GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN F_2 POPULATION OF WHITE MAIZE (*Zea mays* L.)

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BY

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This is to certify that thesis entitled, " **GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN F_2 POPULATION OF WHITE 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 bona fide research work carried out by **MD. MAHMUDUL HASAN**, Registration No. **11-04266** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
Place: Dhaka, Bangladesh

Prof. Dr. Jamilur Rahman
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

AND MY DADA (ELDER BROTHER)

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to determine the mean performance, genetic variability, correlation and path coefficient of nine F_2 populations of white maize. Significant variations were observed among the different genotypes of nine F_2 populations for all the traits studied. The F_2 populations of KS 510 showed the maximum mean performance in plant height (218.61 cm), days to maturity (135 DAS) and yield per plant (83.85 g), while the populations of Yungnuo 7 showed the minimum mean performance in plant height (120.94 cm), days to maturity (106 DAS) and yield per plant (43.42 g). In analysis of different genetic parameters, the highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) values were observed for cob height (19.64, 21.58), number of branches of tassel (20.12, 25.41), leaf blade area (17.3, 20.87) and yield per plant (18.25, 22.98). High heritability coupled with high genetic advances in percent mean were obtained for plant height, cob height, number of branches per tassel, number of cob bearing node, leaf blade area and grain yield per plant. The correlation studies revealed that significant positive relation of yield per plant with plant height, days to maturity, number of leaves per plant, cob length, cob breadth and number of grains per row at both genotypic and phenotypic levels. The path coefficient analysis showed positive direct effect towards yield contributed through days to 50% tasselling, days to 50% silking, cob height, days to maturity, number of branches of tassel, cob breadth and number of grains per row. Thus the results suggested that direct selection on the basis of plant height, days to maturity, cob height, number of leaves per plant, cob length, number of row per cob and number of grains per row could be reliable for yield improvement in white maize. Moreover, considering the mean performance, the populations of KS 510 for grain yield per plant, the populations of Yungnuo 7 for early maturity, dwarf type, cob height and populations of PSC 121 for bold grains, highest number of rows per cob, cob breadth and leaf blade area would be selected for advancing these population through selfing for developing of potential inbred lines for varietal development of white maize.

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SOME COMMONLY USED ABREVIATIONS

Full word	Abbreviation
At the rate	@
Agro Ecological Zone	AEZ
Agriculture	Agric.
Agricultural	Agril.
Agronomy	Agron.
Analysis of variance	ANOVA
And others	*et al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Base diameter	BD
By way of	Via
Cob diameter	CD
Cob length	CL
Cob height	CH
Cultivars	cv.
Centimeter	CN
Canonical Variate Analysis	CVA
Degree Celsius	^{0}C
Degrees of Freedom	df
Days to 6^{th} leaf stage	DSLS
Days to 50% tasselling	D50%T
Days to 50% Silking	D50%S
Days after Sowing	DAS
Days to Maturity	DM
Etcetera	etc.
Environmental variance	$\sigma^2{}_e$
Food and Agricultural Organization	FAO
Genotypic variance	$\sigma^2{}_g$
Gram	g
Genotype	G
Genetic Advance	GA
Genotypic coefficient of variation	GCV
Genotype	G
Genetic Advance	GA
Heritability in broad sense	$h^2{}_b$

SOME COMMONLY USED ABREVIATIONS (*Continued...*)

Full word	Abbreviation
Journal	J.
Kilogram	Kg
Leaf blade area	LBA
Meter	M
Mean sum of square	MS
Murate of Potash	MP
Ministry of Agriculture	MOA
Number	No.
Namely	Viz.
Number grains per row	NGPR
Phenotypic coefficient of variation	PCV
Percent	%
Phenotypic variance	$\sigma^2{}_p$
Percentage of Coefficient of Variation	CV%
Residual Effect	R
Randomized Complete Block Design	RCBD
Science	Sci.
Standard Error	SE
Yield per plant	YYP
Square meter	m^2
Sher-e-Bnagla Agicultural University	SAU
University	Uni.
Variety	var.

CHAPTER I
INTRODUCTION

Maize is known as "queen of cereal". It is the third most important cereal food crop of the world after wheat and rice. Maize has attracted the attention in the world due to its importance being used as fodder and human food (Guruprasad *et al.*, 2016; Dogan *et al.*, 2015). In many countries it has been contributing to human food security (Katinila *et al.*, 1998). Among the cereal crops, maize is comparatively a new crop in Bangladesh. It was incepted during 1960 after the Second World War through testing some varieties provided by the CIMMYT mainly for research purpose (Karim, 1992). At present its cultivated area accounts near about 0.304 million hectares with a production of over two million tons a year. Almost the sole of the produced maize is used as livestock or poultry feed. Only a very small fraction is used for human consumption in the form of roasted grain and chips. Among the cereals it is rich in starch, oil and sucrose. The maize has 72% starch, 10% protein and 4%fat supplying an energy density of 365 Kcal/100g and is suitable as fodder (Nuss and Tanumihardjo, 2010).

Globally 67% of maize is used for livestock feed, 25% human consumption, industrial purposes and balance is used as seed and demand for grain is increasing worldwide (Reddy *et al.*, 2013). In Bangladesh maize cultivation was started in the late 19th century. Since 1993 maize production has an increasing tendency with the introduction of hybrid varieties and adoption improved technology. Recently it occupied 2nd position next to rice (DAE, 2012) and occupied of 4.8% of the total cropped land area (Ahmed *et al*., 2011). Due to the expansion of poultry industry since 2004 the popularity of growing maize got a momentum among farmers raising the acreage of yellow maize from 50 thousand hectares to 307 thousand hectares in 2012-13 growing season with the total production of 2.12 million M tons (BBS, 2016) of which the most of the amount is being used as poultry feed. The maize is also consumed as human food throughout the world most of which is of white-grained type. Bangladesh although produces enough food grains of nearly 38.332 Million tons annually for its 160 million people (BBS, 2016) most of which comes from rice and wheat. However, such amount cannot be guaranteed in all the years especially in the year(s) when natural calamities such as flood, cyclone and drought happen. Moreover, after 2050 when the population has been projected to be 202 million (UN, 2015 and Timsina *et al*., 2016) posing an increased demand for foods for Bangladesh leaving an uncertainty in sustaining food security. So, under this assumption a third crop maize, being a C_4 crop and having two to three-fold productivity as compared to that of rice and wheat which has a higher productivity might be considered. The United States, China, Brazil and Mexico contribute 70% and India contributes 2% of world production. Like India climate condition of Bangladesh favors maize cultivation.

Maize 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). This oil is used as one of the best quality edible oil. Green plant and grain are used as the feed of livestock and poultry. Stover and dry leaves are used as good fuel. 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).

The yield of maize is low in Bangladesh as compared to the other maize growing countries, even though, it is well adapted to the climate and soils of the country. Every day the country is losing about 200 hectares of crop land owing to industrialization, urbanization and river erosion. Therefore to face this challenge cultivation of high productive crop like maize breeding is necessity. Previously sporadic attempts were taken to accelerate yellow maize production.

However, little attempts were made to develop the improved and adapted variety of white maize.

White maize is generally considered a human food crop. Market prices are usually higher for white maize compared to the yellow type. In addition, white maize have medium GI (Glycemic Index) which help in reducing the obesity. So the country need to develop suitable white maize varities.

Segregating populations are more important for improving plant types by operating further selection improvement. To quantify the extent of genetic variation available for grain yield and yield components in the segregating generations and to assess the genetic gain that can be made by selection. To achieve this goal, the breeder has the option of selecting desirable genotypes in early generations or delaying intense selection until advanced generations, when progenies are nearly homozygous (Savitha, 2015). Since grain yield of maize is quantitative in nature and polygenically controlled the selection criteria depends upon yield and yield component traits. To enhance the yield productivity, genetic parameters and correlation studies between yield and yield components are prerequisite to plan a meaningful breeding program to develop high yielding inbreeds as well as hybrids.

Genetic variability, marked as a heritable difference among cultivars, is required in an optimal level within a population. 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). Larger genetic variability has been found in the segregating population that represents different climatic, geographical regions (Ilarslan *et al.,* 2002). Abayi *et al*. (2004) signifies the genetic variation in important agronomic traits like earliness, cob height and grains per cob to sufficiently justify the initiation of selection program.

Information of genetics on yield and other associated characters is prerequisite for breeding purposes in respect to develop high yielding varieties (Agrawal, 2002). Grain yield is the most important and complex quantitative traits in maize controlled by numerous genes (Zdunic *et al.*, 2008). Different yield contributing components like ear height, plant height and 1000-grain weight influences yield (Rahman *et al.*, 1995). Grain yield is proportionately associated with ear weight. Yield achievement can be improved by selection for grain yield, plant height and ear height (Prodhan, 1997).

We therefore having the above scheme and discussion in mind, the study were conducted to determine the different genetic parameters, associations in yield contributing traits in the F_2 population of white maize to fulfill the following objectives:

Objectives:

1. To study the genetic variability, heritability and genetic advance in the nine families of F_2 population of white maize;
2. To study the correlation and path coefficient analysis among the yield and its contributing traits;
3. To advance the suitable lines through selfing of the selected lines from F_2 to F_3 population.

CHAPTER II
REVIEW OF LITERATURE

Various investigators at home and abroad worked with different maize genotypes and studied their performance regarding the characterization. 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 Reproductive biology
2.2 Mean performance
2.3 Genetic Variability
2.4 Heritability and Genetic Advance
2.5 Correlation co-efficient and
2.6 Path analysis

2.1 Reproductive biology

Maize is a tall, determinate, monoecious, annual plant. It produced large, narrow, opposite leaves, borne alternatively along the length of stem. All maize varieties follow same general pattern of development, although specific time and interval between stages and total number of leaves developed may vary between different hybrids, seasons, time of planting and location.

Silking stage involving the formation of the female flowers or cobs is the first reproductive stage and occurs 2-3 days after tasselling stage. This stage begins when any silks are visible outside the husk. These are auxillary flowers unlike tassels that are terminal ones. Pollination occurs when these new moist silks catch the falling pollen grains. Maize is a monoecious plant, that is, the sexes are partitioned into separate pistillate (ear), the female flower and staminate (tassel), the male flower. It has determinate growth habit and the shoot terminates into the inflorescences bearing staminate or pistillate flowers (Dhillon and Prasanna, 2001).

Maize is generally protandrous, that is, the male flower matures earlier than the female flower. Within each male flower spikelet, there are usually two functional florets, although development of the lower floret may be delayed slightly in comparison to the upper floret. Each floret contains a pair of thin scales i.e. lemma and palea, three anthers, two lodicules and rudimentary pistil. Pollen grains per anther have been reported to range from 2000 to 7500 (Kiesselbach, 1949). Kiesselbach (1949) estimated that 42,500 pollen grains are produced per square inch of cornfield. The pollen grains are very small, barely visible to the naked eye, light in weight, and easily carried by wind. The wind borne nature of the pollen and protandry lead to cross-pollination, but there may be about five percent self-pollination. In maize, the pollen shed is not a continuous process and usually begins two to three days prior to silk emergence and continues for five to eight days. The silks are covered with fine, sticky hairs which serve to catch and anchor the pollen grains. Pollen shed stops when the tassel is too wet or too dry and begins again when temperature conditions are favourable. Under favourable conditions, pollen grain remains viable for only 18 to 24 hours. Cool temperatures and high humidity favor pollen longevity. Under optimal conditions the interval between anthesis and silking is one to two days. Fertilization occurs after the pollen grain is caught by the silk and germinates by growth of the pollen tube down the silk channel within minutes of coming in contact with a silk and the pollen tube grows the length of the silk and enters the embryo sac in 12 to 28 hours. Pollen is light and is often carried considerable distances by the wind. Under field conditions 97% or more of the kernels produced by each plant are pollinated by other plants in the field. Fertilization of ovules begins about one third of the way up from the base of the ear.

2.2 Mean performance of maize

Breeders are interested in screening and development of open pollinated population in any crop. In maize range of any trait is the major indicator of more genetic variation. When the range is high then it is possible to select best genotype for any breeding purpose.

Chowdhury and Islam (1993) reported that maize varieties Barnali, Khoibhutta, Mohor and Shuvra were 200, 160, 210 and 175 cm tall respectively.

Akhtar and Mitra (1990) found that plant height was significantly different among the 6 CIMMYT entries and one local cheek.

Jotshi *et al.* (1988) worked with 25 varieties of maize and observed that leaves per plant differed significantly among the varieties studied. Lee *et al.* (1986) studying with 28 maize hybrids also observed significant differences in number of leaves per plant among the varieties.

Singh *et al.* (1991) conducted an experiment with with 5 maize cultivars (R2, Ganga 5, Ganga 11, HH 216 and D765) and found that Ganga 5 was significantly superior to HLL with regard to growth and yield which was due to ear length.

Ear length is an important yield component for maize and had a direct effect on grain yield (Subramanin *et al.*, l98l). BARI (1990) reported that cv. Bamali gave more ear per plant than Khaibhutta.

Paradkar and Sharma (1993) observed that out of 5 maize varieties (R1, Ganga 5, Ganga 11, HH2l6 and D765), Ganga 11 had higher grain rows per ear. Ganga 11 gave more ear length followed by Gonga 5 and D 7654.

Kamen (1983) observed that early maturity hybrids had fewer grain rows per ear than late maturating hybrids. Number of grains per row may differ among the varieties. Grains per ear one of the important yield contributing characters which varied in variety to variety.

Khaibhutta produced significantly higher (432.5) number of grains per ear than Barnali (343.5) as reported by Anonymous (1988). On the other hand, Khoibhutta produced the highest number of grains per ear when compared with variety Pirsabak 8l46, Lamaquina 7827 and Guaira 8045 (Anonymous, l987).

Begum and Roy (1987) reported that yield variation among the varieties were due to varietal characteristics. Guaria 8045 gave significantly higher grain yield (5.15 t/ha), whereas Pirsabak 8146, LaMaquina and Khoibhutta produced grain yields of 4.50, 5.07 and 4.00 t/ha respectively (Anonymous 1987).

Viola *et al.* (2004) reported that maize displayed an orderly sequence of development of yield components namely number of ear per plant, number of kernel per row, number of kernel row per ear and hundred kernel weights.

Grzesiak (2001) observed considerable genotypic variability among various maize genotypes for different traits. Ibsan *et al.* (2005) also reported significant genetic differences for morphological parameter for maize genotypes.

Hossain (2015) conducted an experiment with white maize at Sher-e-Bangla Agricultural University. The results revealed that highest grains per row ((33.98) and rows per cob ((13.67) were recorded from variety PSC 121. KS 510 showed maximum 100 grain weight (37.20 g). PSC-121 showed the tallest plant (204.73 cm at harvest) and KS-510 showed the shortest plant (198.82 cm at harvest). KS 510 and PSC 121 showed the highest (274.11 cm^2) and lowest (188.42 cm^2) leaf area, respectively. PSC 121 showed the highest base diameter (9.02 cm) and KS 510 showed the lowest base diameter (8.87 cm).

2.3 Genetic Variability

The achievement in any crop improvement program depends on the capability of the breeder to define and accumulate the required genetic variability and to select for yield indirectly through yield associated and highly heritable characters after eliminating the environmental component of phenotypic variation.

Grzesiak (2001) observed that considerable variability among maize genotypes for different traits. Significant variability was observed for cob length, grains rows, fresh cob weight and grain moisture content. The possible reason for the observed differences could be variation in their genetic makeup.

An experiment was conducted by Sola *et al.* (2004) under the field conditions using two-factor factorial arrangement in RCBD with four replications. Significant variations in plant height, ear height, stalk diameter, number of days to 50% silking and tasselling, maturity, percentage of barren plants, percent ear fill, ear length, ear diameter and 1000-seed weight were attributed to the independent effects of generation and nitrogen application.

Ihsan *et al.* (2005) reported significant genetic differences for morphological parameter for maize genotypes.

Naushad *et al*. (2007) conducted an experiment to observe the magnitude of genetic variability in maize genotypes for yield and yield components and significant variability was assessed for ear length, grains rows per cob, cob weight, grain moisture content, 300-grains weight and grain yield.

Rahman (2008) used 41 maize populations which were evaluated for plant height, ear height, number of branches per tassel, days to 50% anthesis and days to 50% silk emergence. 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.

Shanthi *et al*. (2011) found that grain yield and its component characters viz., total anthers dehiscence period, total period of silk appearance, active pollination period, number of seeds per cob, cob weight, protein yield and oil yield had expressed high estimates of GCV (genotypic coefficient of variation) and PCV (phenotypic coefficient of variation) indicating the genetic variances for these traits.

Hussain *et al.* (2011) observed that the maize varieties significantly differed in days to 50% pollen shedding. The highest (81) days taken to 50% pollen shedding were recorded in maize variety Islamabad White and the lowest (67) in Soan-3. Other varieties, except for EV-1097, EV-1098, Soan-3 and Agaiti 2002, showed statistically similar days to pollen shedding.

Idris and Mohammed (2012) studied to develop a suitable procedure for selecting the most sustainable maize genotype to grow by considering genetic variability for vegetative, yield and yield components under irrigated farming. Significant variability was observed for plant height, stem diameter, number of rows per cob and ear length during the first season 2007/08 and for days to 50% flowering and 100-seed weight during the second season 2008/09. Frantic genotype scored maximum seed weight (81.0g) while Baladi had least seed weight (57.48g). Frantic genotype had maximum grain yield (0.577 t/ha), while minimum grain yield ton/ha was recorded in Baladi (0.473 t/ha).

Farhan *et al*. (2012) revealed that testcrosses differed significantly for all the characters studied except days to 50% anthesis, days to 50% silk emerging and ASI (Anthesis to Silking Interval). The Genotype x environment interaction was also significant for all the traits except for cob length.

Ogunniyan and Olakojo (2014) found significant variation existed in all the characters. The coefficients of variation were low except ear weight and grain yield. The anthesis silk emergence interval was highest in lines TZEI 124 and TZEI 16. These characters were less influenced by the environment thus the traits can be used for selection.

Praveen *et al*. (2014) revealed that the mean sum of squares due to genotypes showed significant variation for all the 12 characters studied. Traits yield per plant, plant height, ear height, number of seeds per row, 100-seed weight were shown high to moderate genotypic and phenotypic coefficient of variation.

Breeders are interested in screening and development of open pollinated population in maize. Ishaq *et al.* (2015) 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 per plant (11.33), flag leaf area (106.5 cm), grain rows per cob (13.67) and grain yield (5927 kg/ha) were recorded. They found a considerable amount of genetic variation that could be manipulated for further improvement in maize breeding.

Asim Gazal *et al.* (2017) assessed the genetic variability in 100 homozygous maize inbred lines during kharif 2013 and 2014. These inbred lines were evaluated for obtaining information on genetic variability for yield attribute and quality traits. A wide range of variability was observed in the analysis. Medium to high values of genetic coefficient of variability was exhibited for anthesis-silking interval, leaf relative water content, stomatal count, chlorophyll content before flowering, chlorophyll content before maturity, ears per plant, grain yield per plot.

Matin *et al.* (2017) studied with twenty one locally developed maize hybrids for ten characters to access variability and found that high genotypic coefficient of variation (GCV) was obtained from thousand seed weight, days to 50% silking, cob diameter and anthesis silking interval. The highest phenotypic coefficient of variation (PCV) was observed in thousand seed weight followed by days to 50% silking and cob diameter.

Pandey *et al.* (2017) studied on genetic parameters included the mean performance, genotypic variances, phenotypic variances, genotype by environment variances, broad sense heritability in maize. Significant differences were recorded for all traits studied thereby revealing the variability of the maize genotypes. Grain yield per plant, shelling%, and 100 seed weight (g) showed high heritability and high genotypic variances suggesting the involvement of additive gene action. Days to 50% tasselling, days to 50% silking and physiological maturity showed the highest heritability but low genotypic variance suggesting the preponderance of non-additive gene action.

Barua *et al.* (2017) studied on genetic variability in maize (*Zea mays L.*) genotypes for grain yield and yield contributing traits. High heritability exertion along with high genetic advance was recorded for plant height (95.00, 44.07), ear height (95.00, 30.42) and grain yield (90.00, 4484.69), indicating that these traits were controlled by additive genes and suggesting hybridization to be effective.

Singh *et al.* (2017) studied and revealed highly significant differences for all the characters studied in maize, indicating the presence of substantial genetic variability. The phenotypic and genotypic coefficient of variation (PCV and GCV) was high for days to 50% tasselling followed by kernel rows per year and 100 grains weight, respectively.

Kumar *et al.* (2017) studied on genetic variability parameters in Quality Protein Maize (QPM) genotypes with 18 lines and 4 standard checks. In the present investigation significant differences were observed for all the yield and yield contributing traits and quality parameters.

Asim *et al.* (2017) studied heritability on 100 homozygous maize inbred lines during kharif 2013 and 2014. High heritability and high genetic gain (as % of mean) were exhibited for anthesis-silking interval, leaf relative water content, stomatal count, chlorophyll content before flowering, chlorophyll content before maturity, ears per plant, grain yield per plot, protein content all confirming that these traits can be given more weightage while applying selection for improvement of these traits and in identifying elite drought tolerant lines.

