GENETIC VARIABILITY, CORRELATION AND PATH CO-EFFICIENT ANALYSIS FOR YIELD AND YIELD CONTRIBUTING CHARACTERS OF MAIZE (*Zea mays* L.)

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BY

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CERTIFICATE

This is to certify that the thesis entitled **'Genetic Variability, Correlation and Path Co-efficient Analysis for Yield and Yield Contributing Characters of Maize (*Zea mays* L.)** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Genetics and Plant Breeding**, embodies the result of a piece of bonafide research work carried out by **Md. Nazmul Huda**, Registration number: **09-03477** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2015
Dhaka, Bangladesh

Prof. Dr. Md. Sarowar Hossain
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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SOME COMMONLY USED ABBREVIATIONS

FULL NAME	ABBREVIATION
Agro-Ecological Zone	AEZ
and others	*et al.*
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Degree Celsius	^{0}C
Date After Seeding	DAS
Etcetera	etc
Food and Agriculture Organization	FAO
Muriate of Potash	MoP
Randomized Complete Block DesiHCG	RCBD
Square meter	m^2
Triple Super Phosphate	TSP
United Nations Development Program	UNDP
Sher-e-Bangla Agricultural University	SAU

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ABSTRACT

The experiment was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during March to June, 2014 to study the genetic variability, correlation and path co-efficient analysis for yield and yield contributing characters of maize. In this experiment 25 maize genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Mean performance, variability, correlation matrix and path analysis on different yield contributing characters and yield of maize genotypes were estimated. The highest grain yield/plant (272.21 g) was recorded in the genotype of BARI Hybrid Maize-6, whereas the lowest grain yield/plant (180.40 g) from the genotype of NZ-003. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits. In correlation study, significant positive association was recorded for grain yield/plant of maize genotypes with plant height (0.235), tassel height (0.359), number of grains/cob (0.854), cob length (0.390), cob diameter (0.313) and weight of 1000-grains (0.689). Path analysis revealed that days to initiation of male flower had positive direct effect (0.132), days to initiation of female flower had negative direct effect (-0.254), days to maturity had positive direct effect (0.178), plant height had positive direct effect (0.314), tassel height had positive direct effect (0.234), ear length had positive direct effect (0.197), number of grains/cob had negative direct effect (-0.095), cob length had positive direct effect (0.167), cob diameter had positive direct effect (0.168) and that weight of 1000-grains had positive direct effect (0.217) on yield/plant. Clustering pattern denoted that, cluster III was the largest cluster comprising of 9 genotypes and cluster I belonged 4 genotypes of maize. Inter cluster distance was maximum (13.034) between clusters I and III, followed by clusters III and IV (10.098).

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Poaceae is one of the most important photo-insensitive, cross pollinated cereal crops and ranks 3rd in acreage and production in Bangladesh. It is the third most important grain crop after wheat and rice and it accounts for 4.8% of the total cropped land area and 3.5% of the value of agricultural output (Ahmad *et al.*, 2011). It was originated from subtropical regions, probably from the highlands of Mexico and today it is a leading crop in many temperate regions. In Bangladesh, maize cultivated in about 152 thousand hectares of land and total annual production is 887 thousand Metric tons with an average yield of 5.83 t ha^{-1} (BBS, 2014). Introduction of quality protein maize (QPM) in Bangladesh is a long aspiration to feed the million malnourished populations. Thus, maize should get priority considering the protein malnutrition of the people, because it contains more digestible protein than the other cereals (Ahamed, 2010).

Maize is grown as grains as well as fodder crop, although it has been cultivated in limited area ranking 3rd most important cereal crops in Bangladesh, recently its cultivation gaining popularity and it occupied 2nd position next to rice in the preceding year (DAE, 2012). As food, it can be consumed directly as green cob, roasted cob or popped grain. Maize grain can be used for human consumption in various ways such as corn meal, fried grain and flour. Its grain has high nutritive value containing 66.2% starch 11.1% protein, 7.12% oil and 1.5% minerals. Moreover, 100 g maize grains contain 90 mg carotene, 1.8 mg niacin 0.8 mg thiamin and 0.1 mg riboflavin (Chowdhury and Islam, 1993). Maize oil is used as the best quality edible oil. Green parts of the plant and grain are used as the feed of livestock and poultry. Stover and dry leaves are used as good fuel (Ahmed, 1994). The important industrial use of maize includes in the manufacture of starch and other products such as glucose, high fructose sugar, maize oil, alcohols, baby foods and breakfast cereals (Kaul, 1985).

In Bangladesh the cultivation of maize was started in the late 19th century but the cultivation has started to gain the momentum as requirement of maize grain is being increased as poultry industry flourishes in Bangladesh. Maize is one of the most productive C4 plant with a high rate of photosynthetic activity. Maize has the highest potential for carbohydrate production per unit area per day. Stem and foliage of maize plant can be used as livestock feed. Stalk, dry leave covering of cobs (husks) and shelled cobs can be used as fuel (Ahmed *et al.*, 2011). It can be grown all the year round in Bangladesh, and fitted in the gap between the main cropping seasons without affecting the major crops. It can also be grown in flood prone areas under no tillage, and with no inputs (Efferson, 1982). With its multipurpose properties, it will undoubtedly play a vital role in reducing the food shortage around the world, especially in Bangladesh. Maize is being cultivated all over the world but the yield of maize is low in Bangladesh as compared to the other maize growing countries.

To guarantee high yield of maize crop, farmers often grow improved varieties usually from different sources either alone or with other local varieties, resulting in diversity among cultivars grown within and among farmers. Genetic variability, which is a heritable difference among cultivars, is required in an appreciable level within a population to facilitate and sustain an effective long-term plant breeding program. Progress from selection has been reported to be directly related to the magnitude of genetic variance in the population (Helm *et al*., 1989; Hallauer and Miranda, 1995; Tabanao and Bernardo, 2005). Large amount of genetic variability has been observed to occur in the original accessions and races among sampled population representing different climatic, geographical regions (Ilarslan *et al.,* 2002). Abayi *et al*. (2004) observed significant genetic variation in important agronomic traits, especially earliness to sufficiently justify the initiation of selection program. The results of Jotshi *et al*. (1988), Alvarez and Lasa (1994), Lu *et al*. (1994) and Zhang *et al*. (1995) demonstrated the importance of quantifying genetic variability among maize cultivars grown in an area before initiation of breeding program.

Information of genetics on yield and other associated characters those are influenced by the local environment is limited but such information is prerequisite to plan any breeding program for development of high yielding maize (Agrawal, 2002). Among the various traits, grain yield in maize is the most important and complex quantitative traits controlled by numerous genes (Zdunic *et al*., 2008). Yield being a complex trait, is considerably influenced by different contributing yield components like ear height, plant height and 1000-grain weight (Rahman *et al*., 1995). The yield of hybrids obtained from inbred lines that have high grain yield. Likewise, the yield of hybrids obtained from inbred lines that have low grain yield. It was attempted to select hybrid maize parent lines that give the highest yield using discriminate analysis techniques (Oz, 2012). Grain yield is directly and positively associated with ear weight. Improvements in yield can be achieved by selection for grain yield, plant height and ear height (Prodhan, 1997). The additive genetic variance component is the most important component of genetic variability for all the traits (Oz, 2012; Betran and Hallauer, 1996).

With conceiving the above scheme and discussion in mind, the study was conducted to determine the genetic variability among the different maize genotypes in Bangladesh in order to fulfilling the following objectives:

- To know the yield potentiality of different maize genotypes;
- To know the nature of association of traits, direct and indirect relation between yield contributing characters of maize genotypes;
- To screen out the suitable maize genotypes for future breeding program.

CHAPTER II

REVIEW OF LITERATURE

Maize is one of the common and most important cereal crops of Bangladesh and as well as many countries of the world. The growth and yield of maize is largely controlled by the environmental variables, management practices and varieties. Research works have been done by various workers in many parts of the globe to study the effect variety on the growth and yield of maize. The crop has received much attention by the researchers on various aspects of its production and utilization for different consumer uses. Many studies on the growth, yield, variability, correlation, heritability and genetic advance have been carried out in many countries of the world. The work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter under the following headings:

2.1 Yield attributes and yield of maize

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 were 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 season. Variations in yield both in kharif and rabi might be due to seasonal variation (BARI, 1988).

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 modern input (fertilizer) to a traditional variety.

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. 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.

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.

Terbea and Ciocazanu (1999), reported that the aim of this study was to establish the influence of limited water supply on some physiological traits in four maize inbred lines (1268H, 1267E, B73 and Mo17S) differing in drought tolerance.

The experiments were conducted in a growth chamber, with maize plants are grown in a peat-sand (1:1) mixture in PVC tubes (36 cm long and 9cm diameter). Limited water supply (LWS) in tolerant inbred line 1268H produced a significant increase in photosynthetic rate, root length, and lateral root area. Significant decreases in photosynthetic rate, leaf area, root length, lateral root area, stomata conductance, transpiration rate and chlorophyll content were observed in highly drought sensitive line B73. These results showed that under normal soil moisture, the genetic variability of maize for these parameters was less pronounced than under decreased soil water content. The genotypic responses to soil water content were different.

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 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.

Ogunboded *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.

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 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.

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.

Quaranta *et al*. (2004); carried out Maize trials on a deep alluvial clayey soil with good water retention in central Italy. Of 46 maize hybrids of FAO classes 400, 500 and 600, 33 had been in trials at least once before. Yields were generally lower than in previous years due to the exceptionally prolonged hot, dry weather, but even so, a number of hybrids performed well. Hybrids DK585 and DK 537 scored relatively much better than in 2002, Cecilia was outstanding, confirming its good performance in 11 previous years and making the best use of the available water. Senegal and PR34B23 also performed well with grain humidity at harvest below average. The number of sterile plants was above average, due no doubt to the drought.

Field trials were conducted by Quaranta *et al*. (2005); in the north of Rome, Italy, with 53 hybrids of which 18 had been tested. Data are presented on the number of hybrids tested, their sowing, emergence, flowering and harvesting dates, the height of plants, yield, humidity of grain at harvest, percentage of broken plants, weight of 1000 seeds and protein content. Evidence was obtained that of 18 hybrids tested, Narbone, Net, Potenza 581, KWS 0551, Helder and Aristo had the highest yield even in drier years.

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-opllinating; Big717 and Big949-single-cross hybrids) and five cultivation practices (conventional (CT)); mungbean residue (Mn); spineless mimosa (*Mimosa invisa*) live mulch (Mi); manure (Ma); and plastic mulch (Pl) were studied for two cropping seasons. The two hybrid varieties produced significantly higher grain yields than the open-pollinating variety, i.e, Big-717> Big-949 > Suwan-5. The effects of cultivation practices were less prominent and the highest average yields were produced by Pl; the lowest by Ma.

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.

A field experiment was conducted by Salami *et al*. (2007); with the aim of estimating variation among maize cultivars grown in Ekiti State. Twenty maize cultivars obtained from various locations within the state was evaluated at the Teaching and Research Farm, University of Ado-Ekiti. Result shows that there were significant difference for in day to first silking and anthesis, days to 50% anthesis and silking, plant and ear heights, leaf blight and curvularia leaf spot and grain yield. Grain yield ranges from 3.02 t ha^{-1} for Ijelu and 4.91 t ha^{-1} for Ilupeju.

Field studies were conducted by Fanadzo *et al.* (2009); in South Africa to evaluate the relationship between cultivar, nitrogen (N) fertilizer rate, plant population and planting date on maize grain yield (experiment 1) and compare grain yields of new hybrids to cultivars commonly grown by farmers (experiment 2). The treatments for experiment 1 were maize cultivars (PAN6777 and DKC61-25), N rate (60 and 250 kg N/ha), plant population (40,000 and 90,000 plants/ha) and planting time (early: within the first 28 days of beginning of season on 15 November or late: planting after 15 December). In Experiment

2, eight cultivars were compared; 2 popularly grown by farmers at ZIS and 2 each from the 3 maturity classes (early, medium and late), which were top performers in regional variety trials conducted by the ARC. Regardless of cultivar, higher yields were obtained when maize was planted early and fertilized at 250 kg N/ha. The short-season cultivar DKC61-25 yielded optimally when grown early at 90,000 plants/ha, while the long-season cultivar PAN777 performed better at 40,000 plants/ha.

