertilizer combination was significant. The V_1F_2 (hybrid variety with 100% Chemical fertilizer) gave the highest harvest index (0.377) that was similar to V_1F_1 (hybrid variety with 50% Chemical fertilizer + 50% Nutrismart) and V_1F_3 (hybrid variety with 40% Chemical fertilizer + 60% Nutrismart) but V_1F_1 and V_1F_3 gave 3.71 and 4.509% lower harvest index (HI) than that of V_1F_2. On the other hand, V_1F_4 (hybrid variety with 25% Chemical fertilizer + 75% Nutrismart), V_1F_5 (hybrid variety with 100% Nutrismart), V_2F_1 (composite variety with 50% Chemical + 50% Nutrismart), V_2F_2 (composite variety with 50% Chemical fertilizer + 50% Nutrismart) and V_2F_3 (composite variety with 40% Chemical fertilizer + 60% Nutrismart) were also statiscally similar but V_2F_2 gave 2.258% higher harvest index (HI) compared to V_2F_1 (Figure 11). Among all the interaction of variety and fertilizer combination V_2F_4 gave the lowest harvest index and it was 27.59% lower than that of V_1F_2

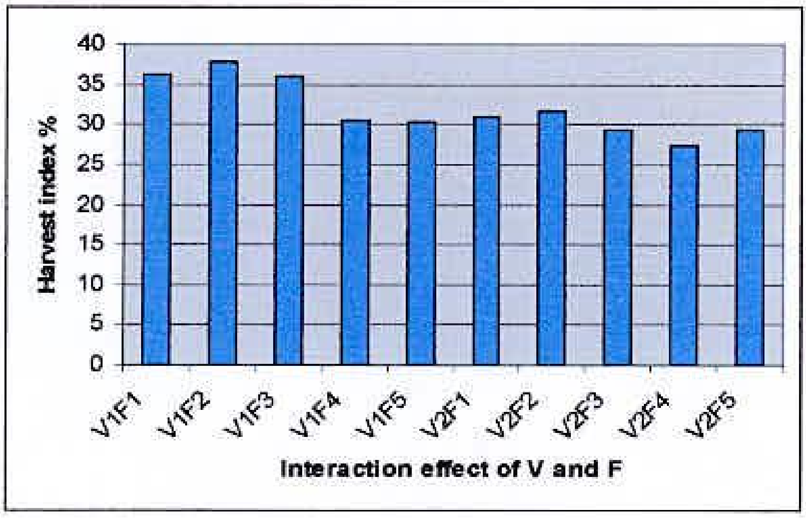

Figure 11. Interaction effect of variety and fertilizer combination on harvest index (HI) ($LSD_{0.05} = 3.40$).

Chapter 5

Summary and Conclusion

CHAPTER 5
SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from November 2007 to April 2008 with the objective to find out the optimum combination of chemical fertilizer and Nutrismart (an eco-friendly fertilizer) and there by reducing the use of chemical fertilizer in Maize. The experiment was carried out in split -plot design with 3 replications having the two variety (1) BARI hybrid bhutta-5 and (2) Composite variety Khaibhutta in the main plot and 5 fertilizer combination like F_1 (100% recommended Chemical fertilizer), F_2 (50% Chemical fertilizer+ 50% Nutrismart), F_3 (40% Chemical fertilizer + 60% Nutrismart), F_4 (25%Chemical fertilizer+ 75% Nutrismart) and F_5 (100% Nutrismart) in the sub-plot on the experimental field.

The data on crop growth characters like plant height (cm), leaf area index (LAI), dry matter production (leaf, stem and root) were recorded at different days after sowing (DAS) as well as the crop characters like cob diameter (cm), cob length (cm), number of cobs plant^{-1}, number of grain rows cob^{-1}, number of grains cob^{-1}, weight of 1000 grains, shelling percentage, grain yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (HI) were also recorded after harvest and the analysis were completed using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference test (LSD) at 5% level of significance.