Bhiusal *et al.* (2017) estimated the extent of genetic variability in maize with fifty five genotypes during rabi 2013-14. Analysis of variance revealed significant differences for 18 characters studied among the genotypes. High genotypic and phenotypic coefficient of variation was recorded for grain yield/plant, biological yield/plant and cob weight coupled with high heritability and genetic advance. Thus, traits showing variability need to be paid attention while formulating breeding strategies for improvement of grain yield of maize.

2.4 Heritability and Genetic Advance

The knowledge of the heritability along with genetic advance aids in drawing valuable conclusions for selection of breeding methods to be employed for further improvement of the traits. Estimation of heritability serves as a useful guide to breeder for determination of variation that is due to genotypic broad sense heritability or narrow sense heritability effects. The information on heritability alone may be misleading but when used in combination with genetic advance, the utility of heritability estimate increases. Broad sense heritability estimate provides information on relative magnitude of genetic and environmental variation in germplasms pool.

Benjamin (2001) studied 13 reciprocal full-sib recurrent selection cycles in two maize populations, BS10 and BS11 in a 8 x 8 simple lattice on 9 locations, in Iowa and one location in USA. Relatively high estimates of heritability were observed in both the populations for days to mid-anthesis, days to mid-silk, plant height, ear height, grain moisture percentage and grain yield.

A series of tropical maize hybrids, involving 10 single, 4 double and 4 three-way crosses, were examined along with their parental inbred lines and three local varieties as check entries at University Putra Malaysia, Serdang, Malaysia by Saleh *et al.* (2002). Broad sense heritability estimates varied with characters, Moderate heritability estimates were observed for grain yield indicating a substantial amount of genetic variation in the hybrids. They further added that low and negligible heritability estimates for days to silking and 100- grain weight indicated that these traits were highly influenced by environmental factors.

Presterl *et al*. (2003) conducted experiments in a series of 21 in different locations in typical maize growing regions of Germany and France on 48 to 144 entries derived from maize inbred lines of dent and flint gene pools in various combinations under low and high nitrogen levels. They observed moderate to high levels of heritability for grain yield and grain dry matter content under both the low nitrogen (LN) and high nitrogen (HN) levels in all the experiments. The estimates of heritability ranged from 35.9% to 94.1% under low nitrogen level while under high nitrogen level, it varied from 40.7% to 88.0%.

A total of 66 cross combinations evaluated by Sujiprihati *et al*. (2003) in two locations in a randomized complete block design (RCBD) in Malaysia. They observed heritability estimates of 0.3-54.0% for gain yield and number of kernel rows per ear at one location while a range of 0.3 to 36.7% was observed for ear length and number of kernel rows per ear, respectively at the other location.

Amer and Mosa (2004) reported that heritability estimates in narrow sense were 44% for silk emergence date, 39% for plant height, 44% for ear height, 27% for ear length, 31% for ear circumference, 29% for number of rows per cob, 23% for number of seed per row and 36% for grain yield.

In a study of heritability among grain yield and its components in 49 maize hybrids and 14 parental lines by Rafique *et al*. (2004) and observed that heritability estimates higher than 80% for plant height, ear height, ear length, ear diameter, kernels per row and grain yield.

36 F_1s with 9 parental inbred lines and a commercial hybrid were evaluated at the Agriculture Faculty Experiment Station, Adnan Menderes University Andin, Turkey in 4 replications by Unay *et al*. (2004). They observed heritability estimate for grain yield in broad sense (0.97) and in narrow sense (0.24) from their study.

Beyene (2005) evaluated 180 maize accessions in a randomized complete block design in Alemaya University, Ethiopia. He observed heritability estimates of high levels for days to tasselling (78.5%), days to silking (77.8%), plant height (70.1), number of leaves plant-1 (86.9%), days to maturity (84.1%) and kernels row-1 (69.5%), moderate for ear height (53.0%), leaf length (45.8%) ear diameter (44.7%) and kernel rows ear-1 (46.4), while low levels of 17.0%, 17.7%, 18.1% and 21.6%, respectively for grain yield, leaf width, 1000- seed weight and ear length.

Two hundred and thirty four F_2 families were evaluated along with their parents for drought response (Xiao *et al*., 2005). They observed high estimates of heritability under well water regime as compared to water stress regime for ear weight, kernel weight per ear, kernel numbers per ear, 100-kernel weight and grain yield. The estimates of heritability ranged from 0.49–0.71 and 0.31–0.64, respectively under well water and water stress regimes.

High levels of heritability estimates of 96.8%, 98.5%, 94.5%, 97.2%, 89.4%, 97.0%, 98.8%, 88.1%, 99.2% and 98.7% were observed, respectively for days to 50% flowering, days to 50% silking, plant height, ear height, number of kernel rows per ear, number of kernels per row, number kernels per ear, 100-seed weight, grain yield and shelling percentage in a set of 47 diverse maize genotypes collected from CIMMYT, Mexico (Sumathi *et al*., 2005).

Abdelmula and Sabiel (2007) estimated genetic parameters including heritability in 15 maize genotypes during evaluation at two locations in Sudan. They observed moderate levels of heritability estimates for days to 95%

anthesis (26%), leaf area index (27%), days to 95% silking (29%), stem diameter (36%), grain yield (40%), number of leaves per plant (41%) and plant height (56%).

Twenty diverse maize cultivars obtained from various locations within the Ekiti State were evaluated at Teaching and Research Farm, University of Ado-Ekiti, Nigeria for various plant traits (Salami *et al*., 2007). They estimated low levels of heritability in broad sense for days to 50% anthesis, days to 50% silking (0.20), plant height (0.35) and grain yield (0.24). From these low levels of heritability they noticed that perhaps the heritability estimates would have been improved if the evaluation had been conducted in multiple environments.

Shanthi *et al*. (2011) found that grain yield and its component characters viz., total anthers dehiscence period, total period of silk appearance, active pollination period, number of seeds per cob, cob weight, protein yield and oil yield had expressed high heritability (more than 85%) coupled with high genetic advance, indicating the genetic variances for these traits probably owing to their high additive gene effects. Hence, it was inferred that direct selection was a better scope for improvement of these traits.

Data recorded by Idris and Mohammed (2012) for heritability showed that days to 50% flowering had maximum heritability (79.1%) while the minimum heritability (4.46%) was recorded for 100 seed weight.

Ogunniyan and Olakojo (2014) found that heritability was greater than 80% for all characters whereas expected genetic advance ranged from low (8.91) in days to silk emergence to high (72.03) in number of ear per plant.

Praveen *et al*. (2014) revealed that traits yield per plant, plant height, ear height, number of seeds per row, 100-seed weight were shown high heritability accompanied with 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% tasselling, days to 50% silk emerge, shelling percentage, ear length and days to maturity ear girth and number of seed rows per cob.

Ishaq *et al.* (2015) reported that broad sense heritability (h^2b) ranged from 0.29 to 0.95 for various traits. The study revealed a considerable amount of heritability estimates that could be manipulated for further improvement in maize breeding.

Alhussein and Idris (2017) studied that heritability for all the traits except ear height and grain yield had non additive type of gene action with high heritability. The exploitation of these traits would be effective in hybrid maize breeding. Ear height and grain yield showed both additive and non additive type of gene action with environmental influence due to high environmental variance. These traits can be utilized effectively through selection in varietal development.

Higher values of broad sense heritability were obtained for almost all the characters except days to 50% tasselling which is moderate. High heritability coupled with high genetic advance as per cent of mean was reported for plant height, grain yield per plant and ear height (Singh *et al.*, 2017).

Matin *et al.* (2017) studied on twenty one locally developed maize hybrids for ten characters to access their heritability. The highest heritability (H_b) was observed for cob diameter (95.25) followed by days to 50% silking (94.15), days to maturity (93.85) and ear height (93.06). The characters with high GCV and higher values of heritability indicated high potential for selection.

2.5 Correlation co-efficient

Improvement of a specific trait in all the breeding programs can be achieved by indirect selection via other characters. This needs a good understanding of the association of different characters with the target character and among the different characters themselves. It is necessary to have the estimates of correlation of yield with other characters for which the genotype could be assessed visually. The phenotypic and genotypic correlation reveals the extent of association between different characters, thus, it helps to base selection procedure to a required balance, when two opposite desirable characters affecting the principal characters are being selected.

Analysis of correlation among different traits is important in breeding program. A good number of literatures are available on correlation among characters of maize. Some of these literatures are reviewed here:

Genotypic and phenotypic correlation determination is the basic step in the formulation and implementation of various breeding programs. The correlation among traits is important for successful selections to be conducted in breeding activities. Again analysis of correlation coefficient is the most widely used one among several methods that can be used (Yagdi and Sozen, 2009).

Two types of correlations, phenotypic and genetic, are commonly discussed in plant breeding. Phenotypic correlation (rp) involves both genetic and environmental effects. Genetic correlation is the association of breeding values (i.e., additive genetic variance) of the two characters. Both measure the extent to which degree the same genes or closely linked genes cause co-variation in two different characters (Hallauer and Miranda, 1988).

Pande *et al*. (1971) observed that 100-seed weight was positively correlated with grain yield.

An experiment conducted by Debnath (1991b) with 23 fourth generation lines of maize showed that grain yield was positively and significantly correlated with plant height, ear height, ear diameter and seed rows per cob, number of seeds per row and 1000-seed weight.

AL-Ahmad (2004) found positive and significant correlation between grain yield and each of plant height, number of rows per cob, number of seed per row and 100-seed weight and emphasized the role of these traits in selection of high grain yield in corn also indicated that the correlation values were positive and significant between grain yield and each of ear circumference, ear length and number of seeds per row.

Aydin *et al*. (2007) found positive and significant correlation between grain yield and each of plant height, number of rows per cob, number of seed per row and 100-seed weight and emphasized the role of these traits in selection of high grain yield in corn also indicated that the correlation values were positive and significant between grain yield and each of ear circumference, ear length and number of seeds per row.

Bahoush and Abbasdokht (2008) showed that number of grains per cob and 100 grain weights had highly positive effects. Also cob length had positive and moderate direct effect on yield. Furthermore, ear height had low and negative direct effect on grain yield.

When major yield contributing characters are positively associated then selection would be very effective. But when these characters are negatively associated, it would be difficult to practice simultaneous selection for them in developing a variety reported by Nemati *et al*. (2009).

Najeeb *et al*. (2009) found positive and significant correlation between grain yield and each of plant height, number of rows per cob, number of seed per row and 100-seed weight and emphasized the role of these traits in selection of high grain yield in corn also indicated that the correlation values were positive and significant between grain yield and each of ear circumference, ear length and number of seeds per row.

In an experiment carried out by Bello *et al*. (2010) positive and significant phenotypic and genotypic correlations were found for days to 50% tasselling with plant and ear height and grain yield with plant height, number of grains per ear and ear weight. Positive and significant environmental correlation was also recorded for grain yield with plant and ear height and ear weight.

Kumar *et al.* (2014) revealed that positive and significant phenotypic correlations were recorded for grain yield in association with plant and ear height, ear length and diameter, number of seeds row per ear and seeds per row and 100 seeds weight except maturity traits which showed negative association with grain yield.

According to Kwaga (2014) maize grain yield correlated positively with plant height, cob length, cob diameter and 100 grains weight; but related negatively with days to 50% tasselling. The four characters that correlated positively to grain yield also associated positively to each other throughout the experiment.

Bikal and Deepika (2015) showed that traits plant height, cob height, cob length, cob girth, cob weight, number of seed row per cob, number of seed per row exhibited positive and highly significant correlation with grain yield per hectare and five hundred seed weight were given significant correlation. The analysis also indicated that days to 50% tasselling and days to 50% silk emergence explained negative and highly significant correlation with grain yield per hectare. Similarly, days to maturity showed negative and insignificant correlation with grain yield per hectare.

Pandey *et al.* (2017) studied on phenotypic and genotypic correlation coefficients and revealed that the grain yield was positively and strongly correlated with 100 seed weight, shelling%, cob length, plant height, kernels per row and kernel rows per cob.

Barua *et al.* (2017) studied on correlation in maize genotypes for grain yield and yield contributing traits. Grain yield showed highly significant positive genotypic correlation with plant height (0.767) and ear height (0.823) indicating these characters, can be strategically used to improve grain yield of maize. Thus, selection can be exercised on these traits in improving maize population for high grain yield.

Alhussein and Idris (2017) investigated the genotypic association among grain yield components and yield. Correlation studies revealed significant positive phenotypic relationship of grain yield with plant and ear height, ear length and diameter and hundred kernel weight.

Singh *et al.* (2017) showed that grain yield per plant had significant phenotypic correlation with ear length.

Matin *et al.* (2017) studied with twenty one locally developed maize hybrids for ten characters to access correlation and found that positive and significant genotypic, phenotypic correlation coefficient were recorded for yield with anthesis silking interval (rg = 1.00**, rp = 0.96**), cob diameter (rg = 0.99** and rp = 0.95**) and ear height (rg = 0.98** and rp = 0.94**). But days to 50% tasselling had moderate but significant positive correlation at both phenotypic and genotypic level.

Kumar *et al*. (2017) studied on genetic correlations on parameters in Quality Protein Maize (QPM) genotypes with 18 lines and 4 standard checks. The grain yield per plant had highly significant and positive correlations both at genotypic and phenotypic levels with 100-grain weight (rg=0.863, rp=0.829), starch content (rg=0.657, rp=0.649), harvest index (rg=0.529, rp=0.504), lysine Content (rg=0.518, rp=0.486), ear length (rg=0.476, rp=0.463), tryptophan content (rg=0.468, rp=0.457) and ear height (rg=0.351, rp=0.339).

Bhiusal *et al.* (2017) estimated the traits association in maize with fifty five genotypes during rabi 2013-14. Strong positive associations were exhibited to grain yield per plant with plant height, ear height, leaf area index, cobs/plant, cob weight, cob length, cob girth, grains/row and biological yield/plant both at genotypic and phenotypic levels. Thus, traits showing variability and strong positive correlation both at genotypic and phenotypic levels need to be paid attention while formulating breeding strategies for improvement of grain yield of maize.

2.6 Path Analysis

Simple correlation does not consider the complex relationships between the various traits related to the dependent variable. Correlation coefficients show relationships among independent variables and the linear relationship between these variables. But it is not sufficient to describe these relationships when the causal relationship among variables is needed. A clear picture of the interrelationship between seed yield and others yield contributing characters, direct and indirect effects of them can be worked out by using path analysis.

Geetha and Jayaraman (2000) reported that number of grains per row exerted a maximum direct influence on grain yield. Hence, selection of number of grains per row will be highly effective for improvement of grain yield.

Devi *et al*. (2001) reported that ear length, number of seed rows per cob, number of seeds per row and 100-seed weight positively influenced the yield both directly and indirectly through several components.

Mohan *et al*. (2002) studied path analysis on corn cultivars (169 cultivars) for grain yield and oil content and resulted that number of seed per row, 100 seed weight, number of seed row and cob length had direct effect on grain yield. It was revealed that cob height, plant height and number of days until 50% tasselling had most minus direct effect on grain yield.

Venugopal *et al*. (2003) reported that days to 50% tasselling and number of seed rows per cob showed negative indirect association with all traits towards grain yield. Study revealed that direct selection for these traits would be effective. Days to 50% silk exhibited negative direct effect on grain yield indicated that selection for high yield could be done by indirect selection through yield components.

Mohammadi *et al*. (2003) reported that 100-grain weight and total number of seeds per cob revealed highest direct effects on total grain weight, while cob length, ear circumference, number of seed rows and number of seeds per row were found to fit as second-order variables.

Khazaei *et al*. (2010) reported that 100-grains weight and number of seed had the highest direct effect on grain yield.

Bello *et al*. (2010) studied on path analysis and revealed that days to 50% silk emergence, ear weight and number of grains per cob had the highest direct effect on grain yield while number of grains per cob had the highest moderate indirect negative effects on grain yield. Days to flowering, plant and ear height, number of grains per ear and ear weight could be the important selection criteria for the improvement of open pollinated maize varieties and hybrids in terms of high grain yield.

Days to 50% tasselling and number of seed rows per cob showed negative indirect association with all traits towards grain yield. Study revealed that direct selection for these traits would be effective. Days to 50% silk exhibited negative direct effect on grain yield indicated that selection for high yield could be done by indirect selection through yield components (Pavan *et al*., 2011).

The study carried out by Selvaraj and Nagarajan (2011) revealed that direct selection for ear length and numbers of rows per cob are effective for yield improvement. The same author stated that, the positive direct and indirect effects of a trait on grain yield make it possible for its exploitation in selection under specific conditions.

It was revealed by Mustafa *et al.* (2014) that the fresh shoot length had maximum direct effect on fresh root length followed by root density, dry shoot weight, leaf temperature and dry root weight. It may be concluded that fresh root length, dry shoot weight, root density, leaf temperature and dry root weight are the major contributing characters for the fresh shoot length of maize seedlings. These traits had reasonable heritability estimation. Thus selection could be made for high yielding maize genotypes on the basis of these traits.

Kumar *et al*. (2014) revealed that path analysis showed days to 50% tassel had highest magnitude directly effect on grain yield per plant followed by ear height, 100 seeds weight and ear circumference.

Pandey *et al.* (2017) studied on path analysis of maize. Path analysis was used to partition the genetic correlations between grain yield and related characters. Days to 50% silking, physiological maturity, shelling% and 100-seed weight showed positive direct effect on grain yield. The highest direct effect belonged to days to 50% silking the highest direct effect (0.3032), followed by physiological yield (0.1586).

Jakhar *et al.* (2017) studied the path analysis and revealed that it provides an effective measure of direct and indirect causes of association and depicts the relative importance of each factor involved in contributing to the final product. Direct and positive effect on yield was exhibited by days to 75% brown husk, tassel length, cob length without husk, days to 50% tasselling, leaf width, plant height, 100 seed weight, cob length with husk, cob diameter indicating the effectiveness of direct selection, where as direct and negative effects were exhibited by days to 50% silking and ear height indicating the effectiveness of indirect selection.

Barua *et al.* (2017) studied on path analysis in maize genotypes for grain yield and yield contributing traits. Path analysis revealed that days to 50% silk (1.918) had shown the highest positive direct effect on grain yield followed by days to 50% pollen shed (1.779), days to 75% dry husk (0.840), plant height (0.753) and number of kernels per row (0.600) indicating these characters, can be strategically used to improve grain yield of maize. Thus, selection can be exercised on these traits in improving maize population for high grain yield.

Alhussein and Idris (2017); studied to investigate the path analysis of grain yield components on yield and found that ear length and diameter and hundred kernel weight had high positive direct effects on grain yield. Flowering day such as days to tasselling had high negative direct effect on yield. These results depicted that ear length and diameter may be used as reliable criteria for improving grain yield.

Singh *et al.* (2017) studied on path analysis and revealed that high positive direct effect on grain yield per plant for days to maturity followed by kernel rows per ear, grains per ear revealing that these are the major yield contributing traits in maize.

Matin *et al.* (2017) studied with twenty one locally developed maize hybrids for ten characters to access path analysis. Anthesis silking interval (0.79) had the highest positive direct effect on yield followed by cob diameter (0.31), cob length (0.31) and plant height (0.04) indicating the effectiveness of direct selection. While some other characters such as days to 50% tasselling (−0.12), days to 50% silking (−1.78), ear height (−1.16), days to maturity (−0.64) exhibited indirect negative effect on yield indicating the effectiveness of indirect selection.

Kumar *et al*. (2017) studied on path analysis on parameters in Quality Protein Maize (QPM) genotypes with 18 lines and 4 standard checks. The highest positive and direct effect was found for days to 50% tasselling (5.559) followed by lysine content (0.710) and starch content (0.439). The negative and direct effect was found for days to 50% silking (-5.774) and plant height (-0.331).

CHAPTER III
MATERIALS AND METHODS

The experiment was carried out during Rabi season 2016-17 to study the "Genetic Variability, Correlation and Path Analysis in F_2 Population of White Maize (*Zea mays* L.)". The details of materials and methods applied and the experimental procedure adopted during the course of research are described below.

3.1 Location of the experiment

The study was carried out at the research farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from October 2016 to March 2017. The location belongs to the sub-tropical climate and AEZ No. 28 called "Madhupur Tract". It is situated at 23°41N latitude and 90°22E longitude with an elevation of 8.6 meter from the sea level (Appendix-I). It is characterized by high temperature accompanied by moderate high rainfall during Kharif season (April to September) and low temperature in the Rabi season (October to March).

3.2 Climate and Soil

The geographical situation of the experimental site was under the subtropical climate, characterized by three distinct seasons**,** the winter or dry season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979) and also characterized by heavy precipitation during the month of july to August and scanty precipitation during the period from October to March. The record of air, temperature, humidity and rainfall during the period of experiment were recorded from the Bangladesh Metrological Department, Agargaon, Dhaka (Appendix II). The experimental site was situated in the subtropical zone. The soil of the experimental site lies in Agro ecological region of Madhupur Tract (AEZ no. 28) of Noda soil series. The soil was loam in texture. The experimental site was medium high land and the pH was 5.6 to 5.8 and organic carbon content was 0.82%. The physical and chemical characteristics of the soil have been presented in Appendix III.

3.3 Experimental material

The experimental material for this study consisted of nine F_2 populations of white maize hybrids. The F_2 seeds were collected from the Department of Genetics and Plant Breeding, SAU, Dhaka. The details pedigree of F_2 populations were presented in Table 1.