The study was conducted by Charles *et al*. (2013); to select hybrids with improved yield, to identify testers for grain yield and to determine the magnitude of genetic variability in maize hybrids for yield and its elements. Adaptability of double cross hybrids was studied under varying agro-climatic conditions of parts of Western Kenya. Seventeen experimental hybrids and one commercial maize variety (standard) were planted in a 6×6 balanced lattice design with three replicates. Physiological and agronomic traits were observed and recorded from germination to maturity. The results showed that ear height ranged between 169.0 and 214.0 cm showed by genotype (95×F) × (50×82) and (95×8) × (50×16) respectively. The plant height ranged between 309.0 and 330.7 cm showed by genotype (44×A) × (50×93) and (44×A) × (82×93) respectively, grain weight ranged between 253.3 and 441.7 g showed by genotype (44×A) × (82×93) and (64×8) × (82×93) respectively, rows per cob ranged between 12.3 and 13.9 showed by genotype (95×F) × (82×16) and (F×82) × (93×16) respectively. Grains per row ranged between 34.3 and 42.1 which was shown by genotype (A×F) × (50×82) and (95×8) × (50×16) respectively, the cob length ranged between 19.6 cm and 23.4 cm shown by genotype (56×44) × (50×93) and (95×8) × (50×16) respectively and the grain yield ranged between 5.2 and 12.8 t/ha produced by genotypes (95×F) × (82×16) and (56×44) × (50×16) respectively. Evaluating the various results revealed that genotype (56×44) × (50×16) and (95×8) × (50×16) were the most promising and their adaptation to the agro-ecological condition to this area can bring a substantial increase in maize grain yield.

2.2 Variability and genetic associations in maize

Lee *et al*. (1986); analyzed data on maize yield (grain weight per plant) and eight agronomic traits from an 8×8 diallel cross. Significant heterosis and heterobeltosis were observed for all characters except days to harvest. Heterosis took the form of incomplete dominance (additive variation) for plant height and over dominance (non additive variation) for other characters.

Ganguli *et al*. (1989); got a total of 33 interoperation hybrids from crosses between 11 female and three male lines. Positive heterosis over the better parent was observed for grain yield, ear insertion height, plant height, days to maturity and days to silk.

Debnath (1991a), studied heterosis over mild parent and better parent in a 36 hybrids involving nine maize inbreds for grain yield, earliness (days to silk and grain moisture) plant height and ear height. Significant and positive heterosis over mid and better parent for yield was observed in thirteen and eight crosses respectively. For days to silk, significantly negative heterosis was exhibited by twelve crosses over mid parent and eight crosses over better parent. None of the crosses possessed negative and significant heterosis for rest of the characters studied.

Debnath (1991b), studying with 23 fourth generation lines of maize showed that grain yield was positively and significantly correlated with plant height, ear height, ear height, ear diameter and kernel rows per ear, number of kernels per row and 1000-kernel weight.

Debnath (1992), studied heterosis in a 10×10 dialled cross of maize inbreeds and reported that heterobeltosis for grain yield varied from 38.56 to 71.60 percent. Positive and significant heterobeltosis were also observed in ear length, ear diameter, and kernel rows per ear, number of kernels per row and 1000-kernel weight.

A field experiment was conducted by Begna *et al*. (2000); on clay loam soil at the E. A. lodes Agronomy Research Center, Ste. Anne de Bellevue, Quebec. Hybrids were arranged in a randomized complete block design and included 11 newly developed leafy reduced stature (LRS), four non-leafy reduced-stature (LMBL) hybrids. One is conventional (Pioneer Brand 3979), and one late maturing big leaf (LMBL). In both years, generally above-ground dry matter was greater for the taller LMBL and Pioneer Brand 3979 than for the shorter hybrids, but greater grain yields were measured for both the tallest and five of the 11 LRS hybrids. Moreover grain yields averaged over canopy groups were not different. The shorter hybrids had greater assimilate allocation to the grain than the taller (especially LMBL) hybrids and this was evident in their harvest index values. However, within the LRS group, hybrids differed for both dry matter and grain yield with some being similar to the NLRS hybrids while others were similar to the taller pioneer Brand 3979 hybrid.

Elings (2000), investigated the area of individual leaves as a function of leaf number from 1995 to 1996 in several tropical environment in Mexico (both favorable and moisture limited). He observed that when the environment was normalized for area the largest and maximum numbers of leaves were produced.

To identify better the required traits, in some generations the selection was carried out by Virk *et al*. (2005); on a research farm under fertility levels that approximated farmers' practice. The improvement of the subpopulations resulted in several varieties that performed well in research station and on-farm trials. One of them, BVM 2, was released in Jharkhand state, India. In multilocational research station trials, it yielded more than the control variety BM 1 but silked earlier. In the less favourable environments of on-farm trials, its yield superiority, in percentage terms, was higher. Farmers perceived BVM 2 to have better grain quality and stover yield than the local varieties. BVM 2 was specifically bred to meet the needs of the clients (resource-poor farmers with no access to irrigation) and has earlier maturity combined with higher grain yield. The returns were higher from this highly client-oriented approach, than by classical breeding, mainly because uptake was faster as a result of research and extension being done in tandem.

High-stable coefficients, high-stable yield coefficients and drought resistance coefficients of 10 maize cultivars were calculated by Ouyang *et al*. (2007); according to the experimental data from 4 sites (in China). The high-stable yield and drought resistance of maize cultivars were analysed comprehensively. The results indicated that there were significant differences in maize yields among cultivars and experimental sites. There was significant difference in adaptability of maize cultivars to environment. Irrigation increased the yields of all the tested cultivars. Luoyu No. 1 and Yudan No. 3 are the best cultivars, with high-stable yield. The high yield coefficient indicated the yield differences among maize cultivars. High-stable coefficients represented completely and accurately the characteristics of high and stable yield of maize cultivars. There was no significant difference in the drought resistance coefficients of maize cultivars.

Trethowan and Crossa (2007), reported that yield potential is the maximum attainable yield within the limits imposed by the production environment. Better understanding of these constraints and the underlying causes of genotype x environment interaction will improve productivity regionally and globally. For 40 years, the International Maize and Wheat Improvement Center (CIMMYT) has distributed wheat yield trials, and collaborators from across the world have provided yield, disease, and agronomic data. Various analyzes of these data have been conducted over the years to assess the effectiveness of CIMMYT's Mexican based breeding program, and to identify key selection environments and genotypes with broad adaptation. Analysis of these data confirmed the value of shuttle breeding in Mexico. Well-watered and terminal heat stress selection environments generated in Mexico associate well with their global target areas. Germplasm targeting dry areas is selected and screened for drought tolerance in Mexico using limited irrigation. This type of screening correlated well with environments in South Asia, but less so with sites in West Asia and South America.

A field experiment was conducted by Salami *et al*. (2007); with the aim of estimating variation among maize cultivars grown in Ekiti State. Twenty maize cultivars obtained from various locations within the state was evaluated at the Teaching and Research Farm, University of Ado-Ekiti. Result shows that there were significant ($p<0.05$) difference for in day to first silking and anthesis, days to 50% anthesis and silking, plant and ear heights, leaf blight and curvularia leaf spot and grain yield. Grain yield ranges from 3.02 t ha for Ijelu and 4.91 t ha for Ilupeju. Phenotypic and genotypic variance was highest for plant and ear heights and least for the foliar disease rating and significant for all the traits except ear plant. Correlation coefficient was positive and significant between grain yield and both plant and ear heights, but negative with Curvularia leaf spot. These results are suggestive that the cultivars evaluated in this study are good candidates on which improvement activates can be initiated the incorporation of high grain yield traits would also have a long run advantage.

Field trials were initiated in 16 localities of Italy (of which 3 were conducted in Friuli-Venezia Giulia) to compare performance of 56 hybrids of FAO maturity groups 500, 600 and 700 by Barbiani *et al.* (2008);. The final stage of the trials was conducted in 11 localities with medium late hybrids compared with 30 early hybrids, of which 17 belonged to maturity group 400. Information is included on soil characteristics, irrigation, cropping systems, use of fertilizers, herbicides and control of Pyralidae with Contest [alpha-cypermethrin]. Data are presented on plant height, grain humidity level at harvest, hectolitric weight and yield of hybrids belonging to maturity groups 300, 400, 500, 600 and 700 and showed significant differences.

Rahman (2008), used 41 maize populations which were evaluated for plant height, ear height, number of tassel branches, days to 50% anthesis and days to 50% silking. Significant amount of variability was observed among these populations for all the traits. A wide range of variability was found among these populations through cluster analysis that could be utilized in breeding programs.

Performance of 54 FAO 500, 600 and 700 maize hybrids was compared by Barbiani *et al.* (2009); at 15 sites in north and central Italy. There were 14 medium cycle (FAO 500), 27 medium late cycle (FAO 600) and 13 late cycle (FAO 700) hybrids involved. Details of the different soil conditions, preceding crop, fertilisation and various types of irrigation are affected yield attributes and yield of maize in relation to the site and the management practices.

Subramanian and Subbaraman (2010), studied genetic diversity among 38 maize germplasm accessions by observing 25 morphological traits. The genotypes were grouped into four cluster using Un-weighted Paired Group Arithmetic Average (UPGMA) method and Sequential Agglomerative Hierarchical Non-overlapping (SAHN) clustering method. Widely divergent clusters and genotypes were identified that could be exploited in maize crop improvement.

A research work was done by Amiruzzaman (2010), who took 42 inbreed lines and grouped them into eight clusters with the assumption that those within the same clusters have smaller D^2 value among themselves, than those belonging to others clusters.

Genetic variability and correlation were studied by Yusuf (2010), in 36 maize genotypes (15 single cross hybrids, 9 parents and 12 checks), with 26 quality protein maize genotypes among them. They were evaluated at Samaru, Northern Guinea Savanna Zone of Nigeria. Analysis of variance revealed significant differences for all the traits observed. Highest grain yield of 9.5 t/ha was obtained from the hybrid: CML178 × CML181. The mean plant height of the genotypes ranged from 51-136 cm for the inbred parent CML177 and the hybrid, CML181 × CML176. Significant differences were observed among the genotypes, indicating that they were genetically distinct with regard to the genes controlling the expression of this character. Similarly ear height ranged from 13-

53 cm, indicating wide variability for this character among the genotypes. Days to maturity which is a baseline for selection of early maturing genotypes ranged from 67-109 days. The inbred parent CML493 had the lowest days to maturity (67-days). This indicates that this inbred parent can be included in cross combinations for selection of early maturity. Highly significant correlation was observed between ear height and plant height ($p<0.01$). Similarly, days to silking and tasselling correlated positively and significantly at $p<0.05$. Grain yield correlated positively and significantly with one thousand seed weight ($p<0.05$). Number of leaves per plant had a significant positive correlation with ear height at $p<0.05$, indicating that these traits could be selected together for simultaneous improvement. The phenotypic coefficients of variations were higher than the genotypic coefficients of variations for all the traits studied. Thousand seed weight had the highest genotypic coefficients of variation. The highest genetic gain was obtained for plant height. Thousand seed weight and ear height also recorded high genetic gain. It is anticipated that these findings will be useful in future breeding programs involving this very important crop.

Shahrokhi and Khorasani (2013), reported that morphological traits variation can be measured by different multivariate methods. The study was conducted to characterize 28 commercial corn hybrids in a randomized complete block design (RCBD). Significant variations were observed among the hybrids for the measured characteristics. Correlation coefficients between the studied variables and total yields showed significant values for plant and ear height with total yield of maize.

The present study was conducted by Kumar *et al*. (2014); at Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad during Rabi, to determine the various parameters of genetic variability, broad sense heritability and genetic advance estimates in newly developed 86 maize genotypes. Analysis of variance revealed that the mean sum of squares due to genotypes showed significant differences for all the 12 characters studied. Traits yield per plant, plant height, ear height, number of kernels per row, 100-kernel

weight were showed high heritability accompanied with high to moderate genotypic and phenotypic coefficient of variation and genetic advance which indicates that most likely the heritability is due to additive gene effects and selection may be effective in early
generations for these traits. Whereas high to moderate heritability along with low estimates of genetic advance were observed for days to 50 per cent tasseling, days to 50 per cent silking, shelling percentage, ear length and days to maturity ear girth and number of kernel rows per ear.

Studies were carried out by Umar *et al*. (2015); to estimate the extent of genetic variability in fifty six maize (Zea mays L.) genotypes (6 drought tolerant inbred lines, 7 other inbred lines, 42 crosses and a check) under non-stress and water stress at flowering. The genotypes were evaluated in 2012/2013 dry season across two locations, to obtain more information on their genetic and morphological diversity. The experimental design used was simple lattice design with two replications under each condition. Significant mean squares were obtained for the seven traits measured under non-stress and water stress in the combined analysis across locations.