Results of the experiment showed that variety had a significant influence on growth characters (plant height, leaf area index, dry matter production of both stem and root but it was insignificant in case of dry matter production of leaf. On the other hand, significant effects were observed on the yield contributing characters like cob diameter (cm), cob length (cm), number of grain rows cob^{-1}, weight of 1000 grains, shelling percentage, grain yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) but it had showed the insignificant influence on number of cobs $plant^{-1}$, number of grains cob^{-1} and stover yield (t ha^{-1}). At harvest, the highest and lowest plant height was 228.17 and 219.40 cm by the BARI hybrid bhutta 5 and the composite variety Khaibhutta respectively. In case of leaf area index it was found that though both the variety showed the significant effect on leaf area index at 30 DAS but the trend was changed when the data were recorded at 60 and 90 DAS and at harvest where the BARI hybrid variety gave the more leaf area index compared to the composite variety. Both the variety showed the similar dry matter production of leaf at harvest but BARI hybrid bhutta 5 gave the higher dry matter production of stem and root at harvest. BARI hybrid bhutta 5 gave the superior result in case of cob diameter, cob length, and weight of 1000 grains, shelling percentage, biological yield and harvest index. For the other parameters both the variety showed the similar effect.

Among the growth characters, plant height, leaf area index and dry matter production of leaf and stem were significantly influenced by the fertilizer combination but the production of dry matter of root where though the highest output was found in F_1 (recommended chemical fertilizer) but compared to other combination. With the reduction of Chemical fertilizer, the yield and yield contributing characters were also reduced but F_2 (50% chemical fertilizer + 50% Nutrismart) gave the result statistically similar with F_1 for plant height and dry matter production. In case of leaf area index, F_1 gave only 8.43% higher value at harvest. For the yield and yield contributing characters, the variation due to fertilizer combination were also significant where F_1 gave the higher response but it was statistically similar for the parameters like cob length, number of cobs $plant^{-1}$, number of grain rows/cob and number of grains $cob^{-1.}$ F_2 gave the economic (grain yield) and the biological yield which was only 9.1 and 11.99% lower than F_1 but in case of harvest index F_2 gave the best result among all the fertilizer combination and it was 1.09 % higher than the F_1

Interaction effect of variety and fertilizer combination was found significant for all the studied parameters. The highest plant height (257.90 cm) at harvest was found in V_1F_1 that was similar to V_1F_2, V_1F_3, V_2F_1 and V_2F_2. The leaf area index was affected by the reduction of chemical fertilizers. Application of 100% Nutrismart reduced the dry matter production of maize. The parameters like cob diameter, cob length, number of cobs/plant and number of grain rows/cob were found superior and similar with 100% chemical fertilizer application treatment and 50% chemical + 50% Nutrismart application for both the variety.

The grains number cob^{-1} as well as grain weight was affected with reduction of chemical fertilizer from the recommended dose. For hybrid variety reduction of chemical fertilizer also reduced grain yield by 10.18 and 17.10% for 50 and 40% reduction respectively but for composite variety similar grain yield was observed between recommended chemical fertilizer and 50% chemical + 50% Nutrismart treatment. The stover yield and biological yield were also affected with reduction of chemical fertilizer but similar harvest index was recorded upto 40% reduction of chemical fertilizers for both the varieties.

Based on the results of the present study, the following conclusions may be drawn-

- Recommended dose of chemical fertilizer showed the highest performance on most of the growth parameters but for the yield contributing characters like cob length, number of cobs $plant^{-1}$, number of grain rows cob^{-1}, number of grains cob^{-1} gave the similar statistical result compared to F_2 (50% chemical fertilizer + 50% Nutrismart) treatments.

- With the 50% reduction of chemical fertilizer yield of maize was reduced slightly in the hybrid variety but similar yield of 100% chemical fertilizer (F_1) and 50% chemical fertilizer + 50% Nutrismart (F_2) was found in the composite variety khaibhutta.