3.4 Details of the experiment

The experiment was conducted on nine families of F_2 populations of white maize during Rabi season of 2016-2017. Seeds were collected from Department of Genetics and Plant Breeding and sown in continuous line on 20th November 2016 in research farm of Sher-e-Bangla Agricultural University, Dhaka-1207. The total experimental area was 194.15m^2 whereas each replication area was 17.65 m x 2.5 m = 44.125 m^2. The plant spacing provided was 65 cm between rows and 25 cm between plants of the same row. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

3.5 Cultural practices

3.5.1 Land Preparation

The experimental plot was opened in the first week of November in 2016 with a power tiller and was exposed to the sun for a weak. After a week the land was prepared by several ploughing and cross ploughing followed by laddering and harrowing with power tiller and country plough to bring about good tilth. This was carried out to manage weeds, provide good soil aeration and to obtain good

Table 1. List of plant materials of F_2 population of white maize used in the experiment

Sl. no	Materials	Name of F_1 hybrids selfed
1.	WM- F_1-F_2-1	Changnuo-1
2.	WM- F_1-F_2-2	Yungnuo-30
3.	WM- F_1-F_2-3	Plough-201
4.	WM- F_1-F_2-4	KS-510
5.	WM- F_1-F_2-5	Changnuo-6
6.	WM- F_1-F_2-6	Yungnuo-7
7.	WM- F_1-F_2-7	PSC-121
8.	WM- F_1-F_2-8	Q-Xianguo-1
9.	WM-F_1-F_2-9	Yungnuo-3000

seedling emergence and root penetration. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly. The final land preparation was done on 17th November 2016. Special care was taken to remove the rhizomes of mutha grass.

3.5.2 Manure and Fertilizer Application

Generally cow dung, Urea, TSP and MP fertilizers are required for maize cultivation. The field was fertilized with 10 ton cow dung per ha. The field was also fertilized with 185-276-276-185-17-12 kg N, P, K, S, Zn and B per ha respectively. The entire amount of cow dung was applied seven days before sowing. TSP. MP, Gypsum and Boron were applied during final land preparation and incorporated into the soil. The total amount of urea was divided by three splits. One third of the urea was applied after 30 days of seed germination and the rest two splits of the urea applied after 50 and 70 days of seed germination (before flowering) of the plants, respectively.

3.5.3 Seed sowing

After the lay out, the seeds of F_2 populations of white maize were assigned to different plots in each replication by using random numbers. The plot size was 2.5 m x 2 m. 10 hills were assigning 2.5 m length row with three rows for each plot. The seeds of each F_2 populations were sown by dibbling two seeds per hill. The gap filling was done by re-sowing within a week after germination. Seeds were sown in main field on 20th November 2016. Before sown the seeds they were treated with Sevin 75 WP @ 2 g per Kg of seeds for controlling ants. Seed sowing is shown in Plate 1.

Plate 1: Sowing of the seed in the experimental plot

3.5.4 Thinning of excess seedlings

The weak seedlings were thinned out leaving only one vigorous seedling per hill after 25 days of sowing. The first one third dose of nitrogen fertilizer was top dressed at 30 days after sowing. All recommended cultural practices were followed to raise a good white maize crop.

3.5.5 Other intercultural operations

The 1^{st} and 2^{nd} weeding were done respectively after 20 and 40 days of sowing to keep the soil free from weeds. Irrigation was given when it was necessary during the crop growing period. Earthling up was done twice during the growing period. The first earthling up was done at 45 days after sowing (DAS) and the second earthling up was done after 65 DAS. Intercultural operations viz. roughing and earthing up was shown in Plate 2.

3.5.6 Plant protection

Adult and larva of insects maize earworm and maize aphid were found in the crop during the vegetative and silking or tasselling stage of the plant. To control such insects Malathion-57 EC @2ml/litre and dursban-20EC @0.2% were sprayed at 65-75 and 75-85 DAS, respectively.

3.6 Observations recorded

Observations were recorded from the five (5) randomly selected plants at random from each unit plot per replication. Data were collected in respect of the following parameters.

3.6.1 Days to 6^{th} leaf stage

Days to 6^{th} leaf stage were documented as number of days from planting to the time of 6^{th} leaf had fully emerged.

Plate 2: Showing the intercultural operations (A & B)

3.6.2 Days to 50% tasselling

Days to tasselling were recorded as number of days from planting to the time 50% of plant had fully emerged tassels (Plate 3).

3.6.3 Days to 50% silking

Days to silking were recorded as number of days from planting to the time 50% of plants had completely extruded silks (Plate 3).

3.6.4 Plant height (cm)

Plant height refers to the length of the plant from ground level up to the last node (base of the tassel/flag leaf node) of the plant (Figure 1). Height of five randomly selected plants of each unit plot was measured and the mean was calculated. It was measured in cm with a measuring tape.

3.6.5 Cob height (cm)

The heights of cob from ground level to the cob node (Figure 1) from randomly selected plants were measured from each unit plot in centimeters with a measuring tape. Cob height was taken from the soil surface (ground level) to the node bearing the uppermost cob node. Cob heights were measured from the same plant from which plant heights were recorded.

3.6.6 Days to maturity

Days to maturity were recorded as number of days from planting to the time cob cover turn in straw color and base of kernel in black color.

3.6.7 Base diameter (cm)

Base of plant diameter was calculated with calipers and average was done in centimeters.

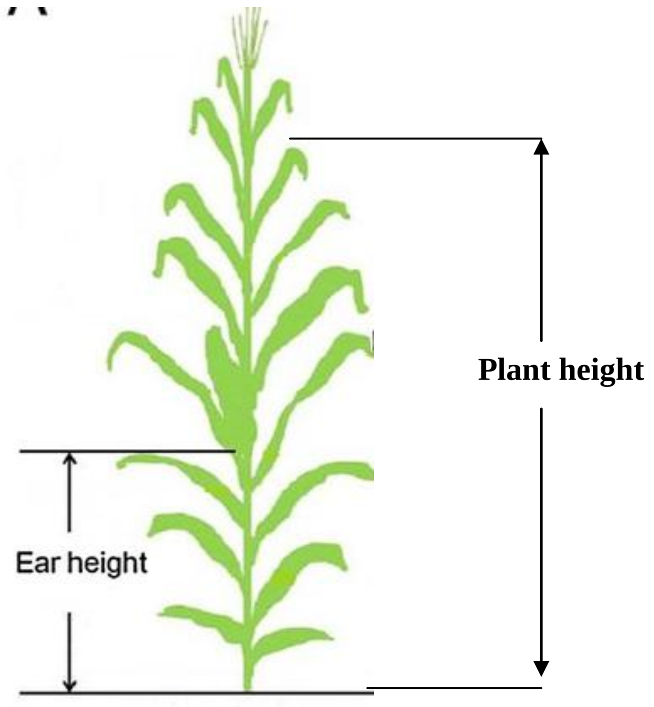

Figure 1. Plant and cob height measurement

Male flower of maize

Female flower of maize

Plate 3: Photographs showing tasselling and silking of maize

3.6.8 Leaves per plant

Number of leaves per plant was recorded by counting all the leaves from the selected plants of each unit plot and the mean was calculated.

3.6.9 Branches of tassel

Number of branches of tassel was recorded by counting all the branches of a tassel from the selected plants of each unit plot and the mean was calculated.

3.6.10 Number of cob bearing node

Number of nodes of cob bearing was recorded from the ground level by counting the nodes from the selected plants of each unit plot and the mean was calculated.

3.6.11 Leaf blade area (cm^2)

Leaf area was calculated by using the equation given by Montgomery (1911) of maize from leaf length and width measurements:

LA = L* W * A

Where

LA = Leaf area (cm^2)
L = Leaf length (cm)
W = Leaf maximum width (cm)
A = Constant, The value of the constant (A) is 0.75.

3.6.12 Cob length (cm)

The lengths of cobs were measured from the cob base to the apex (Figure 2 & plate 4) in centimeter by using measuring scale.

3.6.13 Cob diameter (cm)

The diameter of cobs at the top, basal and central part was measured in centimeter by using a measuring tape and the average was recorded. Cob length and diameter measurement was shown on Figure 2 and Plate 4.

3.6.14 Rows per cob

The total number of rows of each cob were counted and the average was recorded (Figure 3).

3.6.15 Grains per row

The total number of grains from each row of a cob were counted and the average was recorded (Figure 4).

3.6.16 100-grain weight (gm)

A sample of 100 seeds were taken at random and weighed in gram.

3.6.17 Grain yield

All cobs were shelled from selected plants and yield was measured as a bulk weight then average was calculated by dividing the number of selected plants. Yield was measure as gram per plant.

Selfing was done in required number of plants for production of selfed seed in respective F_2 populations to advance them in F_3 generation for developing desirable inbreed (Plate 5).

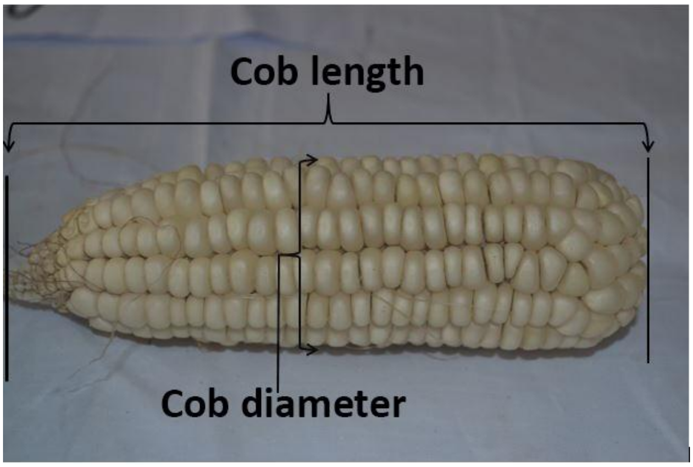

Figure 2. Cob length and cob diameter measurement

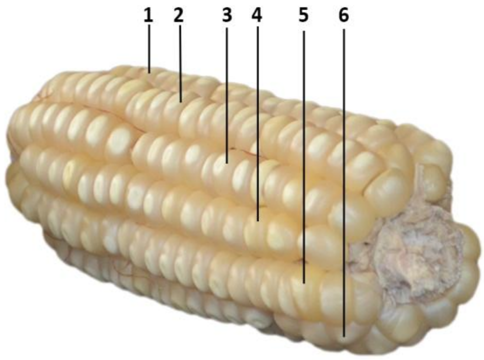

Figure 3. Showing number of rows per cob (1, 2, 3…. Denotes the number of rows)

Figure 4. Showing number of grains per row (1, 2, 3…… Denotes the number grains)

Plate 4: Cob length and diameter measurement

Plate 5: Field view of selfing in selected F_2 plants to advance them to F_3 generation

3.7 Statistical analysis

The mean of the three replicated data collected on 17 traits mentioned above were subjected to biometrical analysis following appropriate biometrical procedures.

3.7.1 Analysis of Variance

Analysis of Variance was carried out as per the procedure given by Panse and Sukhatme (1985). The structure of analysis of variance is as follows.

Source of variation	Degrees of freedom (df)	Sum of squares (SS)	Expected Mean sum of square (MSS)
Replication	r-1	M_1	$\sigma^2_e + t\,\sigma^2_r$
Treatment	t-1	M_2	$\sigma^2_e + r\,\sigma^2_g$
Error	(r-1) (v-1)	M_3	σ^2_e
Total	rv-1	$(M_1 + M_2 + M_3)$	

Where,

r = Number of replications

v = Number of genotypes (treatments)

σ^2_e = Error variance

σ^2_g = Genotypic variance

Statistical significance of variation due to genotype was tested by comparing calculated values to F-table values at one per cent and five per cent level of probability, respectively.

Data on the 17 (seventeen) characters, namely Days to 6th leaf stage, days to 50% tasselling, days to 50% silking, plant height (cm), cob height (cm), days to maturity, base diameter (cm), no. of leaves per plant, no. of branches of tassel, no. of cob bearing node, leaf blade area (cm^2), cob length (cm), cob diameter (cm), no. of rows per cob, no. grains per row, 100 grains weight (g) and yield per plant (g) were recorded from five randomly selected plants from each plot.

3.7.2 Genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula given by **Johnson *et al.* (1955)**.

Genotypic variance (σ^2_g) $= \dfrac{GMS - EMS}{r}$

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

r = number of replications

Phenotypic variance (σ^2_p) $= \sigma^2_g + \sigma^2_e$

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

σ^2_e = Error variance

3.7.3 Genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the formula suggested by Burton (1952)

Genotypic co-efficient of variation (GCV %) = $\sqrt{\dfrac{\sigma_g^2}{\bar{x}}} \times 100$

Where,

σ^2_g = Genotypic variance

$\bar{x}$ = Population mean

Similarly, the phenotypic co-efficient of variation was calculated from the following formula.

Phenotypic co-efficient variation (PCV) = $\sqrt{\dfrac{\sigma_{ph}^2}{\bar{x}}} \times 100$

Where,

σ^2_p = Phenotypic variance

$\bar{x}$ = Population mean

3.7.4 Heritability

Broad sense heritability was estimated (Lush, 1943) by the following formula, suggested by Johnson *et al.* (1955).

Heritability, $h^2{}_b\% = \frac{\sigma^2{}_g}{\sigma^2 p} \times 100$

Where,

$h^2{}_b$ = Heritability in broad sense

$\sigma^2{}_g$ = Genotypic variance

$\sigma^2{}_p$ = Phenotypic variance

3.7.5 Genetic advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Lush (1943) and Johnson *et al.* (1955).

Genetic advance, GA = K. h^2. σ_p

Or Genetic advance, GA = K. $\frac{\sigma^2{}_g}{\sigma^2 p}.\sigma_p$

Where,

K = Selection intensity, the value which is 2.06 at 5% selection intensity

σ_p = Phenotypic standard deviation

$h^2{}_b$ = Heritability in broad sense

$\sigma^2{}_g$ = Genotypic variance

$\sigma^2{}_p$ = Phenotypic variance

3.7.6 Genetic advance mean's percentage

Genetic advance as percentage of mean was calculated from the following formula as proposed by Comstock and Robinson (1952):

$$\text{Genetic advance (\% of mean)} = \frac{\text{Genetic Advance}}{\text{Population mean}} \times 100$$

3.7.7 Genotypic and phenotypic correlation co-efficient

The calculation of genotypic and phenotypic correlation co-efficient for all possible combinations through the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted. The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

Genotypic correlation, $r_{gxy} = \dfrac{GCOVxy}{\sqrt{GVx.GVy}} = \dfrac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx} . \sigma^2_{gy})}}$

Where,

σ_{gxy} = Genotypic co-variance between the traits x and y

σ^2_{gx} = Genotypic variance of the trait x

σ^2_{gy} = Genotypic variance of the trait y

Phenotypic correlation (r_{pxy}) = $\dfrac{PCOVxy}{\sqrt{PVx.PVy}} = \dfrac{\sigma_{pxy}}{\sqrt{(\sigma^2_{px} . \sigma^2_{py})}}$

Where,

σ_{pxy} = Phenotypic covariance between the trait x and y

σ^2_{px} = Phenotypic variance of the trait x

σ^2_{py} = Phenotypic variance of the trait y

3.7.8 Path coefficient analysis

To establish a cause and effect relationship the first step used was to partition genotypic and phenotypic correlation coefficient into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959) and developed by Wright (1921).

The second step in path analysis was to prepare path diagram based on cause and effect relationship. In the present study, path diagram was prepared by taking yield as the effect i.e. function of various components like X_1, X_2, X_3 and these component showed following type of association with each other.

In path diagram the yield is the result of X_1, X_2, X_3…..X_n and some other undefined factors designated by R. The double arrow lines indicated mutual association as measured by correlation coefficient. The single arrow represents direct influence as measured by path coefficient P_{ij}.

Path coefficients were obtained by solving a set of simultaneous equation of the form as per Dewey and Lu (1959).

$r_{ny} = P_{ny} + r_{n2} P_{2y} + r_{n3}P_{3y} + \ldots\ldots\ldots\ldots\ldots$

Where,

r_{ny} = represents the correlation between one component and yield

P_{ny} = represents path coefficient between that character and yield

r_{n2} = represents correlation between that character and each of the other components in turn.

CHAPTER IV
RESULTS AND DISCUSSIONS

In the present investigation the data was collected from nine F_2 populations of white maize hybrids on seventeen traits related to vegetative, reproductive and yield contributing parameters emphasizing growth and yield. The data were subjected to study the genetic variability, correlation and path coefficient analysis in F_2 populations. For achieving the objectives of the study the results obtained are presented below under the following headings:

4.1 Mean performance

4.2 Variability

4.3 Correlation matrix

4.4 Path coefficient analysis

4.1 Mean performance

The analysis of variance and mean performance are presented in Table 2 and Table 3. ‘F’ test revealed highly significant variation among nine families of F_2 populations of white maize genotypes for all the yield contributing characters and yield traits except cob breadth and number of row per cob under studied. It was revealed that the ample possibilities of genetic improvement of the yield potential of white maize genotypes.

4.1.1 Days to 6^{th} leaf stage

Days to 6^{th} leaf stage showed statistically significant variation for different white maize F_2 populations under study (Table 2). Mean days to 6^{th} leaf stage was recorded 44.56 with a range from 43.67 (Yungnuo 7) to 46.00 (Yungnuo 3000) (Table 3 & 4).

Table 2. Analysis of variance for different characters in F_2 populations in white maize

Characters	Mean sum of square		
	Replication (r-1) = 2	**Genotype (g-1) = 8**	**Error (r-1)(g-1) = 16**
Days to 6^{th} leaf stage	7.11	2.17**	0.57
Days to 50% tasselling	3.59	38.40**	3.93
Days to 50% silking	8.33	58.50**	3.75
Plant height (cm)	120.55	2302.98**	141.88
Cob height (cm)	21.36	736.85**	47.77
Days to Maturity	0.11	252.08**	1.44
Base diameter (cm)	0.31	1.57**	0.13
No. of leaves per plant	0.51	5.92**	0.37
No. of branches of tassel	4.84	22.62**	3.74
No. of cob bearinbg node	0.08	2.02**	0.16
Leaf blade area (cm^2)	11972.29	27329.83**	3603.24
Cob length (cm)	5.39	4.89**	1.04
Cob diameter (cm)	0.15	0.11	0.06
No. of rows per cob	0.60	0.92	0.55
No. grains per row	7.66	17.20**	5.07
100 grains weight (g)	34.30	34.55**	8.70
Yield per plant (g)	90.97	506.72**	82.81

** Denote Significant at 1% level of probability

Table 3. Range, mean, CV (%) and standard deviation of nine families of F_2 populations of white maize

Parameters	Range				Mean	CV (%)	SD	SE
	Min		Max					
	Genotype	Value	Genotype	Value				
Days to 6th leaf stage	Yungnuo 7	43.67	Yungnuo 3000	46.00	44.56	1.69	0.44	0.17
Days to 50% tasselling	Yungnuo 7	65.67	Yungnuo 30	77.67	73.26	2.70	1.98	0.75
Days to 50% silking	Yungnuo 7	72.33	Yungnuo 30	85.67	78.11	2.48	1.94	0.73
Plant height (cm)	Yungnuo 7	120.94	KS 510	218.61	162.71	7.32	11.91	4.50
Cob height (cm)	Yungnuo 7	49.78	KS 510	107.22	77.18	8.96	6.91	2.61
Days to maturity	Yungnuo 7	106.00	KS 510	135.00	119.67	1.00	1.20	0.40
Base diameter (cm)	Yungnuo 7	6.13	KS 510	8.29	7.28	5.06	0.37	0.14
No. of leaves per plant	Yungnuo 7	9.72	Q Xiangnuo 1	14.33	13.21	4.63	0.61	0.23
No. of branches of tassel	Yungnuo 7	8.05	Yungnuo 30	16.28	12.47	15.53	1.94	0.73
No. of cob bearinbg node	Yungnuo 7	5.05	KS 510	7.83	6.83	6.02	0.41	0.16
Leaf blade area (cm^2)	Yungnuo 7	359.29	PSC 121	649.02	514.05	11.68	60.03	22.69
Cob length (cm)	Plough 201	14.37	KS 510	18.71	15.92	6.41	1.02	0.39
Cob diameter (cm)	Changnuo 6	4.44	PSC 121	5.05	4.64	5.34	0.25	0.09
No. of rows per cob	Changnuo 6	12.39	PSC 121	14.00	13.20	1.88	0.25	0.09
No. grains per row	Yungnuo 7	21.38	KS 510	30.11	25.70	8.77	2.25	0.85
100 grains weight (g)	Plough 201	30.96	PSC 121	40.78	36.03	8.19	2.95	1.12
Yield per plant (g)	Yungnuo 7	43.42	KS 510	83.85	65.13	13.97	9.10	3.44

CV (%) = coefficient of variation, SD = standard deviation and SE = standard error

Table 4. Mean performance of different characters of nine families of F_2 populations of white maize