Ishaq *et al*. (2015); carried out a study with a set of four maize populations, *i.e.* PSEV-3-2ES, Pop 2004-BS, Pop 2006 and Jalal 2003 were evaluated for genetic potential and variability. Analysis of variance results showed highly significant differences ($P \leq 0.01$) for all the traits. The highest values for plant height (169.1 cm), ear height (75.13 cm), leaves plant^{-1} (11.33), flag leaf area (106.5 cm^2), grain rows ear^{-1} (13.67) and grain yield (5927 kg ha^{-1}) were recorded for Jalal-2003. Broad sense heritability (h^2bs) ranged from 0.29 to 0.95 for various traits. Among the tested populations Jalal-2003 proved to be superior for most of the traits studied. The present study revealed a considerable amount of genetic variation and heritability estimates that could be manipulated for further improvement in maize breeding.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during to study the genetic variability, correlation and path co-efficient analysis for yield and yield contributing characters of maize. The details of the materials and methods i.e. description of the experimental location, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis that used or followed in this experiment has been presented below under the following headings:

3.1 Description of the experimental location

3.1.1 Experimental period

The field experiment was conducted during the period of March to June, 2014.

3.1.2 Location of the experiment

The present research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. Location of the experimental site presented in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February and the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and details has been presented in Appendix II.

3.1.4 Soil characteristics of the experimental plot

The soil belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix III.

3.2 Experimental details

3.2.1 Planting materials

In this experiment 25 maize genotypes (Table 1) were used as experimental materials which were produced in the 2012-2013 cropping season, and the purity and germination percentage were leveled as 94% and 91%, respectively.

Table 1. Name and origin of the maize genotypes used in the present study

#	Maize genotypes	Source of origin	#	Maize genotypes	Source of origin
01.	BARI Hybrid Maize-6	BARI	14.	Pioneer-3785	Petrocem Co.
02.	BARI Hybrid Maize-7	BARI	15.	Pioneer-07	Petrocem Co.
03.	BARI Hybrid Maize-9	BARI	16.	GP-50	Getco
04.	Shuvra	BARI	17.	987 Aotu	Getco
05.	Barnali	BARI	18.	GP-901	Getco
06.	AS-999	ACI	19.	GP-838	Getco
07.	Kaberi-369	ACI	20.	PAC-555	Lal Teer
08.	NZ-001	ACI	21.	Elite	Lal Teer
09.	NZ-003	ACI	22.	Krishibid PS-102	Krishibid group
10.	NZ-510	ACI	23.	Krishibid Bhutta-550	Krishibid group
11.	25KSS	ACI	24.	Krishibid-222	Krishibid group
12.	ACI-3110	ACI	25.	AGRO G8255	Agoa
13.	BRAC-984	BRAC			

3.2.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 1557.5 m^2 with length 89.0 m and width 17.5 m. The total area was divided into three equal blocks. Each block was divided into 25 plots where 25 maize genotypes were allotted at random. There were 75 unit plots altogether in the experiment. The size of the each plot was 4.5 m × 3.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. Experimental field is presented in Plate 1.

3.3. Growing of crops

3.3.1 Preparation of the Main Field

The plot selected for the experiment was opened in the first week of March 2014 with a power tiller, and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil for planting of maize seeds. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in 3.4. Recommended doses of well-rotten cowdung manure and chemical fertilizers as indicated in 3.7 were mixed with the soil of each unit plot of the experiment.

3.3.2 Application of Manure and Fertilizers

Green manure and decomposed organic matter are used @ of 6.0 ton /hectare before final land preparation. The chemical fertilizers such as Urea, TSP, MOP, Gypsum, Boric acid and Zinc sulphate were applied in the rows at the rate of 50-195-35-100-10-10 and 10 kg/ha respectively as basal doze. The rest 120 kg Urea was applied in three equal splits (i.e. 40 kg/splits) at 25, 45 and 65 days after planting as side dressing, 3-5 cm away from the plant and the furrows of the fertilizer are hilled up immediately. At the time of third dressing of Urea 35 kg of MOP (rest) was also used. The dose and method of application of fertilizer are shown in Table 2.

Plate 1. Photograph showing experimental plot

Table 2. Dose and method of application of fertilizers in maize field

Manures and Fertilizers	Dose/ha	Application (kg)			
		Basal	25 DAP	45 DAP	65 DAP
Cowdung	06 tons	06 tons	--	--	--
Urea	170 kg	50 kg	40 kg	40 kg	40 kg
TSP	195 kg	195 kg	--	--	--
MP	70 kg	35 kg	--	--	35 kg
Gypsum	100 kg	100 kg	--	--	--
Zinc sulphate	10 kg	10 kg	--	--	--
Magnesium	10 kg	10 kg	--	--	--
Boric acid	10 kg	10 kg	--	--	--

3.3.3 Planting of Seeds in the Field

The maize seeds were planted in lines each having a line to line distance of 75 cm under direct planting in the well prepared plot on 23 March 2014.

3.3.4 After Care

When the seedlings started to emerge in the beds it was always kept under careful observation. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the maize seedlings.

3.3.4.1 Irrigation

Irrigation was provided at knee stage, pre-flowering stage and milking stage at 45, 65 and 78 days after planting (DAP) for three times for proper growth and development of the plants.

3.3.4.2 Thinning and Gap Filling

The seedling were first thinned from all of the plots at 10 Days after planting (DAP) 2nd thinning was carried out after 7 days for maintaining proper spacing the experimental plots.

3.3.4.3 Weeding

Weeding were done to keep the plots free from weeds, easy aeration of soil and to conserve soil moisture, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully after complete emergence of maize seedlings and whenever necessary. Breaking the crust of the soil, when needed was done through mulching.

3.3.4.4 Plant Protection

After 50 days of planting, first spray of chloropyriphose was done against sucking pest such as jassid and aphids.

3.4 Harvesting, threshing and cleaning

The crops were harvested when the husk cover was completely dried and yellowish color was formed in the grain. The cobs of five randomly selected plants of each line were separately harvested.

3.5 Data recording

3.5.1 Days to initiation of male flower

Days to initiation of male flower was recorded as the number of days from planting date to pollen shedding in the plants in the plot.

3.5.2 Days to initiation of female flower

The number of days recorded from the date of planting to the emergence of silks in the plants in the plots and it was the days to initiation of female flower.

3.5.3 Days to maturity

Maturity time was recorded in days from the date of planting to the date of yellowish layer formation of grain.

3.5.4 Plant height (cm)

Plant height was measured in centimeters from the base of the plants up to the tassel base where branching started at each of the five randomly selected plants in each line.

3.5.5 Tassel height (cm)

Tassel height was measured in centimeters from the base of the tassel to the top portion of tassel at each of the five randomly selected plants in each line.

3.5.6 Ear length (cm)

Ear was recorded in centimeters from the base of the plant up to the base of the uppermost ear.

3.5.7 Number of grains/cob

It was measured in number by counting the total grain from selected 5 cobs from each unit plot.

3.5.8 Cob length (cm)

It was measured in millimeter from the base to the tip of the cob with the help of a meter scale.

3.5.9 Cob diameter (mm)

Cob diameter measured in millimeter with the help of a slide calipers from the three position of cob and average was recorded.

3.5.10 Weight of 1000-grains

From the composite sample of ears of five randomly selected plants in each plot, weight of 1000-grain was taken.

3.5.11 Grain yield/plant

Weight of cleaned and well dried grains of five randomly selected plants in each plot was weighted in grams.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference among the maize genotypes. The mean values of all the characters were evaluated and analysis of variance was performing by the ‘F’ test. The significance of the difference among the treatments means was estimated by the Duncan’s Multiple Range Test (DMRT) test at 5% level of probability (Gomez and Gomez, 1984).

3.7 Estimation of variability

Genotypic and phenotypic coefficient of variation and heritability were estimated by using the following formulae:

3.7.1 Estimation of components of variance from individual environment

Genotypic and phenotypic variances were estimated with the help of the following formula suggested by Johnson *et al.* (1955). The genotypic variance (σ^2_g) was estimated by subtracting error mean square (σ^2_e) from the genotypic mean square and dividing it by the number of replication (r) as per following formula -

$$\text{Genotypic variance } (\sigma^2_g) = \frac{MS_V - MS_E}{r}$$

Where,

MS_V = genotype mean square

MS_E = error mean square

r = number of replication

The phenotypic variance (σ^2_p), was derived by adding genotypic variances with the error variance, as given by the following formula –

$$\text{Phenotypic variance } (\sigma^2_{ph}) = \sigma^2_g + \sigma^2_e$$

Where,

σ^2_{ph} = phenotypic variance

σ^2_g = genotypic variance

σ^2_e = error variance

3.7.2 Estimation of genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated following formula as suggested by Burton (1952):

$$\% \text{ Genotypic coefficient of variance} = \frac{\sigma_g}{\bar{x}} \times 100$$

Where,

σ_g = genotypic standard deviation;

$\bar{x}$ = population mean

$$\% \text{ Phenotypic coefficient of variance} = \frac{\sigma_{ph}}{\bar{x}} \times 100$$

Where,

σ_{ph} = phenotypic standard deviation;

$\bar{x}$ = population mean

3.7.3 Estimation of heritability

Heritability in broad sense was estimated following the formula as suggested by Johnson *et al*. (1955):

$$\text{Heritability } (\%) = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$$

Where,

σ^2_g = genotypic variance and

σ^2_{ph} = phenotypic variance

3.7.4 Estimation of genetic Advance

The following formula was used to estimate the expected genetic advance for different characters under selection as suggested by Allard (1960):

$$GA = \frac{\sigma^2_g}{\sigma^2_p} \times K.\ \sigma_p$$

Where,

GA = Genetic advance

σ^2_g = genotypic variance

σ^2_{ph} = phenotypic variance

σ_{ph} = phenotypic standard deviation

K = Selection differential which is equal to 2.64 at 5% selection intensity

3.7.5 Estimation of Genetic Advance in percentage of mean

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952):

$$\text{Genetic Advance in percentage of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

3.8 Estimation of correlation

Simple correlation was estimated for different traits with the following formula (Singh and Chaudhary, 1985):

$$r = \frac{\sum xy - \frac{\sum x . \sum y}{N}}{\left[\left\{\sum x^2 - \frac{(\sum x)^2}{N}\right\}\left\{\sum y^2 - \frac{(\sum y)^2}{N}\right\}\right]^{1/2}}$$

Where,

$\sum$ = Summation

x and y are the two variables

N = Number of observations

3.9 Path co-efficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect of independent variables on the dependent variable.

In order to estimate direct and indirect effect of the correlated characters, say x_1, x_2, x_3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as given below:

$$ryx_1 = Pyx_1 + Pyx_2rx_1x_2 + Pyx_3rx_1x_3$$
$$ryx_2 = Pyx_1rx_1x_2 + Pyx_2 + Pyx_3rx_2x_3$$
$$ryx_3 = Pyx_1rx_1x_3 + Pyx_2\,rx_2x_3 + Pyx_3$$

Where, r's denotes simple correlation co-efficient and P's denote path co-efficient (unknown). P's in the above equations may be conveniently solved by arranging them in matrix form. Total correlation, say between x_1 and y is thus partitioned as follows:

Pyx_1 = The direct effect of x_1 on y

$Pyx_1rx_1x_2$ = The indirect effect of x_1 via x_2 on y

$Pyx_1rx_1x_3$ = The indirect effect of x_1 via x_3 on y

After calculating the direct and indirect effect of the studied characters, residual effect (R) was calculated by using the formula given below according to the Singh and Chaudhary, 1985):

$$P^2RY = 1 - \sum Piy.riy$$

Where,

$P^2RY = (R^2)$; and hence residual effect, $R = (P^2RY)^{1/2}$

Piy = Direct effect of the character on yield

riy = Correlation of the character with yield

3.10 Analysis of genetic divergence

Genetic divergences among the genotypes studied were assessed by using Mahalanobis' D^2 statistics and its auxiliary analysis. Both techniques estimate divergences among a set of genotypes on multivariate scale.

Mahalanobis' D^2 statistics

First the variation among the materials were tested by Wilkin's criteria '^'.

$$\text{'}\wedge\text{'} = \frac{|W|}{|S|} = \frac{|\text{Determination of error matrix}|}{|\text{Determination of error + variety matrix}|}$$

Now, 'v' $_{(stat)}$ = -m $\log_{e\wedge}$ = - {n-(p+q+1)/2}$\log_{e\wedge}$

Where,

m = n-(p+q+1)/2

p = number of variables or characters

q = number of varieties – 1 (or df for population)

n = df for error + varieties

e = 2.7183

Data were then analysed for D^2 statistics according to Rao (1952). Error variance and covariance matrix obtained from analysis of variance and covariance were inverted by pivotal condensation method. Using the pivotal elements the original means of the characters (X_1, X_2---------X_8) were transformed into a set of uncorrelated variables (Y_1, Y_2---------Y_8).