- It is possible to replace 50% chemical fertilizer use in maize by the eco-friendly fertilizer Nutrismart by minimum yield reduction for hybrid variety but no yield sacrifice in the composite variety. Government or any other investors should take initiative to import or local production of Nutrismart for economic benefit, less soil and environmental pollution and availability of a single fertilizer to the farmers in an acute fertilizer crisis.

However, to reach a specific conclusion, more research work on other varieties and different fertilizer combinations should be done in different Agro-ecological zones of Bangladesh.

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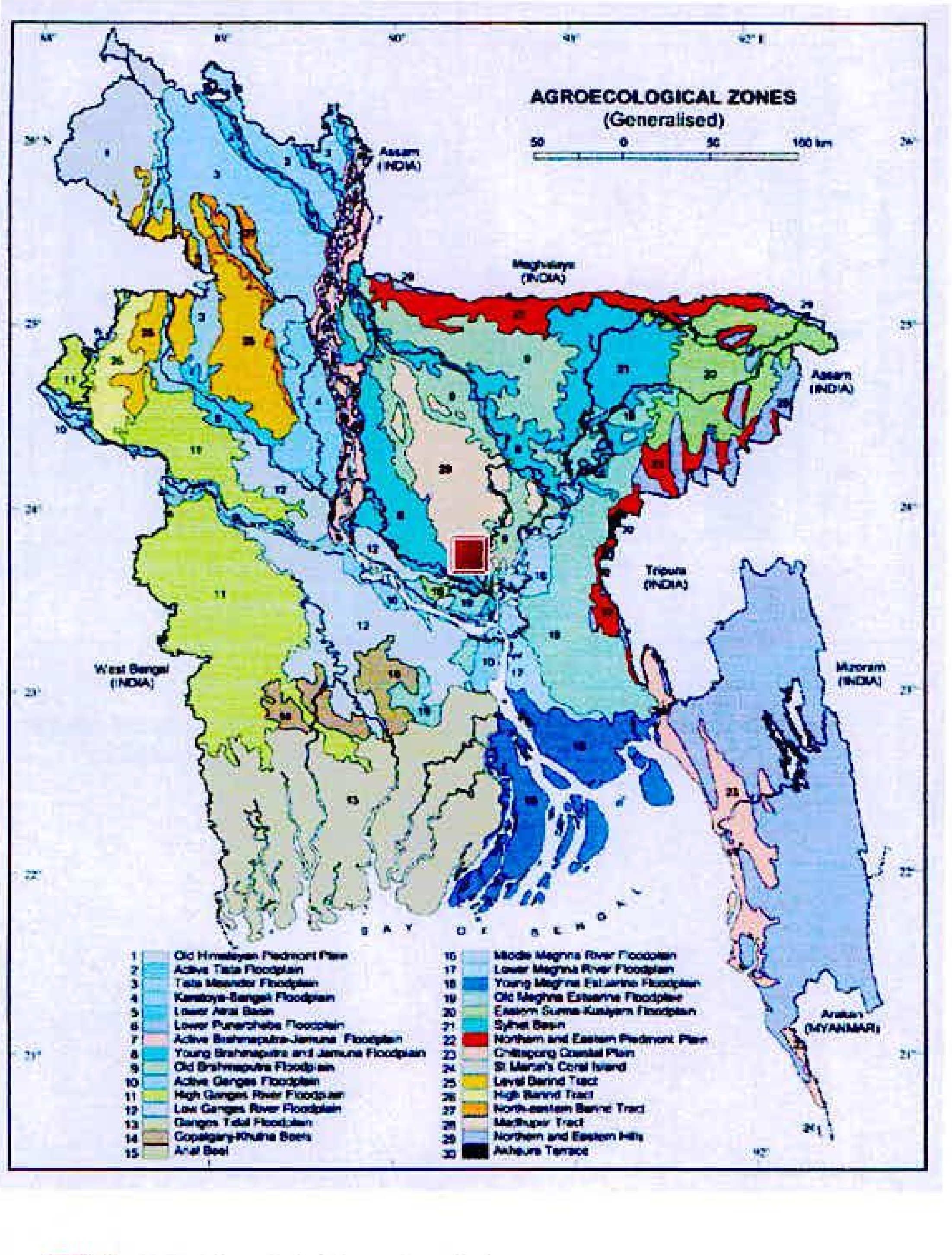
Appendices

APPENDICES

Appendix 1. Map showing the experimental site under study



🟥 The experimental site under study

Appendix II. Records of meteorological information (monthly) of the experimental site during the period from November 2007- April 2008.