Genotype	DSLS	D50%T	D50%S	PH	CH	DM	BD	NL	NB
Changnuo 1	44.00bc	75.00a-c	79.00cd	166.3b-d	87.17b	117e	7.30	14.06ab	10.33cd
Yungnuo 30	43.67bc	77.67a	85.67a	173.4bc	77.44bc	125c	7.76	13.56ab	16.28a
Plough 201	44.00bc	71.67c	74.67e	142.6e	66.45c	111.7f	7.12	12.94b	10.94b-d
KS 510	45.00ab	75.67ab	81.33bc	218.6a	107.2a	135a	8.29	14.33a	16.17a
Changnuo 6	45.00ab	72.00bc	76.00de	146.4de	69.28c	116e	6.43	13.00b	11.00b-d
Yungnuo 7	43.33c	65.67d	72.33e	120.9f	49.78d	106g	6.13	9.723c	8.053d
PSC 121	45.00ab	71.33c	76.00de	181.9b	82.66b	130.3b	7.94	13.33ab	12.11bc
Q Xiangnuo 1	45.00ab	74.33a-c	75.00e	161.5bc-e	78.72bc	115e	7.72	14.33a	14.22ab
Yungnuo 3000	46.00a	76.00a	83.00ab	152.5c-e	75.89bc	121d	6.77	13.61ab	13.11a-c

Table 4. Continued

Genotype	NN	LBA	CL	CD	NRPC	NGPR	HGW	YPP
Changnuo 1	7.22ab	505.3bc	15.88bc	4.49b	12.67ab	26.12ab	36.74abc	71.54ab
Yungnuo 30	6.89b	634.1a	16.75b	4.72ab	13.06ab	25.78b	40.23ab	73.02ab
Plough 201	6.44b	448.0cd	14.37c	4.62ab	13.99a	24.78bc	30.96d	60.77bc
KS 510	7.83a	570.8ab	18.71a	4.76ab	13.55ab	30.11a	36.29abcd	83.85a
Changnuo 6	6.44b	551.9abc	16.07bc	4.44b	12.39b	25.83b	31.52cd	54.01cd
Yungnuo 7	5.05c	359.3d	14.60c	4.52b	12.94ab	21.38c	34.73bcd	43.42d
PSC 121	6.83b	649.0a	15.33bc	5.05a	14.00a	27.61ab	40.78a	74.72ab
Q Xiangnuo 1	7.66a	453.8cd	15.61bc	4.44b	13.00ab	23.95bc	37.78ab	53.03cd
Yungnuo 3000	7.11ab	454.2cd	15.94bc	4.67ab	13.16ab	25.72b	35.22abcd	71.82ab

Value within same letter don`t varied significant at 5% level

DSLS = days to 6th leaf stage, D50%T = days to 50% tasselling, D50%S = days to 50% silking, PH = plant height (cm), CH = cob height (cm), DM = Days to maturity, BD = base diameter (cm), NL = no. of leaves per plant, NB = no. of branches of tassel**,** NN = no. of cob bearinbg node, LBA = leaf blade area (cm^2), CL = cob length (cm), CD = cob diameter (cm), NRPC = no. of rows per cob, NGPR = no. grains per row, HGW = 100 grains weight (g) and YPP = yield per plant (g)

4.1.2 Days to 50% tasselling

Days to 50% tasselling showed statistically significant variation for different white maize F_2 populations under study (Table 2). Data revealed that the average days to 50 % tasselling was recorded around 73.26 with a range from 65.67 to 77.67 (Table 3 & 4). The highest (77.67) days to 50% tasselling was found in the genotypes Yungnuo 30 which was statistically similar with Youngnuo 3000 (76.00) and KS 510 (75.67) whereas the lowest (65.67) days was found from the genotype Yungnuo 7. Data revealed that different variety required different days to 50% male flowering. Huda (2015) reported that the minimum and maximum duration for 50% tasselling was observed in the genotype G5 (55.33 days) and G14 (63.33 days), respectively .Which was supported this experiment findings.

4.1.3 Days to 50% silking

Statistically significant variation was observed for days to 50% silking among white maize F_2 populations under investigation (Table 2 and Figure 5). The average days to 50% silking was recorded 78.11 days with a range from 72.33 to 85.67 (Table 3). The minimum (72.33) days to 50% silking was observed the genotype Yungnuo 7 which was statistically similar with Plough 201 (74.67) and Q Xiangnuo 1 (75.00). The highest (85.67) days to 50% silking was found in the genotypes Yungnuo 30 which was statistically similar with Yungnuo 3000 (83.00).The differences in days to 50% flowering might be due to influences of both the genetical and environmental factors in the controlling of the trait. According to Huda (2015), the mean for this character was 60.69 days, which ranged from 57 - 65.33 days. The minimum days required for 50% silking was in G5 (57 days) and maximum days were for G14 (65.33 days).

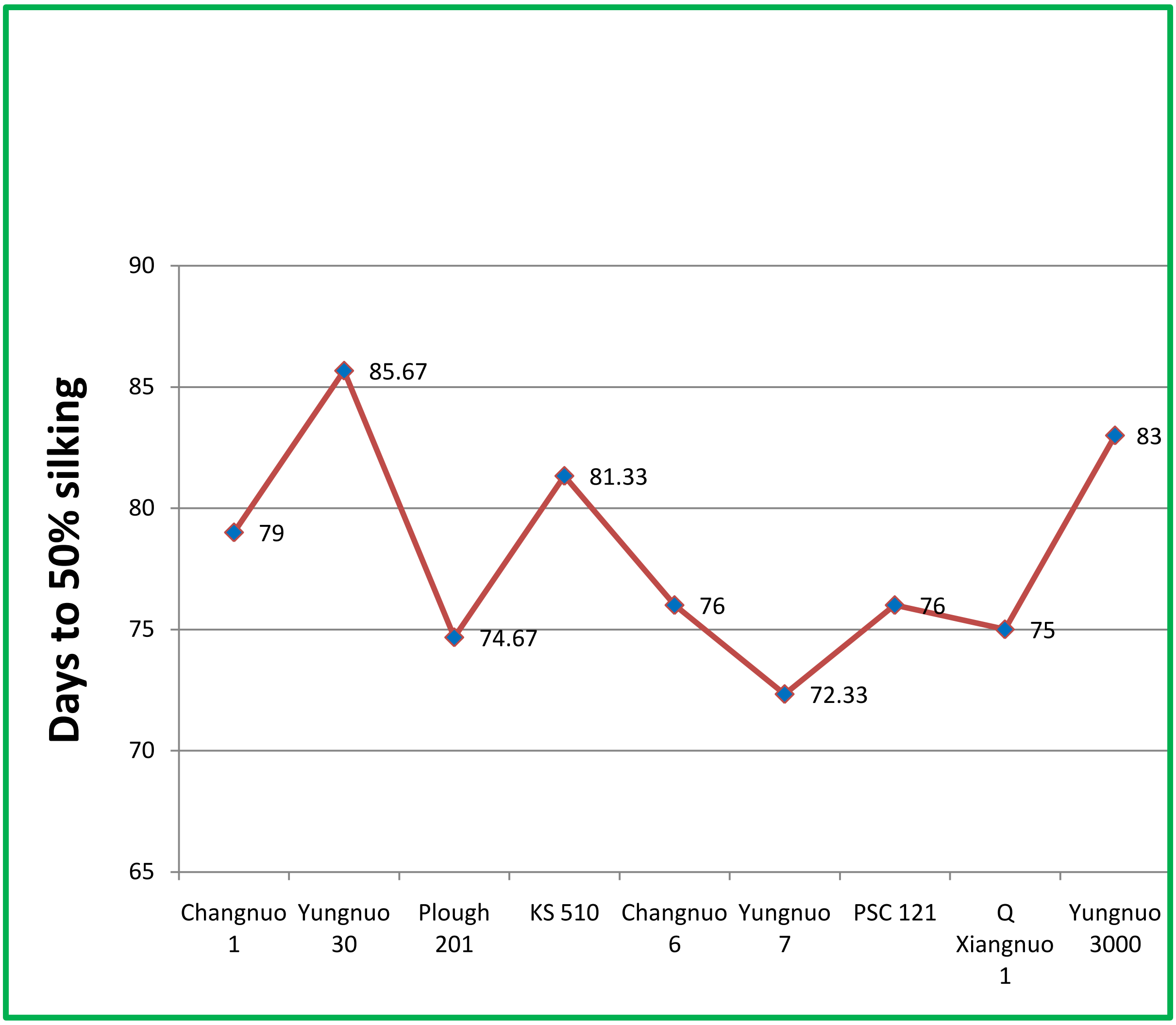

Figure 5. Figure showing mean performance of 50% silking of the nine families of F_2 populations of white maize

4.1.4 Plant height (cm)

Plant height is an important agronomic character for selecting desirable genotype for breeding program (Ali *et al*., 2012). Plant height is a genetically as well as environmental controlled trait and different hybrid cultivars and their segregating generations represents different plant height. Plant height varied significantly due to different white maize F_2 populations indicated considerable difference among the genotypes studied (Table 2 and Figure 6). The lowest (120.94 cm) plant height was recorded in the genotype Yungnuo 7. In the investigation the highest (218.61 cm) plant height was observed from the genotype KS 510. The average plant height was recorded 162.71 cm with a ranged from 120.94 cm to 218.61 cm (Table 3 & 4). Tahir *et al. (*2008) reported that maximum (206.00) plant height was found in Pioneer-32B33 which was followed by FSH-421 (200.00), HG-3740 (196.75) and pioneer-3062 (195.00); and the minimum (173.75) plant height was observed in Rafhan-2303. These results are also in accordance with the results of Ali (1994) who also reported difference of plant height in different hybrids.

4.1.5 Cob height (cm)

Cob height means the distance between cob formation node (where the cob is formed) and base of the plant (in soil surface). It is measured by a measuring scale or tape. Cob height of different families was varied significantly in different white maize F_2 populations (Table 2). This result are in line with those of Dijak *et al*. (1999) who observed significant differences while evaluating maize genotypes for this trait. The average cob height was recorded 77.18 cm with a range from 49.78 cm to 107.22 cm (Table 3). The lowest (49.78 cm) cob height was recorded in Yungnuo 7. The highest (107.22 cm) cob height was observed in KS 510. Huda (2015), found that cob height ranges from 60.67 cm (G16) to 89.33 cm (G7) with mean value 76.56 cm.

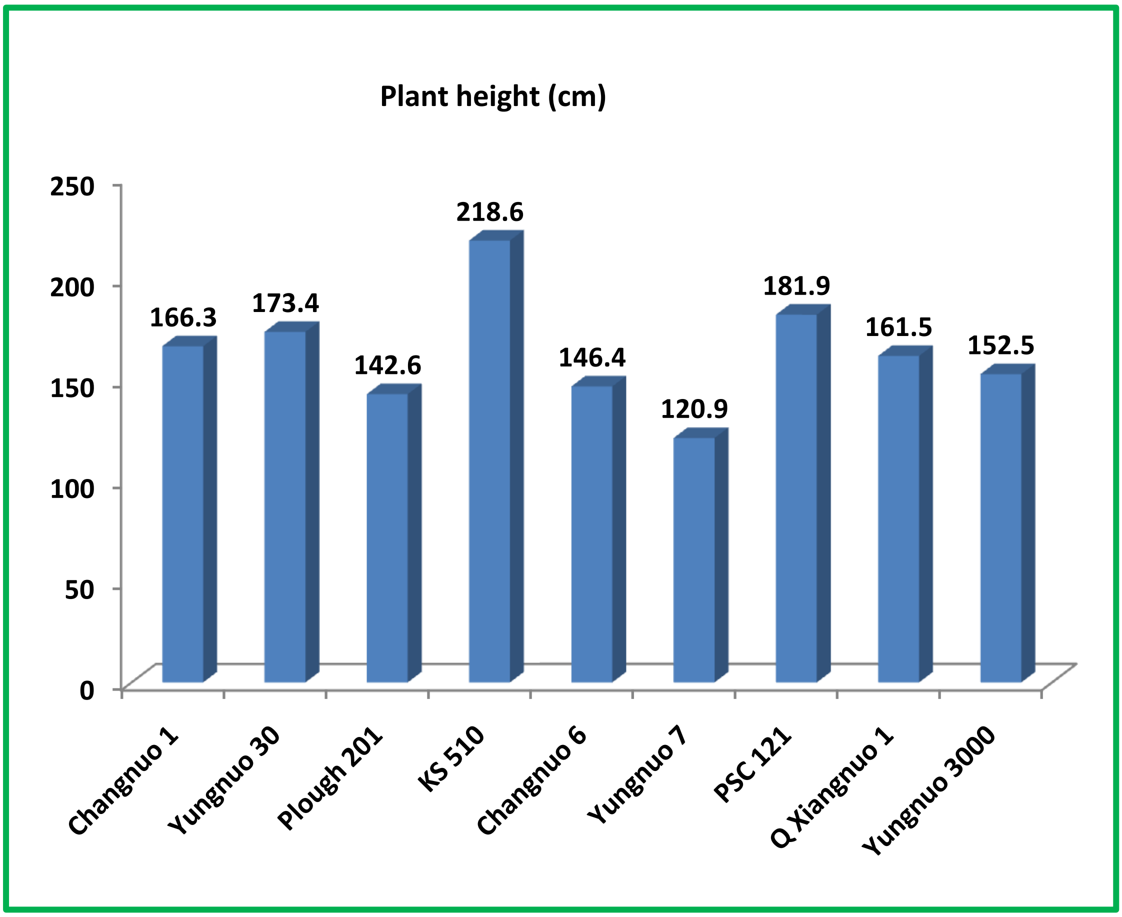

Figure 6. Showing of different F_2 population of white maize for plant height

4.1.6 Days to maturity

Statistically significant variation was recorded for days to maturity for different white maize F_2 populations (Table 2 and Figure 7). The average days to maturity was recorded 119.67 with a range from 106.00 to 135.00 (Table 3). The highest (135) days to maturity was found in the genotype KS 510 which was followed by PSC 121 (130.3). The minimum (106) days to maturation was found from the genotype Yungnuo 7 which was followed by the genotype Plough 201 (111.7). Nine families of F_2 populations are shown in Plate 6 which indicating the variation among them in days to maturity respectively (The photographs are taken in the same date).

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4.1.7 Base diameter (cm)

Base diameter was significantly varied among different F_2 populations of white maize (Table 2). The average value of base diameter was observed 7.28 cm. The maximum base diameter was found in the F_2 populations of KS 510 (8.29 cm) whereas the minimum value in Yungnuo 7 (6.13 cm) (Table 3 & 4).

4.1.8 Leaves per plant

Significant variation was observed for number of leaves per plant among different white maize genotypes (Table 2 and Figure 8). The average number of leaves per plant was recorded around 13.21 with a range from 9.72 to 14.33 (Table 3). The most (14.33) number of leaves per plant was recorded in both the genotypes KS 510 and Q Xiangnuo 1 which were statistically similar with Changnuo 1 (14.06) and Yungnuo 3000 (13.61) (Table 4) whereas the least (9.72) number was observed from the genotype Yungnuo 7. These results are in line with those of Dijk *et al.* (1999) who observed significant differences while evaluating maize genotypes for different morphological and yield traits.

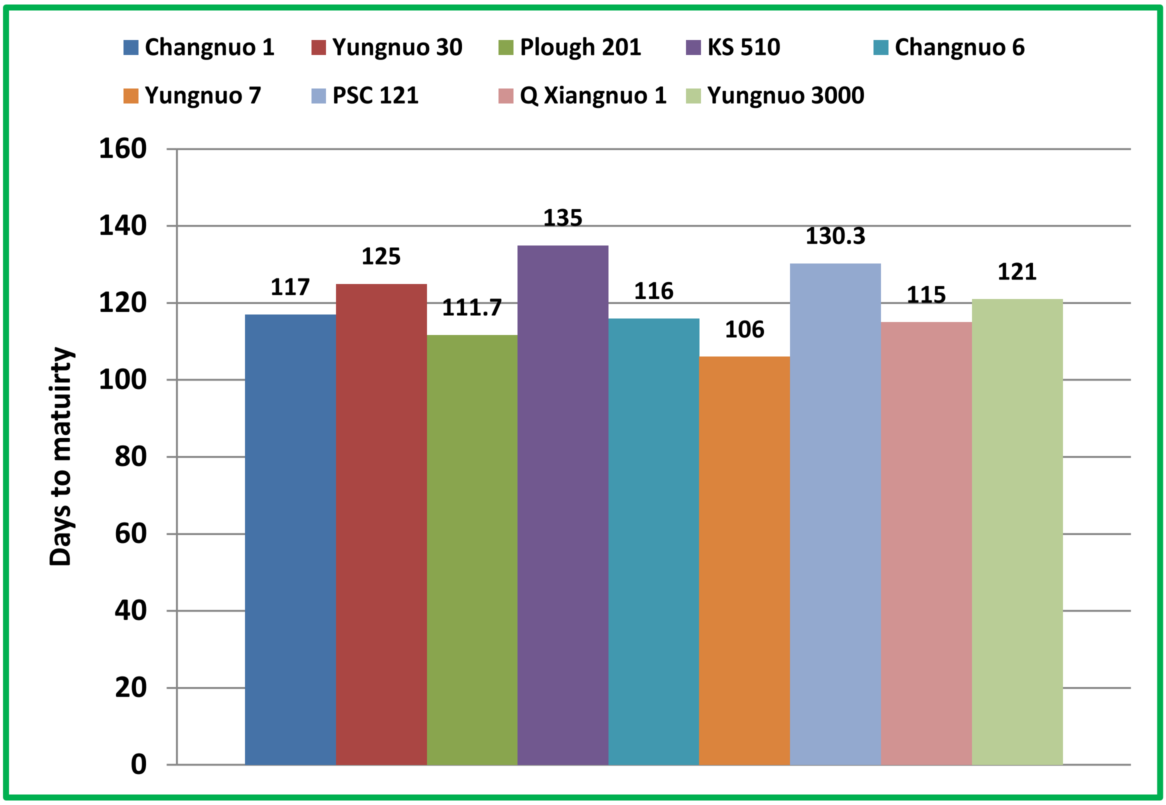

Figure 7. Variation in days to maturity of nine families of F_2 population of white maize

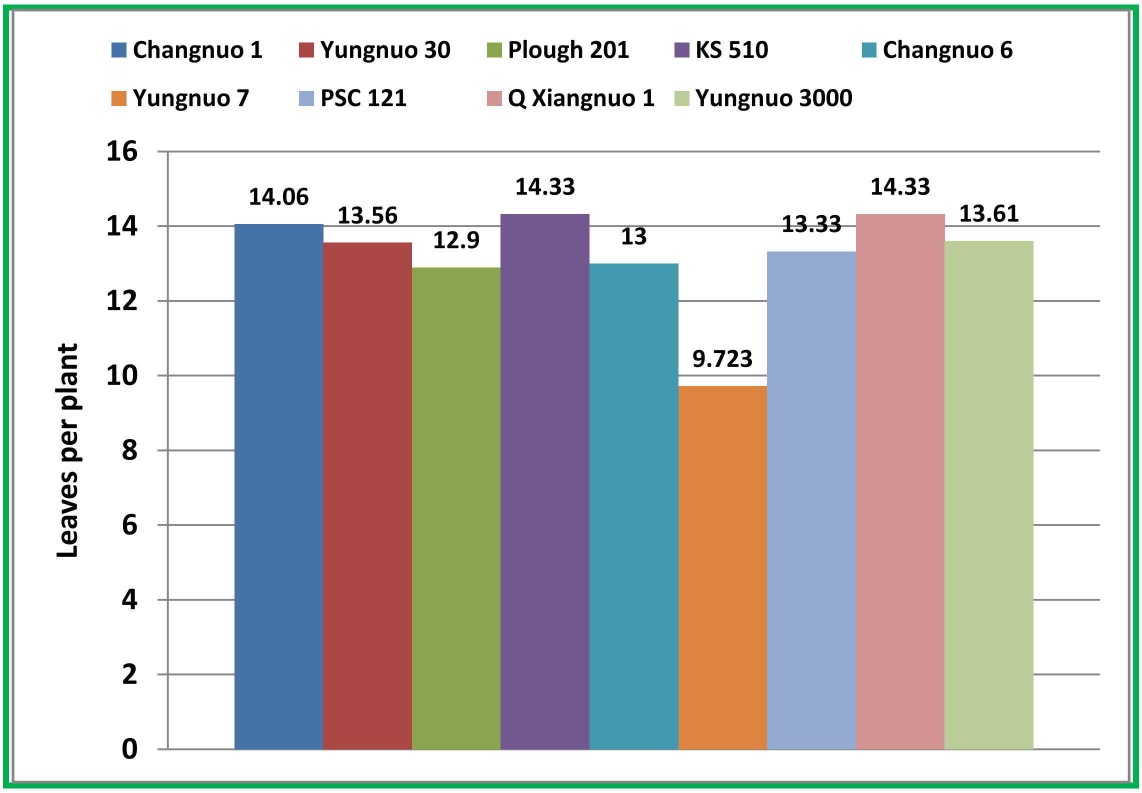

Figure 8. Variation in leaves per plant of nine families of F_2 population of white maize