Now, the genetic divergence between two varieties/lines (suppose Vi and Vj was calculated as –

$$D^2ij = \sum_{k=1}^{8} (Vik - Vjk)^2$$

Where,

D^2ij = Genetic divergence between 'i' th and 'j' th genotypes

Vik = Transformed mean of the 'i' th genotype for 'k' th character

Vjk = Transformed mean of the 'j' th genotype for 'k' th character

The D^2 values between all the studied genotypes were arranged in order of relative distances from each other and were used for clusters formation, as suggested by Rao, 1952.

$$\text{Average intra-cluster } D^2 = \frac{\sum D^2 i}{n}$$

Where,

$\sum D^2 i$ = Sum of distances between all possible combinations (n) of the genotypes included in a cluster.

N = All possible combinations.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the genetic variability, correlation and path co-efficient analysis for yield and yield contributing characters of maize. Mean performance, variability, correlation matrix and path analysis on different yield contributing characters and yield of maize genotypes was estimated. The findings of the experiment have been presented under the following headings and sub-headings:

4.1 Evaluation of mean performance of different yield contributing characters and yield of maize genotypes

Analysis of variance and mean performance was estimated and presented in Table 3 and Table 4. 'F' test revealed highly significant variation among 25 maize genotypes in terms of all the yield contributing characters and yield of maize. Significantly high level of variation for different yield contributing characters and yield of maize for the genotypes revealed the possibilities of improving the genetic yield potential of maize genotypes.

4.1.1 Days to initiation of male flower

Days to initiation of male flower showed statistically significant variation for different maize genotypes (Table 3). Data revealed that the average days to initiation of male flower was recorded around 71.67 days with a range from 65.00 to 80.00 days (Table 4). The highest days to initiation of male flower (80.00) was found in the genotype of Krishibid Bhutta-550 which was statistically similar (77.00 days and 76.67 days) to the maize genotypes of Krishibid PS-102 and AGRO G8255, whereas the lowest days (65.00) was found from the genotype of BARI Hybrid Maize-6. Data revealed that different variety required different days to initiation of male flower. BARI (1985) reported that around 78 days required for the initiation of male flowers.

Table 3. Analysis of variance (ANOVA) of the data on yield attributes and yield of different maize genotypes

Characters	Degrees of freedom (df)			Mean Sum of Square (MSS)		
	Replication	Genotypes	Error	Replication	Genotypes	Error
Days to initiation of male flower	2	24	48	1.213	33.486*	8.686
Days to initiation of female flower	2	24	48	5.880	37.013**	6.838
Days to maturity	2	24	48	5.813	53.598*	20.216
Plant height (cm)	2	24	48	64.819	190.585**	24.644
Tassel height (cm)	2	24	48	6.559	20.065**	4.524
Ear length (cm)	2	24	48	0.120	29.341*	5.780
Number of grains/cob	2	24	48	1187.487	4187.134*	161.643
Cob length (cm)	2	24	48	0.238	3.142**	0.349
Cob diameter (mm)	2	24	48	2.920	9.620**	2.248
Weight of 1000-grains (g)	2	24	48	241.773	1186.639**	294.204
Grain yield/plant (g)	2	24	48	168.070	1421.238**	158.309

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Table 4. Mean performance of yield attributes and yield of different maize genotypes

Genotypes	Days to initiation of male flower	Days to initiation of female flower	Days to maturity	Tassel height (cm)	Number of grains/cob	Cob diameter (mm)	Weight of 1000-grains (g)	Grain yield/plant (g)
BARI Hybrid Maize-6	65.00 d	68.33 c	101.67 e	47.81 a	629.12 a	35.84 a	432.67 a	272.21 a
BARI Hybrid Maize-7	70.33 b-d	71.00 bc	113.00 a-d	44.45 a-e	592.05 a-c	34.08 a-d	376.00 b-f	222.33 b-d
BARI Hybrid Maize-9	68.33 b-d	69.33 c	109.67 a-e	43.67 a-e	496.36 de	34.06 a-d	370.67 b-f	184.11 d
Shuvra	67.00 cd	68.67 c	105.67 de	46.40 a-c	589.40 a-d	31.42 b-e	363.67 d-f	214.22 b-d
Barnali	69.00 b-d	69.67 c	110.00 a-e	44.59 a-e	525.16 c-e	31.60 b-e	381.33 b-f	200.43 cd
AS-999	68.33 b-d	70.00 c	113.67 a-d	46.47 a-c	556.66 a-e	34.85 ab	373.00 b-f	207.73 cd
Kaberi-369	69.67 b-d	71.67 bc	115.33 a-d	45.73 a-c	616.49 ab	33.99 a-d	410.67 a-c	253.15 ab
NZ-001	69.67 b-d	71.67 bc	107.00 b-e	43.97 a-e	542.17 a-e	33.07 a-d	392.00 a-f	212.50 cd
NZ-003	69.00 b-d	70.33 bc	110.67 a-e	41.95 a-e	512.35 c-e	34.66 a-c	354.00 f	180.40 d
NZ-510	71.67 a-d	72.67 bc	114.67 a-d	46.44 a-c	539.20 a-e	34.77 a-c	378.33 b-f	204.94 cd
25KSS	73.67 a-d	75.67 a-c	117.67 ab	45.96 a-c	520.89 c-e	34.33 a-d	374.67 b-f	195.33 cd
ACI-3110	69.67 b-d	70.67 bc	114.33 a-d	46.90 ab	552.01 a-e	33.59 a-d	367.33 c-f	202.88 cd
BRAC-984	70.33 b-d	71.67 bc	110.33 a-e	42.00 a-e	500.68 c-e	32.13 a-d	385.00 b-f	193.22 cd
Pioneer-3785	72.33 a-d	74.00 a-c	112.67 a-d	41.49 b-e	499.00 c-e	32.54 a-d	368.67 b-f	183.50 d
Pioneer-07	72.33 a-d	74.67 a-c	111.67 a-e	42.89 a-e	529.74 b-e	30.65 c-e	407.00 a-d	215.58 b-d
GP-50	71.67 a-d	74.00 a-c	106.00 c-e	40.35 c-e	539.35 a-e	35.79 a	387.67 b-f	209.28 cd
987 Aotu	73.00 a-d	74.33 a-c	109.67 a-e	41.63 b-e	511.59 c-e	32.51 a-d	365.67 d-f	186.72 cd
GP-901	73.00 a-d	74.67 a-c	111.67 a-e	40.70 c-e	547.51 a-e	35.47 ab	382.00 b-f	209.45 cd
GP-838	72.33 a-d	74.67 a-c	110.00 a-e	40.95 b-e	546.22 a-e	33.27 a-d	375.67 b-f	204.57 cd
PAC-555	72.33 a-d	73.67 a-c	109.00 a-e	43.31 a-e	499.38 c-e	33.70 a-d	365.33 d-f	183.49 d
Elite	73.67 a-d	74.67 a-c	115.00 a-d	38.87 e	568.29 a-e	33.13 a-d	401.67 a-e	228.20 bc
Krishibid PS-102	77.00 ab	78.33 ab	117.00 a-c	45.91 a-c	494.42 e	33.09 a-d	410.33 a-c	202.74 cd
Krishibid Bhutta-550	80.00 a	81.67 a	117.00 a-c	41.29 b-e	513.26 c-e	30.44 de	412.00 ab	211.70 cd
Krishibid-222	75.33 a-c	75.67 a-c	114.33 a-d	39.09 de	510.13 c-e	28.20 e	361.67 ef	183.58 d
AGRO G8255	76.67 ab	81.33 a	120.00 a	45.14 a-d	515.16 c-e	33.00 a-d	361.33 ef	186.24 cd
Mean	71.67	73.33	112.00	43.52	537.86	33.21	382.33	205.94
CV(%)	6.03	5.60	4.91	7.09	8.64	6.21	5.81	10.40

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Plate 2. Photograph showing male and female flower of maize

4.1.2 Days to initiation of female flower

Statistically significant variation was recorded for days to initiation of female flower of different maize genotypes (Table 3). The average days to initiation of female flower was recorded around 73.33 days with a range from 68.33 to 81.67 days (Table 4). The highest days to initiation of female flower (81.67) was found in the genotype of Krishibid Bhutta-550 which was statistically similar (81.33 days) to the maize genotypes of AGRO G8255, while the lowest days (68.33) was found from the genotype of BARI Hybrid Maize-6.

4.1.3 Days to maturity

Statistically significant variation was recorded for days to maturity of different maize genotypes (Table 3). The average days to maturity was recorded around 120.00 days with a range from 101.67 to 120.00 days (Table 4). The highest days to maturity (120.00) was found in the genotype of AGRO G8255 which was statistically similar (117.67 days) to the maize genotypes of 25KSS, whereas the lowest days (101.67) was found from the genotype of BARI Hybrid Maize-6. BARI (1985) reported that same varieties took 123 days (Pirsabak) to 138 days (Across 7740) to attain maturity.

4.1.4 Plant height (cm)

Plant height varied significantly due to different maize genotypes under the present trial (Table 3). The average plant height was recorded around 183.12 cm with a range from 160.80 cm to 194.90 cm (Figure 1). The longest plant (194.90 cm) was found in the genotype of GP-50 which was statistically similar (193.66 cm and 191.18 cm) to the maize genotypes of GP-901 and AS 999, while the shortest plant (160.80 cm) was observed from the genotype of Krishibi-222. Yusuf (2010) mean plant height of the genotypes ranged from 51-136 cm for the inbred parent CML177 and the hybrid, CML181 × CML176. Different plant height is presented Plate 3.

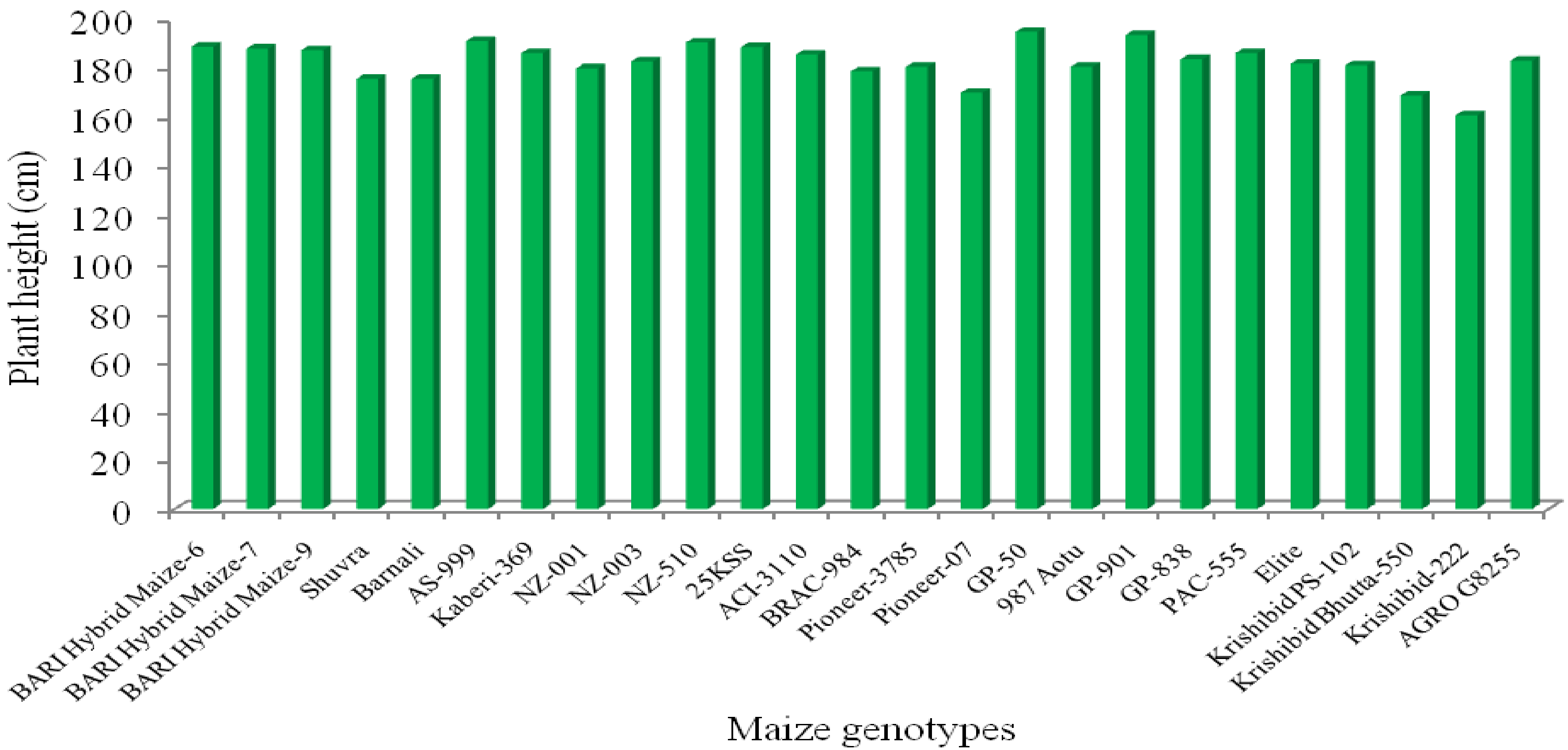

Figure 1. Plant height of maize for different genotypes


BARI Hybrid Maize-6


BARI Hybrid Maize-7


BARI Hybrid Maize-9


Shuvra


Barnali

AS-999


Kaberi-369


NZ-001


NZ-003

NZ-510


25KSS


ACI-3110


BRAC-984


Pioneer-3785


Pioneer-07

Plate 3. Photograph showing the plant height of different genotypes of maize (cont'd)


GP-50


987 Aotu


GP-901


GP-838


PAC-555


Elite


Krishibid PS-102


Krishibid Bhutta-550


Krishibid-222


AGRO G8255

Plate 3. Photograph showing the plant height of different genotypes of maize

4.1.5 Tassel height (cm)

Tassel height varied significantly due to different maize genotypes (Table 3). The average tassel height was recorded around 43.54 cm with a range from 38.87 cm to 47.81 cm (Table 4). The longest tassel (47.81 cm) was recorded in the genotype of BARI Hybrid Maize-6, while the shortest tassel (38.87 cm) was observed from the genotype of Elite.