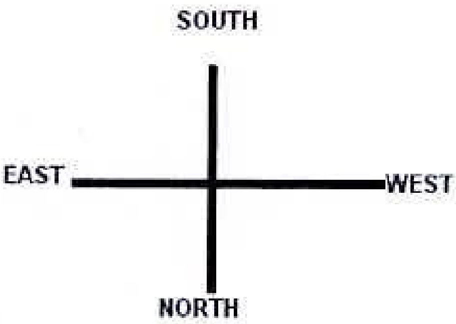
Month	Rainfall (mm)	Average maximum temperature (° C)	Average minimum temperature (° C)
November, 2007	423	29.03	19.9
December, 2007	0	25.87	15.1
January, 2008	23	24.57	14.53
February, 2008	54	26.65	15.1
March, 2008	38	31.15	21.45
April, 2008	81	34.35	24.5

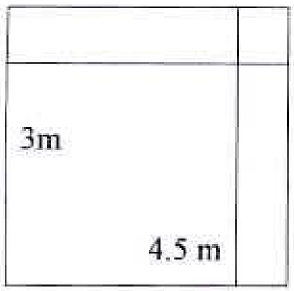
Source: Agronomy Division of Bangladesh Jute Research Institute (BJRI), Dhaka.

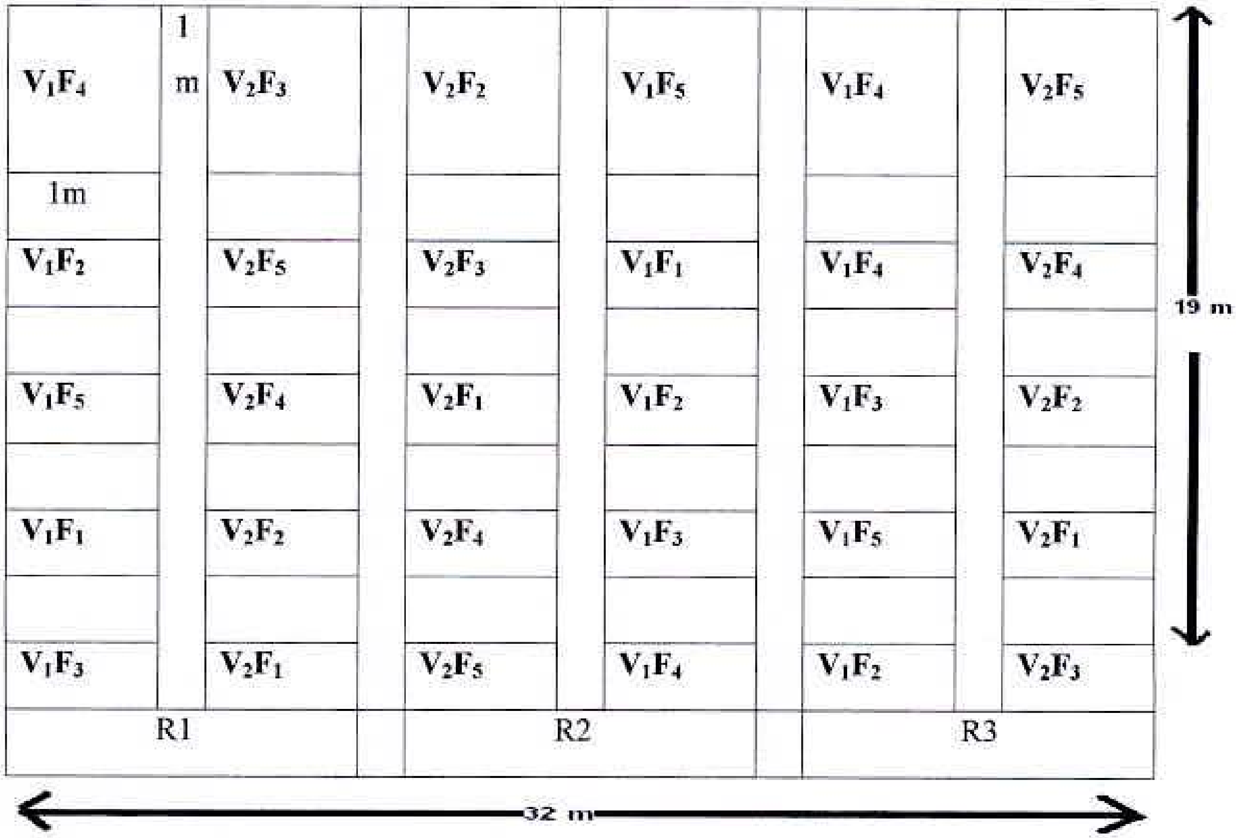
Appendix III. Chemical properties of soil sample in the study area.