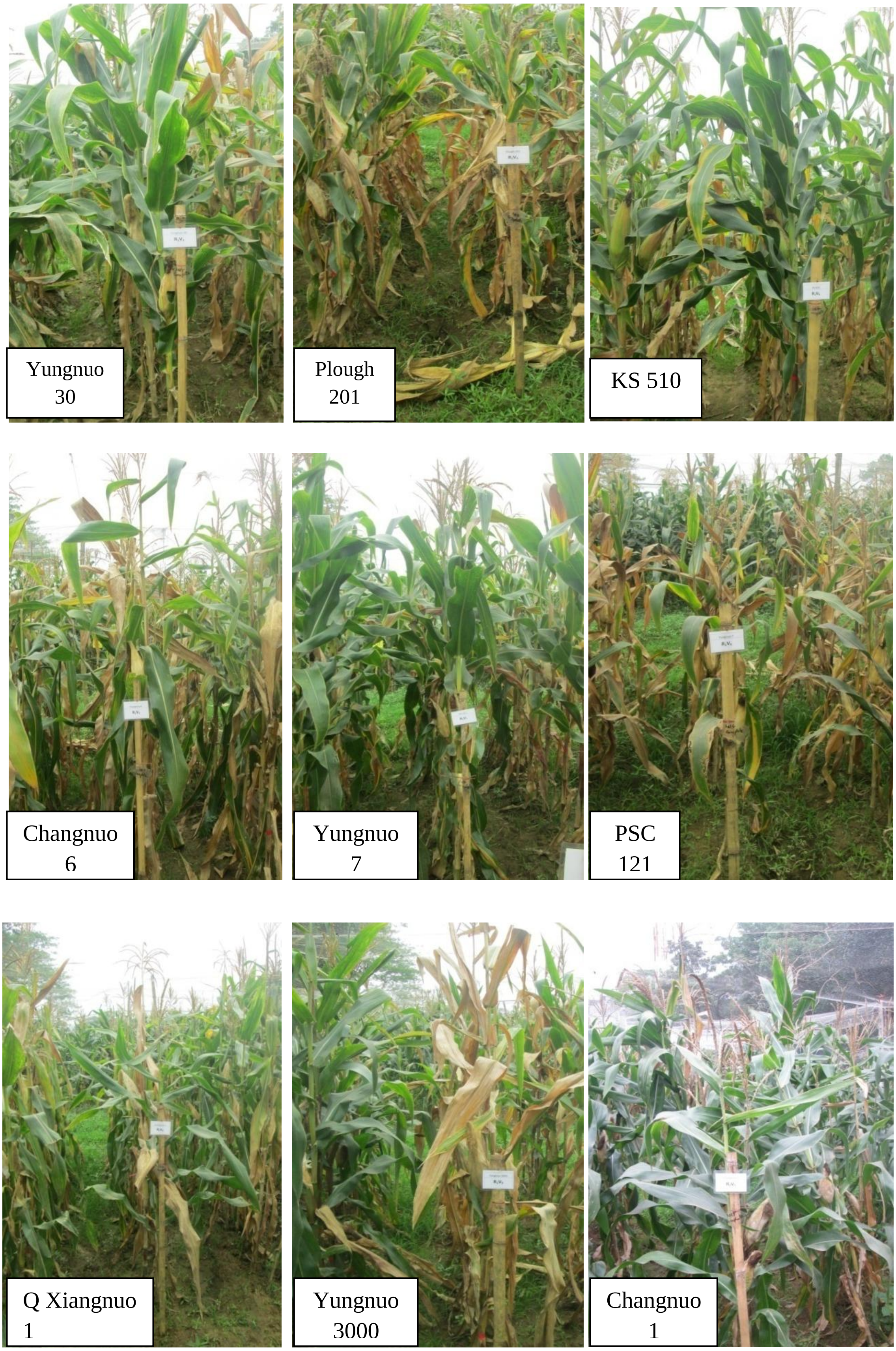

Plate 6: Photographs of nine F_2 populations of white maize in the research field showing variation in days to maturity

4.1.9 Number of branches of tassel

Number of branches of tassel was found significant variation among different white maize F_2 populations (Table 2). The mean value of this trait was 12.47. The highest number of branches of tassel was observed in maize F_2 populations of Yungnuo 30 (16.28) which were statistically similar with KS 510 (16.17) and Q Xiangnuo 1 (14.22). The lowest number of branches of tassel was found in maize F_2 populations of Yungnuo 7 (8.05) and which was statistically similar with Changnuo 1 (10.33) (Table 3 & 4).

4.1.10 Number of cob bearing node

Number of cob bearing node varied significantly among the white maize found in F_2 populations (Table 2). It was highest number in the F_2 populations of KS 510 (7.83) which was similar in statistically with F_2 populations Q Xiangnuo 1 (7.66). The lowest number of cob bearing node was performed by the F_2 populations of Yungnuo 7 (5.05) (Table 3 & 4).

4.1.11 Leaf blade area (cm^2)

Leaf blade area varied significantly among the different F_2 populations of white maize under the study (Table 2). The average leaf blade area was observed 514.05 cm^2. The highest leaf area was found by the F_2 populations of PSC 121 (649.04 cm^2) whereas the lowest leaf area observed in F_2 population of Yungnuo 7 (359.29 cm^2) (Table 3).

4.1.12 Cob length (cm)

Significant variation was exhibited in respect of cob length among different families of F_2 populations under studied (Table 2 and Plate 6). Naushad *et al.* (2007) was observed significant variation in maize genotypes for cob length.The average cob length was recorded 15.92 with a range from 14.37 to 18.71.

Plate 7: Representing different cob length (very long, long, medium, short, very short) within same F_2 population of white maize

The longest (18.71) cob was observed in the genotype KS 510, whereas the shortest (14.37) cob length was observed from the genotype Plough 201. Huda (2015) reported that cob length ranged from 15.07 cm to 21.67 cm which was observed in G13 and G18, respectively.

4.1.13 Cob diameter (cm)

Cob diameter varied insignificantly in different white maize genotypes (Table 2). The average cob diameter was recorded 4.64 cm with a range from 4.44 cm to 5.05 cm (Table 3). The highest (5.05) cob diameter was recorded in the genotype PSC 121 which was statistically similar with KS 510 (4.76 cm), whereas the lowest (4.44 cm) cob diameter was observed from the genotype Changnuo 6.

4.1.14 Number of rows per cob

Number of rows per cob is a genetically controlled factor but environmental and nutritional level may also influence the number of rows per cob (Tahir *et al.*, 2008). The more number of rows per cob results in more grain yield. Row per cob varied insignificantly in different maize genotypes (Table 2). The average row per cob was recorded 13.20. The highest (14.00) row per cob was recorded in the genotype PSC 121 and it was statistically similar with the genotype Plough 201 (13.99) and KS 510 (13.55), while the lowest (12.39) number of row per cob was observed from the genotype of Changnuo 6. These results were in line with Ahmad *et al.* (1978) in maize.

4.1.15 Grains per row

Number of grains per row varied significantly due to different maize genotypes (Table 2). The average number of grains per row was recorded around 25.70 with a range from 21.38 to 30.11 (Table 3 & 4). The highest (30.11) number of grains per row was recorded in the genotype KS 510 which was statistically similar with PSC 121 (27.61) and Changnuo 1 (26.12), whereas the lowest (21.38) number was observed from the genotype Yungnuo 7. According to Huda (2015), the maximum grains per row were found (40.4) in the genotype G13 and minimum number of grains per row were found (16.27) in the genotype G18.

4.1.16 100-grain weight (g)

100-grain weight is an important factor directly contributing to final grain yield. In the present study significant variation in 100-grain weight was found in the studied populations (Figure 9). This might be due to genetically factors controlling 100-grain weight. The data indicated that highly significant variation observed in 1000-grain weight among different maize genotypes (Table 2). The average 100-grain weight was 36.03 g with a range from 30.96 g to 40.78 g (Table 3 & 4). The highest (40.78 g) 100-grain weight was recorded in the genotype PSC 121 while the lowest (30.96 g) weight of 100-grain was observed from the genotype Plough 201. The similar results were also reported by Jing *et al.* (2003) and Ali (1994).

4.1.17 Grain yield per plant (g)

Grain yield trait is found to be varied significantly due to different maize genotypes under the present study (Table 2). Data revealed that the average grain yield per plant was recorded 65.13 g with a range from 43.42 g to 83.85 g (Table 3 & 4). The highest (83.85 g) grain yield per plant was recorded in the genotype KS 510 which was statistically similar with PSC 121 (74.72 g) and Yungnuo 30 (73.02 g) (Figure 10). Tahir *et al. (*2008) observed that **t**he maximum grain yield was obtained from HG-3740. The lowest (43.42 g) grain yield was observed from the genotype yungnuo 7 which was statistically similar with Changnuo 6 (54.01 g).

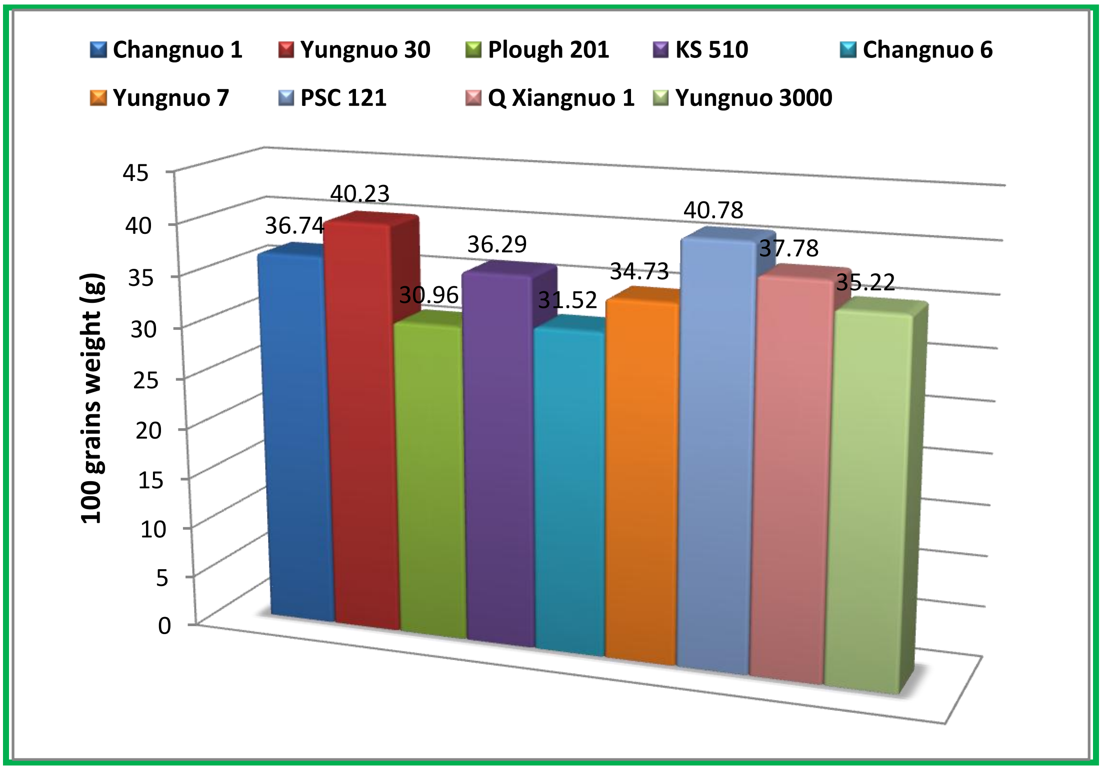

Figure 9. Variation in 100 grains weight of nine families of F_2 population of white maize

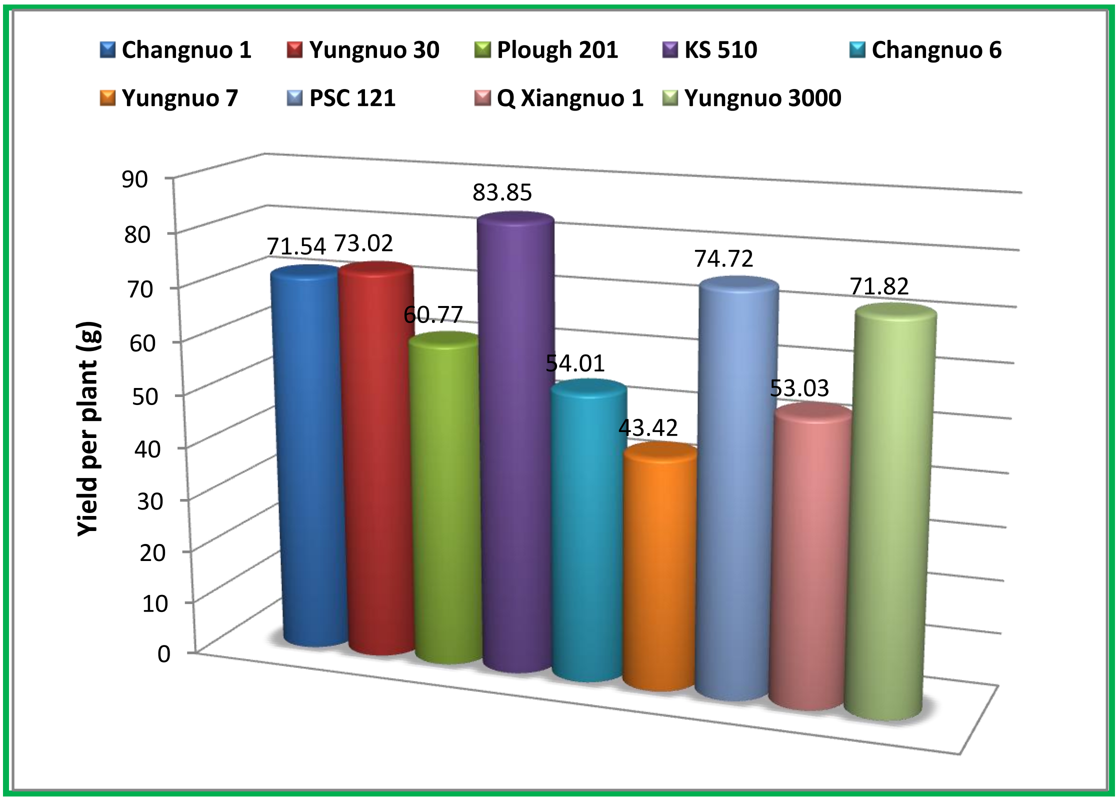

Figure 10. Variation in yield per plant of nine families of F_2 population of white maize

4.2 Variability

The achievement in any crop improvement program depends on the capability of the breeder to define and accumulate the required genetic variability and to select for yield indirectly through yield associated and highly heritable characters after eliminating the environmental component of phenotypic variation (Mather, 1949). Therefore, it is necessary to have prior information on both Phenotypic coefficient variation and Genotypic coefficient variation, so that the estimate of heritability that helps the breeder to predict the expected GA possibly by selection for a character can be computed.

The results are pertained to analysis of variance (ANOVA), range, grand mean, CV%, mean performance, genotypic and phenotypic variance, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2_b) and expected genetic advance as per cent of mean (GA) for all the seventeen traits are furnished in Table 5. Genotypic and phenotypic coefficient of variation is shown in Figure 11, heritability and genetic advance as per cent of mean is represented in Figure 12. The character wise details of these variability are discussed below of the nine families of F_2 population of white maize evaluated for 17 characters are presented in below**.**

4.2.1 Days to 6th leaf stage

The phenotypic variance of days to 6th leaf stage (0.69) was slightly higher than the genotypic variance (0.49) that indicating less environmental influence on this characters which was supported by narrow difference between phenotypic (1.86%) and genotypic (1.57%) co-efficient of variation (Table 5). Least difference of phenotypic variance to genotypic variance indicating that these characters were less responsive to environmental factors for their phenotypic expression.

Table 5. Estimation of genetic parameters for different characters of F_2 population of white maize

Parameters	σ^2p	σ^2g	σ^2 e	PCV	GCV	ECV	Heritability	Genetic advance (5%)	Genetic advance (% mean)
Days to 6th leaf stage	0.69	0.49	0.19	1.86	1.57	0.99	71.62	1.22	2.74
Days to 50% tasselling	15.42	11.49	3.93	5.36	4.63	2.70	74.53	6.03	8.23
Days to 50% silking	22.00	18.25	3.75	6.00	5.47	2.48	82.95	8.02	10.26
Plant height (cm)	862.25	720.36	141.88	18.05	16.50	7.32	83.55	50.54	31.06
Cob height (cm)	277.46	229.70	47.77	21.58	19.64	8.96	82.78	28.41	36.81
Days to maturity	84.99	83.55	1.44	7.70	7.64	1.00	98.30	18.67	15.60
Base diameter (cm)	0.62	0.48	0.14	10.79	9.53	5.06	78.01	1.26	17.34
No. of leaves per plant	2.23	1.85	0.37	11.29	10.30	4.63	83.20	2.56	19.35
No. of branches of tassel	10.04	6.29	3.75	25.41	20.12	15.53	62.68	4.09	32.82
No. of cob bearinbg node	0.79	0.62	0.17	12.99	11.51	6.02	78.52	1.44	21.01
Leaf blade area (cm^2)	11512.11	7908.86	3603.25	20.87	17.30	11.68	68.70	151.85	29.54
Cob length (cm)	2.33	1.28	1.04	9.58	7.12	6.41	55.22	1.73	10.90
Cob diameter (cm)	0.08	0.02	0.06	6.07	2.89	5.34	22.64	0.13	2.83
No. of rows per cob	0.68	0.12	0.55	6.23	2.66	5.63	18.22	0.31	2.34
No. grains per row	9.12	4.04	5.08	11.75	7.82	8.77	44.34	2.76	10.73
100 grains weight (g)	17.32	8.62	8.70	11.55	8.15	8.19	49.75	4.27	11.84
Yield per plant (g)	224.11	141.30	82.81	22.98	18.25	13.97	63.05	19.44	29.85

σ^2p = Phenotypic variance
σ^2g = Genotypic variance
σ^2 e = Environmental variance

PCV = Phenotypic coefficient of variation
GCV = Genotypic coefficient of variation
ECV = Environmental coefficient of variation

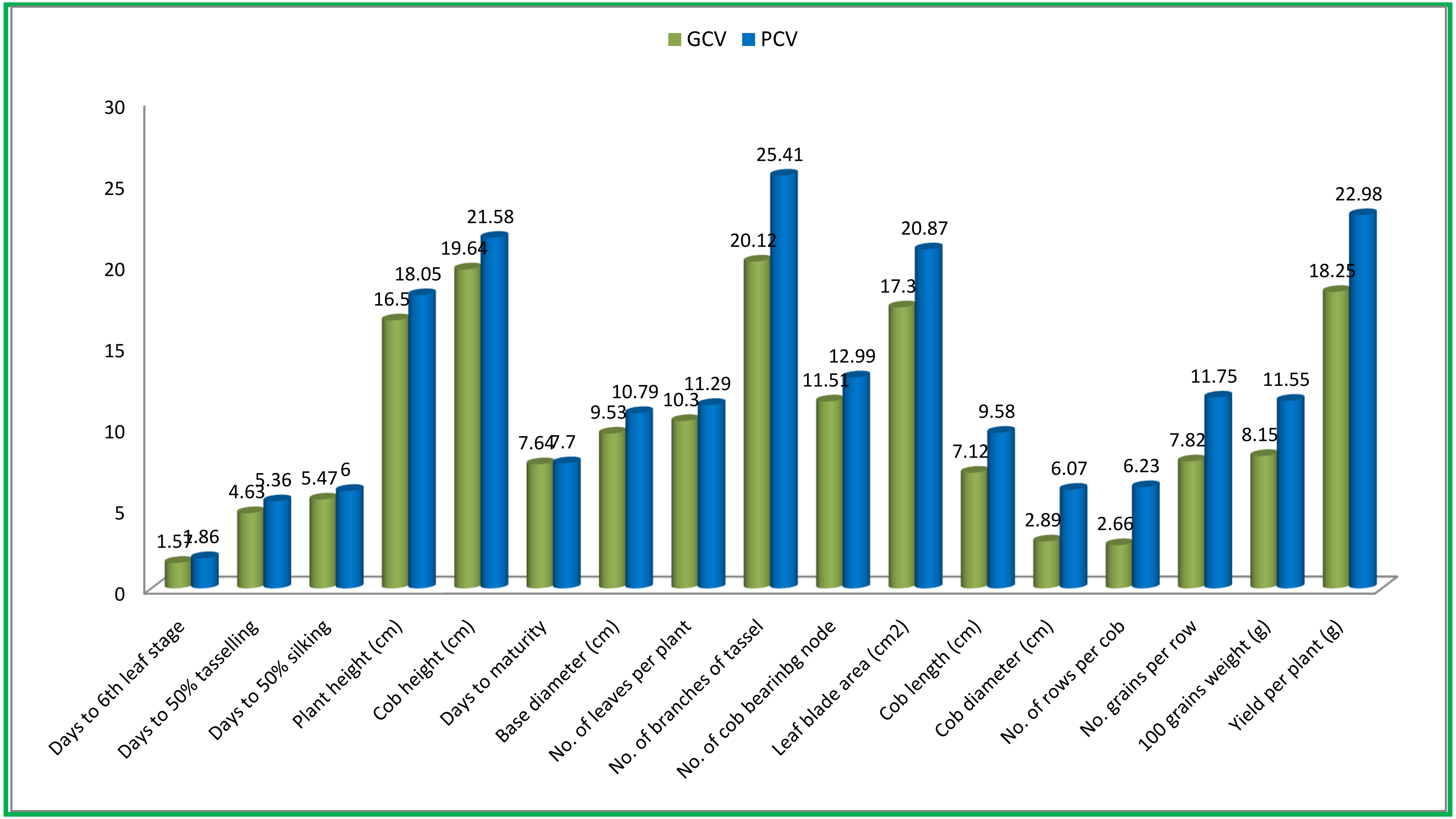

Figure 11. Genotypic and phenotypic coefficient of variation of 17 traits of F_2 population of white maize