4.1.6 Ear length (cm)

Ear length varied significantly due to different maize genotypes (Table 3). The average ear length was recorded around 83.85 cm with a range from 78.31 cm to 92.03 cm (Figure 2). The longest ear (92.03 cm) was recorded in the genotype of Krishibid Bhutta-550 which was statistically similar (88.88 cm) to AGRO G8255, while the shortest ear (78.31 cm) was observed from the genotype of BARI Hybrid Maize-6.

4.1.7 Number of grains/cob

Number of grains/cob varied significantly due to different maize genotypes (Table 3). The average number of grains/cob was recorded around 537.86 with a range from 494.42 to 629.12 (Table 4). The highest number of grains/cob (629.12) was recorded in the genotype of BARI Hybrid Maize-6 which was statistically similar (616.49) to Kaberi-369, whereas the lowest number (494.42) was observed from the genotype of Krishibid Bhutta-550.

4.1.8 Cob length (cm)

Cob length varied significantly due to different maize genotypes (Table 3). The average cob length was recorded around 17.87 cm with a range from 15.28 cm to 19.53 cm (Figure 3). The longest cob (19.53 cm) was recorded in the genotype of BARI Hybrid Maize-6 which was statistically similar (19.21 cm) to Kaberi-369, whereas the shortest cob (15.28 cm) was observed from the genotype of Krishibid-222. Cob of different genotypes is presented in Plate 4.