Soil sample (plot)	P^{H}	Organic Matter %	Total Nitrogen %	Phosphorus (ppm)	Potassium (K) ml/100g soil
Initial	7.0	0.87	0.043	3.0	0.24
V_1F_1	5.7	1.14	0.057	4.4	0.18
V_1F_2	5.8	1.21	0.060	9.1	0.24
V_1F_3	6.1	1.61	0.080	8.7	0.22
V_1F_4	6.0	2.02	0.101	5.5	0.16
V_1F_5	6.0	1.34	0.067	4.5	0.17
V_2F_1	5.9	1.21	0.060	6.8	0.16
V_2F_2	6.2	1.55	0.078	5.9	0.17
V_2F_3	6.0	1.55	0.077	8.0	0.15
V_2F_4	6.0	1.55	0.078	5.7	0.17
V_2F_5	5.9	1.61	0.080	6.2	0.14

Appendix IV. Layout of experimental field







V_1F_4	**V_2F_3**	**V_2F_2**	**V_1F_5**	**V_1F_4**	**V_2F_5**
V_1F_2	**V_2F_5**	**V_2F_3**	**V_1F_1**	**V_1F_4**	**V_2F_4**
V_1F_5	**V_2F_4**	**V_2F_1**	**V_1F_2**	**V_1F_3**	**V_2F_2**
V_1F_1	**V_2F_2**	**V_2F_4**	**V_1F_3**	**V_1F_5**	**V_2F_1**
V_1F_3	**V_2F_1**	**V_2F_5**	**V_1F_4**	**V_1F_2**	**V_2F_3**
R1		R2		R3	

Appendix V. Analysis of variance on plant height at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square (MS)			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	49.716	67.990	754.562	2.303
Variety(V)	1	144.102**	384.564**	272.586*	576.05NS
Error (a)	2	10.676	201.763	245.513	599.067
Fertilizer combination(F)	4	255.682**	2287.01**	3172.55**	3226.53**
V× F	4	4.454NS	36.469NS	69.619NS	334.21NS
Error (b)	16	2.191	32.027	48.691	407.925

* Significant at 5% level of probability, ** Significant at 1% level of probability and NS= Not significant.

Appendix VI. Analysis of variance on leaf area index (LAI) at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square (MS)			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.0000019	0.020	0.0104	0.0097
Variety (V)	1	0.000053 NS	0.787 **	0.0897NS	0.139**
Error(a)	2	0.00029	0.0009	0.0046	0.00042
Fertilizer combination(F)	4	0.0288 **	2.218 **	10170**	1.161**
V× F	4	0.00188**	0.0909 **	0.0044**	0.0115 *
Error (b)	16	0.000218	0.000689	0.0048	0.0031

* Significant at 5% level of probability, ** Significant at 1% level of probability and NS= Not significant.