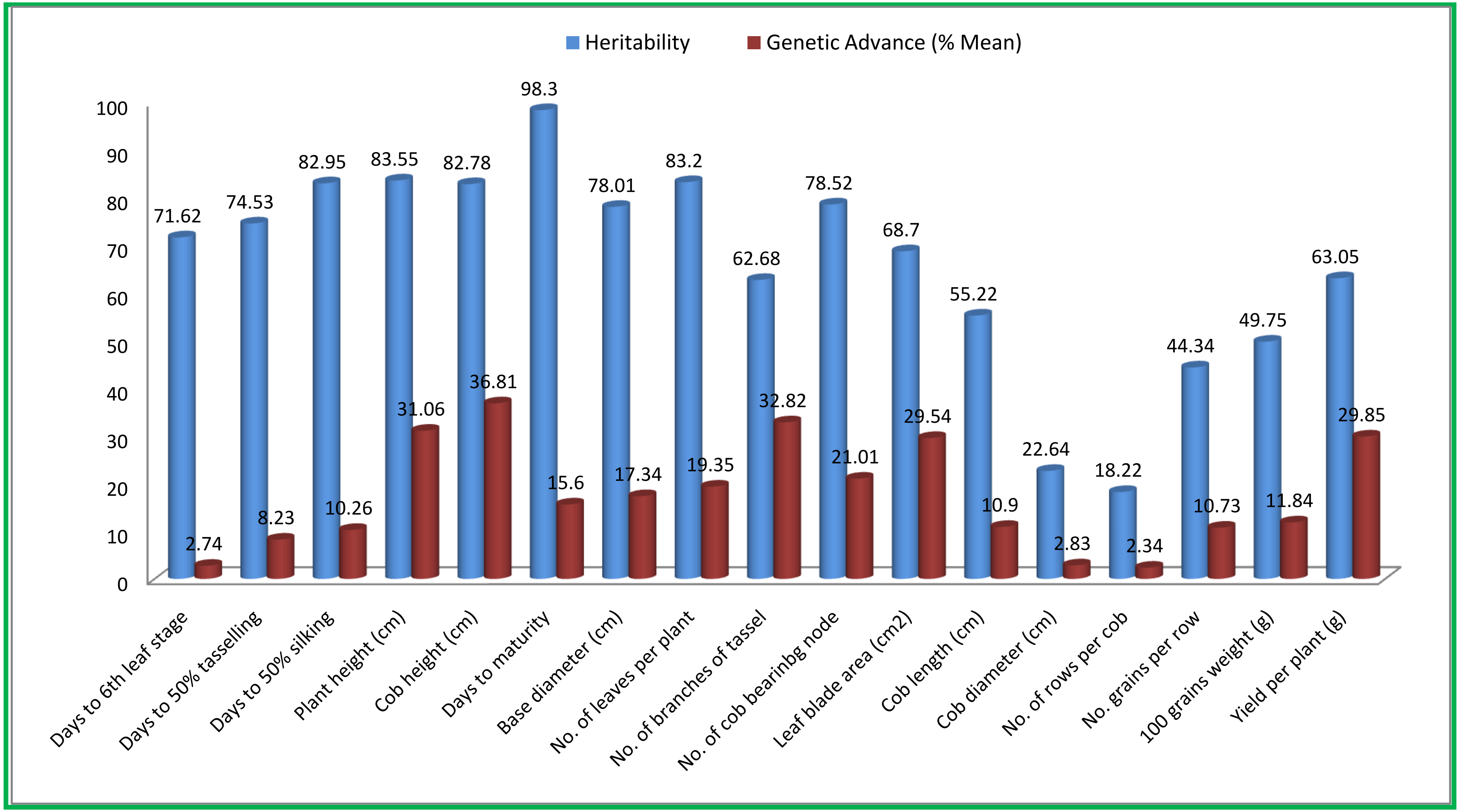

Figure 12. Heritability and genetic advance in percent of mean of 17 traits of F_2 population of white maize

4.2.2 Days to 50% tasselling

In reference to the days to 50% tasselling (15.42) was higher than the genotypic variance (11.49) that indicating environmental influence on this characters which was supported by narrow difference between phenotypic (5.36%) and genotypic (4.63%) co-efficient of variation (Table 5). High heritability (74.53%) in days to 50% tasselling attached with low genetic advance in percentage of mean (8.23%). High estimate of heritability and low genetic advance for days to 50% tasselling suggested that this character was controlled by both additive and non-additive gene action and selection on the basis of this would not be rewarded. Similar results were found by Grzesiak (2001) who reported high heritability for days to 50% tasselling.

4.2.3 Days to 50% silking

In reference to the phenotypic variance of days to 50% silking (22.00) was found higher than the genotypic variance (18.25) that indicating environmental influence on this characters which was supported by narrow difference between phenotypic (6.00%) and genotypic (5.47%) co-efficient of variation (Table 5). High heritability (82.95%) attached with low genetic advance in percentage of mean (10.26%) were found for this trait. High heritability and low genetic advance revealed the major role of non-additive gene action in the transmission of this character from parents to off springs. Similar findings were found by Grzesiak (2001) reported high heritability for days to 50% silking.

4.2.4 Plant height (cm)

The phenotypic variance of plant height (862.25) was higher than the genotypic variance (720.36) indicating that highly environmental influence for expression of this character which was supported by difference between phenotypic

(18.05%) and genotypic (16.50%) co-efficient of variation (Table 5). High heritability (83.55%) along with high genetic advance (50.54%) and high genetic advance in percent of mean (31.06%) revealed the possibility of predominance of additive gene action in the inheritance of this trait. So, selection based on this trait would be effective. Similar findings were also reported by Alvi *et al.* (2003). Mihaljevic *et al.* (2005) obtained high heritability values (0.90) for plant height. The greater the heritability of a particular trait, the lesser will be the environmental effect on its expression.

4.2.5 Cob height (cm)

In reference to phenotypic variance of cob height was found to be (277.46) higher thanits genotypic variance (229.70) indicating that highly environmental influence for expression of this character (Table 5). The phenotypic coefficient of variation (21.58%) was higher than the genotypic coefficient of variation (19.64%), which suggested that environment has a significant role on the expression of this trait. High heritability (82.78) coupled with high genetic advance as percent of mean (36.81) was observed for this trait. These traits were most probably controlled by additive gene action.

4.2.6 Days to maturity

The phenotypic variance of days to maturity (84.99) was little bit higher than its genotypic variance (83.55) indicating less environmental influence on expression of this character. This phenomenon was supported by narrow difference between phenotypic (7.70%) and genotypic (7.64%) co-efficient of variation (Table 5). High heritability (98.30%) along with moderate genetic advance in percentage of mean (15.60%) indicating the trait was most probably controlled by both additive and non-additive gene action.

4.2.7 Base diameter (cm)

A narrow difference between phenotypic variance (0.62) and genotypic variance (0.48) of base diameter was supported the speculation that environment had little effect on this character under the present study (Table 5). A little difference GCV and PCV indicating that these characters were less responsive to environmental factors for their phenotypic expression. High heritability (78.01%) with low genetic advance (1.26%) indicate that this character was controlled by both additive and non-additive gene action and selection on the basis of this would not be rewarded.

4.2.8 Leaves per plant

The difference between phenotypic variances (2.23) and genotypic variances (1.85) was relatively low for leaves per plant indicating low environmental influence on these characters (Table 5). The value of PCV and GCV were 11.29 % and 10.30% respectively for this trait which indicating that less variation exists among different genotypes. Leaves per plant showed high heritability (83.20%) along with low genetic advance (2.56%) and medium genetic advance in percent of mean (19.35%) revealed that predominance of both additive and non-additive gene action in the inheritance of this trait.

4.2.9 Number of branches of tassel

Number of branches of tassel showed the phenotypic variance and genotypic variance were 10.04 and 6.29, respectively with relatively large differences indicating large environmental influences on expression of this character as well as PCV (25.41%) and GCV (20.12%) is indicating presence of considerable variability among the genotypes (Table 5). Number of branches of tassel showed high heritability (62.68 %) along with low genetic advance (4.09%) and medium genetic advance in percent of mean (32.82%) revealed that predominance of both additive and non-additive gene action in the inheritance of this trait.

4.2.10 Number of cob bearing node

The differences between phenotypic variances (0.79) and genotypic variances (0.62) were relatively low for leaves per plant indicating low environmental influence on these characters (Table 5). The value of PCV and GCV were 12.99% and 11.51% respectively for this trait which indicating that less variation exists among different genotypes. High heritability (78.52%) with low genetic advance (1.44%) indicated that this character was controlled by both additive and non-additive gene action and selection on the basis of this would not be rewarded.

4.2.11 Leaf blade area

The phenotypic variance of leaf blade area (11512.11) was higher than the genotypic variance (7908.86) indicating that highly environmental influence for expression of this character which was supported by high difference between phenotypic (20.87%) and genotypic (17.30%) co-efficient of variation (Table 5). High heritability (68.70%) coupled with high genetic advance as percent of mean (29.54%) was observed for indicating that this trait is controlled by additive gene action which is very useful in selection. The higher value of heritability for grain yield per plant indicates that this character can be used as the genetic parameter for the improvement and selection of higher yielding genotype. Crop improvement could be possible by simple selection because high heritability coupled with high genotypic variation revealed the presence of an additive gene effect.

4.2.12 Cob length (cm)

Cob length showed less differences between phenotypic variance (2.33) and genotypic variance (1.28) indicating less environmental influence on this character and relatively moderate difference between PCV (9.58%) and GCV (7.12%) value indicating the apparent variation not only due to genotypes but also due to the moderate influence of environment (Table 5 and Plate 8). Huda (2015) found that phenotypic and genotypic coefficient of variations was 13.10 and 12.43. The moderate heritability estimates of 55.22% with an expected genetic advance as percent of mean of 10.90 percent. Moderate heritability coupled with low genetic advance was observed for this character, indicating little scope for the selection upon this character due to the non-additive gene action. In the contrary Huda (2015) reported that heritability of this trait was high (89.95%) but genetic advance was low (4.22) along with high genetic advance as a percentage of mean (24.28).

4.2.13 Cob diameter (cm)

The phenotypic variance of cob diameter refers to phenotypic variance (0.08) was less higher than the genotypic variance (0.02) that indicating less environmental influence on this characters where high difference between phenotypic (6.07%) and genotypic (2.89%) co-efficient of variation (Table 5). Low heritability (22.64%) along with low genetic advance in percentage of mean (2.83%) indicating the little scope for the selection upon this character due to the non-additive gene action.

4.2.14 Row per cob

Phenotypic and genotypic variance for row per cob were observed 0.68 and 0.12, respectively with significant differences between them, suggested the influence of environment on the expression of the genes controlling of this

Plate 8: Variation of cob length found in nine F_2 populations of white maize

trait. The phenotypic coefficient of variation (6.23%) was higher than the genotypic coefficient of variation (2.66%) (Table 5), which suggested that environment has a significant role in the expression of this trait. Low heritability (18.22%) coupled with moderate genetic advance in percent of mean (2.34%) attributed non-additive gene action. Similar results were reported by Chen *et al.* (1996), Satyanarayan and Kumar (1995) and Ojo *et al*. (2006).

4.2.15 Grains per row

Grain per row showed 9.12 and 4.04, respectively the phenotypic and genotypic variances with large differences between them indicating large environmental influences on expression of this character as well as PCV (11.75%) and GCV (7.82%) indicating presence of considerable variability among the genotypes (Table 5). Moderate heritability (44.34%) coupled with moderate genetic advance in percent of mean (10.73) attributed to non-additive gene actions. Similar results were reported by Rather *et al.* (2003) and Rajesh *et al.* (2013). In the present investigation high heritability was estimated for number of seed per row. The similar results were also reported by Abd El-Sattar (2003).

4.2.16 100-grain weight (g)

Hundred grains weight showed moderate phenotypic (17.32) and genotypic (8.62) variance with high differences indicating that they were high responsive to environmental factors and the values of GCV and PCV were 11.55% and 8.15% indicating that the genotype had considerable variation for this trait (Table 5). Similar results of PCV and GCV values for this trait were reported by Abirami *et al*. (2005). Moderate heritability (49.75%) along with moderate genetic advance in percentage of mean (11.84%) revealed the possibility of predominance of both additive and non-additive gene action in the inheritance of this trait. Similar results were also reported by Anshuman *et al.* (2013) who found the high heritability and high genetic advance in percent of mean.

4.2.17 Grain yield per plant (g)

The phenotypic variance (224.11) appeared high difference with the genotypic variance (141.30), suggested high influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (22.98%) was moderately higher than the genotypic co-efficient of variation (18.25%) which suggested that environment has a moderate influence on the expression of this trait (Table 5). Moderate high heritability (63.05%) coupled with high genetic advance as percent of mean (29.85%) was observed for indicating that this trait is controlled by additive gene action which is very useful in selection. The moderate higher value of heritability for grain yield per plant indicates that this character can be used as the genetic parameter for the improvement and selection of higher yielding genotype. Crop improvement could be possible by simple selection because high heritability coupled with high genotypic variation revealed the presence of an additive gene effect.

In the present investigation, high heritability coupled with high genetic advance as per cent of mean was observed for plant height, cob height, number of leaves per plant, number of branches per tassel, number of cob bearing node, leaf blade area and grain yield per plant. These traits are most probably controlled by additive gene action which is very useful in selection.

4.3 Correlation Matrix

Yield is the resultant of combined effect of several component characters and environment. Understanding the interaction of characters among themselves and with environment has been of great use in the plant breeding. Correlation studies provide information on the nature and extent of association between only two pairs of metric characters. From this it would be possible to bring about genetic up-gradation in one character by selection of the other of a pair. Obviously, knowledge about character associations would surely help to identify the characters to make selection for higher yield with a view to determine the extent and nature of relationship prevailing among yield contributing characters. Hence, an attempt has been made to study the character association in the F_2 population of white maize at both the levels.

Firstly Pearson's correlation coefficients were worked out (Table 6). In the Pearson correlation the significant positive associations were observed of characters like days to 50% tasselling, days to 50% silking, plant height, cob height, days to maturity, base diameter, number of leaves per plant, number of cob bearing node, leaf blade area, cob length and number of grains per row with yield.

Further, the correlation coefficients were separated into genotypic and phenotypic levels shown in Table 7. The genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the genetic reason of association among the traits. In some cases phenotypic correlation coefficient were higher than genotypic correlation coefficient indicating suppressing effect of the environment which modified the expression of the characters at phenotypic level. Genotypic and phenotypic correlation of different yield contributing traits with yield are shown in Figure 13.

Table 6. Pearson`s correlation coefficient of different traits of F_2 population of white maize

	DSLS	D50%T	D50%S	PH	CH	DM	BD	NL	NB	NN	LBA	CL	CD	NRPC	NGPR	HGW
D50%T	0.345															
D50%S	0.286	0.861**														
PH	0.129	0.620	0.534													
CH	0.223	0.699*	0.536	0.95**												
DM	0.304	0.591	0.618	0.932**	0.848**											
BD	-0.073	0.601	0.418	0.896**	0.830**	0.799**										
NL	0.389	0.869**	0.539	0.709*	0.818**	0.620	0.725*									
NB	0.257	0.816**	0.733*	0.761*	0.696*	0.743*	0.773*	0.711*								
NN	0.379	0.834**	0.524	0.782*	0.882**	0.662	0.778*	0.964**	0.762*							
LBA	0.123	0.510	0.514	0.704*	0.587	0.811**	0.660	0.533	0.583	0.445						
CL	0.256	0.641	0.668 *	0.837**	0.820**	0.772*	0.581	0.553	0.755*	0.649	0.521					
CD	0.063	0.103	0.274	0.534	0.361	0.727*	0.554	0.138	0.327	0.147	0.631	0.187				
NRPC	-0.125	-0.052	-0.060	0.329	0.207	0.385	0.498	0.098	0.194	0.117	0.207	-0.094	0.754*			
NGPR	0.330	0.588	0.527	0.913**	0.905**	0.919**	0.719*	0.701*	0.613	0.705*	0.740*	0.772*	0.555	0.328		
HGW	-0.131	0.355	0.402	0.517	0.403	0.565	0.650	0.299	0.488	0.362	0.564	0.280	0.562	0.173	0.269	
YPP	0.215	0.709*	0.740*	0.854**	0.849**	0.894**	0.738*	0.675*	0.645	0.679*	0.686*	0.681*	0.649	0.401	0.891**	0.459

** = Significant at 1%. * = Significant at 5%.

DSLS = days to 6th leaf stage, D50%T = days to 50% tasselling, D50%S = days to 50% silking, PH = plant height (cm), CH = cob height (cm), DM = Days to maturity, BD = base diameter (cm), NL = no. of leaves per plant, NB = no. of branches of tassel**,** NN = no. of cob bearinbg node, LBA = leaf blade area (cm^2), CL = cob length (cm), CD = cob diameter (cm), NRPC = no. of rows per cob, NGPR = no. grains per row, HGW = 100 grains weight (g) and YPP = yield per plant (g).

Table 7. Genotypic and phenotypic correlation coefficients of yield and yield contributing traits in white maize

Traits		DSLS	D50%T	D50%S	PH	CH	DM	BD	NL	NB	NN	LBA	CL	CD	NRPC	NGPR	HGW
D50%T	G	0.414*															
	P	0.356															
D50%S	G	0.276	0.878**														
	P	0.183	0.834**														
PH	G	0.439*	0.699**	0.581**													
	P	0.191	0.495**	0.456*													
CH	G	0.532**	0.784**	0.571**	0.979**												
	P	0.288	0.566**	0.479**	0.920**												
DM	G	0.453*	0.602**	0.623**	0.954**	0.876**											
	P	0.345*	0.564**	0.607**	0.905**	0.812**											
BD	G	0.251	0.643**	0.428*	0.956**	0.876**	0.823**										
	P	0.094	0.534**	0.396*	0.799**	0.756**	0.675**										
NL	G	0.674**	0.962**	0.565**	0.731**	0.838**	0.654**	0.749**									
	P	0.383*	0.722**	0.493**	0.673**	0.786**	0.567**	0.686**									
NB	G	0.489**	0.993**	0.865**	0.799**	0.734**	0.745**	0.870**	0.763**								
	P	0.204	0.575**	0.546**	0.711**	0.645**	0.654**	0.639**	0.640**								
NN	G	0.697**	0.916**	0.542**	0.841**	0.905**	0.643**	0.842**	0.908**	0.858**							
	P	0.418*	0.710**	0.497**	0.689**	0.847**	0.564**	0.677**	0.895**	0.631**							
LBA	G	0.228	0.633**	0.641**	0.762**	0.655**	0.821**	0.747**	0.594**	0.628**	0.544**						
	P	0.113	0.335	0.324	0.617**	0.486**	0.765**	0.529**	0.441*	0.523**	0.303						
CL	G	0.436*	0.748**	0.740**	0.917**	0.887**	0.712**	0.640**	0.599**	0.787**	0.735**	0.655**					
	P	0.179	0.509**	0.580**	0.739**	0.740**	0.654**	0.509**	0.499**	0.718**	0.545**	0.358					
CD	G	0.093	0.214	0.452*	0.690**	0.469*	0.723**	0.768**	0.114	0.383*	0.296	0.979**	0.174				
	P	0.270	0.031	0.148	0.455*	0.307	0.654**	0.429*	0.186	0.312	0.046	0.407*	0.203				
NRPC	G	0.250	-0.079	-0.025	0.340	0.161	0.321	0.838**	0.150	0.186	0.113	0.279	-0.264	0.611**			
	P	-0.013	-0.040	-0.096	0.363	0.270	0.234	0.299	0.070	0.217	0.136	0.171	0.011	0.411*			
NGPR	G	0.728**	0.761**	0.634**	0.840**	0.843**	0.934**	0.874**	0.840**	0.671**	0.820**	0.898**	0.866**	0.603**	0.316		
	P	0.226	0.399*	0.411*	0.783**	0.762**	0.845**	0.549**	0.551**	0.557**	0.587**	0.575**	0.682**	0.221	0.345		
HGW	G	-0.192	0.395*	0.449*	0.683**	0.525**	0.543**	0.730**	0.348	0.738**	0.452*	0.757**	0.409*	0.706**	0.670**	0.566**	
	P	0.198	0.310	0.350	0.314	0.255	0.534**	0.556**	0.241	0.211	0.253	0.342	0.146	0.487**	-0.117	-0.011	
YPP	G	0.293	0.813**	0.850**	0.919**	0.916**	0.934**	0.857**	0.724**	0.683**	0.747**	0.772**	0.749**	0.774**	0.462*	0.804**	0.552**
	P	0.400*	0.567**	0.584**	0.765**	0.757**	0.865**	0.570**	0.607**	0.596**	0.589**	0.572**	0.602**	0.594**	0.390*	0.673**	0.357

** = Significant at 1%, * = Significant at 5%, DSLS = days to 6^{th} leaf stage, D50%T = days to 50% tasselling, D50%S = days to 50% silking, PH = plant height (cm), CH = cob height (cm), DM = Days to maturity, BD = base diameter (cm), NL = no. of leaves per plant, NB = no. of branches of tassel**,** NN = no. of cob bearinbg node, LBA = leaf blade area (cm^2), CL = cob length (cm), CD = cob diameter (cm), NRPC = no. of rows per cob, NGPR = no. grains per row, HGW = 100 grains weight (g) and YPP = yield per plant (g).