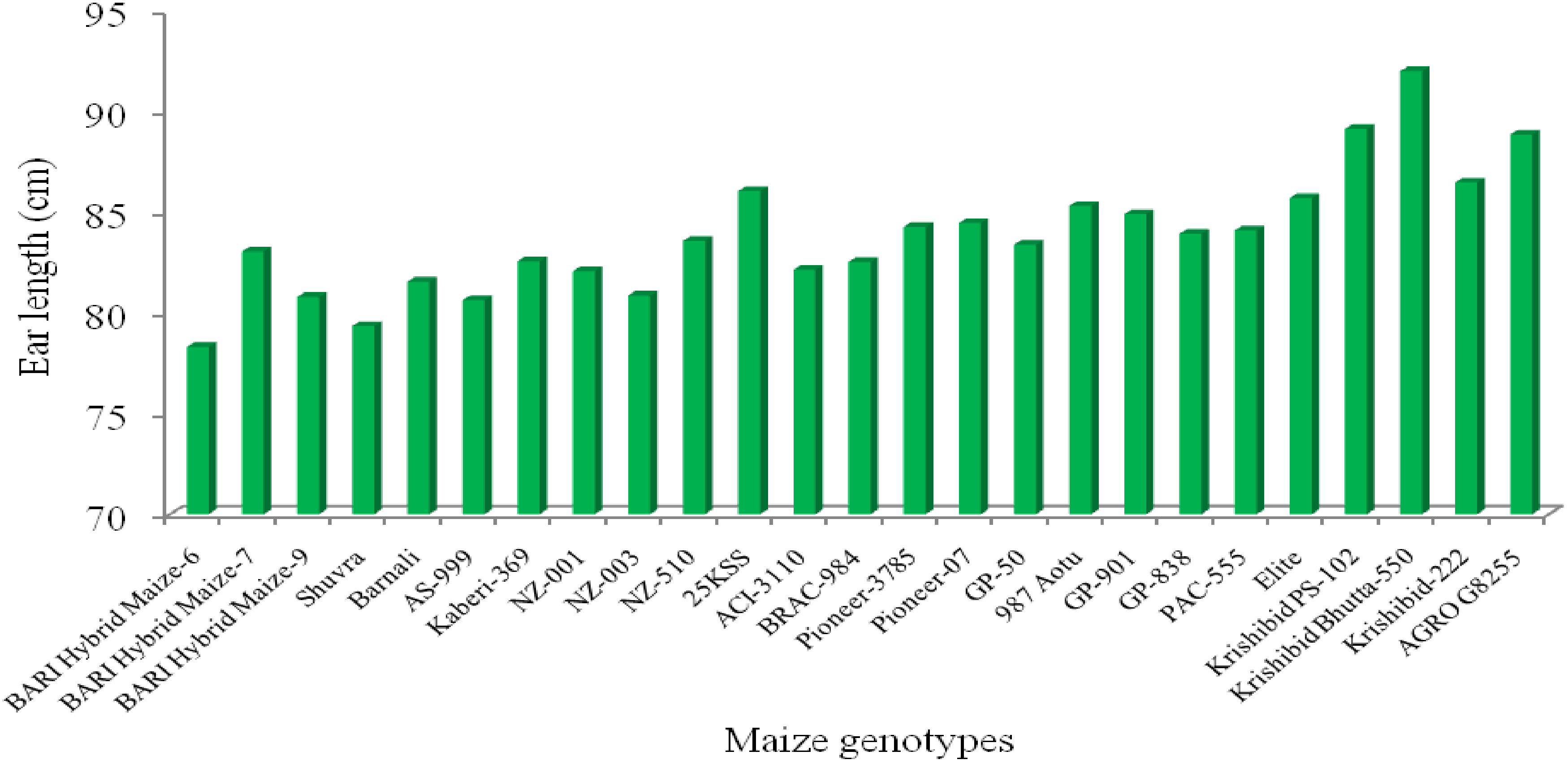

Figure 2. Ear length of maize for different genotypes

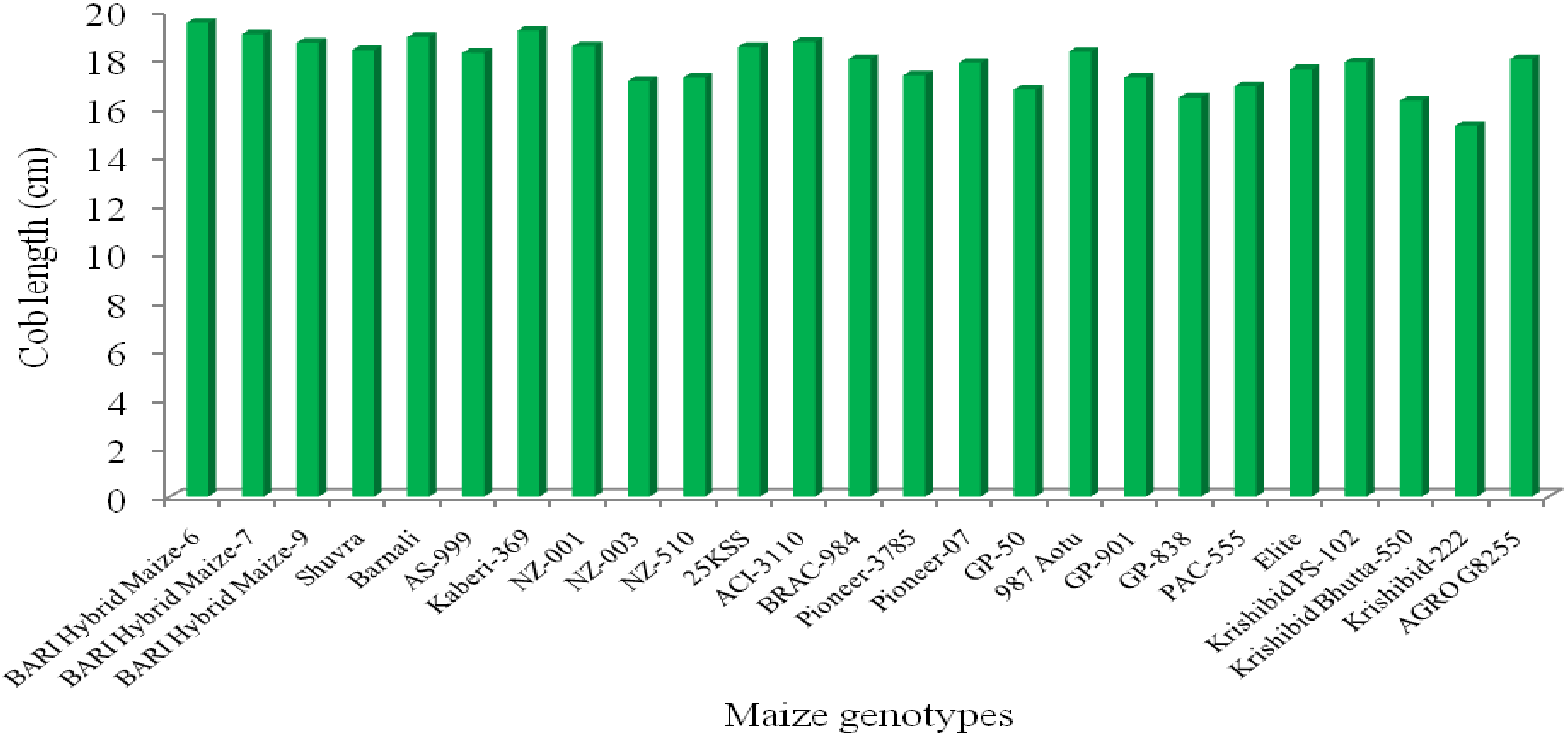

Figure 3. Cob length of maize for different genotypes

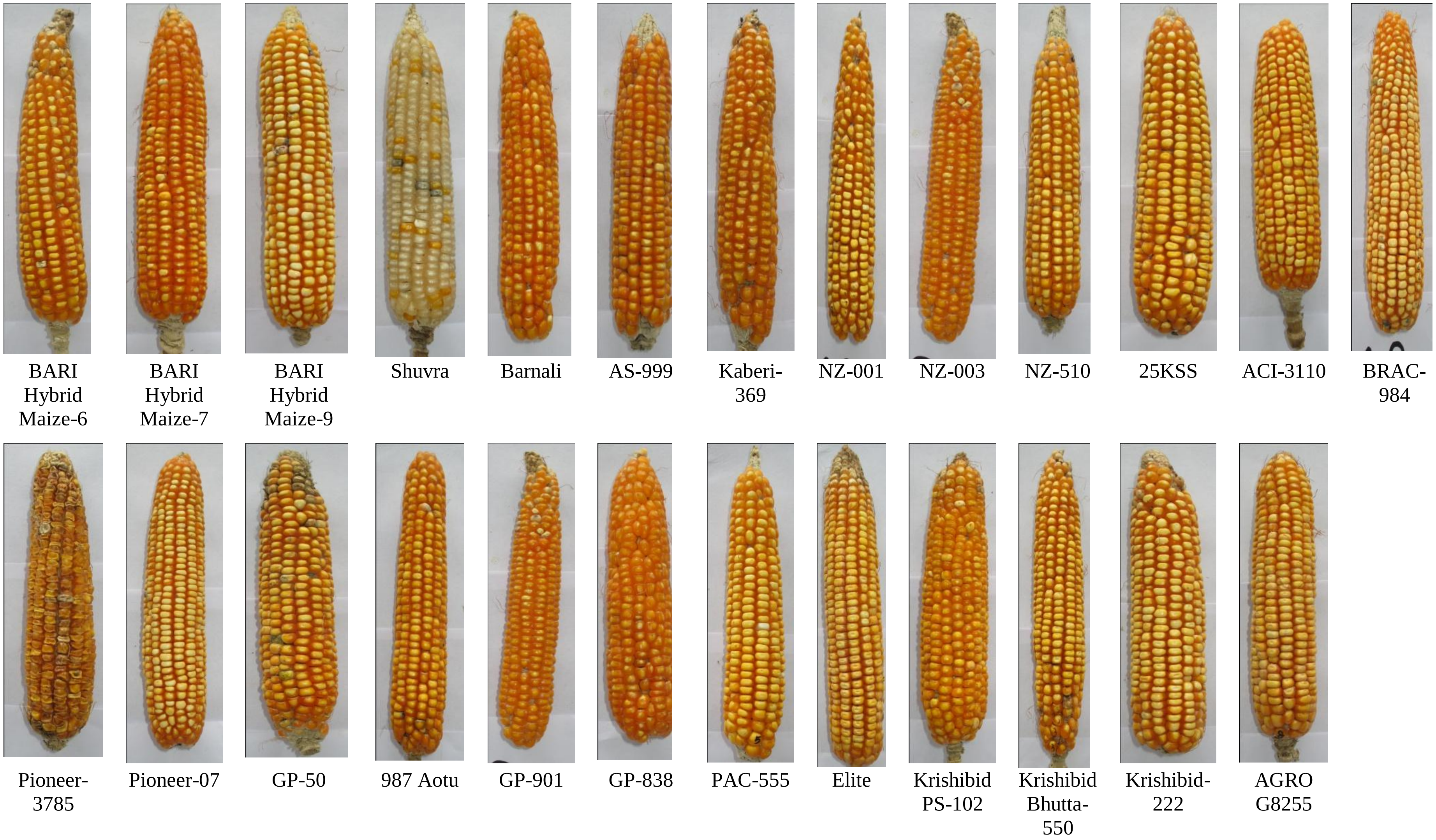

Plate 4. Photograph showing cob of different maize genotypes

4.1.9 Cob diameter (mm)

Cob diameter varied significantly due to different maize genotypes (Table 3). The average cob diameter was recorded around 33.21 mm with a range from 28.20 mm to 35.84 mm (Table 4). The highest cob diameter (35.84 mm) was recorded in the genotype of BARI Hybrid Maize-6 which was statistically similar (35.79 mm) to GP-50, whereas the lowest cob diameter (28.20 mm) was observed from the genotype of Krishibid-222.

4.1.10 Weight of 1000-grains (g)

Weight of 1000-grains varied significantly due to different maize genotypes (Table 3). The average weight of 1000-grains was recorded around 382.33 g with a range from 354.00 g to 432.67 g (Table 4). The highest weight of 1000-grains (432.67 g) was recorded in the genotype of BARI Hybrid Maize-6, while the lowest weight of 1000-grains (354.00 g) was observed from the genotype of NZ-003.

4.1.11 Grain yield/plant (g)

Grain yield/plant varied significantly due to different maize genotypes under the present trial (Table 3). Data revealed that the average cob length was recorded around 205.94 g with a range from 180.40 g to 272.21 g (Table 4). The highest grain yield/plant (272.21 g) was recorded in the genotype of BARI Hybrid Maize-6 which was statistically similar (253.15 g) to Kaberi-369, whereas the lowest grain yield/plant (180.40 g) was observed from the genotype of NZ-003. Quaranta *et al*. (2005) reported that hybrids Narbone, Net, Potenza 581, KWS 0551, Helder and Aristo had the highest yield.

4.2 Variability study for 11 traits of maize

Genotypic and phenotypic variance, heritability, genetic advance and genetic advance in percentage of mean were estimated for 11 traits in 25 genotypes of maize and presented in Table 5.

4.2.1 Days to initiation of male flower

Days to initiation of male flower refers to phenotypic variance (16.95) was higher than the genotypic variance (8.27) that indicating high environmental influence on this characters which was supported by narrow difference between phenotypic (5.74%) and genotypic (4.01%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (48.76%) in days to initiation of male flower attached with low genetic advance (5.30) and high genetic advance in percentage of mean (7.40). Moderate estimate of heritability and low genetic advance for days to initiation of male flower suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.2 Days to initiation of female flower

Days to initiation of female flower refers to phenotypic variance (16.90) was higher than the genotypic variance (10.06) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (5.61%) and genotypic (4.32%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (59.53%) in days to initiation of female flower attached with low genetic advance (6.46) and high genetic advance in percentage of mean (8.81). Moderate estimate of heritability and low genetic advance for days to initiation of female flower suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

Table 5. Genetic parameters for yield attributes and yield of different maize genotypes

Characters	Genotypic variance ($\sigma^2 g$)	Phenotypic variance ($\sigma^2 p$)	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (%)	Genetic Advance (GA)	GA in percentage of mean
Days to initiation of male flower	8.27	16.95	4.01	5.74	48.76	5.30	7.40
Days to initiation of female flower	10.06	16.90	4.32	5.61	59.53	6.46	8.81
Days to maturity	11.13	31.34	2.98	5.00	35.50	5.25	4.68
Plant height (cm)	55.31	79.96	4.07	4.90	69.18	16.33	8.94
Tassel height (cm)	5.18	9.70	5.23	7.16	53.38	4.39	10.09
Ear length (cm)	4.85	10.63	2.63	3.89	45.64	3.93	4.69
Number of grains/cob	1341.83	1503.47	6.81	7.21	89.25	91.36	16.99
Cob length (cm)	0.93	1.28	5.40	6.33	72.73	2.17	12.16
Cob diameter (mm)	2.46	4.71	4.72	6.53	52.22	2.99	9.01
Weight of 1000-grains (g)	297.48	591.68	4.51	6.36	50.28	32.29	8.44
Grain yield/plant (g)	420.98	579.29	9.96	11.69	72.67	46.18	22.42

4.2.3 Days to maturity

Days to maturity refers to phenotypic variance (31.34) was higher than the genotypic variance (11.13) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (5.00%) and genotypic (2.98%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Low heritability (35.50%) in days to maturity attached with moderate genetic advance (5.25) and high genetic advance in percentage of mean (4.68). The low heritability along with moderate genetic advance in percentage of mean for days to maturity indicated that environment control was not predominant for this character.

4.2.4 Plant height (cm)

Plant height refers to phenotypic variance (79.96) was higher than the genotypic variance (55.31) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (4.90%) and genotypic (4.07%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. High heritability (69.18%) in plant height attached with low genetic advance (16.33) and high genetic advance in percentage of mean (8.94). The high heritability along with low genetic advance in plant height indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.5 Tassel height (cm)

Tassel height refers to phenotypic variance (9.70) was higher than the genotypic variance (5.18) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (7.16%) and genotypic (5.23%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (53.38%) in tassel height attached with low genetic advance (4.39) and high genetic advance in percentage of mean (10.09).

Moderate estimate of heritability and low genetic advance for tassel height suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.6 Ear length (cm)

Ear length refers to phenotypic variance (10.63) was higher than the genotypic variance (4.85) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (3.89%) and genotypic (2.63%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (45.64%) in ear length attached with low genetic advance (3.93) and high genetic advance in percentage of mean (4.69). Moderate estimate of heritability and low genetic advance for ear length suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.7 Number of grains/cob

Number of grains/cob refers to phenotypic variance (1503.47) was higher than the genotypic variance (1341.83) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (7.21%) and genotypic (6.811%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. High heritability (89.25%) in number of grains/cob attached with low genetic advance (91.36) and high genetic advance in percentage of mean (16.99). The high heritability along with low genetic advance in number of grains/cob indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.8 Cob length (cm)

Cob length refers to phenotypic variance (1.28) was higher than the genotypic variance (0.93) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (6.33%) and genotypic (5.40%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. High heritability (72.73%) in cob length attached with low genetic advance (2.17) and high genetic advance in percentage of mean (12.16). The high heritability along with low genetic advance in cob length indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in respect of this trait.

4.2.9 Cob diameter (mm)

Cob diameter refers to phenotypic variance (4.71) was higher than the genotypic variance (2.46) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (6.53%) and genotypic (4.72%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (52.22%) in cob diameter attached with low genetic advance (2.99) and high genetic advance in percentage of mean (9.01). Moderate estimate of heritability and low genetic advance for cob diameter suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.10 Weight of 1000-grains (g)

Weight of 1000-grains refers to phenotypic variance (591.68) was higher than the genotypic variance (297.48) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (6.36%) and genotypic (4.51%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. Moderate heritability (50.28%) in weight of 1000-

grains attached with high genetic advance (32.29) and low genetic advance in percentage of mean (8.44). Moderate estimate of heritability and low genetic advance for weight of 1000-grains suggested that this character was predominantly controlled by environment with complex gene interaction and this also indicated the importance of both additive and non additive genetic effects for the control of this character.

4.2.11 Grain yield/plant (g)

Grain yield/plant refers to phenotypic variance (579.29) was higher than the genotypic variance (420.98) that indicating that high environmental influence on this characters which was supported by narrow difference between phenotypic (11.69%) and genotypic (9.96%) co-efficient of variation (Table 5). The high difference for this parameter was also suggested a highly significant influence of environment. High heritability (72.67%) in grain yield/plant attached with high genetic advance (46.18) and low genetic advance in percentage of mean (22.42). The high heritability along with low genetic advance in grain yield/plant indicated the possible scope for improvement through selection of the character and breeder may expect reasonable benefit in next generation in respect of this trait.

4.3 Correlation Matrix

To measure the mutual relationship among yield and yield contributing characters of maize genotypes correlation matrix analysis was done and also to determine the component characters on which selection could be based for improvement in yield of 25 genotypes of maize (Table 6).

4.3.1 Days to initiation of male flower

Highly significant positive association was recorded for days to initiation of male flower of maize genotypes with days to initiation of female flower (0.892), days to maturity (0.475) and ear length (0.940), while the non significant positive association was recorded for weight of 1000-grains (0.016) (Table 6). On the other hand, highly significant negative association was recorded for cob length (-0.380), whereas non significant negative association was observed with plant height (-0.055), tassel height (-0.071), number of grains/cob (-0.214), cob diameter (-0.201) and grain yield/plant (-0.155).

4.3.2 Days to initiation of female flower

Highly significant positive association was recorded for days to initiation of female flower of maize genotypes with days to initiation of male flower (0.892), days to maturity (0.516) and ear length (0.832), whereas the non significant positive association was recorded for weight of 1000-grains (0.013) (Table 6). On the other hand, significant negative association was recorded for cob length (-0.344) and cob diameter (-0.240), while non significant negative association was observed with plant height (-0.122), tassel height (-0.073) and number of grains/cob (-0.208) and grain yield/plant (-0.149).

4.3.3 Days to maturity

Highly significant positive association was recorded for days to maturity of maize genotypes with days to initiation of male flower (0.475), days to initiation of female flower (0.516) tassel height (0.320) and ear length (0.475), while the non significant positive association was recorded for plant height (0.054), cob length (0.001) and weight of 1000-grains (0.065) (Table 6).

Table 6. Correlation matrix for yield attributes and yield of different maize genotypes

Characters	Days to initiation of male flower	Days to initiation of female flower	Days to maturity	Plant height (cm)	Tassel height (cm)	Ear length (cm)	Number of grains/cob	Cob length (cm)	Cob diameter (mm)	Weight of 1000-grains (g)	Grain yield/plant (g)
Days to initiation of male flower	1.00										
Days to initiation of female flower	0.892**	1.00									
Days to maturity	0.475**	0.516**	1.00								
Plant height (cm)	-0.055	-0.122	0.054	1.00							
Tassel height (cm)	-0.071	-0.073	0.320**	0.271*	1.00						
Ear length (cm)	0.940**	0.832**	0.475**	-0.058	0.017	1.00					
Number of grains/cob	-0.214	-0.208	-0.172	0.164	0.243*	-0.226*	1.00				
Cob length (cm)	-0.380**	-0.344**	0.001	0.171	0.312**	-0.299**	0.373**	1.00			
Cob diameter (mm)	-0.201	-0.240*	-0.038	0.817**	0.308**	-0.187	0.249*	0.181	1.00		
Weight of 1000-grains (g)	0.016	0.013	0.065	0.187	0.320**	0.048	0.213	0.208	0.222*	1.00	
Grain yield/plant (g)	-0.155	-0.149	-0.099	0.235*	0.359**	-0.147	0.854**	0.390**	0.313**	0.689**	1.00

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

On the other hand, non negative association was observed with number of grains/cob (-0.172), cob diameter (-0.038) and grain yield/plant (-0.099).

4.3.4 Plant height (cm)

Highly significant positive association was recorded for plant height of maize genotypes with tassel height (0.271), cob diameter (0.817) and yield/plant (0.235), while the non significant positive association was recorded for days to maturity (0.054), number of grains/cob (0.164), cob length (0.171) and, weight of 1000-grains (0.187) (Table 6). On the other hand, non significant negative association was observed with days to initiation of male flower (-0.055), days to initiation of female flower (-0.122), ear length (-0.058).