Appendix VII. Analysis of variance on dry matter accumulation of leaves at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square (MS)			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.1011	5.214	6.362	32.371
Variety (V)	1	6.449 **	68.799 **	2.476NS	46.675 NS
Error(a)	2	0.1052	5.573	2.516	19.897
Fertilizer combination(F)	4	0.5238 **	88.652 **	48.466 **	81.29 **
V× F	4	0.2358 **	13.389 *	3.471NS	23.632 NS
Error (b)	16	0.0289	4.239	6.281	12.798

* Significant at 5% level of probability, ** Significant at 1% level of probability and NS= Not significant.

Appendix VIII. Analysis of variance on dry matter accumulation of stem at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square (MS)			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.021	18.79	2.13	1092.52
Variety (V)	1	0.012 **	117.770**	150.53 **	4599.42**
Error (a)	2	0.00058	3.200	14.73	298.09
Fertilizer combination(F)	4	0.03 **	11.260 **	122.323 **	816.942**
V× F	4	0.002 NS	4.490 NS	21.781 *	42.494 NS
Error (b)	16	0.0011	1.792	6.051	143.705

* Significant at 5% level of probability, ** Significant at 1% level of probability and NS= Not significant.

Appendix IX. Analysis of variance on dry matter accumulation of root At different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square (MS)			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.0024	0.229	11.019	25.989
Variety (V)	1	0.387 **	1.986 **	51.745 *	196.096**
Error (a)	2	0.00014	0.093	7.158	15.538
Fertilizer combination(F)	4	0.035 **	0.437 **	25.503 *	30.480 NS
V× F	4	0.0179 **	0.515 **	26.363 *	62.297**
Error (b)	16	0.00186	0.0819	6.635	11.702

* Significant at 5% level of probability ,** Significant at 1% level of probability and NS= Not significant

Appendix X. Analysis of variance for yield and yield attributes

Source of variation	Degrees of freedom	Mean square (MS)					
		Cob diameter (cm)	Cob length (cm)	No. of cobs plant^{-1}	No. of grain rows cob^{-1}	No. of grains cob^{-1}	Weight of 1000 grains
Replication	2	0.051	0.375	0.433	0.030	381.060	1647.91
Variety (V)	1	92.99**	15.094**	0.033 NS	0.972**	0.0672 NS	92942.20**
Error(a)	2	0.1300	1.311	0.049	0.481	495.271	1100.01
Fertilizer combination (F)	4	3.807**	11.554**	0.698**	4.176**	7532.52**	4939.41 **
V×F	4	0.0537 NS	0.135 NS	0.0266 NS	0.332**	506.272**	72.389 NS
Error (b)	16	0.127	0.919	0.496	0.390	88.480	128.212

* Significant at 5% level of probability, ** Significant at 1% level of probability and NS= Not significant

Appendix XI. Analysis of variance for yield and yield attributes

Source of variation	Degrees of freedom	Mean square (MS)				
		Shelling percentage	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (HI)
Replication	2	1.304	0.285	7.215	9.667	0.0021
Variety (V)	1	10.788**	8.427**	0.121 NS	6.524 *	0.014 **
Error(a)	2	0.035	0.643	0.617	2.509	0.00034
Fertilizer combination (F)	4	39.871**	8.501**	12.995 **	41.344 **	0.0036**
V×F	4	1.625**	0.726**	0.315 NS	1.469 NS	0.00079 NS
Error (b)	16	0.172	0.1103	0.856	1.035	0.00040

* Significant at 5% level of probability, ** Significant at 1% level of probability and NS= Not significant

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Plate 4. Field view at maximum vegetative stage showing the interaction of V_1F_1

Plate 5. Field view at maximum vegetative stage showing the interaction of V_1F_2