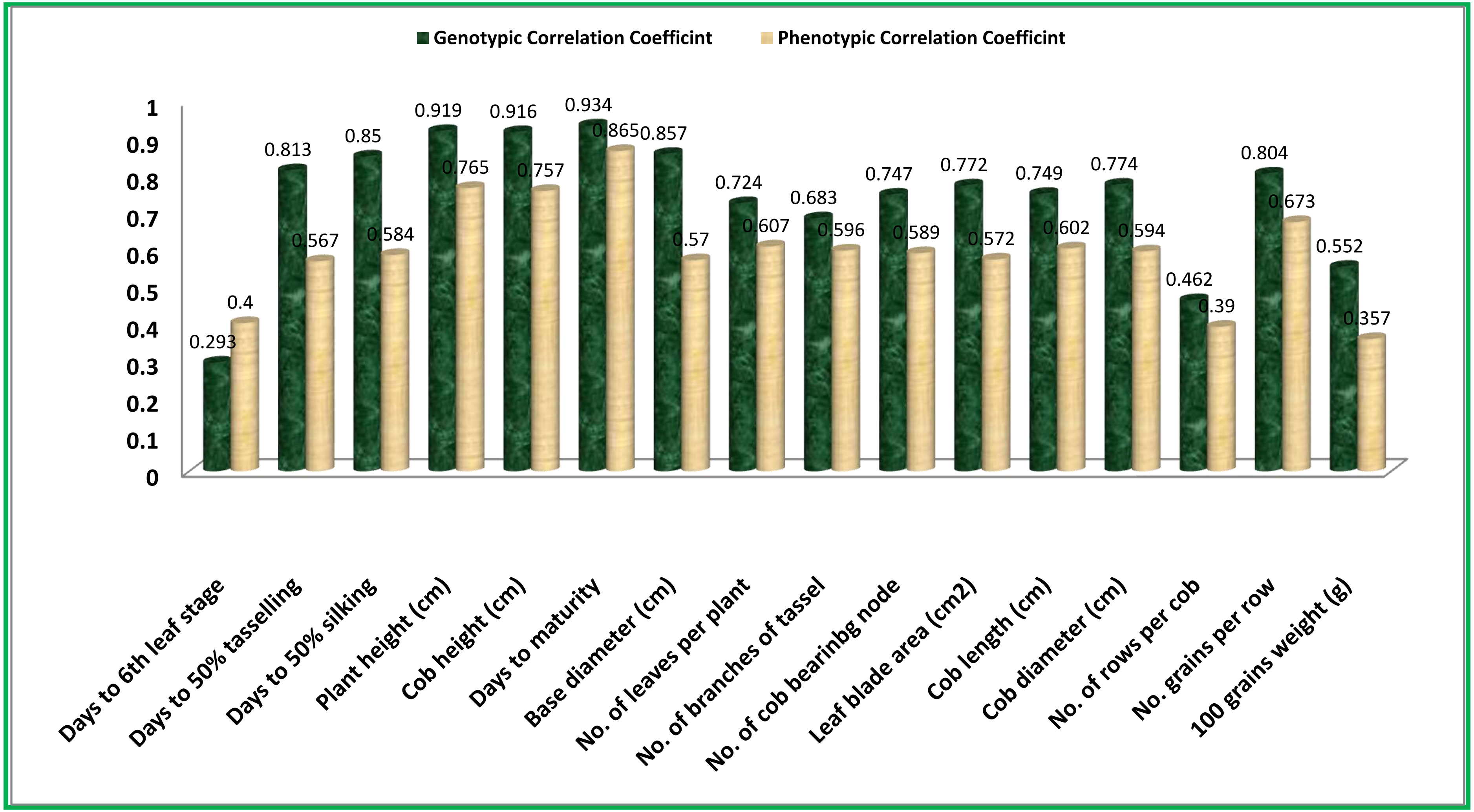

Figure 13. Genotypic and phenotypic correlation of different yield contributing traits with yield

4.3.1 Days to 6th leaf stage

Days to 6th leaf stage was highly significant and positively associated with number of leaf per plant (0.674 and 0.383), number of cob bearing node (0.697 and 0.418) at both levels (Table 7). But it was positively and significantly correlate with days to 50% tasselling (0.414), plant height (0.439), cob height (0.532), number of branches of tassel (0.489), cob length (0.436) and number of grains per row (0.728) at genotypic level.

4.3.2 Days to 50% tasselling

Highly significant positive association was recorded of days to 50% tasselling of maize genotypes with days to 50% silking (0.878 and 0.834), plant height (0.699 and 0.495), cob height (0.784 and 0.566), days to maturity (0.602 and 0.564), base diameter (0.643 and 0.534), number of leaves per plant (0.962 and 0.722), number of branches of tassel (0.993 and 0.575), number of cob bearing node (0.916 and 0.710), cob length (0.748 and 0.509) and grain yield per plant (0.813 and 0.567) at both level (Table 7). Triveni *et al*. (2014) found number of leaf per plant of maize was significantly and positively correlated with its grain yield supporting the present findings. Results of this study imply that maize grain yield can be improved by considering number of leaf per plant.

4.3.3 Days to 50% silking

Days to 50% silking was observed significantly positive association with days to 50% tasselling (0.878 and 0.834), cob height (0.571 and 0.479), days to maturity (0.623 and 0.607), number of leaves per plant (0.565 and 0.493), number of branches of tassel (0.865 and 0.546), number of cob bearing node (0.542 and 0.497), cob length (0.740 and 0.580) and grain yield per plant (0.850 and 0.584) at both level (Table 7). Almost similar findings were reported by Kumar *et al.* (2014). Afzal *et al.* (2005) reported that days to silking showed positive correlation with grain yield per plant.

4.3.4 Plant height

Plant height highly significant and positively correlate with days to 50% tasselling (0.699 and 0.495), days to 50% silking (0.581 and 0.456), cob height (0.979 and 0.920), days to maturity (0.954 and 0.905), base diameter (0.956 and 0.799), number of leaves per plant (0.731 and 0.673), number of branches of tassel (0.799 and 0.711), number of cob bearing node (0.841 and 0.689), leaf blade area (0.762 and 0.617), cob length (0.917 and 0.739), cob diameter (0.690 and 0.455), number of grains per row (0.840 and 0.783) and grain yield per plant (0.919 and 0.765) at both genotypic and phenotypic levels (Table 7). Mohammadi *et al.* (2003); Ojo *et al.* (2006); Sadek *et al.* (2006) and Abou-Deif (2007) reported that plant height was significantly and positively correlated with each of number of rows per cob and cob diameter. However, in the contrary Srekove *et al.* (2011) reported negative correlation between grain yield and plant height. Plant height (0.586) was positively and significantly correlated with grain yield per plant (Triveni *et al*., 2014).

4.3.5 Cob height

Cob height highly significant and positively correlate with days to 50% tasselling (0.784 and 0.566), days to 50% silking (0.571 and 0.479), plant height (0.979 and 0.920), days to maturity (0.876 and 0.812), base diameter (0.876 and 0.756), number of leaves per plant (0.838 and 0.786), number of branches of tassel (0.734 and 0.645), number of cob bearing node (0.905 and 0.847), leaf blade area (0.655 and 0.486), cob length (0.887 and 0.740), number of grains per row (0.843 and 0.762) and grain yield per plant (0.916 and 0.757) at both the levels (Table 7). Cob height showed significant and positive phenotypic correlations with rows per cob; on the other hand, it was significantly and negatively correlated with number of kernel per row (Amin *et al.* 2003; Sadek *et al.* 2006 and Abou- Deif, 2007).

4.3.6 Days to maturity

Highly significant and positive correlation was observed of days to maturity with base diameter (0.823 and 0.675), number of leaves per plant (0.654 and 0.567), number of branches of tassel (0.745 and 0.654), number of cob bearing node (0.643 and 0.564), leaf blade area (0.821 and 0.765), cob length (0.712 and 0.654), cob breadth (0.723 and 0.654), number of grain per row (0.934 and 0.845), hundred grain weight (0.543 and 0.534) and grain yield per plant (0.934 and 0.865) at both levels (Table 7).

4.3.7 Base diameter (cm)

Highly significant positive correlation was observed of base diameter with days to 50% tasselimg, plant height, cob height, days to maturity, number of leaves per plant, number of branches of tassel, number of cob bearing node, leaf blade area, cob length, number of grain per row, hundred grain weight and yield per plant (Table 7).

4.3.8 Number of leaves per plant

Number of leaves per plant showed positive and highly significant association with days to 50% tasselling (0.962 and 0.722), days to 50% silking (0.565 and 0.493), plant height (0.731 and 0.673), cob height (0.838 and 0.786), days to maturity (0.654 and 0.567), base diameter (0.749 and 0.686), number of branches of tassel (0.763 and 0.640), cob bearing node (0.908 and 0.895), cob length (0.599 and 0.499), number of grain per row (0.840 and 0.551) and grain yield per plant (0.724 and 0.607) (Table 7).

4.3.9 Number of branches of tassel

Number of branches per tassel exhibited highly positive significant correlation with days to 50% tassel (0.993 and 0.575), days to 50% silking (0.865 and 0.546), plant height (0.799 and 0.731), cob height (0.734 and 0.645), days to maturity (0.745 and 0.654), base diameter (0.870 and 0.639), number of leaves per plant (0.763 and 0.640), number of cob bearing node (0.858 and 0.631), leaf blade area (0.628 and 0.523), cob length (0.787 and 0.718), number of grains per row (0.671 and 0.557) and yield per plant (0.683 and 0.569) (Table 7).

4.3.10 Number of cob bearing node

Number of cob bearing node performed highly significant and positively correlated with days to 6^{th} leaf stage (0.697 and 0.418), days to 50% tasselimg (0.916 and 0.710), days to 50% silking (0.542 and 0.497), plant height (0.841 and 0.689), cob height (0.905 and 0.847), days to maturity (0.643 and 0.564), base diameter (0.842 and 0.677), number of leaves per plant (0.908 and 0.895), number of cob bearing node (0.858 and (0.631), cob length (0.735 and 0.545), number of grains per row (0.820 and 0.587) and grain yield per plant (0.747 and 0.589) (Table 7).

4.3.11 Leaf blade area (cm^2)

Leaf blade area exhibited highly significant and positive association with plant height (0.762 and 0.617), cob height (0.655 and 0.486), days to maturity (0.821 and 0.7650, base diameter (0.747 and 0.529), number of leaves per plant (0.594 and 0.441), number of cob bearing node (0.544 and 0.303), cob diameter (0.979 and 0.407), number of grains per row (0.898 and 0.575) and grain yield per plant (0.772 and 0.572) (Table 7).

4.3.12 Cob length

Cob length showed highly significant and positive correlation with days to 50% tasselling (0.748 and 0.509), days to 50% silking (0.740 and 0.580), plant height (0.917 and 0.739), cob height (0.887 and 0.740), days to maturity (0.712 and 0.654), base diameter (0.640 and 0.509), number of leaves per plant (0.599 and 0.499), number of branches of tassel (0.787 and 0.718), number of grains per row (0.866 and 0.682) and grain yield per plant (0.749 and 0.602) at both levels (Table 7). The result indicated that grain yield was positively and significantly associated with cob length (0.618) and plant height with cob length (0.471) reported by Pandey *et al.* (2017).

4.3.13 Cob diameter

Cob diameter exhibited highly significant and positive association with plant height (0.690 and 0.455), days to maturity (0.723 and 0.654), base diameter (0.768 and 0.429), lead blade area (0.979 and 0.407), number of row per cob (0.611 and 0.411), hundred grain weight (0.706 and 0.487) and grain yield per plant (0.774 and 0.594) at both levels (Table 7).

4.3.14 Number of row per cob

The number of row per cob had a highly positive and significant correlation with cob breadth (0.611 and 0.411) and grain yield per plant (0.462 and 0.390)at both levels. Significant positive correlation observed with base diameter (0.838) and hundred seed weight (0.670) at genotypic level. Number of rows per cob negatively correlated with 100 grain weight (-0.117) at phenotypic level. This results supported by EL-Hosary *et al.* (1989); Amin *et al.* (2003); EL-Beially (2003) and Mohammadi *et al.*(2003) who found number of rows per cob showed significant and negative correlations with 100-seed weights.

4.3.15 Number of grains per row

The number of grains per row had positive and highly significant correlation with plant height (0.849 and 0.783), cob height (0.843 and 0.762), days to maturity (0.934 and 0.845), base diameter (0.549 and 0.730), number of branches of tassel (0.557 and 0.738), leaf blade area (0.575 and 0.757) and grain yield per plant (0.804 and 0.673) at both levels. Amin *et al.* (2003) indicated that number of grains per row was the highest contributors to variation in grain yield directly or indirectly. Grains per row (0.656) were positively and significantly associated grain yield per plant reported by Pandey *et al.* (2017).

4.3.16 100-grain weight

Highly significant positive correlation were observed between 100-grain weight with days to maturity (0.543 and 0.534), base diameter (0.730 and 0.556), cob breadth (0.706 and 0.487) at both the genotypic and phenotypic level and with grain yield per plant (0.552) at genotypic level (Table 7). The result showed significant positive correlation with days to 50% tasselling (0.395), days to silking (0.449), plant height (0.683), cob height (0.525), number of cob bearing node (0.452), leaf blade area (0.757), cob length (0.409), number of rows per cob (0.670) and number of grains per row (0.566) at genotypic level. Grain yield is considered to have positive correlation with hundred seed weight (Ajmal *et al.*, 2000). Sumathi *et al.* (2005) also found medium strong correlative relation between hundred grain weight and grain yield per plant, but that relation was negative, while the majority of authors (Alvi *et al.* 2003; Sofi and Rather 2005; Bocanski *et al.* 2009) who studied relation between these two traits established strong correlations between grain yield and 100-grain weight.The correlation matrix showed that plant height (PH), cob diameter (CD), days to maturity (DM) and number of grain per row (NGPR) was highly correlated with yield per plant (YPP) at 1% level of significance as shown in Figure 14. Among the sixteen traits studied here, the association of these four traits viz. plant height (PH), cob diameter (CD), days to maturity (DM) and number of

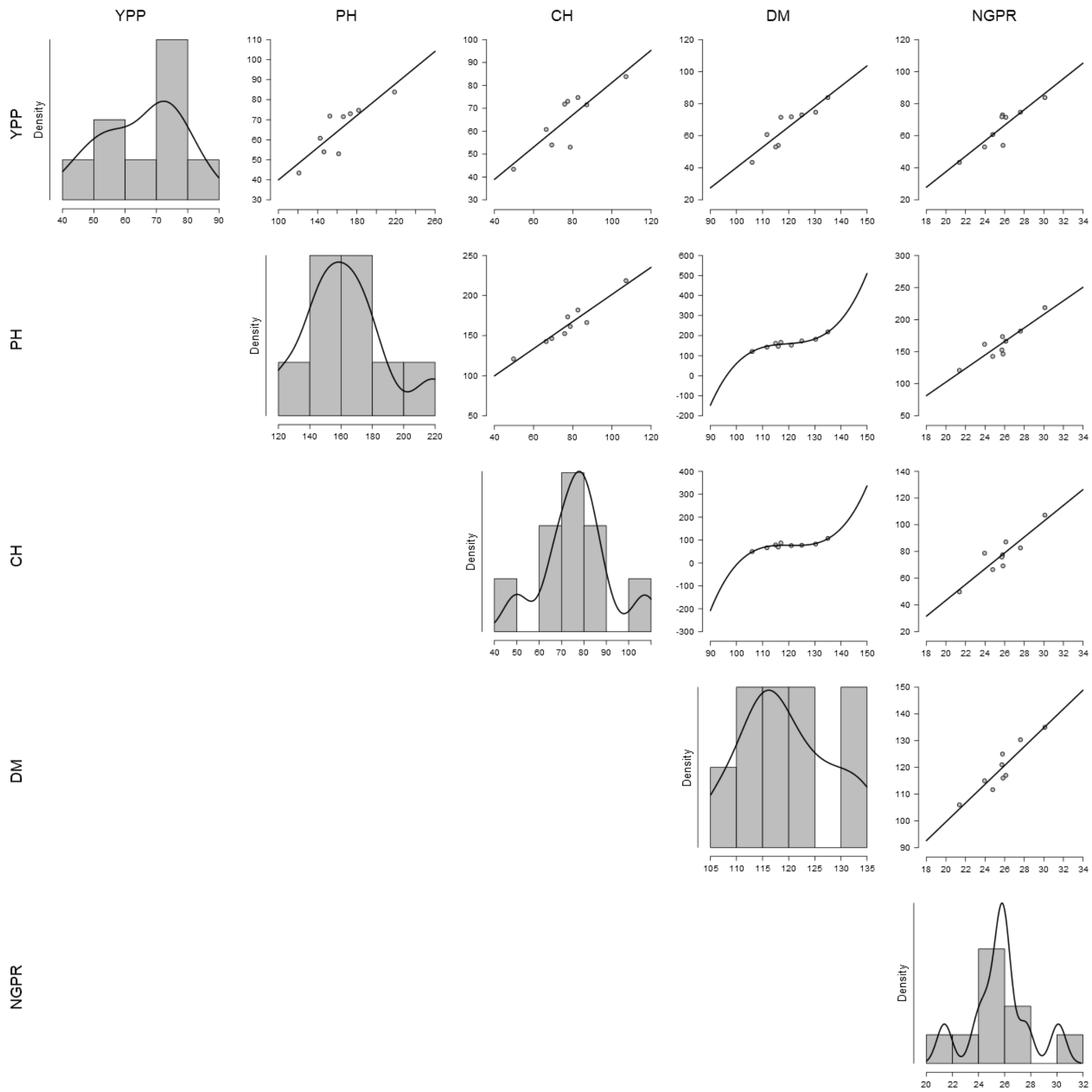

Figure 14. Correlation matrix plot of Yield per plant (YPP) with Plant height (PH), Cob height (CH), Days to maturity (DM) & Number of grain per row (NGPR)

grain per row (NGPR) with yield per plants was strongly correlated as the correlation matrix data shown (Figure 4). The strong correlation matrix of these four traits with yield per plants implies that selection of these traits directly influence the yield of the genotypes.

4.4 Path co-efficient analysis

Association among the characters determined by correlation co-efficient might not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on total yield per plant. As a matter of fact, in order to find out a clear picture of the inter-relationship between total yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at genotypic level which also measured the relative importance of each component. Grain yield per plant was considered as relient (dependent) variable and days to 6^{th} leaf stage, days to 50% tasselling, days to 50% silking, plant height (cm), cob height (cm), days to Maturity, base diameter (cm), no. of leaves per plant, no. of branches of tassel, no. of cob bearinbg node, leaf blade area (cm^2), cob length (cm), cob diameter (cm), no. of rows per cob, no. grains per row and 100 grains weight (g) were casual (independent) variables. Estimation of direct and indirect effect of path co-efficient analysis for white maize is presented in Table 8.

4.4.1 Days to 6^{th} leaf stage

Days to 6^{th} leaf stage had negative direct effect (-0.257) on grain yield per plant (Table 8). It showed positive indirect effect through cob height (1.020), days to 50% tasselling (0.389), days to maturity (0.058) and number of grains per row (0.27), whereas it showed negative indirect effect via plant height (-0.270), number of leaf per plant (-0.163), number of cob bearing node (-0.50).

Table 8. Partitioning of genotypic correlations into direct (bold and underline) and indirect effects of seventeen traits by path analysis of white maize

	DSLS	D50%T	D50%S	PH	CH	DM	BD	NL	NB	NN	LBA	CL	CD	NRPC	NGPR	HGW	Genotypic correlation with yield
DSLS	**-0.257**	0.389	0.006	-0.270	1.020	-0.058	-0.048	-0.163	0.076	-0.50	-0.09	-0.17	0.035	0.02	0.27	0.03	0.293
D50%T	-0.106	**0.940**	0.018	-0.431	1.504	-0.011	-0.122	-0.233	0.154	-0.66	-0.25	-0.29	0.080	-0.01	0.28	-0.06	0.813**
D50%S	-0.071	0.825	**0.020**	-0.358	1.095	0.014	-0.081	-0.137	0.134	-0.39	-0.25	-0.28	0.170	0.00	0.23	-0.07	0.850**
PH	-0.113	0.657	0.012	**-0.616**	1.878	0.023	-0.182	-0.177	0.124	-0.60	-0.30	-0.35	0.259	0.03	0.38	-0.11	0.919**
CH	-0.137	0.737	0.011	-0.603	**1.918**	-0.004	-0.166	-0.203	0.114	-0.65	-0.25	-0.34	0.176	0.01	0.39	-0.08	0.916**
DM	0.164	0.114	0.003	0.153	0.081	**1.347**	-0.052	0.093	0.016	0.26	-0.21	-0.09	0.300	0.05	0.07	0.08	0.934**
BD	-0.065	0.604	0.009	-0.589	1.680	0.025	**-0.190**	-0.181	0.135	-0.61	-0.29	-0.24	0.288	0.07	0.32	-0.12	0.857**
NL	-0.173	0.904	0.011	-0.450	1.607	-0.035	-0.142	**-0.242**	0.118	-0.72	-0.23	-0.23	0.043	0.01	0.31	-0.05	0.724**
NB	-0.126	0.933	0.017	-0.492	1.408	0.009	-0.165	-0.185	**0.155**	-0.62	-0.24	-0.30	0.144	0.02	0.25	-0.12	0.683**
NN	-0.18	0.86	0.01	-0.52	1.74	-0.03	-0.16	-0.24	0.13	**-0.72**	-0.21	-0.28	0.111	0.01	0.30	-0.07	0.747**
LBA	-0.06	0.60	0.01	-0.47	1.26	0.05	-0.14	-0.14	0.10	-0.39	**-0.39**	-0.25	0.367	0.02	0.33	-0.12	0.772**
CL	-0.11	0.70	0.01	-0.56	1.70	0.02	-0.12	-0.14	0.12	-0.53	-0.25	**-0.38**	0.065	-0.02	0.32	-0.06	0.749**
CD	-0.02	0.20	0.01	-0.43	0.90	0.07	-0.15	-0.03	0.06	-0.21	-0.38	-0.07	**0.38**	0.14	0.41	-0.11	0.774**
NRPC	-0.06	-0.07	0.00	-0.21	0.31	0.05	-0.16	-0.04	0.03	-0.08	-0.11	0.10	0.60	**0.09**	0.12	-0.11	0.462*
NGPR	-0.19	0.72	0.01	-0.64	2.00	0.02	-0.17	-0.20	0.10	-0.59	-0.35	-0.33	0.41	0.03	**0.37**	-0.09	1.104**
HGW	0.05	0.37	0.01	-0.42	1.01	0.04	-0.14	-0.08	0.11	-0.32	-0.29	-0.16	0.26	0.06	0.21	**-0.16**	0.552**

Residual effect: **0.322** ** = Significant at 1%. * = Significant at 5%.