4.3.5 Tassel height (cm)

Highly significant positive association was recorded for tassel height of maize genotypes with days to maturity (0.320), plant height (0.271), cob length (0.312), cob diameter (0.308), weight of 1000-grains (0.320) and grain yield/plant (0.359) and significant positive association was recorded in number of grains/cob (0.243), while the non significant positive association was recorded for ear length (0.017) (Table 6). On the other hand, non significant negative association was observed with days to initiation of male flower (-0.071), days to initiation of female flower (-0.073).

4.3.6 Ear length (cm)

Highly significant positive association was recorded for ear length of maize genotypes with days to initiation of male flower (0.940), days to initiation of female flower (0.832) and days to maturity (0.475), while the non significant positive association was recorded for tassel height (0.017) and weight of 1000-grains (0.048) (Table 6). On the other hand, significant negative association was recorded for number of grains/cob (-0.226) and cob length (-0.299), whereas non significant negative association was observed with plant height (-0.058), cob length (0.187) and grain yield/plant (-0.147). Shahrokhi and Khorasani (2013) reported that total yields showed significant association with ear height of maize.

4.3.7 Number of grains/cob

Highly significant positive association was recorded for number of grains/cob of maize genotypes with tassel height (0.243), cob length (0.373), cob diameter (0.249) and grain yield/plant (0.854), while the non significant positive association was recorded for plant height (0.164) and weight of 1000-grains (0.213) (Table 6). On the other hand, significant negative association was recorded for ear length (-0.226), whereas non significant negative association was observed with days to initiation of male flower (-0.214), days to initiation of female flower (-0.208), days to maturity (-0.172).

4.3.8 Cob length (cm)

Highly significant positive association was recorded for cob length of maize genotypes with days to tassel height (0.312), number of grains/cob (0.373) and grain yield/plant (0.390), while the non significant positive association was recorded for days to maturity (0.001), plant height (0.171), cob diameter (0.181) and weight of 1000-grains (0.208) (Table 6). On the other hand, significant negative association was recorded for days to initiation of male flower (-0.380), days to initiation of female flower (-0.344) and ear length (-0.299).

4.3.9 Cob diameter (mm)

Significant positive association was recorded for cob diameter of maize genotypes with plant height (0.817), tassel height (0.308), number of grains/cob (0.249), weight of 1000-grains (0.222) and grain yield/plant (0.313), while the non significant positive association was recorded for cob length (0.181) (Table 6). On the other hand, significant negative association was recorded for days to initiation of female flower (-0.240), whereas non significant negative association was observed with days to initiation of male flower (-0.201), days to maturity (-0.038) and ear length (-0.187).

4.3.10 Weight of 1000-grains (g)

Highly significant positive association was recorded for weight of 1000-grains of maize genotypes with tassel height (0.320), cob diameter (0.222) and grain yield/plant (0.689), while the non significant positive association was recorded for days to initiation of male flower (0.016), days to initiation of female flower (0.013), days to maturity (0.065), plant height (0.187), ear length (0.048), number of grains/cob (0.213) and cob length (0.208) (Table 6).

4.3.11 Grain yield/plant (g)

Highly significant positive association was recorded for grain yield/plant of maize genotypes with plant height (0.235), tassel height (0.359), number of grains/cob (0.854), cob length (0.390), cob diameter (0.313) and weight of 1000-grains (0.689), while non significant negative association was observed with days to initiation of male flower (-0.155), days to initiation of female flower (-0.149), days to maturity (-0.099) and ear length (-0.147). Tusuz and Balabanl (1997) reported that 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).

4.4 Path co-efficient analysis

Path co-efficient analysis denotes the components of correlation co-efficient within different traits into the direct and indirect effects and indicates the relationship in more meaningful way. The results of the path co-efficient analysis are presented in Table 7.

4.4.1 Yield/plant *vs* days to initiation of male flower

Path analysis revealed that days to initiation of male flower had positive direct effect (0.132) on yield/plant (Table 7). It showed negligible positive indirect effect through days to maturity, tassel height and ear length, whereas days to initiation of male flower showed negative indirect effect through days to initiation of female flower, plant height, number of grains/cob, cob length, cob diameter and weight of 1000-grains.

4.4.2 Yield/plant *vs* days to initiation of female flower

Path analysis revealed that days to initiation of female flower had negative direct effect (-0.254) on yield/plant (Table 7). It showed negligible positive indirect effect through plant height, number of grains/cob and weight of 1000-grains, whereas days to initiation of female flower showed negative indirect effect through days to initiation of male flower, days to maturity, tassel height, ear length, cob length and cob diameter.

4.4.3 Yield/plant *vs* days to maturity

Path analysis revealed that days to maturity had positive direct effect (0.178) on yield/plant (Table 7). It showed negligible positive indirect effect through days to initiation of male flower, days to initiation of female flower, days to maturity, plant height, ear length and number of grains/cob, while days to maturity showed negative indirect effect through tassel height, cob length, cob diameter and weight of 1000-grains.

Table 7. Path coefficients for yield attributes and yield of different maize genotypes

Characters	Days to initiation of male flower	Days to initiation of female flower	Days to maturity	Plant height (cm)	Tassel height (cm)	Ear length (cm)	Number of grains/cob	Cob length (cm)	Cob diameter (mm)	Weight of 1000-grains (g)	Grain yield/plant (g)
Days to initiation of male flower	**0.132**	-0.109	0.168	-0.098	0.230	0.079	-0.158	-0.207	-0.133	-0.059	-0.155
Days to initiation of female flower	-0.167	**-0.254**	-0.156	0.249	-0.026	-0.107	0.216	-0.008	-0.209	0.313	-0.149
Days to maturity	0.202	0.055	**0.178**	0.213	-0.279	0.085	0.081	-0.234	-0.167	-0.233	-0.099
Plant height (cm)	0.115	0.232	-0.212	**0.314**	-0.079	-0.155	0.104	-0.209	0.167	-0.042	0.235
Tassel height (cm)	-0.167	-0.111	0.096	-0.195	**0.234**	0.198	-0.044	0.267	-0.133	0.214	0.359
Ear length (cm)	-0.109	0.071	-0.215	0.067	-0.270	**0.197**	0.056	0.098	0.213	-0.255	-0.147
Number of grains/cob	0.178	-0.143	0.222	-0.047	0.294	0.194	**-0.095**	-0.038	-0.048	0.337	0.854
Cob length (cm)	0.139	0.212	-0.155	0.234	-0.118	0.167	-0.031	**0.167**	-0.127	-0.098	0.390
Cob diameter (mm)	-0.128	-0.087	0.154	-0.109	0.158	0.158	0.098	-0.241	**0.168**	0.142	0.313
Weight of 1000-grains (g)	0.095	0.145	0.254	-0.109	0.158	-0.034	0.269	-0.241	-0.065	**0.217**	0.689

Residual effect = 0.2198

4.4.4 Yield/plant *vs* plant height

Path analysis revealed that plant height had positive direct effect (0.314) on yield/plant (Table 7). It showed negligible positive indirect effect through days to initiation of male flower, days to initiation of female flower, number of grains/cob and cob diameter, whereas plant height showed negative indirect effect through days to maturity, tassel height, ear length, cob length and weight of 1000-grains.

4.4.5 Yield/plant *vs* tassel height

Path analysis revealed that tassel height had positive direct effect (0.234) on yield/plant (Table 7). It showed negligible positive indirect effect through days to maturity, ear length, cob length and weight of 1000-grains, while tassel height showed negative indirect effect through days to initiation of male flower, days to initiation of female flower, plant height, number of grains/cob and cob diameter.

4.4.6 Yield/plant *vs* ear length

Path analysis revealed that ear length had positive direct effect (0.197) on yield/plant (Table 7). It showed negligible positive indirect effect through days to initiation of female flower, plant height, number of grains/cob, cob length and cob diameter, whereas ear length showed negative indirect effect through days to initiation of male flower, days to maturity, tassel height and weight of 1000-grains.

4.4.7 Yield/plant *vs* number of grains/cob

Path analysis revealed that number of grains/cob had negative direct effect (-0.095) on yield/plant (Table 7). It showed negligible positive indirect effect through days to initiation of male flower, days to maturity, tassel height, ear length and weight of 1000-grains, whereas number of grains/cob showed negative indirect effect through days to initiation of female flower, plant height, cob length and cob diameter.

4.4.8 Yield/plant *vs* cob length

Path analysis revealed that cob length had positive direct effect (0.167) on yield/plant (Table 7). It showed negligible positive indirect effect through days to initiation of male flower, days to initiation of female flower, plant height and ear length, while cob length showed negative indirect effect through days to maturity, tassel height, number of grains/cob, cob diameter and weight of 1000-grains.

4.4.9 Yield/plant *vs* cob diameter

Path analysis revealed that cob diameter had positive direct effect (0.168) on yield/plant (Table 7). It showed negligible positive indirect effect through days to maturity, tassel height, ear length, number of grains/cob and weight of 1000-grains, whereas cob diameter showed negative indirect effect through days to initiation of male flower, days to initiation of female flower, plant height and cob length.

4.4.10 Yield/plant *vs* weight of 1000-grains

Path analysis revealed that weight of 1000-grains had positive direct effect (0.217) on yield/plant (Table 7). It showed negligible positive indirect effect through days to initiation of male flower, days to initiation of female flower, days to maturity, tassel height and number of grains/cob, while weight of 1000-grains showed negative indirect effect through plant height, ear length, cob length and cob diameter.

4.5 Genetic diversity analysis

Study of genetic diversity among 25 genotypes of maize evaluated through Mahalanobis' D^2 statistics and which has been discussed below:

Mahalanobis D^2 statistics was used to measure the degree of diversification among the maize genotypes. Using this technique, grouping of genotypes was done in four clusters where genotypes grouped together were less divergent than the ones placed in different clusters. The clusters separated by greatest statistical distance exhibited maximum divergence. Composition of different clusters with their corresponding genotypes and their source are shown in Table 8. In clustering pattern denoted that, cluster III was the largest cluster comprising of 9 genotypes followed by cluster II and IV with 6 genotypes for each cluster, cluster I belongs 4 genotypes of maize (Table 8).

Cluster distances indicated by the average inter and intra-cluster distances are the approximate measure of the cluster divergence (Table 9). Inter cluster distance was maximum (13.034) between clusters I and III, followed by clusters III and IV (10.098). The intra and inter cluster distance presented in Figure 4. The results revealed that genotypes chosen for hybridization from clusters with highest distances would give high heterotic F_1 and broad spectrum of variability in segregating generations.

Table 8. Clustering pattern of 25 maize genotypes by Tocher's method

Cluster	Members	Genotypes
I	4	BARI Hybrid Maize-6; NZ-001, Elite and BARI Hybrid Maize-7
II	6	Shuvra, Barnali, AS-999, Kaberi-369, NZ-003, 25KSS,
III	9	ACI-3110, BRAC-984, Pioneer-3785, GP-50, 987 Aotu, GP-901, GP-838, Krishibid PS-102, Krishibid Bhutta-550
IV	6	BARI Hybrid Maize-9, NZ-510, Pioneer-07, PAC-555, Krishibid-222, AGRO G8255

Table 9. Average intra (bold) and inter-cluster D^2 and D values of 4 clusters for 25 maize genotypes formed by Torcher's method

Cluster	I	II	III	IV
I	**0.463**			
II	3.897	**0.230**		
III	13.034	4.267	**0.563**	
IV	6.951	3.691	10.098	**0.387**

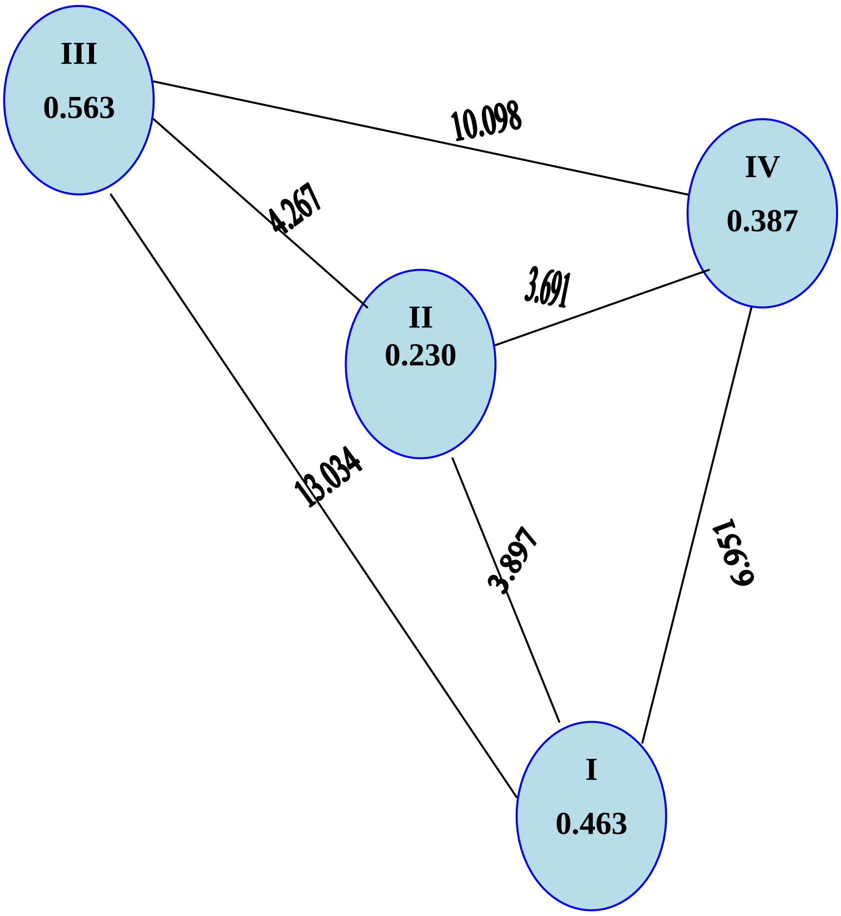

Figure 4. Intra and inter cluster distance between different cluster

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during March to June, 2014 to study the genetic variability, correlation and path co-efficient analysis for yield and yield contributing characters of maize. In this experiment 25 maize genotypes were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Mean performance, variability, correlation matrix and path analysis on different yield contributing characters and yield of maize genotypes was estimated.