DSLS = days to 6^{th} leaf stage, D50%T = days to 50% tasselling, D50%S = days to 50% silking, PH = plant height (cm), CH = cob height (cm), DM = Days to maturity, BD = base diameter (cm), NL = no. of leaves per plant, NB = no. of branches of tassel**,** NN = no. of cob bearinbg node, LBA = leaf blade area (cm^2), CL = cob length (cm), CD = cob diameter (cm), NRPC = no. of rows per cob, NGPR = no. grains per row, HGW = 100 grains weight (g) and YPP = yield per plant (g).

4.4.2 Days to 50% tasselling

Path analysis revealed that days to 50% tasselling had positive direct effect (0.940) on grain yield per plant (Table 8). Zarei *et al.* (2012) reported similar result for this trait. It showed more positive indirect effect through cob height (1.504) and negligible positive indirect effect through days to 5o% silking (0.018), number of branches of tassel (0.154), cob diameter (0.080) and number of grains per row (0.28), whereas it showed negative indirect effect via plant height (-0.431), number of cob beraing node (-0.66), leaf blade area (-0.25), cob length (-0.29) and hundred grain weight (-0.06).

4.4.3 Days to 50% silking

Path analysis revealed that days to 50% silking had positive direct effect (0.020) on grain yield per plant (Table 8). The similar result was reported by Pandel *et al.* (2017) and Lingaiah *et al.* (2014). The result showed positive indirect effect through cob height (1.095) and negligible positive effect via days to 50% tasselling (0.825), days to maturity (0.014), number of branches of tassel (0.134), cob diameter (0.170) and number of grains per row (0.23). On the other hand days to 50% silking showed negative indirect effect through plant height (-0.358), base diameter (-0.081), number of leaves per plant (-0.137), number of cob bearing node (-0.39), leaf blade area (-0.25) and cob length (-0.28).

4.4.4 Plant height

Plant height had negative direct effect (-0.616) on grain yield per plant (Table 8) and the result was in agreement with results of Pandey *et al.* (2017). They found negative direct effect of plant height on grain yield. Plant height is an important trait that effect grain yield. Taller plants need more plant nutrients to complete more vegetative growth than reproductive phase that results in late maturation of cob. It showed high positive indirect effect through cob height (1.878) and negligible positive indirect effect via days to 50% tasselling (0.657), number of branches of tassel (0.124), cob diameter (0.259) and number of grains per row (0.38). The plant height showed highly positive indirect effect for cob height (0.1421) (Jakhar *et al.*, 2017). It showed negative indirect effect through days to six leaf stage (-0.113), base diameter (-0.182), number of branches of tassel (-0.177), number of cob bearing node (-0.60), leaf blade area (-0.30) and cob length (-0.35). The results indicated that plant height had negative direct effect (-0.616) on yield because of its negative indirect effect through cob length and 100-grain weight (Emer, 2011 and Mohan *et al.* 2002).

4.4.5 Cob height (cm)

Cob height had positively direct effect (1.918) on grain yield per plant (Table 8). Cob height is an important trait that effect grain yield. Taller cob denoted late maturation of cob. It showed positive indirect effect through days to 50% tasselling (0.737), number of branches of tassel (0.114), cob breadth (0.176) and number of grains per row (0.39). It showed negative indirect effect through days to 6^{th} leaf stage (-0.137), plant height (-0.603), base diameter (-0.166), number of leaves per plant (-0.203), number of cob bearing node (-0.65), leaf blade area (-0.25) and cob length (-0.34). The cob height showed highly negative indirect effect for plant height (-0.0852) reported by Jakhar *et al.* (2017).

4.4.6 Days to maturity

Path analysis revealed that days to maturity had positive direct effect (1.347) on grain yield per plant (Table 8). It showed negligible positive indirect effect through days to six leaf stage (0.164), days to 50% tasselling (0.114), plant height (0.153), number of leaves per plant (0.093), cob height (0.081) number of cob bearing node (0.26), cob diameter (0.30), number of grains per row (0.07) and hundred garin weight (0.08). On the other hand, days to maturity represented negative indirect effect via leaf blade area (-0.21) and cob length (-0.09).

4.4.7 Base diameter (cm)

Path analysis revealed that base diameter had negative direct effect (-0.190) on grain yield per plant (Table 8). It showed high positive indirect effect through cob height (1.680) and negligible positive indirect effect through days to maturity (0.025), number of cob bearing node (0.135), cob diameter (0.288), number of grains per row (0.32). On the other hand, base diameter represented negative indirect effect via plant height (-0.589), number of leaves per plant (-0.181), number of cob bearing node (-0.61), leaf blade area (-0.29), cob length (-0.24) and 100-seed weight (-0.12).

4.4.8 Number of leaves per plant

Number of leaves per plant had negative direct effect (-0.242) on grain yield. It was found that number of leaves per plant had high positive indirect effect on grain yield through cob height (1.607), whereas negligible positive indirect effect via days to tasselling (0.904), number of cob bearing node (0.118), number of grains per row (0.31) (Table 8).

4.4.9 Number of branches of tassel

Number of branches of tassel had positive direct effect (0.1555) on grain yield. It was found that number of branches of tassel had high positive indirect effect on grain yield through cob height (1.408), whereas negligible positive indirect effect via days to tasselling (0.933), cob diameter (0.144), number of grains per row (0.25) (Table 8).

4.4.10 Number of cob bearing node

Number of cob bearing node had negative direct effect (-0.72) on grain yield. It was found that number of leaves per plant had high positive indirect effect on grain yield through cob height (1.74), whereas negligible positive indirect effect via days to tasselling (0.86), number of branches of tassel (0.13), cob diameter (0.111) and number of grains per row (0.30) (Table 8).

4.4.11 Leaf blade area (cm^2)

Leaf blade area had negative direct effect (-0.39) on grain yield. It was found that leaf blade area had high positive indirect effect on grain yield through cob height (1.26), whereas negligible positive indirect effect via days to tasselling (0.60), number of branches of tassel (0.10), cob diameter (0.367) and number of grains per row (0.33) (Table 8).

4.4.12 Cob length

Cob length had negative direct effect (-0.38) on grain yield. It was found that cob length had positive indirect effect on grain yield through days to 50% tasselling (0.70), cob height (1.70), number of branches of tassel (0.12) and number of grains per row (0.32) (Table 8). Wannows *et al.* (2010) reported similar findings. These results coincide with those obtained by Amin *et al.* (2003); AL-Ahmad (2004) and Sadek *et al.* (2006). Its indirect effects via plant height and number of leaves per plant also negative (Parh *et al.*, 1986).

4.4.13 Cob diameter

Path analysis revealed that cob diameter had positive direct effect (0.38) on yield per plant (Table 8). It showed negligible positive indirect effect through days to 50% teaseling (0.20), cob height (0.90), days to maturity (0.07), number of row per cob (0.14) and number of grain per row (0.41)., whereas cob diameter showed negative indirect effect through plant height (-0.43), base diameter (-0.15), number of cob bearing node (-0.21), leaf blade area (-0.38) and hundred grain weight (-0.11). The cob diameter showed highly positive indirect effect for cob height (0.90) reported by Jakhar *et al.* (2017) and it was similar with this present experiment.

4.4.14 Number of rows per cob

Number of row per cob revealed positive direct effect (0.09) on grain yield per plant. It was positive indirect effect on grain yield through cob height (0.31), cob length (0.10), cob diameter (0.60) and number of grains per row (0.12). These results were in agreement with results which Ahmad and Saleem (2003) and Najeeb *et al*. (2009) found in their research. Rafiq *et al.* (2010) also found positive direct effect of kernel row number on grain yield, but it wasn't significant.

4.4.15 Number of grains per row

Path analysis revealed that number of grains per row had positive direct effect (0.37) on yield per plant (Table 8). It showed negligible positive indirect effect through days to 50% tasselling (0.72), days to maturity (0.02), number of cob bearing node (0.10), cob diameter (0.41) and number of rows per cob (0.03), whereas number of grains per row showed negative indirect effect through days to 6^{th} leaf stage (-0.19), plant height (-0.64), base diameter (-0.17), number of leaves per plant (-0.20), number of cob bearing node (-0.59), leaf blade area (-0.35) and cob length (-0.33). The number of grains per row showed highly positive indirect effect for cob height (2.00) reported by Jakhar *et al.* (2017) and it was similar with this present experiment.

4.4.16 100 grain weight

Path analysis revealed that weight of 100-grains had negative direct effect (-0.16) on yield per plant (Table 8). It showed high positive indirect effect through cob height (1.01) and negligible positive indirect effect through days to 50% tasselling (0.37), number of cob bearing node (0.11), cob diameter (0.26), and number of grains per row (0.21). While in via plant height (-0.42), base diameter (-0.14), number of cob bearing node (-0.32), leaf blade area (-0.29) and cob length (-0.16) were showed negative indirect effect on yield. Huda (2015) reported that 100-grain weight had positive indirect effects on days to 50% tasselling and days to 50% silking and it showed negative indirect effect on plant height, ear height, ear length, ear circumference, number of kernel row per cob, number of kernel per row and number of kernel per cob.

The estimation of correlation indicates only the extent and nature of association between yield and its attributes, but does not show the direct and indirect effects of different yield attributes on yield per se. Grain yield is dependent on several characters which are mutually associated; these will in turn impair the true association exiting between a component and grain yield. A change in any one component is likely to disturb the whole network of cause and effect. Thus, each component has two paths of action viz., the direct influence on grain yield, indirect effect through components which are not revealed from the correlation studies. The highly positive and direct effect on yield was exhibited by days to 50% tasselling (0.940), days to 50% silking (0.020), cob height (1.918), days to maturity (1.347), number of branches of tassel (0.155), cob diameter (0.38), number of rows per cob (0.09) and number of grains per row (0.37) indicating the effectiveness of direct selection, where direct and negative effects were exhibited by days to 6th leaf stage (-0.257), plant height (-0.616), base diameter (-0.190), number of leaves per plant (-0.242), number of cob bearing node (-0.72), leaf blade area (-0.39), cob length (-0.38) and hundred seed weight (-0.16) indicating the effectiveness of indirect selection.

CHAPTER V
SUMMARY AND CONCLUSION

The present investigation was envisaged on nine families of F_2 populations of white maize on the title 'Genetic variability, correlation and path coefficient analysis of F_2 segregating population of white maize (*Zea mays L.*). The objectives of this study were selecting the best genotypes for further research. The mean performance, genetic variability, heritability, correlation and path analysis were analyzed for nine families of F_2 population of white maize. The wide genetic variability that exists in the available genotypes provides enormous scope for further improvement. Yield is a complex quantitative character, direct selection for yield may not result in successful improvement. Therefore, it is necessary to allocate the observed variability into heritable and non-heritable components by calculating genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic gain. The material for the present study comprised of nine families of F_2 population of white maize was collected from Genetics and Plant Breeding Department, were evaluated using RCBD design for 17 quantitative characters at Sher-e-Bangla Agricultural University, Dhaka The experiment was conducted in the experimental plot in Sher-e-Bangla Agricultural University on 2016 with three replications.

Analysis of variance revealed highly significant difference among the nine families of F_2 population for all the characters except cob breadth and number of rows per cob. The minimum days to 50% tasselling was recorded in the F_2 population of Yungnuo 7 (65.67) and maximum in Yungnuo 30 (77.67). Minimum days to 50% silking were observed in Yungnuo 7 (72.33) and maximum in Yungnuo 30 (85.67). The minimum and maximum plant height were observed in the F_2 population of Yungnuo 7 (120.94 cm) and KS 510 (218.61 cm) respectively. Minimum cob height was noted in Yungnuo 7 (49.78) while maximum in KS 510 (107.22). Minimum days to maturity were noted in Yungnuo 7 (106.00) while maximum in KS 510 (135.00). The cob length was maximum in KS 510 (18.71 cm) and minimum in Plough 201 (14.37 cm) were observed. The highest number of rows per cob was observed in F_2 population of PSC 121 (14.00) while lowest in Changnuo 6 (12.39). F_2 population of KS 510 (30.11) shown the highest number of grains per row Yungnuo 7 (21.38) represented the lowest value. 100-grains weight ranged from 30.96 g to 40.78 g which was observed in Plough 201 and PSC 121, respectively. The highest grain yield per plant was observed in the genotype KS 510 (83.85 g). The lowest grain yield per plant was observed in the genotype Yungnuo 7 (43.42 g).

Characters like cob height (21.58 and 19.64), number of branches of tassel (25.41 and 20.12), leaf blade area (20.87 and 17.30) and yield per plant (22.98 and 18.25) exhibited high genotypic and phenotypic co-efficient of variation. The phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation for all characters which indicated greater influence of environment for the expression of these characters. The high differences between phenotypic and genotypic co-efficient of variation were number of branches of tassel, cob breadth, number of rows per cob and yield per plant which indicated these traits were mostly dependent on the environment condition. Amongst the characters, the highest genotypic co-efficient of variation was recorded for number of branches of tassel (20.12), cob height (19.64), yield per plant (18.25) and leaf blade area (17.30). The maximum genotypic and phenotypic variations were 11512.11and 7908.86, respectively observed in leaf blade area.

The highest estimated heritability amongst seventeen characters of maize was 98.30% for days to maturity and the lowest was 22.64% for cob breadth. The highest genetic advance amongst seventeen characters was found in leaf blade area (151.85) and the lowest genetic advance was carried out in cob breadth (0.31). The maximum genetic advance in percent of mean was observed for cob height (36.81), followed by number of branches of tassel (32.82), yield per plant (29.85) and leaf blade area (29.54). In the present study, high heritability coupled with high genetic advance as per cent of mean was observed for plant height (83.55 and 31.06), cob height (82.78 and 36.81), number of branches per tassel (62.68 and 32.82), number of cob bearing node (78.52 and 21.01), leaf blade area (68.70 and 29.54) and grain yield per plant (63.05 and 29.85). The result suggested that traits are most probably controlled by additive gene action which is very useful in selection of the desirable traits for improving of the traits.

Again, considering both genotypic and phenotypic correlation co-efficient among seventeen yields contributing characters of nine F_2 families, yield per plant was positively and significantly correlated with days to 50% tasselling, days to 50% silking, plant height, cob height, days to maturity, number of leaves per plant, number of branches of tassel, number of cob bearing node, leaf blade area, cob length, cob breadth and number of grains per row. Path analysis revealed that days to 50% tasselling, days to 50% silking, cob height, days to maturity, number of branches of tassel, cob breadth and number of grains per row showed positive direct effects on yield per plant indicating these traits effectiveness for direct selection. On the other hand plant height, base diameter, number of leaves per plant, number of cob bearing node, leaf blade area, cob length and hundred grains weight showed negative direct effects on yield per plant indicating the effectiveness of indirect selection.

Results of the present studies indicated significant variation was existed among the nine families of F_2 population for all the characters studied. Cob height, days to maturity, days to 50% tasselling, number of grains per row, plant height contributed maximum towards yield improvement. Plant height, cob diameter, days to maturity and number of grain per row strongly correlated with yield per plants suggesting these four traits could be the selection criteria in improving the yield per plant. Considering yield and other agronomic performance KS 510 could be selected for highest value of grain yield per plant, number of grains per row, cob length, number of leaves per plant and number of branches of tassel. For early flowering and early maturity, dwarf plant height and less cob height Yungnuo 7 would be selected for developing of short stature variety. Moreover, PSC 121 could be considered suitable genotypes for bold grains, highest number of rows per cob, cob breadth and leaf blade area.

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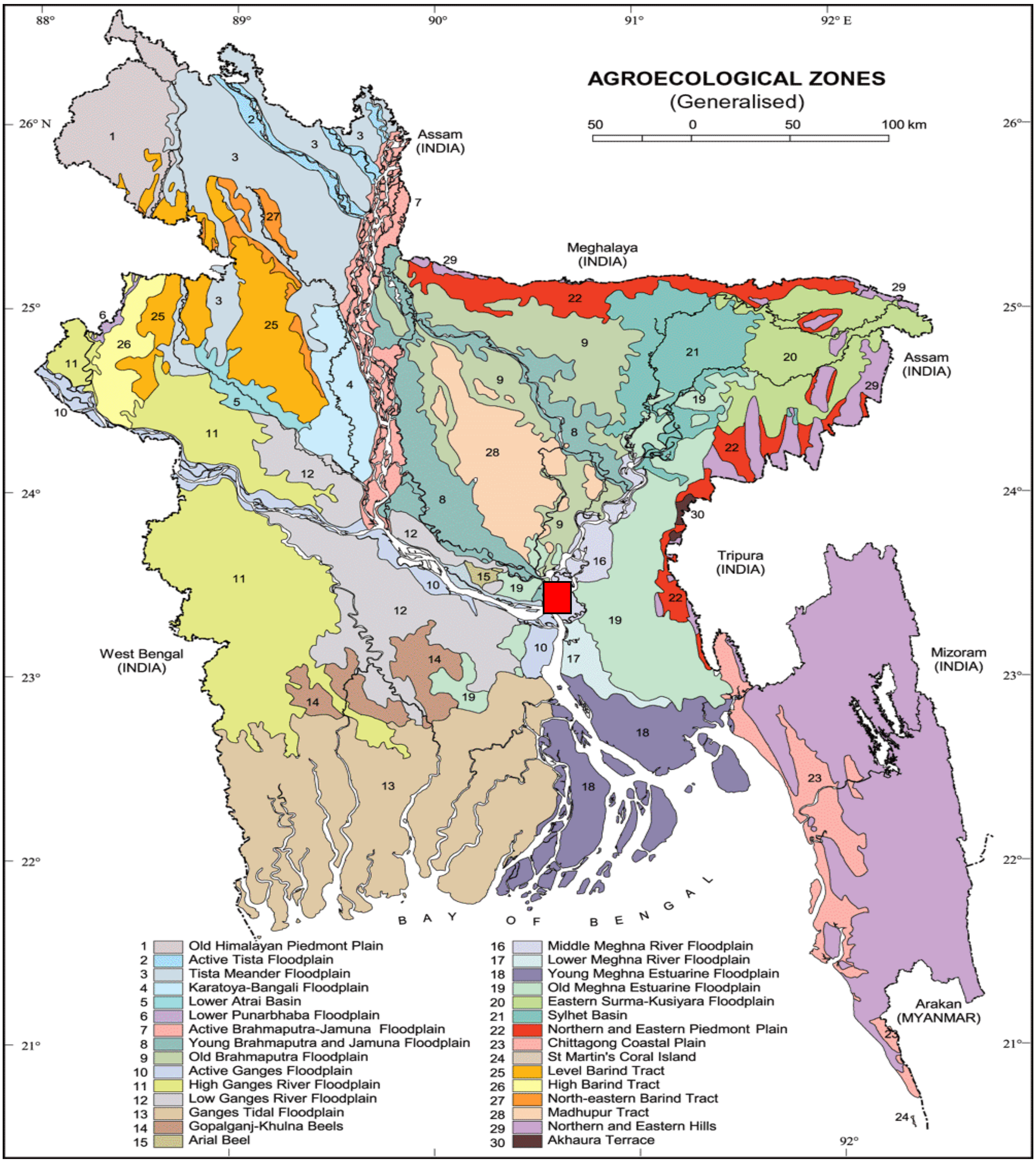
APPENDICES

Appendix I. Map showing the experimental site of the study



Legend showing the research site

Appendix II. Monthly average Temperature, Relative Humidity, Total Rainfall and Sunshine of the experimental site during the period of November, 2016 to March, 2017

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2016	33.8	25.0	81.81	0	5.8
November, 2016	29.3	18.3	72	0	7.9
December, 2016	27.0	17.0	89	0	3.9
January, 2017	26.2	16.1	67	0	5.7
February, 2017	28.9	23.0	45	0	8.7
March, 2017	29.8	20.5	65	0.1	7.3

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargaon, Dhaka – 1212

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil Characteristics	Analytical Results
Agrological Zone	Madhupur Tract
p^H	6.00-6.63
Organic matter	0.84
Total (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41meq/ 100 g soil

Source: Soil Research and Development Institute (SRDI), Dhaka