The highest days to initiation of male flower (80.00) was found in the genotype of Krishibid Bhutta-550, whereas the lowest days (65.00) from BARI Hybrid Maize-6. The highest days to initiation of female flower (81.67) was found in the genotype of Krishibid Bhutta-550, while the lowest days (68.33) from Maize-6. The highest days to maturity (120.00) was found in the genotype of AGRO G8255, whereas the lowest days (101.67) from BARI Hybrid Maize-6. The longest plant (194.90 cm) was found in the genotype of GP-50, while the shortest plant (160.80 cm) from Krishibi-222. The longest tassel (47.81 cm) was recorded in the genotype of BARI Hybrid Maize-6, while the shortest tassel (38.87 cm) from Elite. The longest ear (92.03 cm) was recorded in the genotype of Krishibid Bhutta-550, while the shortest ear (78.31 cm) from BARI Hybrid Maize-6. The highest number of grains/cob (629.12) was recorded in the genotype of BARI Hybrid Maize-6, whereas the lowest number (494.42) from Krishibid Bhutta-550. The longest cob (19.53 cm) was recorded in the genotype of BARI Hybrid Maize-6, whereas the shortest cob (15.28 cm) from Krishibid-222. The highest cob diameter (35.84 mm) was recorded in the genotype of BARI Hybrid Maize-6, whereas the lowest cob diameter (28.20 mm) from Krishibid-222. The highest weight of 1000-grains (432.67 g) was recorded in the genotype of BARI Hybrid Maize-6, while the lowest weight of 1000-grains

(354.00 g) from NZ-003. The highest grain yield/plant (272.21 g) was recorded in the genotype of BARI Hybrid Maize-6, whereas the lowest grain yield/plant (180.40 g) from NZ-003.

In consideration of days to initiation of male flower refers to phenotypic variance (16.95) was higher than the genotypic variance (8.27) which was supported by narrow difference between phenotypic (5.74%) and genotypic (4.01%) co-efficient of variation attached with moderate heritability (48.76%) attached with low genetic advance (5.30) and high genetic advance in percentage of mean (7.40). Days to initiation of female flower refers to phenotypic variance (16.90) was higher than the genotypic variance (10.06) which was supported by narrow difference between phenotypic (5.61%) and genotypic (4.32%) co-efficient of variation attached with moderate heritability (59.53%) attached with low genetic advance (6.46) and high genetic advance in percentage of mean (8.81). Days to maturity refers to phenotypic variance (31.34) was higher than the genotypic variance (11.13) which was supported by narrow difference between phenotypic (5.00%) and genotypic (2.98%) co-efficient of variation with low heritability (35.50%) attached with low genetic advance (5.25) and high genetic advance in percentage of mean (4.68). Plant height refers to phenotypic variance (79.96) was higher than the genotypic variance (55.31) supported by narrow difference between phenotypic (4.90%) and genotypic (4.07%) co-efficient of variation with high heritability (69.18%) attached with low genetic advance (16.33) and high genetic advance in percentage of mean (8.94). Tassel height refers to phenotypic variance (9.70) was higher than the genotypic variance (5.18) which was supported by narrow difference between phenotypic (7.16%) and genotypic (5.23%) co-efficient of variation with moderate heritability (53.38%) attached with low genetic advance (4.39) and high genetic advance in percentage of mean (10.09). Ear length refers to phenotypic variance (10.63) was higher than the genotypic variance (4.85) which was supported by narrow difference between phenotypic (3.89%) and genotypic (2.63%) co-efficient of variation with moderate heritability (45.64%) attached with low genetic advance (3.93) and high genetic advance in percentage of mean (4.69). Number of grains/cob refers to phenotypic variance (1503.47) was higher than the genotypic variance (1341.83) which was supported by narrow difference between phenotypic (7.21%) and genotypic (6.811%) co-efficient of variation with high heritability (89.25%) attached with low genetic advance (91.36) and high genetic advance in percentage of mean (16.99). Cob length refers to phenotypic variance (1.28) was higher than the genotypic variance (0.93) which was supported by narrow difference between phenotypic (6.33%) and genotypic (5.40%) co-efficient of variation with high heritability (72.73%) attached with low genetic advance (2.17) and high genetic advance in percentage of mean (12.16). Cob diameter refers to phenotypic variance (4.71) was higher than the genotypic variance (2.46) which was supported by narrow difference between phenotypic (6.53%) and genotypic (4.72%) co-efficient of variation with moderate heritability (52.22%) attached with low genetic advance (2.99) and high genetic advance in percentage of mean (9.01). Weight of 1000-grains refers to phenotypic variance (591.68) was higher than the genotypic variance (297.48) which was supported by narrow difference between phenotypic (6.36%) and genotypic (4.51%) co-efficient of variation with moderate heritability (50.28%) attached with high genetic advance (32.29) and low genetic advance in percentage of mean (8.44). Grain yield/plant refers to phenotypic variance (579.29) was higher than the genotypic variance (420.98) which was supported by narrow difference between phenotypic (11.69%) and genotypic (9.96%) co-efficient of variation with high heritability (72.67%) with high genetic advance (46.18) and low genetic advance in percentage of mean (22.42).

In correlation study, significant positive association was recorded for grain yield/plant of maize genotypes with plant height (0.235), tassel height (0.359), number of grains/cob (0.854), cob length (0.390), cob diameter (0.313) and weight of 1000-grains (0.689), while non significant negative association was observed with days to initiation of male flower (-0.155), days to initiation of female flower (-0.149), days to maturity (-0.099) and ear length (-0.147).

Path analysis revealed that, days to initiation of male flower had positive direct effect (0.132) on yield/plant. Days to initiation of female flower had negative direct effect (-0.254) on yield/plant. Days to maturity had positive direct effect (0.178) on yield/plant. Plant height had positive direct effect (0.314) on yield/plant. Path analysis revealed that tassel height had positive direct effect (0.234) on yield/plant. Ear length had positive direct effect (0.197) on yield/plant. Number of grains/cob had negative direct effect (-0.095) on yield/plant. Cob length had positive direct effect (0.167) on yield/plant. Path analysis revealed that cob diameter had positive direct effect (0.168) on yield/plant. Weight of 1000-grains had positive direct effect (0.217) on yield/plant. Clustering pattern denoted that, cluster III was the largest cluster comprising of 9 genotypes and cluster I belongs 4 genotypes of maize. Inter cluster distance was maximum (13.034) between clusters I and III, followed by clusters III and IV (10.098).

In considering yield contributing characters and yield, BARI Hybrid Maize-6, performed better followed by NZ-001 and Shuvra. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the yield contributing traits of maize indicating that high environmental influence on the studied characters. In correlation study revealed that, plant height, tassel height, number of grains/cob, cob length, cob diameter and weight of 1000-grains had highly positive correlation with yield per plant.

Considering the above findings of the present experiment, the following recommendations and suggestions may be made

- Selected maize genotypes are needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
- More genotypes with different crosses may be included for further study.

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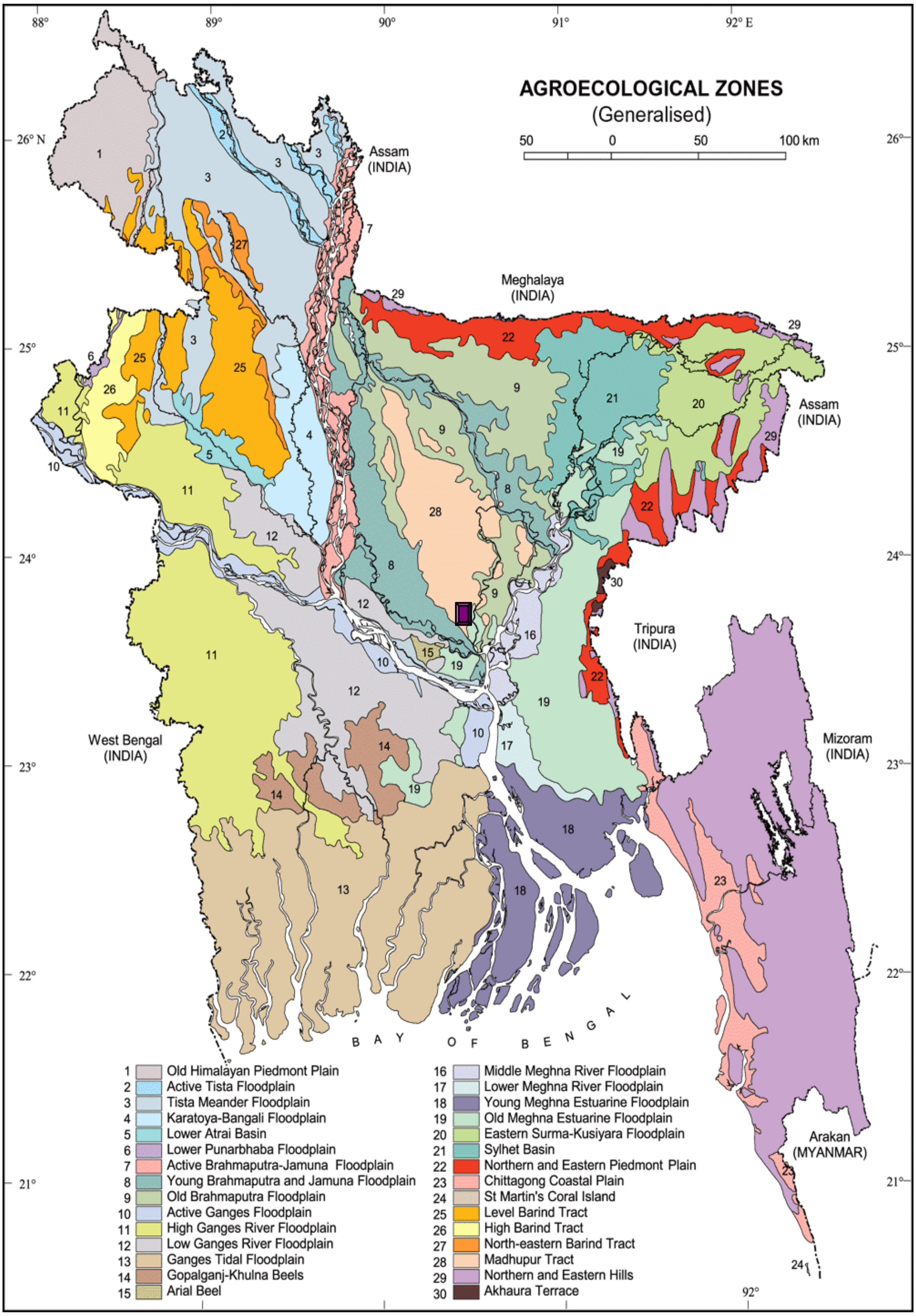
APPENDICES

Appendix I. The map of the experimental site



Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from March to June, 2014

Month (2014)	*Air temperature (^oC)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
March	28.1	19.5	65	00
April	33.4	23.2	67	78
May	34.7	25.9	70	185
June	35.4	22.5	80	277

* Monthly average, **Source:** Bangladesh Meteorological Department, Agargoan, Dhaka - 1212

Appendix III. Characteristics of the soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.7
Organic matter (%)	1.13
Total N (%)	0.061
Available P (ppm)	5.46
Exchangeable K (me/100 g soil)	0.13
Available S (ppm)	12.7
Available B (ppm)	0.41

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka