GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN F_3 SHORT STATURE POPULATIONS OF WHITE MAIZE (*Zea mays* L.)

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BY

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CERTIFICATE

This is to certify that thesis entitled, "Genetic Variability, Character Association and Path Analysis in F_3 Short Stature Populations 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 BODRUN NESSA SHOMPA, Registration No. 11-04320 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, 2018
Place: Dhaka, Bangladesh

(Prof. Dr. Jamilur Rahman)
Supervisor

HUMBLY DEDICATED
TO MY PARENTS, SISTER
AND BROTHER

SOME COMMONLY USED ABBREVIATIONS

Full word	**Abbreviation**
Agricultural	Agril.
Agriculture	Agric.
Agro Ecological Zone	AEZ
Agronomy	Agron.
Analysis of variance	Anova
And others	*et al.*
At the rate	@
Bangladesh	BD
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Cultivars	cv.
Degree Celsius	^0C
Degrees of Freedom	Df
Emulsifiable concentrate	EC
Environmental variance	σ^2_e
Etcetera	etc.
Food and Agricultural Organization	FAO
Genetic Advance	GA
Genotype	G
Genotypic coefficient of variation	GCV
Genotypic variance	σ^2_g
Gram	G
Harvest Index	HI
Heritability in broad sense	$h^2{}_b$
Indian Agricultural Research Institute	IARI
International Center for Agricultural Research in Dry Areas	ICARDA
Journal	J.
Kilogram	Kg
Mean sum of square	MS
Meter	m
Mililiter	ml
Ministry of Agriculture	MOA
Murate of Potash	MP

SOME COMMONLY USED ABBREVIATIONS (CONT'D)

Full word	Abbreviation
Percent	%
Percentage of Coefficient of Variation	CV%
Phenotypic coefficient of variation	PCV
Randomized Complete Block Design	RCBD
Standard deviation	SD
Standard error	SE
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
The third generation of a cross between two dissimilar homozygous parents	F_3
Triple Super Phosphate	TSP

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Dated:June, 2018 *The Author*
Place: SAU, Dhaka, Bangladesh

LIST OF CONTENTS

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS (CONT'D)

LIST OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN F_3 SHORT STATURE POPULATIONS OF WHITE MAIZE (*Zea mays* L.)

By

BODRUN NESSA SHOMPA

ABSTRACT

The investigation was carried out with 24 F_3 white maize populations to study the genetic variability, character association and finally to select the short duration and dwarf promising populations based on yield and yield contributing traits at Sher-e-Bangla Agricultural University, Dhaka during November 2017 to March 2018. Significant variations were observed among the F_3 populations for all the traits studied. The F_3 population of KS-510-F_3-S_2 showed the maximum mean performance in plant height (220.61 cm), cob length (19.65 cm), number of grains per row (33.83), while the population of Youngnuo-7-F_3-S_1 showed the minimum mean performance in plant height (122.33 cm), cob height (53.00 cm), base diameter (6.10 cm). The population PSC-121-F_3-S_2 showed the maximum yield per plant (97.67), while Youngnuo-7-F_3-S_1 showed the minimum yield per plant (46.94). 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 (20.99, 21.55), leaf blade area (19.20, 20.31), yield per plant (19.04, 22.59). High heritability coupled with high genetic advances in percent mean were obtained for plant height, cob height, number of cob bearing node, leaf blade area, number of grains per row and yield per plant. Correlation studies revealed that yield per plant positively and significantly associated with plant height, base diameter, number of leaves per plant, cob length, cob diameter and number of grains per row at both genotypic and phenotypic levels. Path coefficient analysis indicated positive direct contribution towards yield per plant through plant height, base diameter, branches of tassel, leaf blade area, cob length, cob diameter, number of rows per cob, number of grains per row and 100 grain weight. Based upon the mean performance among the 24 F_3 segregating population, PSC-121-F_3-S_2 and KS-510-F_3-S_1 would be selected for high grain yield per plant. Again Youngnuo-7-F_3-S_2 and Changnuo-1-F_3-S_1 might be selected as promising for both of the traits short duration and dwarf plant stature.

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L., 2n=2x=20) is considered as the third most important cereal food crop of the world after wheat *(Triticum aestivum* L.) and rice (*Oryza sativa* L.). Maize has gain rapid popularity due to its diversified uses. Globally 67% of maize is used for livestock feed, 25% human consumption, industrial purposes and balance is used as seed and its demand for grain food is increasing worldwide (Reddy *et al.*, 2013). Green plant and grain are used as the feed of livestock and poultry. Its oil is used as the best quality edible oil. 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 United States, China, Brazil and Mexico account for 70% and India contributes 2% of world production of maize. Like as India climate condition of Bangladesh favors maize cultivation. In Bangladesh maize 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 and its production has an increasing tendency with the introduction of hybrid and adoption improved technology since 1993. Recently it occupied 2nd position next to rice and occupied of 4.8% of the total cropped land area (Ahmad *et al*., 2011). Total cultivated area about 990 thousand acres and total annual production was 3288 thousand M. tons (BBS, 2018). Bangladesh although produces enough cereal food grains such as rice and wheat but now a days maize avail popularity besides these crops.

Maize has gain popularity because as it is a C_4 crop, per unit area profit is higher than any other crops. It can be cultivated all the year round like both Kharif (I and II) and Rabi season. Insects and disease attack is comparatively lower than the other crop. Biomass production in per unit area is higher than the rice and wheat.

Maize (*Zea mays* L.) has two major types according to kernel color viz. white maize and yellow maize, which are generally considered as human food crop and livestock respectively. Generally maize grain has high nutritive value containing 66.2%, starch 11.1% protein, 7.12% oil and 1.5% minerals (Chowdhury and Islam, 1993). But nutritionally there are some variations among these two types of maize in a specific nutrition. Comparative studies of white and yellow maize shown that per 100 gm grain of white and yellow maize supplied beta carotene zero (0) mg and 11-20 mg respectively. It was clearly shown that white maize contained no beta carotene. On the other hand, yellow maize contained more Beta-carotene (11-20 mg) and it is use in livestock feed purpose. Vitamin B_6 provide by white and yellow maize was 0.475 mg and 0.304 mg. White maize shown more nutritive value than yellow maize for vitamins viz., thiamine, riboflavin, niacin. On the other hand, yellow maize exhibited high value than white maize for vitamin E and pantothonic acid. Proteins content of white and yellow maize are 9.28 g and 8.12 g, respectively from 100 g. White maize supplied more calories than yellow maize. Calcium (Ca) provides more by white maize (136 mg) then yellow maize (6 mg). In case of iron (Fe) white maize exhibited more value than yellow maize (Tawanda *et al.*, 2011). In addition, white maize has a medium GI (Glycemic Index) which help in reducing the obesity. Market prices are usually higher for white maize compared to the yellow type.

The yield of maize is low in Bangladesh as compared to the other maize growing countries. It is mainly cultivated in Bangladesh during kharif I, kharif II and rabi season. Comparatively the yield is higher in rabi season than any other seasons. During kharif I and kharif II (summer-rainy) maize plant faces extreme climate (strong wind, storm, drought etc.). Again every day the country is losing about 200 hectares of crop land owing to industrialization, urbanization and river erosion. Previously sporadic attempts were made to accelerate maize production. But few attempts were made to develop the improved and adapted variety of white maize If we can develop short duration variety it can complete it's life cycle within shorter period of time and in case of dwarf stature variety it becomes less affected by the wind or storm. As a result the yield will increase as well as the cropping intensity of Bangladesh. Therefore, to accomplish this target maize breeding is an inevitable need.

In order to improve this high yielding crop, the proper technique is inbred the parental lines and selection of desirable genotype in early hybrid segregating generations or delaying intense selection until advanced generations. The selection criteria depend upon yield and yield component traits. Since grain yield in maize is quantitative in nature and polygenically controlled, to enhance the yield productivity, genetic parameters and correlation studies between yield and yield components are per-requisited to plan a meaningful breeding program to develop high yielding inbreeds as well as hybrids.

Genetic variability, is marked as a heritable difference among cultivars, is required at an optimal level within a population. Progress from selection has been reported to be directly related to the magnitude of genetic variation in the population (Tabanao and Bernardo, 2005; Hallauer and Miranda, 1995; Helm *et al*., 1989). Larger genetic variability has been found in the segregating population that represents different climatic, geographical regions signifies the genetic variation in important agronomic traits like earliness, cob height and grains per cob to sufficiently justify the initiation of the selection program (Abayi *et al*., 2004; Ilarslan *et al*., 2002).

Information on genetics of 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 contributing yield components like ear height, plant height and 1000-grain weight influences yield trait (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). Therefore, considering the above scheme and discussion in mind, the study was conducted to determine the genetic variability, heritability and character associations among 24 F_3 populations of white maize to fulfill the following objectives:

OBJECTIVES:

1. To study genetic variability and hertiabilty among the 24 F_3 population of white maize.
2. To study the correlation and path coefficient analysis, among the yield contributing traits.
3. To select the best short stature promising lines and advance them from F_3 to F_4 level through selfing.

CHAPTER II
REVIEW OF LITERATURE

Different investigators at home and abroad worked with different maize lines and studied their performance regarding the characterization. Numerous 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 sufficient and conclusive. However, 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 Biology of Maize
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 Biology of maize

Maize plant is tall, determinate, monoecious and annual in nature. It produced large, narrow, opposite leaves, borne alternately along the length of the stem. All maize varieties follow the 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. Various stages of maize growth are broadly divided into vegetative and reproductive stages.

Vegetative stage includes Seedling stage that comes about one week after sowing and the plants have about 2-4 leaves at this stage, Knee height stage of the plant that arrives about 35-45 days after sowing and then the flower initiation stage, at which the tassels or male flowers appear. Generally the maize plant would have attained its full height by this stage.

Reproductive stage includes silking stage involving the formation of the female flowers or cobs is the first reproductive stage and occurs 2-3 days after tasseling stage. This stage begins when any silks are visible outside the husk. These are auxiliary 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 in nature, that means the male flower matures earlier than the female flower. Within each male flower spikelet, there are usually two functional florets, although development of 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 corn field. 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 grain s. Pollen shed stops when the tassel is too wet or too dry and begins again when temperature conditions are favorable. Under favorable 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.

Soft-dough stage is the second stage under reproductive stage that commences after pollination and fertilization is over. Grains start developing but they do not become hard. This soft dough stage is noticed by the silks on the top of the cob which remain partially green at this stage. The covering of the cobs also remains green.Lastly, the hard-dough stage shows that the leaves get dried; silks get dried completely and become very brittle. Harvesting is done at this stage.

2.2 Mean performance

Hasan (2017) conducted an experiment at Sher-e-Bangla Agricultural University with F_2 population of white maize and found that the population of KS 510 showed maximum mean performance in plant height (218.61cm), days to maturity (135 days) and yield per plant (83.85g) while the population Youngnuo 7 showed minimum mean performance in plant height (120.94 cm), days to maturity (106 days) and yield per plant (43.42g).

Hossain (2015), studied in Sher-e-Bangla Agricultural University in 2015 with white maize. 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).

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

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

Paradkar and Sharma (1993) observed that out of 5 maize varieties (R1, Ganga 5, Ganga ll, HH2l6 and D765), Ganga ll gave increased grain rows per ear. Ganga 11 gave more ear length, followed by Gonga 5 and D 7654. Again, ear length is an important yield component for maize and had a direct effect on grain yield (BARI, 1990; Subramanian *et al.*, l98l), reported that cv. Bamali gave more ear per plant than Khaibhutta.

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).

Kamen (1983) investigated 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, varied with variety.

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

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) working with 25 varieties of maize and observed that leaves per plant differed significantly among the varieties.

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).

2.3 Genetic variability

Hasan (2017) studied on genetic variability in F_2 generation of white maize (*Zea mays* L.) revealed that high genotypic and phenotypic coefficient of variation was recorded 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).

Bhiusal *et al.* (2017) observed that the extent of genetic variability in maize with fifty-five genotypes during rabi of 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.

Asim Gazal *et al.* (2017) estimated 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.

Asim Gazal *et al.* (2017) conducted an experiment to assess the genetic variability of 100 homozygous maize inbred lines during kharif 2013 and 2014. Inbred lines were evaluated for obtaining information on genetic variability for yield attribute and quality traits. A wide range of variability revealing significant response was observed. 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) conducted experiment 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% tasseling, 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) 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% tasseling followed by kernel rows per year and 100 grains weight, respectively.

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

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 for Jalal-2003. The study revealed a considerable amount of genetic variation that could be manipulated for further improvement in maize breeding.

Ogunniyan and Olakojo (2014) observed significant variation existed in all the characters. The coefficients of variation were low except ear weight and grain yield that were relatively higher. The anthesis silk emergence interval was highest in lines TZEI 124 and TZEI 16. The 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.

Idris and Mohammed (2012) made a study 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 a 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) observed that testcrosses differed significantly for all the characters studied except days to 50% anthesis, days to 50% silk emerging and ASI. The Genotype x environment interaction was also significant for all the traits except for cob length.

Shanthi *et al*. (2011) revealed 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 and PCV indicating the genetic variances for these traits.

Hussain *et al.* (2011) found 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.

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

Naushad *et al*. (2007) carried out 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.

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

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 tasseling, maturity, percentage of barren plants, percent ear fill, ear length, ear diameter and 1000-seed weight was attributed to the independent effects of generation and nitrogen application.

Grzesiak (2001) observed that considerable variability among maize genotypes for different traits.

2.4 Heritability and genetic advance

Hasan (2017) studied on heritability and genetic advance in F_2 generation of white maize (*Zea mays* L.) and revealed that' high heritability coupled with high genetic advancees 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.

Alhussein and Idris (2017) revealed 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% tasseling 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) conducted an experiment with twenty-one locally developed maize hybrids for ten characters to access heritability. The highest heritability (Hb) 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.

Ishaq *et al.* (2015) found 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.

Ogunniyan and Olakojo (2014) studied with 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) observed 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% tasseling, days to 50% silk emerge, shelling percentage, ear length and days to maturity ear girth and number of seed rows per cob.

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

Shanthi *et al*. (2011) observed 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.

Abdelmula and Sabiel (2007) calculated 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.

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).

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

Presterl *et al*. (2003) carried out 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.

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.

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

2.5 Correlation co-efficient

Genotypic and phenotypic correlation determination is the basic step in the formulation and implementation of various breeding programs. The correlation among traits is also important for successful selections to be conducted in breeding activities. Again, analysis of correlation coefficient is the most widely used one among several methods (Yagdi and Sozen, 2009). Two types of correlations, phenotypic and genetic, are commonly discussed in plant breeding. Phenotypic correlation 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).

An experiment conducted by Hasan (2017) with F2 population of white maize at Sher-e-Bangla Agricultural University found significant positive correlation of yield per plant with plant height, days to maturity, number of leaves per plant, cob length, cob diameter, number of grains per row at both genotypic and phenotypic levels.

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) studied to investigate 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) reported on correlation studies 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% tasseling 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.

Bikal and Deepika (2015) observed 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% tasseling 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.

Kumar *et al*. (2014) found 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 positive with plant height, cob length, cob diameter and 100 grains weight; but related negatively with days to 50% tasseling. The four characters that correlated positively to grain yield also associated positively to each other throughout the experiment.

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 weight.

When major yield characters are positively associated then breeding 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) observed 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) observed 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.

Aydin *et al*. (2007) observed 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.

Al-Ahmad (2004) observed 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.

Pande *et al*. (1971) found that 100-seed weight was positively correlated with grain yield. Debnath (1991) conducted an experiment 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.

2.6 Path analysis

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 a 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 observed 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) and Alhussein and Idris (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.

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) carried out an experiment 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% tasseling (−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% tasseling (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).

Hasan (2017) studied on path analysis in the F_2 generation of white maize at Sher-e-Bangla Agricultural University and revealed 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.

It was stated 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) observed that path analysis showed days to 50% tassel had highest magnitude directly effect on grain yield per plant followed by ear height, 100 seed weight and ear circumference.

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) observed 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.

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 found 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.

Venugopal *et al*. (2003) revealed 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) observed 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.

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% tasseling had most minus direct effect on grain yield.

Devi *et al*. (2001) revealed 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.

Geetha and Jayaraman (2000) observed 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.

CHAPTER III

MATERIALS AND METHODS

An experiment was carried out during Rabi season 2017-18 to study the genetic variability, character association and path analysis in 24 F_3 short duration and dwarf promising lines of white maize. The details of material 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 2017 to March 2018. 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 monsoon or rainy 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 May 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-IV). The experimental site was situated in the subtropical zone. The soil of the experimental site lays 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-V.

3.3 Experimental materials

The experimental material for this study consisted of twenty-four F_3 populations of white maize hybrids. The F_3 seeds were collected from the Department of Genetics and Plant Breeding, SAU, Dhaka. The pedigree of F_3 populations is presented in Table 1.

3.4 Details of the experiment

The experiment was conducted during Rabi season of 2017 and 2018. Seeds were sown in main field on 26th November 2017. No. of plants per row for each genotype were 10 and each genotype occupied two rows in per replication. The plant spacing provided was 60 cm between rows and 25 cm between plants of the same row. The total experimental area was 312.9 m^2 whereas each replication area was 72 m^2. The experiment was laid out in a Randomized Complete Block Design (RCBD). Three replications were performed in this experiment.

Table 1. List of experimental materials of white maize used in the experiment

Sl. No.	Given name	Pedigree	Sources
1	G1	Plough- 201- F_3- S_1	Dept. of Genetics and Plant Breeding Sher-e-Bangla Agricultural University
2	G2	Plough-201- F_3- S_2	
3	G3	Plough-201- F_3- S_3	
4	G4	KS-510- F_3- S_1	
5	G5	KS-510- F_3- S_2	
6	G6	KS-510- F_3- S_3	
7	G7	Changnuo-6- F_3- S_1	
8	G8	Changnuo-6- F_3- S_2	
9	G9	Changnuo-6- F_3- S_3	
10	G10	Youngnuo-7- F_3-S_1	
11	G11	Youngnuo-7- F_3-S_2	
12	G12	Youngnuo-7- F_3-S_3	
13	G13	PSC-121- F_3- S_1	
14	G14	PSC-121- F_3- S_2	
15	G15	PSC-121- F_3- S_3	
16	G16	Q-Xiangnuo-1- F_3- S_1	
17	G17	Q-Xiangnuo-1- F_3- S_2	
18	G18	Q-Xiangnuo-1- F_3- S_3	
19	G19	Youngnuo-3000- F_3- S_1	
20	G20	Youngnuo-3000- F_3- S_2	
21	G21	Youngnuo-3000- F_3- S_3	
22	G22	Changnuo-1-F_3- S_1	
23	G23	Changnuo-1-F_3- S_2	
24	G24	Changnuo-1-F_3- S_3	

3.5 Cultural practices

3.5.1 Land preparation

The experimental plot was opened in the first week of November 2017 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 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 15th November 2017. 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 525, 250, 200, 250, 125, and 6 kg Urea, TSP, MoP, Gypsum, Zinc Sulfate and Boric Acid, respectively. The entire amount of cow dung was applied seven days before sowing. TSP. MP, Gypsum, Zinc Sulfate 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 (Table 2).

3.5.3 Seed sowing

After the lay out, the F_3 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_3 population's 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 26^{th} November 2017 (Plate 1 and 2).

Table 2. Fertilizer doses applied in the experiment

Sl. no	Fertilizer	Kg/ha
1	Cowdung	10 ton
2	Urea	525
3	TSP	250
4	MOP	200
5	Gypsum	250
6	Zinc Sulfate	12.5
7	Boric acid	6.0

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 was top dressed at 30 days after sowing. All recommended cultural practices were followed to raise a good white maize crop (Plate 3 and 4).

3.5.5 Other operations

The 1^{st} and 2^{nd} weeding were done respectively after 20 and 40 days of sowing to keep the soil free from weed. Irrigation was given when it is necessary during the crop period. Earthling up was done twice during growing period. The first earthling up was done at 45 days after sowing (DAS) and the second earthling up was done after 65 DAS (Plate 5).

Plate 1. Photograph showing preparation of the field for seed sowing

Plate 2. Photograph showing seed sowing in the experimental plot

Plate 3. Photographs showing intercultural operation

Plate 4. Photographs showing intercultural operation (weeding and thinning)

Plate 5. Photographs showing intercultural operation (earthing up)

Plate 6. Photograph showing spraying of insecticide to control pest

3.5.6 Plant protection

Adult and larva of maize cutworm and maize aphid were found in the crop during the vegetative and flowering stage of the plant. To control maize cutworm Ripcord 10 EC @1ml/litre were sprayed at 65-75 and 75-85 DAS respectively. To control maize aphid Malathion-57 EC @ 2ml/litre and were sprayed at 70 and 90 DAS respectively. The insecticide was applied in the afternoon (Plate 6).

3.6 Observations recorded

Observations were recorded from the 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 6th leaf stage

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

3.6.2 Days to 50% tasseling

Days to tasseling were recorded as number of days from planting to the time 50% of plant had fully emerged tassels.

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.

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. Height of randomly selected plants of each unit plot was measured and the mean was calculated. It was measured in cm with a graduated measuring stick.

3.6.5 Cob height (cm)

The heights of cob from ground level to the cob node from randomly 5/10 selected plants were measured from each unit plot in centimeters with a graduated measuring stick. 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.

3.6.5 Days to maturity

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

3.6.6 Base diameter (cm)

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

3.6.7 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.

3.6.8 Branches of tassel

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

3.6.9 Number of cob bearing node

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

3.6.10 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
L = Leaf length (cm)
W = Leaf maximum width (cm)
A = Constant, The value of the constant (A) is 0.75.

3.6.11 Cob length (cm)

The lengths of cobs were measured from the cob base to the apex in centimeter by using measuring scale (Plate 7).

3.6.12 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 (Plate 8).

3.6.13 Number of rows per cob

The total number of rows each cob were counted and the average was recorded (Plate 9).

3.6.14 Number of grains per row

The total number of grains from each row of a cob was counted and the average was recorded (Plate 10).

3.6.15 100-grain weight (g)

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

Plate 7. Photograph showing measurement of cob length

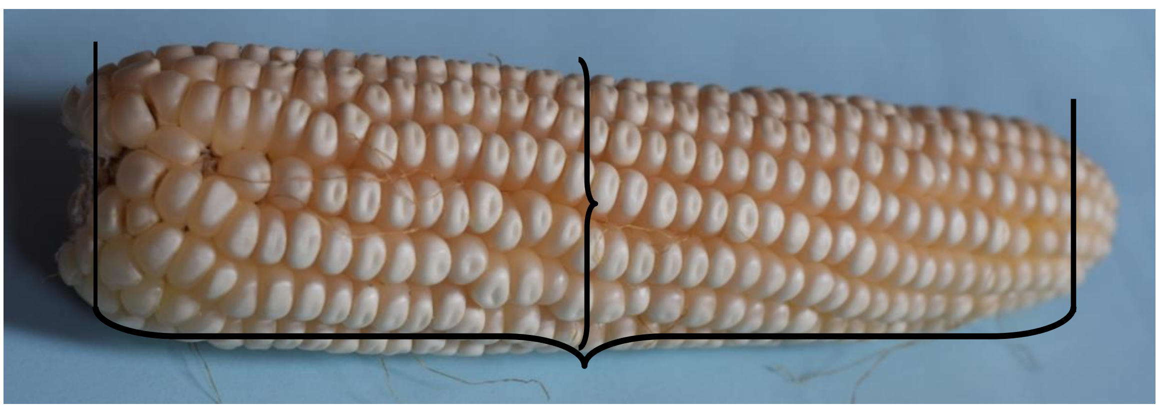


Plate 8. Photograph showing cob diameter measurement

Plate 9. Photograph showing measurement of rows per cob (1,2,3…denotes the number of rows)

Plate 10. Photograph showing measurement of grains per row (1,2,3…denotes the number of grains)

Plate 11. Photographs showing selfing of F_3 generation to advance them F_4 Level

Plate 12. Photographs showing supervisor visited to show the selfed plant

3.6.16 Grain yield per plant (g)

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 to the nearest gram. Yield was measure as gram per plant.

Selfing was performed in required number of plants of F_3 generation for production of inbred line of F_4 generation.

3.7 Statistical analysis

The mean replicated data collected on 17 traits were subjected to biometrical analysis following appropriate biometrical procedures.

3.7.1 Analysis of variance

The analysis of variance for different characters was carried out using mean data in order to assess the genetic variability among populations as given by Cochran and Cox (1957). The level of significance was tested at 5% and 1% using F test. The model of ANOVA used is presented below:

ANOVA

Sources of variation	**Degrees of freedom (D.F.)**	**Mean sum of squares (MS)**	**Expected MS**
Replication	(r-1)	Mr	$p\,\sigma_r^2 + \sigma_e^2$
Population	(p-1)	Mp	$r\,\sigma_p^2 + \sigma_e^2$
Error	(p-1) (r-1)	Me	σ_e^2
Total	(rp-1)		

Where,

r = number of replications

p = number of treatments (population)

σ_r^2 = variance due to replications

$б_p^2$ = variance due to treatments (population)

$б_e^2$ = variance due to error

To test significance of the difference between any two-adjusted genotypic mean, the standard error of mean was computed using the formula:

$$S.E = \sqrt{\frac{2\,Ee}{r}}\ (1 + \frac{rqu}{q+1})$$

Where,

S. E = Standard error of mean

Me = Mean sum of square for error (Intra block)

r = Number of replications

q = Number of population in each sub-block

u = Weightage factor computed

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 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 bearinbg 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).

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

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

r = number of replications

Phenotypic variance (σ^2_p)=σ^2_g + σ^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 %) = $\sqrt{\frac{\sigma_g^2}{\bar{x}}} \times 100$

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) = $\sqrt{\frac{\sigma_{ph}^2}{\bar{x}}} \times 100$

Where,

σ^2_p = Phenotypic variance

$\bar{x}$ = Population mean

PCV and GCV were classified into three following categories as suggested by Sivasubramanian and Menon (1973).

Categories: Low: Less than 10% Moderate: 10-20% High: More than 20%

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

Heritability estimates in cultivated plants could be placed in the following categories as suggested by Robinson *et al*. (1966).

Categories Low: 0-30%; Moderate: 30-60%; High: >60%

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

Categories: High (>20%) Moderate (10-20%) Low (<10%)

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):

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

Genetic advance as per cent mea ... groups as suggested by Johnson *et al.* (1955).

Categories: Low - Less than 10% Moderate -10-20% High - More than 20%

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:

$$\text{Genotypic correlation, } r_{gxy} = \frac{GCOVxy}{\sqrt{GVx.GVy}} =$$

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

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

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 is 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.

Categories:

Negligible- 0**.**00 to 0**.**09; Low- 0**.**10 to 0**.**19; Moderate- 0**.**20 to 0**.**29;

High- 0**.**30 to 1**.**0; Very High- >1**.**00

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was undertaken with a view to select short duration and dwarf stature promising lines by comparing the performance of 24 population on 17 characters of white maize and to advance the F_3 lines to F_4 stage. The study was also conducted to find out the phenotypic and genotypic variability, co-efficient of variation, heritability, genetic advance, correlation and path co-efficient to estimate direct and indirect effect of yield contributing traits on yield. The data were recorded on seventeen (17) different characters such as days to 6^{th} leaf stage, days to 50% Tasselling, days to 50% Silking, plant height, cob height, days to maturity, base diameter, no. of leaves per Plant, no. of branches of tassel, no. of cob bearing node, leaf blade area, cob length, cob breadth, no. of rows per cob, no. of grains per row, 100 grains weight and yield per plant. The data were statistically analyzed and thus obtained results are described below under the following headings:

4.1 Mean performance

Analysis of variance and mean performance are presented in Table 3, Table 4 and Table 5. 'F' test revealed highly significant variation among 24 white maize promising F_3 lines in terms of all the yield contributing characters and yield except under studied. It was revealed that the possibilities of improving the genetic yield potential of white maize promising lines.

4.1.1 Days to 6^{th} leaf stage

Days to 6^{th} leaf stage showed statistically significant variation for different white maize F_3 populations under study (Table 3). Mean days to 6^{th} leaf stage was recorded 44.64 with a range from 43.00 (Youngnuo-7-F_3-S_2) to 46.00 (Youngnuo-

3000-F_3- S_2) (Table 4 and Table 5). It was found that line Youngnuo-7 was the early promising line among the studied lines.

4.1.2 Days to 50% tasselling

Days to 50% tasseling showed statistically significant variation for different white maize F_3 populations under study (Table 3). Data revealed that the average days to 50 % tasseling was recorded around 73.58 with a range from 66.00 to 77.00 (Table 4). The highest (77.00) days to 50% tasseling was found in the genotypes PSC-121-F_3-S_3 which was followed by Youngnuo 3000 (76.33) and KS 510 (76.00) whereas the lowest (66.00) days was found from the population Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3, which was followed by Youngnuo-7- F_3-S_1 (66.33). Data revealed that different promising lines required different days to 50% male flowering and it was might be due to genetic factors of the genotype. It was also found that lines Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3 were the early male flowering.

4.1.3 Days to 50% silking

Statistically significant variation was observed for days to 50% silking among white maize F_3 populations under the investigation (Table 3). The average days to 50% silking was recorded 77.86 days with a range from 70.67 to 84.33 (Table 4). The minimum (70.67) days to 50% silking was observed the population Youngnuo-7-F_3-S_1which was followed by Youngnuo-7-F_3-S_2 (71.33) and Youngnuo-7-F_3-S_3 (72.00). The highest (84.33) days to 50% silking was found in the genotypes Youngnuo-3000-F_3-S_3 which was followed by Youngnuo-3000-F_3-S_2 (83.00). The differences in days to 50% flowering might be due to genetic factor of the genotype concerned.

Table 3. Analysis of variance for different characters of 24 F_3 population of white maize

Characters	Mean sum of square		
	Replication (r-1) = 2	**Genotype (g-1) = 23**	**Error (r-1) (g-1) = 46**
Days to 6th leaf stage	5.06	1.88**	0.33
Days to 50% Tasselling	6.13	32.56**	2.40
Days to 50% Silking	3.85	38.43**	2.85
Plant height (cm)	84.38	1649.19**	45.51
Cob height (cm)	40.06	775.22**	13.60
Days to maturity	22.51	236.29**	6.50
Base diameter (cm)	0.19	1.54**	0.06
No. of leaves per Plant	0.49	4.46**	0.40
No. of branches of tassel	3.82	9.60**	2.37
No. of cob bearing node	0.11	1.97**	0.10
Leaf blade area (cm^2)	721.48	28564.22**	1090.01
Cob length (cm)	0.06	10.07**	1.64
Cob breadth (cm)	0.0002	0.14**	0.05
No. of rows per cob	0.33	0.94**	0.42
No. of grains per row	129.87	41.45**	4.99
100 grains weight (g)	2.81	35.37**	4.51
Yield per plant (g)	688.78	548.37**	65.63

**: Denote Significant at 1% level of probability *: Denote Significant at 5% level of probability

Table 4. Range, mean and CV (%) of 24 F_3 population of white maize

Parameters	Range		Mean	CV (%)	SD	SE
	Min	Max				
Days to 6th leaf stage	43.00	46.00	44.64	1.29	0.58	0.22
Days to 50% Tasselling	66.00	77.00	73.58	2.11	1.55	0.59
Days to 50% Silking	70.67	84.33	77.86	2.17	1.69	0.64
Plant height (cm)	122.33	220.61	161.55	4.18	6.75	2.55
Cob height (cm)	49.72	111.33	75.90	4.86	3.69	1.39
Days to maturity	105.50	137.33	120.98	2.11	2.55	0.96
Base diameter (cm)	6.10	8.23	7.16	3.53	0.25	0.10
No. of leaves per Plant	9.44	13.83	12.66	4.98	0.63	0.24
No. of branches of tassel	9.47	15.67	12.19	12.63	1.54	0.58
No. of cob bearing node	5.05	8.11	6.75	4.58	0.31	0.12
Leaf blade area (cm^2)	349.59	678.26	498.36	6.62	33.02	12.48
Cob length (cm)	12.53	19.65	15.80	8.11	1.28	0.48
Cob diameter (cm)	4.30	5.10	4.62	4.70	0.22	0.08
No. of rows per cob	12.17	14.21	13.14	1.65	0.22	0.08
No. of grains per row	20.50	34.72	28.38	7.87	2.23	0.84
100 grains weight (g)	27.70	42.77	35.55	5.97	2.12	0.80
Yield per plant (g)	46.94	97.67	66.64	12.16	8.10	3.06

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

Table 5. Mean performance of different characters of 24 F_3 population of white maize

Genotypes	Pedigree	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
G1	Plough- 201-F_3-S_1	44.00	71.67	74.67	165.61	65.83	112.33	7.12	12.94	10.67
G2	Plough-201-F_3-S_2	44.33	72.00	76.33	167.50	68.00	115.83	6.92	12.22	10.78
G3	Plough-201-F_3-S_3	44.00	73.67	77.33	169.66	67.83	115.50	7.33	12.56	11.44
G4	KS-510-F_3-S_1	44.67	75.67	80.67	204.01	111.33	133.17	8.23	13.67	15.40
G5	KS-510-F_3-S_2	45.33	76.00	81.33	220.61	108.17	135.17	8.14	13.73	14.98
G6	KS-510-F_3-S_3	44.67	75.67	81.00	204.78	110.33	137.33	8.17	13.73	15.67
G7	Changnuo-6-F_3-S_1	45.67	72.00	75.00	152.50	67.06	124.33	6.48	12.96	12.47
G8	Changnuo-6-F_3-S_2	45.33	72.67	75.67	152.22	64.67	120.50	6.26	12.44	13.42
G9	Changnuo-6-F_3-S_3	45.33	72.33	75.00	148.72	68.11	117.83	6.17	12.72	10.45
G10	Youngnuo-7-F_3-S_1	43.33	66.33	70.67	122.33	53.00	107.83	6.10	12.67	11.00
G11	Youngnuo-7-F_3-S_2	43.00	66.00	71.33	126.82	53.67	105.50	6.15	9.44	9.47
G12	Youngnuo-7-F_3-S_3	43.67	66.00	72.00	133.06	49.72	107.50	6.13	10.00	10.31
G13	PSC-121-F_3-S_1	44.33	75.33	78.33	168.67	75.44	131.50	7.58	9.89	10.89
G14	PSC-121-F_3-S_2	44.33	75.67	78.67	181.72	75.94	131.17	8.04	12.61	11.89
G15	PSC-121-F_3-S_3	44.67	77.00	80.00	168.94	76.17	133.17	8.08	13.33	12.09
G16	Q-Xiangnuo-1-F_3-S_1	45.33	73.67	77.67	155.90	76.23	117.17	7.53	13.05	11.33
G17	Q-Xiangnuo-1-F_3-S_2	45.00	74.33	78.33	161.39	75.06	120.83	7.62	13.00	11.67
G18	Q-Xiangnuo-1-F_3-S_3	44.67	73.67	76.67	167.89	76.39	117.17	7.93	12.11	11.87
G19	Youngnuo-3000-F_3-S_1	45.67	76.00	82.00	150.00	75.23	121.50	6.88	13.11	14.11
G20	Youngnuo-3000-F_3-S_2	46.00	76.00	83.00	150.22	74.44	122.83	6.69	13.72	13.44
G21	Youngnuo-3000-F_3-S_3	45.67	76.33	84.33	150.11	74.33	123.83	6.81	13.55	15.33
G22	Changnuo-1-F_3-S_1	44.00	76.00	79.00	143.72	82.72	117.17	7.19	13.50	10.67
G23	Changnuo-1-F_3-S_2	44.00	76.00	79.33	162.72	88.11	117.17	7.15	13.83	12.19
G24	Changnuo-1-F_3-S_3	44.33	76.00	80.33	148.11	83.73	117.17	7.19	13.00	11.09

Table 5. (Cont'd)

Genotypes	Pedigree	No. of cob bearing node	Leaf blade area (cm^2)	Cob length (cm)	Cob diameter (cm)	No. of rows per cob	No. of grains per row	100 grains weight (g)	Yield per plant (g)
G1	Plough- 201-F_3-S_1	6.11	454.55	14.17	4.34	12.89	25.56	32.58	54.21
G2	Plough-201-F_3-S_2	6.54	443.84	13.59	4.47	13.60	24.95	33.14	56.16
G3	Plough-201-F_3-S_3	6.29	459.17	14.11	4.55	14.21	26.83	30.81	58.55
G4	KS-510-F_3-S_1	8.05	490.51	18.85	4.90	13.89	33.00	40.23	91.82
G5	KS-510-F_3-S_2	7.82	608.15	19.65	5.07	13.72	33.83	38.44	89.02
G6	KS-510-F_3-S_3	8.11	673.53	17.60	4.62	13.61	34.72	33.67	80.26
G7	Changnuo-6-F_3-S_1	6.22	532.40	17.81	4.44	13.15	30.83	31.48	62.43
G8	Changnuo-6-F_3-S_2	6.44	549.51	17.42	4.66	13.00	29.22	36.60	69.73
G9	Changnuo-6-F_3-S_3	6.44	559.97	16.32	4.46	12.31	29.45	27.70	50.67
G10	Youngnuo-7-F_3-S_1	5.11	356.43	12.53	4.49	12.89	20.50	35.35	46.94
G11	Youngnuo-7-F_3-S_2	5.05	359.95	13.59	4.55	13.00	23.00	31.30	47.36
G12	Youngnuo-7-F_3-S_3	5.33	349.59	12.80	4.44	13.05	24.33	34.22	54.76
G13	PSC-121-F_3-S_1	6.78	622.88	16.40	4.99	14.17	28.33	38.82	77.77
G14	PSC-121-F_3-S_2	6.95	678.26	16.12	5.10	13.89	32.94	42.77	97.67
G15	PSC-121-F_3-S_3	6.78	660.52	16.39	4.80	12.17	30.45	39.73	73.01
G16	Q-Xiangnuo-1-F_3-S_1	7.33	444.53	16.56	4.35	13.00	28.06	37.21	67.16
G17	Q-Xiangnuo-1-F_3-S_2	7.11	425.06	16.68	4.30	12.72	24.95	37.80	60.31
G18	Q-Xiangnuo-1-F_3-S_3	6.89	478.55	16.22	4.66	12.95	26.50	37.74	64.74
G19	Youngnuo-3000-F_3-S_1	7.13	384.30	15.93	4.64	12.94	30.61	34.13	68.37
G20	Youngnuo-3000-F_3-S_2	7.40	505.21	15.51	4.61	12.67	28.55	36.23	65.27
G21	Youngnuo-3000-F_3-S_3	7.44	440.44	16.72	4.72	12.89	28.33	35.62	65.17
G22	Changnuo-1-F_3-S_1	6.67	469.09	14.05	4.50	12.28	24.11	37.74	55.70
G23	Changnuo-1-F_3-S_2	7.00	491.11	15.51	4.62	13.00	33.39	34.69	75.19
G24	Changnuo-1-F_3-S_3	7.00	523.09	14.58	4.70	13.33	28.73	35.11	66.99

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 segregating generations of white maize represents different plant height. It was varied significantly due to different F_3 populations indicated considerable difference among the genotypes studied (Table 3).The lowest (122.33 cm) plant height was recorded in the genotype Youngnuo-7-F_3-S_1 which was followed by Youngnuo-7-F_3-S_2 (16.82 cm). In contrary the highest (220.61 cm) plant height was observed from the genotype KS-510-F_3-S_2. It was observed that short plant has been benefited against heavy wind and storm. So, short plant stature was found in this experiment were Youngnuo-7-F_3-S_1 and Youngnuo-7-F_3-S2. The average plant height was recorded 161.55 cm (Plate 13). 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 varied significantly due to different selected white maize F_3 populations (Table 3). The average cob height was recorded 75.90 cm with a range from 49.72 cm to 111.33 cm (Table 4). The lowest (49.72 cm) cob height was recorded in the selected population of Youngnuo-7-F_3-S_3 and it was followed by Youngnuo-7-F_3-S_1 (53.00 cm) and Youngnuo-7-F_3 (53.67 cm). The highest (111.33 cm) cob height was observed from the population KS-510-F_3-S_1. Cob height is a indicator for dwarf variety selection.

Plough 201-F_3-S_1

Plough 201-F_3-S_2

Plough 201-F_3-S_3

KS 510-F_3-S_1

KS 510-F_3-S_2

KS 510-F_3-S_3

Changnuo-6-F_3-S_1

Changnuo-6-F_3-S_2

Changnuo-6-F_3-S_3

Plate 13. Photograph showing plant height of different F_3 population of white maize

Youngnuo-7-F_3-S_1

Youngnuo-7-F_3-S_2

Youngnuo-7-F_3-S_3

PSC-121-F_3-S_1

PSC-121-F_3-S_2

PSC-121-F_3-S_3

Q-Xiangnuo-1-F_3-S_1

Q-Xiangnuo-1-F_3-S_2

Q-Xiangnuo-1-F_3-S_3

Plate 13. Photograph showing plant height of different F_3 population of white maize

		
Yungnuo-3000-F_3-S_1	Yungnuo-3000-F_3-S_2	Yungnuo-3000-F_3-S_3
		
Changnuo-1-F_3-S_1	Changnuo-1-F_3-S_2	Changnuo-1-F_3-S_3

Plate 13. Photograph showing plant height of different F_3 population of white maize

It was revealed that selection population of Youngnuo-7F_3-S_3, Youngnuo-7-F_3-S_1 and Youngnuo-7-F_3 was found minimum height of cob. These populations might be resistant against storm and heavy wind.

4.1.6 Days to maturity

Statistically significant variation was recorded for days to maturity for different white maize F_3 populations (Table 3). The average days to maturity was recorded 120.98 with a range from 105.50 to 137.33 (Table 4). The highest (137.33) days to maturity was found in the population of KS-510-F_3-S_3 which was followed by KS-510-F_3-S_2 (135.17). The minimum (105.50) days to maturation was found from the population of Youngnuo-7-F_3-S_2 which was followed by the genotype Youngnuo-7-F_3-S_3 (107.50) and Youngnuo-7-F_3-S_1 (107.83). In case unfavorable weather viz., heavy wind and storm in late time maize cultivation so it was needed to harvest early from the field. That`s why early segregating population need to be selected. For this reason Youngnuo-7-F_3-S_2, Youngnuo-7-F_3-S_3 and Youngnuo-7-F_3-S_1 might be selected for further evaluation.

4.1.7 Base diameter (cm)

Base diameter was represented significant variation among white maize F_3 populations (Table 3). The average value of base diameter was observed 7.16 cm. The maximum base diameter was found the F_3 populations of KS-510-F_3-S_1 (8.23 cm) and it was followed by KS-510-F_3-S_3 (8.17 cm) and KS-510-F_3-S_2 (8.14). In the contrary, the minimum value in Youngnuo-7-F_3-S_1 (6.10 cm) (Table 4). Base diameter is an important trait because it maintains the plant under unfavorable weather conditions like hail storm and other heavy wind. If the base diameter higher, then the plant become strong and still stand without broken in unfavorable condition. So, under this study population of KS-510-F_3-S_1, KS-510-F_3-S_3 and KS-510-F_3-S_2 might be selected for this trait.

4.1.8 Leaves per plant

Significant variation was observed for number of leaves per plant among different white maize genotypes (Table 3). The average number of leaves per plant was recorded 12.66 with a range from 9.44 to 13.83 (Table 4). The most (13.83) number of leaves per plant was recorded in the population of Changnuo-1-F_3-S_2 which were followed by KS-510-F_3-S_2 (13.73), KS-510-F_3-S_3 (13.73) and Youngnuo-3000-F_3-S_2 (13.72) (Table 5) whereas the least (9.44) number of leaves per plant was observed from the population of Youngnuo-7-F_3-S_2.

4.1.9 Number of branches of tassel

Number of branches of tassel was found significant variation among different white maize F_3 populations (Table 3). The mean value of this trait was 12.19. The highest number of branches of tassel was observed in maize F_3 populations of KS-510-F_3-S_3 (15.67) which was followed by KS-510-F_3-S_1 (15.40) and KS-510-F_3-S_2 (14.98). The lowest number of branches of tassel was found in maize F_3 populations of Youngnuo-7-F_3-S_2 (9.47) (Table 5).

4.1.10 Number of cob bearing node

Number of cob bearing node varied significantly among the white maize F_3populations (Table 3). It was highest number in the F_3 populations of KS 510 (8.11) which was followed by in F_3 populations KS-510-F_3-S_1 (8.05). The lowest number of cob bearing node was performed by the F_3 populations of Youngnuo-7-F_3-S_2 (5.05) which was followed by Youngnuo-7-F_3-S_1 (5.11) and Youngnuo-7-F_3-S_3 (5.33) (Table 5). The lower number of cob bearing node is required for short stature plant because it might be tolerant against storm. So, population came from Youngnuo-7-F_3-S_2, Youngnuo-7-F_3-S_1 and Youngnuo-7-F_3-S_3.

4.1.11 Leaf blade area (cm^2)

Leaf blade area varied significantly among the different F_3 populations of white maize under the study (Table 3). The average leaf blade area was observed 498.36 cm^2. The highest leaf area was found by the F_3 populations of PSC-121-F_3-S_2 (678.26 cm^2) whereas the lowest leaf area observed in F_3 population of Youngnuo-7-F_3-S_3 (349.59cm^2) (Table 5).

4.1.12 Cob length (cm)

Significant variation was exhibited in respect of cob length among different varieties under studied (Table 3). The average cob length was recorded 15.80 with a range from12.53 to 19.65. The longest (19.65) cob was observed in the genotype KS-510-F_3-S_2, whereas the shortest (12.53) cob length was observed from the genotype Youngnuo-7-F_3-S_1 (Plate 14).

4.1.13 Cob diameter (cm)

Cob diameter varied insignificantly in different white maize genotypes (Table 3). The average cob diameter was recorded 4.62 cm with a range from 4.30 cm to 5.10 cm (Table 4). The highest (5.10) cob diameter was recorded in the genotype PSC-121-F_3-S_2 which was followed by PSC-121-F_3-S_1 (4.99 cm), whereas the lowest (4.30 cm) cob diameter was observed from the genotype Q-Xiangnuo-1-F_3-S_2.

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 significantly in different white maize genotypes (Table 3). The average row per cob was recorded 13.14. The highest (14.21) row per cob was recorded in the genotype Plough-201-F_3-S_3 and it was followed by the genotype PSC-121-F_3-S_1

(14.17) and KS-510-F_3-S_1 (13.89), while the lowest (12.17) number of row per cob was observed from the genotype of PSC-121-F_3-S_3. These results were in line with Ahmad *et al.* (1978) in maize.

4.1.15 Number of grains per row

Number of grains per row varied significantly due to different maize genotypes (Table 3). The average number of grains per row was recorded around 28.38 with a range from 20.50 to 34.72 (Table 4). The highest (34.72) number of grains per row was recorded in the genotype KS-510-F_3-S_3which was followed by KS-510-F_3-S_2 (33.83) and Changnuo-1-F_3-S_2 (33.39), whereas the lowest (20.50) number was observed from the genotype Youngnuo-7-F_3-S_1.

4.1.16 100-grain weight (g)

100-grain weight is an important factor directly contributing to final grain yield. There was a prominent effect of different segregating population on 100-grain weight. This was due to genetically controlled factor that 100-grain weight of different hybrids was different (Plate 15). As for the effect of environment factors on 100-grain weight is concerned it could not be neglected but the selection of suitable segregating can manage the influence of environment. Data indicated that highly significant due to 100-grain weight among different maize genotypes (Table 3). The average 100-grain weight was 35.55 g with a range from 27.70 g to 42.77 g (Table 4). The highest (42.77 g) 100-grain weight was recorded in the genotype PSC-121-F_3-S_2 which was followed by KS-510-F_3-S_1 (40.23) while the lowest (27.70 g) weight of 100-grain was observed from the genotype Changnuo-6-F_3-S_3. The similar results were also reported by Jing *et al.* (2003) and Ali (1994).

		
Plough- 201- F_3- S_1	Plough- 201- F_3- S_2	Plough- 201- F_3- S_3
		
KS-510- F_3- S_1	KS-510- F_3- S_2	KS-510- F_3- S_3
		
Changnuo-6- F_3- S_1	Changnuo-6- F_3- S_2	Changnuo-6- F_3- S_3
		
Youngnuo-7- F_3-S_1	Youngnuo-7- F_3-S_2	

Plate 14. Photograph showing cob length of different F_3 population of white maize

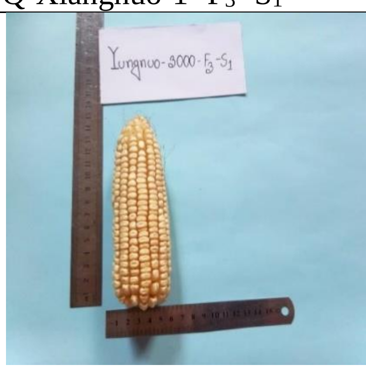
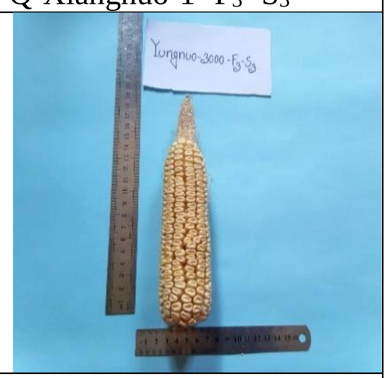
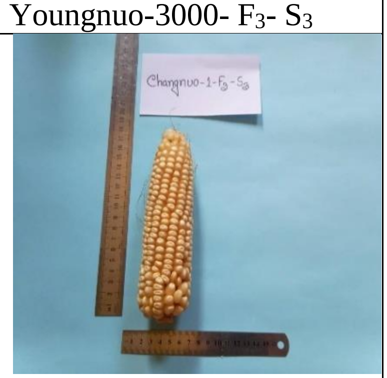
		
PSC-121- F_3- S_1	PSC-121- F_3- S_2	PSC-121- F_3- S_3
		
Q-Xiangnuo-1- F_3- S_1	Q-Xiangnuo-1- F_3- S_2	Q-Xiangnuo-1- F_3- S_3
		
Youngnuo-3000- F_3- S_1	Youngnuo-3000- F_3- S_2	Youngnuo-3000- F_3- S_3
		
Changnuo-1-F_3- S_1	Changnuo-1-F_3- S_2	Changnuo-1-F_3- S_3

Plate 14. Photograph showing cob length of different F_3 population of white maize

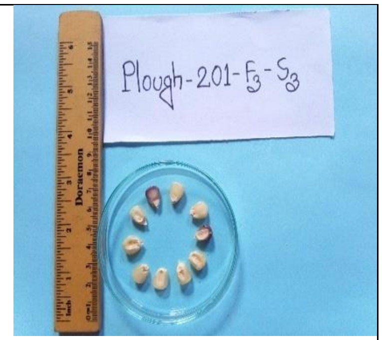
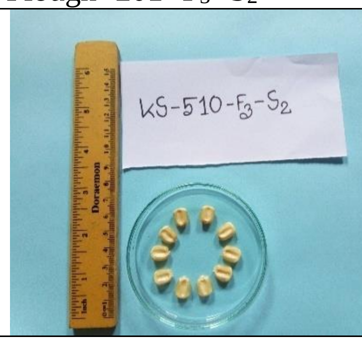
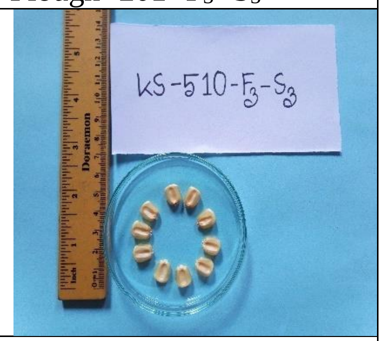
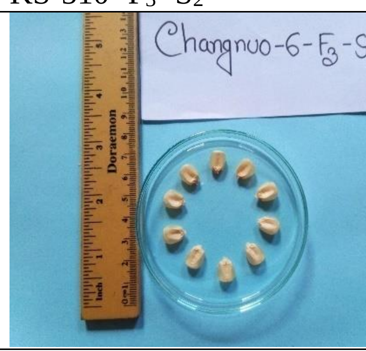
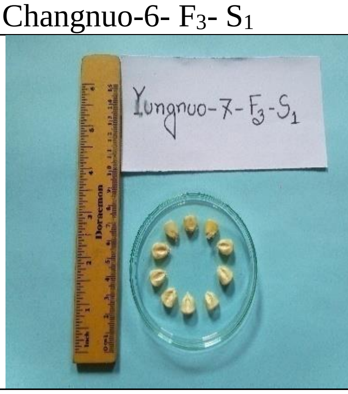
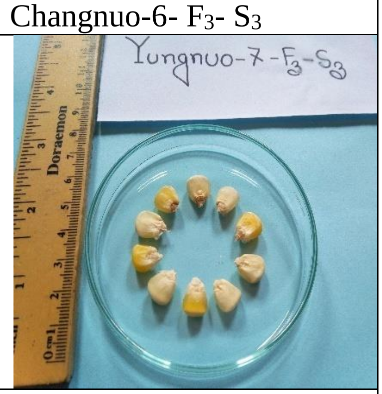
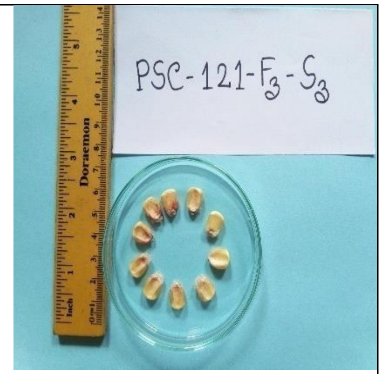
		
Plough- 201- F_3- S_1	Plough- 201- F_3- S_2	Plough- 201- F_3- S_3
		
KS-510- F_3- S_1	KS-510- F_3- S_2	KS-510- F_3- S_3
		
Changnuo-6- F_3- S_1	Changnuo-6- F_3- S_2	Changnuo-6- F_3- S_3
		
Youngnuo-7- F_3-S_1	Youngnuo-7- F_3-S_2	Youngnuo-7- F_3-S_3

Plate 15. Photograph showing grains of different F_3 population of white maize

PSC-121- F_3- S_1

PSC-121- F_3- S_2

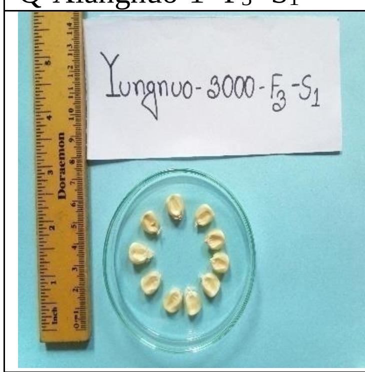


PSC-121- F_3- S_3

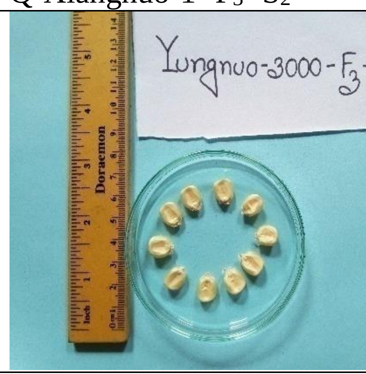
Q-Xiangnuo-1- F_3- S_1

Q-Xiangnuo-1- F_3- S_2

Q-Xiangnuo-1- F_3- S_3



Youngnuo-3000- F_3- S_1

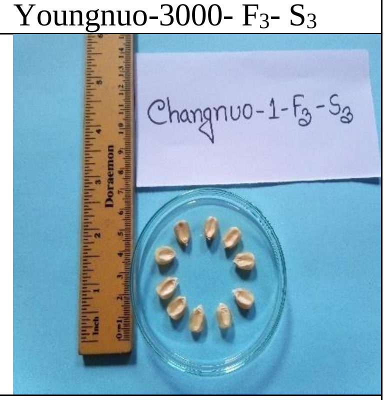


Youngnuo-3000- F_3- S_2

Youngnuo-3000- F_3- S_3

Changnuo-1-F_3- S_1

Changnuo-1-F_3- S_2



Changnuo-1-F_3- S_3

Plate 15. Photograph showing grains of different F_3 population of white maize

4.1.17 Grain yield per plant (g)

Grain yield varied significantly due to different maize genotypes under the present study (Table 3). Data revealed that the average grain yield per plant was recorded 66.64 g with a range from 46.94 g to 97.67 g (Table 4). The highest (97.67 g) grain yield per plant was recorded in the genotype PSC-121-F_3-S_2 which was followed by KS-510-F_3-S_1 (91.82 g) KS-510-F_3-S_2 (89.02 g) and KS-510-F_3-S_3 (80.26 g). Tahir *et al. (*2008) observed that the maximum grain yield was obtained from HG-3740. The lowest (46.94 g) grain yield was observed from the genotype Youngnuo-7-F_3-S_1.

4.2 Variability

Genotypic and phenotypic variance, heritability and genetic advance in percentage of mean were estimated for 17 traits in twenty four population of white maize presented in Table 6; Figure 1 and Figure 2.

4.2.1 Days to 6^{th} leaf stage

Days to 6^{th} leaf stage refers to phenotypic variance (0.85) was slightly higher than the genotypic variance (0.52) that indicating less environmental influence on this characters which was supported by narrow difference between phenotypic (2.06%) and genotypic (1.61%) co-efficient of variation (Table 6). Least difference of phenotypic variance to genotypic variance indicating that these characters were less responsive to environmental factors for their phenotypic expression. High heritability (60.97%) with low genetic advance in percent of mean (2.59%) was observed for this trait indicating both additive and non-additive gene action on the expression of this trait and selection on the basis of this would not be effective.

4.2.2 Days to 50% tasseling

Days to 50% tasseling refers to phenotypic variance (12.45) was higher than the genotypic variance (10.05) that indicating environmental influence on this characters which was supported by narrow difference between phenotypic (4.80%) and genotypic (4.31%) co-efficient of variation (Table 6). High heritability (80.72%) in days to 50% tasseling attached with low genetic advance in percentage of mean (7.97%). High estimate of heritability and low genetic advance for days to 50% tasseling 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.

4.2.3 Days to 50% silking

Days to 50% silking refers to phenotypic variance (14.71) was higher than the genotypic variance (11.86) that indicating environmental influence on this characters which was supported by narrow difference between phenotypic (4.93%) and genotypic (4.42%) co-efficient of variation (Table 6). High heritability (80.64%) attached with low genetic advance in percentage of mean (8.18%) revealed the major role of non-additive gene action in the transmission of this character from parents to off springs.

4.2.4 Plant height (cm)

Plant height refers to phenotypic variance (580.07) was higher than the genotypic variance (534.56) indicating that less environmental influence for expression of this character which was supported by narrow difference between phenotypic (14.91%) and genotypic (14.31%) co-efficient of variation (Table 6). High heritability (92.15%) along with high genetic advance (45.72%) and high genetic advance in percent of mean (28.30%) revealed the possibility of predominance of additive gene action in the inheritance of this trait. So, selection based on this trait for dwarf plant stature 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.

Table 6. Estimation of genetic parameters for different characters in white maize

Parameters	**σ^2p**	**σ^2g**	**$\sigma^2 e$**	**PCV**	**GCV**	**h^2**	**GA (5%)**	**GA (% mean)**
Days to 6th leaf stage	0.85	0.52	0.33	2.06	1.61	60.97	1.16	2.59
Days to 50% Tasselling	12.45	10.05	2.40	4.80	4.31	80.72	5.87	7.97
Days to 50% Silking	14.71	11.86	2.85	4.93	4.42	80.64	6.37	8.18
Plant height (cm)	580.07	534.56	45.51	14.91	14.31	92.15	45.72	28.30
Cob height (cm)	267.47	253.87	13.60	21.55	20.99	94.92	31.98	42.13
Days to maturity	83.10	76.60	6.50	7.53	7.23	92.18	17.31	14.31
Base diameter (cm)	0.56	0.49	0.06	10.42	9.80	88.52	1.36	18.99
No. of leaves per Plant	1.75	1.35	0.40	10.46	9.19	77.31	2.11	16.65
No. of branches of tassel	4.78	2.41	2.37	17.93	12.73	50.40	2.27	18.62
No. of cob bearing node	0.72	0.63	0.10	12.58	11.71	86.74	1.52	22.48
Leaf blade area (cm2)	10248.08	9158.07	1090.01	20.31	19.20	89.36	186.36	37.39
Cob length (cm)	4.45	2.81	1.64	13.36	10.61	63.11	2.74	17.36
Cob diameter (cm)	0.08	0.03	0.05	6.10	3.89	40.63	0.24	5.10
No. of rows per cob	0.59	0.18	0.42	5.86	3.19	29.58	0.47	3.57
No. of grains per row	17.14	12.15	4.99	14.59	12.28	70.87	6.05	21.30
100 grains weight (g)	14.80	10.29	4.51	10.82	9.02	69.53	5.51	15.50
Yield per plant (g)	226.54	160.91	65.63	22.59	19.04	71.03	22.02	33.05

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

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

h^2 :Heritability in broad sense
GA (5%) : Genetic advance (5%)
GA (% mean) : Genetic advance (% mean)

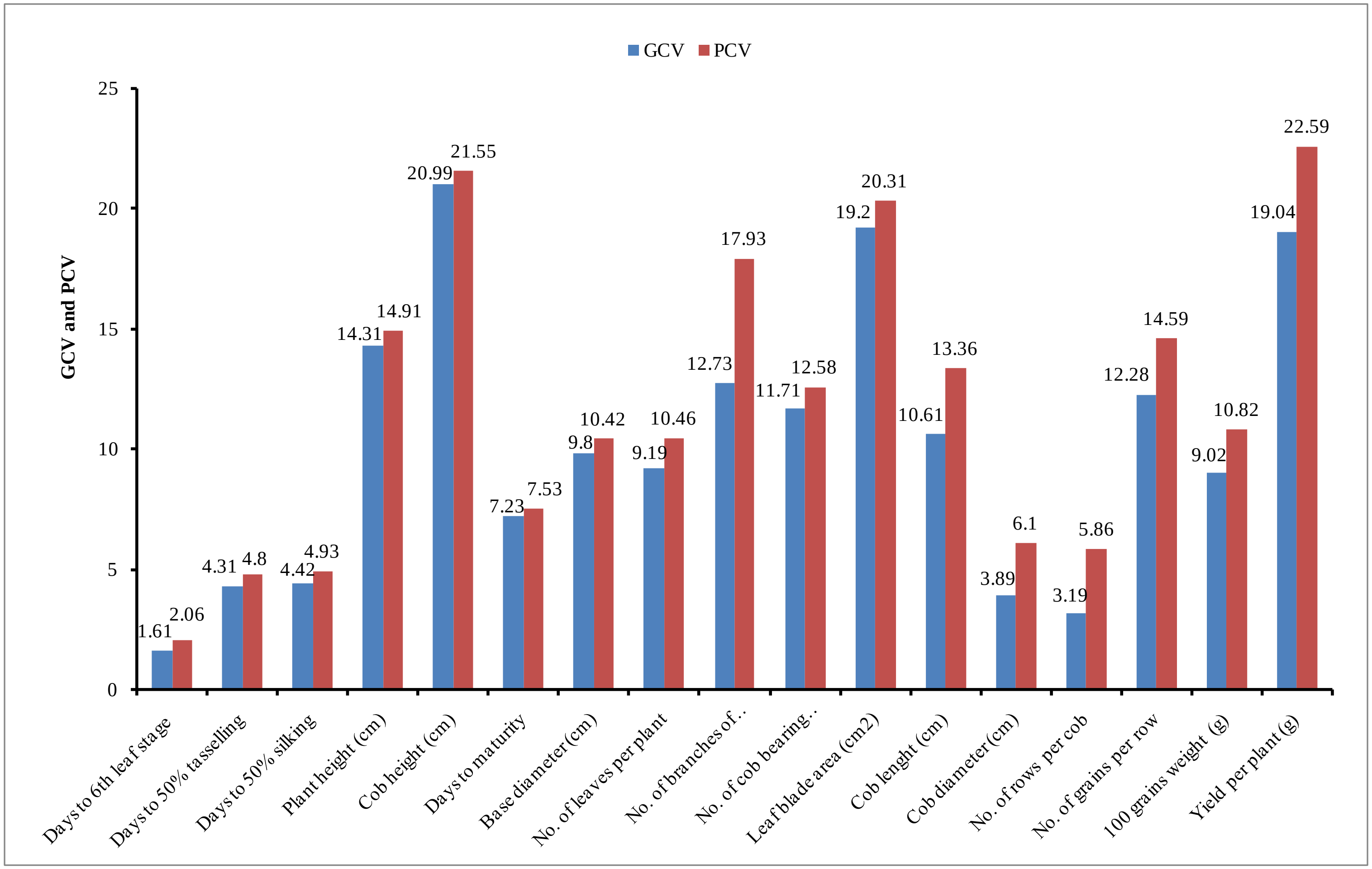


Figure 1. Genotypic and phenotypic coefficient of variation in white maize

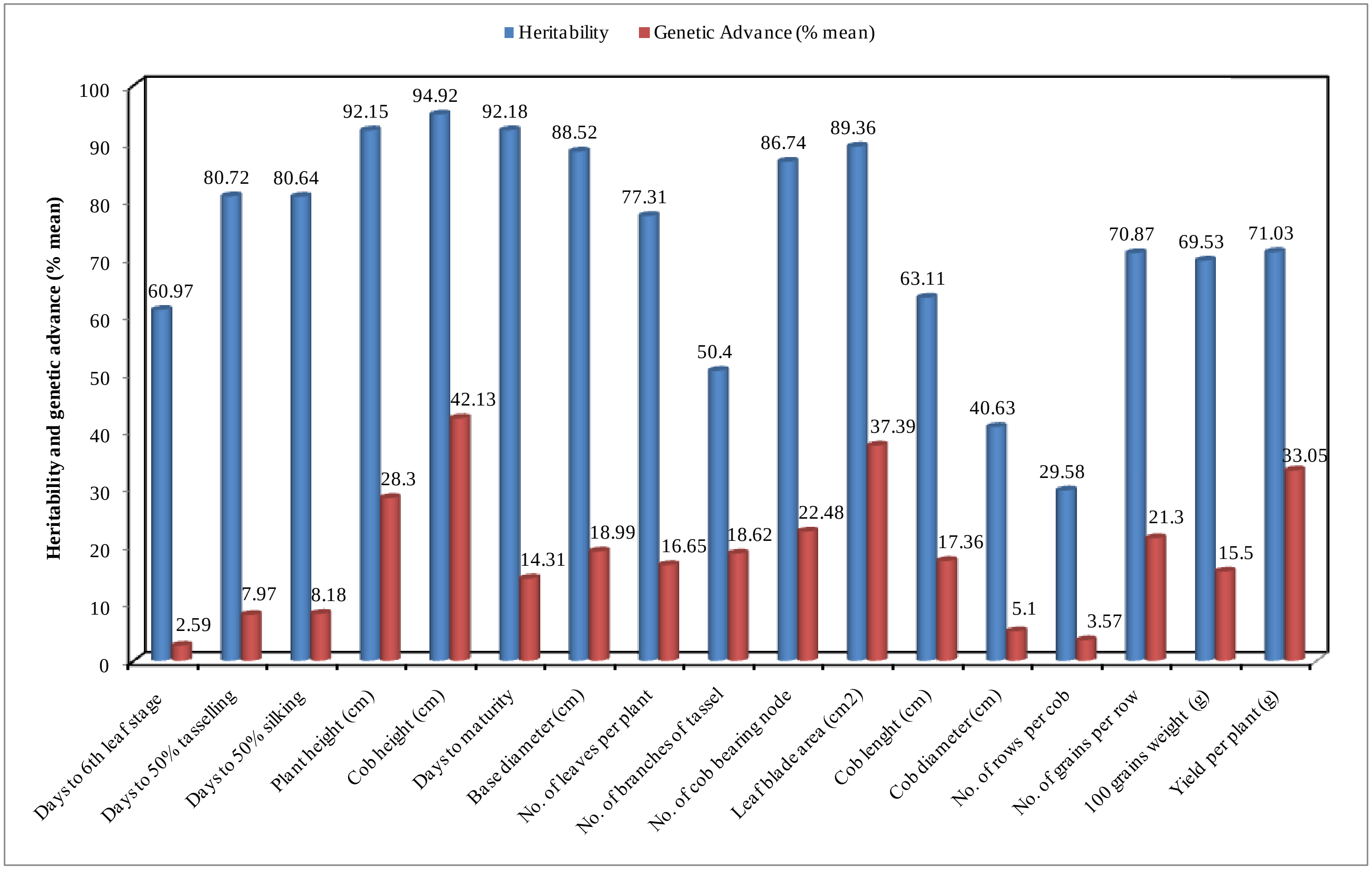


Figure 2. Heritability and genetic advance as percent over mean in white maize

4.2.5 Cob height (cm)

Cob height refers to phenotypic variance (267.47) was higher than the genotypic variance (253.87) indicating that less environmental influence for expression of this character (Table 6). The phenotypic coefficient of variation (21.55%) was higher than the geneotypic coefficient of variation (20.99%), which suggested that environment has less effect f on the expression of this trait. High heritability (94.92) coupled with high genetic advance as percent of mean (42.13) was observed for this trait. These traits are most probably controlled by additive gene action and selection based on this trait for dwarf plant stature would be effective.

4.2.6 Days to maturity

Days to maturity refers to high phenotypic variance (83.10) was less higher than the genotypic variance (76.60) that indicating less environmental influence on expression of this character which was supported by narrow difference between phenotypic (7.53%) and genotypic (7.23%) co-efficient of variation (Table 6). High heritability (92.18%) along with moderate genetic advance in percentage of mean (14.31%). This trait is most probably controlled by both additive and non additive gene action.

4.2.7 Base diameter (cm)

A narrow difference between a phenotypic variance (0.56) and genotypic variance (0.49) supported the speculation that environment had little effect on characters under the present study (Table 6). A little difference GCV (10.42) and PCV (9.80) indicating that these characters were less responsive to environmental factors for their phenotypic expression. High heritability and moderate genetic advance in percent of mean was 88.52% and 18.99%, respectively; indicating this trait is controlled by both additive and non additive gene action.

4.2.8 No. of leaves per plant

The differences between phenotypic variances (1.75) and genotypic variances (1.35) were relatively low for leaves per plant indicating low environmental influence on these characters (Table 6). The value of PCV and GCV were 10.46 % and 9.19% respectively for this trait which indicating that less variation exists among different genotypes. Leaves per plant showed high heritability (77.31%) along with low genetic advance (2.11%) and medium genetic advance in percent of mean (16.65%) 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 4.78 and 2.41, respectively; with relatively large differences indicating large environmental influences on expression of this character as well as PCV (17.93%) and GCV (12.73%) is indicating presence of considerable variability among the genotypes (Table 6).

4.2.10 Number of cob bearing node

The differences between phenotypic variances (0.72) and genotypic variances (0.63) were relatively low for number of cob bearing node indicating low environmental influence on these characters (Table 6). The value of PCV and GCV were 12.58% and 11.71%, respectively; for this trait which indicating that less variation exists among different genotypes. High heritability (86.74%) coupled with high genetic advance as percent of mean (22.48%) was observed for this trait. This trait is most probably controlled by additive gene action and selection based on this trait would be effective.

4.2.11 Leaf blade area (cm^2)

Leaf blades refers to phenotypic variance (10248.08) was higher than the genotypic variance (9158.07) indicating that highly environmental influence for expression of this character which was supported by medium difference between phenotypic (20.31%) and genotypic (19.20%) co-efficient of variation (Table 6). High heritability (89.36%) coupled with high genetic advance as percent of mean (37.39%) was observed for this trait. This trait is most probably controlled by additive gene action and selection based on this trait would be effective.

4.2.12 Cob length (cm)

Cob length showed moderate differences between phenotypic variance (4.45) and genotypic variance (2.81) indicating moderate environmental influence on this character and relatively moderate difference between PCV (13.36%) and GCV (10.61%) value indicating the apparent variation not only due to genotypes but also due to the moderate influence of environment (Table 6). The high heritability estimates of 63.11% with an expected genetic advance as percent of mean of 17.36 percent. High heritability coupled with moderate genetic advance was observed for this character, indicating little scope for the selection upon this character due to the non-additive gene action.

4.2.13 Cob diameter (cm)

Cob diameter refers to the higher phenotype variance (0.08) was found than the genotypic variance (0.03), which indicated that the influence of environmental was less on this character. Thus higher co-efficient of variation observed between the phenotype (6.10%) and genotype (3.89%) (Table 6). Low heritability (40.63%) along with low genetic advances in percentage of the mean (5.10%) indicating little scope for the selection upon this character due to the non-additive gene action.

4.2.14 Number of rows per cob

Phenotypic and genotypic variance for row per cob was observed 0.59 and 0.18, respectively; with fewer differences between them, suggested less influence of environment on the expression of the genes controlling of this trait. The phenotypic coefficient of variation (5.86%) was higher than the genotypic coefficient of variation (3.19%) (Table 6), which suggested that the environment has a significant role in the expression of this trait. Low heritability (29.58%) coupled with moderate genetic advances in percent of the mean (3.57%) 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 Number of grains per row

Grain per row showed 17.14 and 12.15, respectively the phenotypic and genotypic variance with large differences between them indicating large environmental influences on expression of this character as well as PCV (14.59%) and GCV (12.28%) indicating presence of considerable variability among the genotypes (Table 6). High heritability (70.87%) coupled with high genetic advance in percent of mean (21.30%) attributed to additive gene actions and selection based on this trait would be effective. Similar results were reported by Rather *et al.* (2003) and Rajesh *et al.* (2013). On the contrary high heritability estimates for number of seed per row were also reported by Abd El-Sattar (2003).

4.2.16 100-grains weight (g)

Hundred grains weight showed moderate phenotypic (14.80) and genotypic (10.29) variance with high differences indicating that they were highly responsive to environmental factors and the values of PCV and GCV were 10.82% and 9.02% indicating that the genotype has considerable variation for this trait (Table 6). Similar results of PCV and GCV values for this trait were reported by Abirami *et al*. (2005). High heritability (69.53%) along with moderate genetic advances in percentage of mean (15.50%) revealed the possibility of predominance of both additive and non additive gene action in the inheritance of this trait. On the contrary results were reported by Anshuman *et al.* (2013). They found the high heritability and high genetic advance in percent of mean.

4.2.17 Grain yield per plant (g)

The phenotypic variance (226.54) appeared high difference with the genotypic variance (160.91), suggested a high influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (22.59%) was moderately higher than the genotypic co-efficient of variation (19.04%) which suggested that the environment has a moderate influence on the expression of this trait (Table 6). High heritability (71.03%) coupled with high genetic advance as percent of mean (33.05%) 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.

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 cob bearing node, leaf blade area, no. of grain per row and grain yield per plant. These traits are most probably controlled by additive gene action which is very useful in selection.

4.3 Correlation coefficient

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 white maize F_3 segregating population at both genotypic and phenotypic levels.

For clear understanding correlation coefficients are separated into genotypic and phenotypic level in Table 7 and Fig. 3. The genotypic correlation coefficients were higher than their phenotypic correlation coefficients indicating the genetic reason of association.

4.3.1 Days to 6th leaf stage

Days to 6th leaf stage was positively significantly associated with days to 50% tasselling (0.636 and 0.458), days to 50% silking (0.689 and 0.508), cob height (0.328 and 0.273), days to maturity (0.559 and 0.422), number of leaf per plant (0.620 and 0.386), branches of tassel (0.752 and 0.442), number of cob bearing node (0.715 and 0.494), leaf blade area (0.317 and 0.254), cob length (0.845 and 0.491), grains per row (0.592 and 0.381) and yield per plant (0.328 and 0.262) at both levels.

Table 7. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of white maize

		DSLS	D50%T	D50%S	PH (cm)	CH (cm)	DM	BD (cm)	LPP	BT	CBN	LBA (cm^2)	CL (cm)	CD (cm)	RPC	GPR	100GW (g)
D50%T	G	0.636**															
	P	0.458**															
D50%S	G	0.689**	0.916**														
	P	0.508**	0.913**														
PH (cm)	G	0.273*	0.607**	0.544**													
	P	0.230	0.531**	0.459**													
CH (cm)	G	0.328**	0.757**	0.738**	0.849**												
	P	0.273*	0.656**	0.637**	0.822**												
DM	G	0.559**	0.788**	0.729**	0.821**	0.783**											
	P	0.422**	0.662**	0.621**	0.759**	0.730**											
BD (cm)	G	0.127	0.718**	0.590**	0.857**	0.797**	0.751**										
	P	0.102	0.615**	0.520**	0.787**	0.726**	0.690**										
LPP	G	0.620**	0.706**	0.684**	0.436**	0.635**	0.455**	0.400**									
	P	0.386**	0.578**	0.544**	0.364**	0.536**	0.386**	0.340**									
BT	G	0.752**	0.672**	0.870**	0.692**	0.810**	0.840**	0.482**	0.770**								
	P	0.442**	0.430**	0.530**	0.519**	0.570**	0.543**	0.341**	0.401**								
CBN	G	0.715**	0.920**	0.942**	0.773**	0.915**	0.820**	0.765**	0.705**	0.904**							
	P	0.494**	0.766**	0.784**	0.696**	0.823**	0.730**	0.657**	0.585**	0.596**							
LBA (cm^2)	G	0.317**	0.638**	0.444**	0.662**	0.551**	0.841**	0.610**	0.308**	0.411**	0.555**						
	P	0.254*	0.541**	0.362**	0.613**	0.517**	0.784**	0.533**	0.223	0.236*	0.447**						
CL (cm)	G	0.845**	0.712**	0.656**	0.784**	0.784**	0.893**	0.602**	0.500**	0.970**	0.860**	0.656**					
	P	0.491**	0.430**	0.400**	0.610**	0.592**	0.704**	0.458**	0.356**	0.474**	0.596**	0.504**					
CB (cm)	G	0.101	0.596**	0.560**	0.702**	0.622**	0.851**	0.626**	0.079	0.656**	0.552**	0.771**	0.663**				
	P	0.096	0.354**	0.370**	0.427**	0.368**	0.522**	0.421**	-0.010	0.248*	0.299*	0.477**	0.305**				
RPC	G	-0.327**	0.179	0.174	0.737**	0.432**	0.416**	0.516**	-0.278*	0.349**	0.349**	0.300*	0.287*	0.749**			
	P	-0.016	0.011	0.027	0.383**	0.221	0.265*	0.267*	-0.132	0.117	0.105	0.204	0.124	0.319**			
GPR	G	0.592**	0.738**	0.680**	0.783**	0.810**	0.858**	0.601**	0.555**	0.859**	0.826**	0.781**	0.864**	0.691**	0.372**		
	P	0.381**	0.593**	0.553**	0.647**	0.652**	0.724**	0.471**	0.402**	0.493**	0.617**	0.625**	0.671**	0.481**	0.270*		
100GW (g)	G	0.078	0.514**	0.462**	0.416**	0.420**	0.569**	0.680**	0.196	0.380**	0.485**	0.412**	0.380**	0.748**	0.233*	0.265*	
	P	0.087	0.369**	0.319**	0.351**	0.356**	0.464**	0.585**	0.129	0.195	0.366**	0.297*	0.320**	0.496**	0.102	0.234*	
YPP (g)	G	0.328**	0.727**	0.672**	0.842**	0.799**	0.897**	0.803**	0.379**	0.790**	0.815**	0.752**	0.782**	0.966**	0.565**	0.839**	0.707**
	P	0.262*	0.545**	0.506**	0.706**	0.655**	0.758**	0.662**	0.265*	0.447**	0.593**	0.596**	0.619**	0.664**	0.491**	0.825**	0.672**

** = 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 (cm) = plant height (cm), CH (cm) = cob height (cm), DM = days to maturity, BD (cm) = base diameter (cm), LPP = no. of leaves per plant, BT = no. of branches of tassel, CBN = no. of cob bearing node, LBA (cm^2) = leaf blade area (cm^2), CL (cm) = cob length (cm), CD (cm) = cob diameter (cm), RPC = no. of rows per cob, GPR = no. of grains per row, 100GW (g) = 100 grains weight (g), YPP= yield per plant (g)

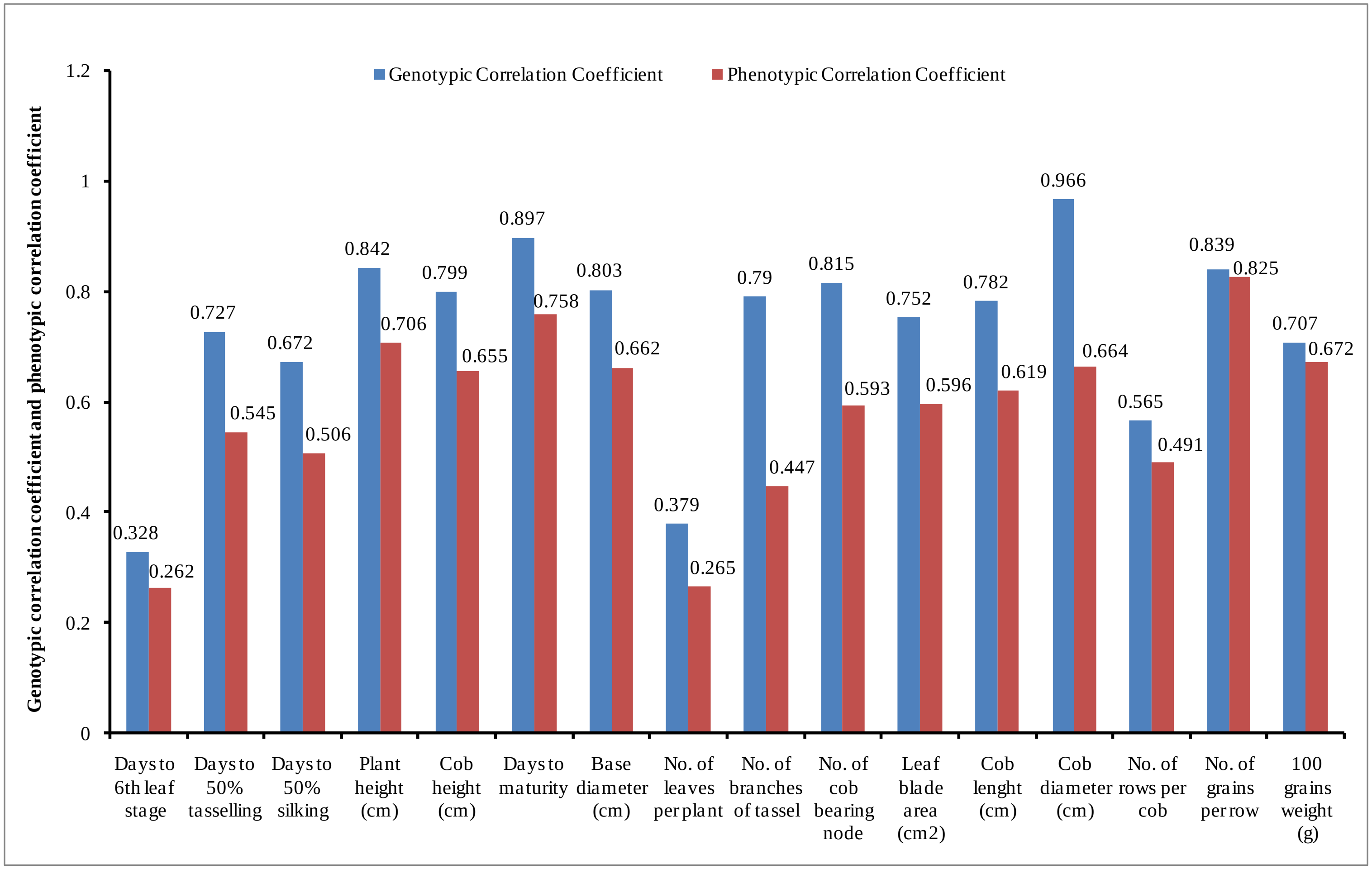


Figure 3. Genotypic and phenotypic correlation coefficient of sixteen characters with yield in white maize

4.3.2 Days to 50% tasseling

Highly significant positive association was recorded of days to 50% tasseling of maize genotypes with days to 50% silking (0.916 and 0.913), plant height (0.607 and 0.531), cob height (0.757 and 0.656), days to maturity (0.788 and 0.662), base diameter (0.718 and 0.615), number of leaves per plant (0.706 and 0.578), number of branches of tassel (0.672 and 0.430), number of cob bearing node (0.920 and 0.766), leaf blade area (0.638 and 0.541), cob length (0.712 and 0.430), cob diameter (0.596 and 0.354), grains per row (0.738 and 0.593), 100 grain weight (0.514 and 0.369) and grain yield per plant (0.727 and 0.545) at both level (Table 7).

4.3.3 Days to 50% silking

Days to 50% silking was observed highly significant positive association with plant height (0.544 and 0.459), cob height (0.738 and 0.637), days to maturity (0.729 and 0.621), base diameter (0.590 and 0.520), number of leaves per plant (0.684 and 0.544), number of branches of tassel (0.870 and 0.530), number of cob bearing node (0.942 and 0.784), leaf blade area (0.444 and 0.362), cob length (0.656 and 0.400), cob diameter (0.560 and 0.370), grains per row (0.680 and 0.553), 100 grains weight (0.462 and 0.319) and grain yield per plant (0.672 and 0.506) at both genotypic and phenotypic level (Table 7).

4.3.4 Plant height (cm)

Plant height had highly significant and positive correlation with cob height (0.849 and 0.822), days to maturity (0.821 and 0.759), base diameter (0.857 and 0.787), number of leaves per plant (0.436 and 0.364), number of branches of tassel (0.692 and 0.519), number of cob bearing node (0.773 and 0.696), leaf blade area (0.662 and 0.613), cob length (0.784 and 0.610), cob diameter (0.702 and 0.427), number of rows per cob (0.737 and 0.383), number of grains per row (0.783 and 0.647),100 grain weight (0.416 and 0.351) and grain yield per plant (0.842 and

0.706) at both genotypic and phenotypic levels. 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 (cm)

Cob height had highly significant and positive correlation with days to maturity (0.783 and 0.730), base diameter (0.797 and 0.726), number of leaves per plant (0.635 and 0.536), number of branches of tassel (0.810 and 0.570), number of cob bearing node (0.915 and 0.823), leaf blade area (0.551 and 0.517), cob length (0.784 and 0.592), number of rows per cob (0.368 and 0.432), number of grains per row (0.810 and 0.652), 100 grain weight (0.420 and 0.356) and grain yield per plant (0.799 and 0.655) at both the levels.

4.3.6 Days to maturity

Highly significant positive correlation was observed of days to maturity with base diameter (0.751 and 0.690), number of leaves per plant (0.455 and 0.386), number of branches of tassel (0.840 and 0.543), number of cob bearing node (0.820 and 0.730), leaf blade area (0.841 and 0.784), cob length (0.893 and 0.704), cob diameter (0.851 and 0.522), number of rows per cob (0.416 and 0.265), number of grain per row (0.858 and 0.724), hundred grain weight (0.569 and 0.464) and grain yield per plant (0.897 and 0.758) at genotypic and phenotypic levels (Table 7).

4.3.7 Base diameter (cm)

Highly significant positive correlation was observed of base diameter with number of leaves per plant (0.400 and 0.340), number of branches of tassel (0.482 and

0.341), number of cob bearing node (0.765 and 0.657), leaf blade area (0.610 and 0.533), cob length (0.602 and 0.458), cob diameter (0.626 and 0.421), rows per cob (0.516 and 0.267), number of grain per row (0.601 and 0.471), hundred grain weight (0.680 and 0.585) and yield per plant (0.803 and 0.662).

4.3.8 Number of leaves per plant

Number of leaves per plant showed positive significant interaction with number of branches of tassel (0.770 and 0.401), cob bearing node (0.705 and 0.585), cob length (0.500 and 0.356), number of grain per row (0.555 and 0.402) and grain yield per plant (0.379 and 0.265) (Table 7). It was negatively correlated with rows per cob (-0.278and -0.132). Triveni *et al*. (2014) found number of leaf per plant of maize highly significantly and positively correlated with its grain yield where support the present findings. Results of this study imply that maize grain yield can be improved by considering number of leaf per plant.

4.3.9 Number of branches of tassel

Number of branches per tassel exhibited a positive significant correlation with number of cob bearing node (0.904 and 0.596), leaf blade area (0.411 and 0.236), cob length (0.970 and 0.474), cob diameter (0.656 and 0.248), number of grains per row (0.859 and 0.493) and yield per plant (0.790 and 0.447) at genotypic and phenotypic level. It was positive significant correlation with rows per cob (0.349) and 100 grain weight (0.380) at the genotypic level.

4.3.10 Number of cob bearing node

Number of cob bearing node performed positively significantly correlated with leaf blade area (0.555 and 0.447), cob length (0.860 and 0.596), cob diameter (0.552 and 0.299), number of grains per row (0.826 and 0.617), 100 grain weight (0.485 and 0.366) and grain yield per plant (0.815 and 0.593).

4.3.11 Leaf blade area (cm^2)

Leaf blade area exhibited significant positive association with cob length (0.656 and 0.504), cob diameter (0.771 and 0.477), numbers of grain per row (0.781 and 0.625), 100 grains weight (0.412 and 0.297) and grain yield per plant (0.752 and 0.596).

4.3.12 Cob length (cm)

Cob length showed highly significant and positive correlation with cob diameter (0.663 and 0.305), number of grains per row (0.864 and 0.671), 100 grain weight (0.380 and 0.320) and grain yield per plant (0.782 and 0.619) at genotypic and phenotypic levels. 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 (cm)

Cob diameter exhibited significant and positive association with number of row per cob (0.749 and 0.319), number of grains per row (0.691and 0.481), hundred grain weight (0.748 and 0.496) and grain yield per plant (0.966 and 0.664) at both genotypic and phenotypic levels.

4.3.14 Number of rows per cob

The number of row per cob had a positive and significant correlation with number of grains per row (0.372 and 0.270), and grain yield per plant (0.565 and 0.491) at both genotypic and phenotypic levels. Significant positive correlation observed with hundred seed weight (0.233) at genotypic level. Number of rows per cob positively insignificant correlated with 100 grain weight (0.102) at phenotypic level. In the contrary Amin *et al.* (2003); and Mohammadi *et al.* (2003) reported that 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 100 grains weight (0.265 and 0.234) and grain yield per plant (0.839 and 0.825) at both genotypic and phenotypic 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-grains weight (g)

Highly significant positive correlation was observed between 100-seed weight with grain yield per plant (0.707 and 0.672) at both genotypic and phenotypic level (Table 7). Grain yield is considered to have positive correlation with hundred seed weight. 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 Alvi *et al.* (2003) studied relation between these two traits established strong correlations between grain yield and 100-seed weight.

4.4 Path co-efficient analysis

Association of character 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 reluctant (dependent) variable and 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 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 maize was presented in Table 8.

4.4.1 Days to 6th leaf stage

Path analysis revealed that days to 6th leaf stage had negative direct effect (-0.025) on grain yield per plant (Table 8). It showed more positive indirect effect through grains per row (0.396) and negligible positive indirect effect through days to 5o% silking (0.058), number of branches of tassel (0.049), leaf blade area (0.026), cob length (0.052) and 100 grains weight (0.039), whereas it showed negative indirect effect via days to maturity (-0.118).

4.4.2 days to 50% tasseling

Path analysis revealed that days to 50% tasseling had negative direct effect (-0.088) on grain yield per plant (Table 8). It showed more positive indirect effect through grian per row (0.494) and 100 grains weight (0.258) and negligible positive indirect effect through days to 5o% silking (0.077), base diameter (0.037), number of branches of tassel (0.044), cob length (0.044), cob diameter (0.024) and number of rows per cob (0.031), whereas it showed negative indirect effect via days to maturity (-0.167), leaves per plant (-0.012) and number of cob bearing node (-0.046).

4.4.3 days to 50% silking

Path analysis revealed that days to 50% silking had positive direct effect (0.084) on grain yield per plant (Table 8) and it was supported by Pandey *et al.* (2017) and Lingaiah *et al.* (2014). It showed more positive indirect effect through grains per row (0.455) and 100 grains weight (0.232) and negligible positive effect via base diameter (0.030), number of branches of tassel (0.057), leaf blade area (0.036), cob length (0.041), cob diameter (0.022) and number of rows per cob (0.030). On the other hand days to 50% silking showed negative indirect effect through days to

6^{th} leaf stage (-0.017), days to maturity (-0.154), number of leaves per plant (-0.012), number of cob bearing node (-0.047).

4.4.4 Plant height (cm)

Plant height had positive direct effect (0.005) on grain yield per plant (Table 8) and it was contrary with results of Pandey *et al.* (2017) and 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 grains per row (0.524), 100 grains weight (0.209) and rows per cob (0.127) and negligible positive indirect effect via base diameter (0.044), number of branches of tassel (0.045), cob length (0.049), cob diameter (0.028) and days to 50% silking (0.046). 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 (-0.007), days to 50% tasseling (-0.053), cob height (-0.008), days to matuirty (-0.174), leaves per plant (-0.007) and number of cob bearing node (-0.038). 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; Mohan *et al.* 2002).

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

	DSLS	D50%T	D50%S	PH (cm)	CH (cm)	DM	BD (cm)	LPP	BT	CBN	LBA (cm^2)	CL (cm)	CB (cm)	RPC	GPR	100GW (g)	Genotypic correlation with yield
DSLS	**-0.025**	-0.056	0.058	0.001	-0.003	-0.118	0.007	-0.010	0.049	-0.036	0.026	0.052	0.004	-0.056	0.396	0.039	0.328^{**}
D50%T	-0.016	**-0.088**	0.077	0.003	-0.007	-0.167	0.037	-0.012	0.044	-0.046	0.051	0.044	0.024	0.031	0.494	0.258	0.727^{**}
D50%S	-0.017	-0.080	**0.084**	0.003	-0.007	-0.154	0.030	-0.012	0.057	-0.047	0.036	0.041	0.022	0.030	0.455	0.232	0.672^{**}
PH (cm)	-0.007	-0.053	0.046	**0.005**	-0.008	-0.174	0.044	-0.007	0.045	-0.038	0.053	0.049	0.028	0.127	0.524	0.209	0.842^{**}
CH (cm)	-0.008	-0.066	0.062	0.004	**-0.010**	-0.166	0.041	-0.011	0.053	-0.045	0.044	0.049	0.025	0.075	0.542	0.211	0.799^{**}
DM	-0.014	-0.069	0.061	0.004	-0.008	**-0.212**	0.038	-0.008	0.055	-0.041	0.068	0.055	0.034	0.072	0.575	0.285	0.897^{**}
BD (cm)	-0.003	-0.063	0.049	0.004	-0.008	-0.159	**0.051**	-0.007	0.032	-0.038	0.049	0.037	0.025	0.089	0.403	0.341	0.803^{**}
LPP	-0.015	-0.062	0.057	0.002	-0.006	-0.096	0.020	**-0.017**	0.050	-0.035	0.025	0.031	0.003	-0.048	0.371	0.098	0.379^{**}
BT	-0.019	-0.059	0.073	0.003	-0.008	-0.178	0.025	-0.013	**0.066**	-0.045	0.033	0.060	0.026	0.060	0.575	0.190	0.790^{**}
CBN	-0.018	-0.080	0.079	0.004	-0.009	-0.174	0.039	-0.012	0.059	**-0.050**	0.045	0.053	0.022	0.060	0.553	0.243	0.815^{**}
LBA (cm^2)	-0.008	-0.056	0.037	0.003	-0.005	-0.178	0.031	-0.005	0.027	-0.028	**0.081**	0.041	0.031	0.052	0.523	0.207	0.752^{**}
CL (cm)	-0.021	-0.062	0.055	0.004	-0.008	-0.189	0.031	-0.008	0.064	-0.043	0.053	**0.062**	0.026	0.050	0.578	0.190	0.782^{**}
CB (cm)	-0.002	-0.052	0.047	0.003	-0.006	-0.180	0.032	-0.001	0.043	-0.027	0.062	0.041	**0.040**	0.129	0.462	0.375	0.966^{**}
RPC	0.008	-0.016	0.015	0.004	-0.004	-0.088	0.026	0.005	0.023	-0.017	0.024	0.018	0.030	**0.173**	0.249	0.117	0.565^{**}
GPR	-0.015	-0.065	0.057	0.004	-0.008	-0.182	0.031	-0.009	0.056	-0.041	0.063	0.054	0.028	0.064	**0.669**	0.133	0.839^{**}
100GW (g)	-0.002	-0.045	0.039	0.002	-0.004	-0.120	0.035	-0.003	0.025	-0.024	0.033	0.024	0.030	0.040	0.178	**0.502**	0.707^{**}

Residual effect: 0.0014 ** = Significant at 1%.

DSLS = days to 6^{th} leaf stage, D50%T = days to 50% Tasselling, D50%S = days to 50% Silking, PH (cm) = plant height (cm), CH (cm) = cob height (cm), DM = days to maturity, BD (cm) = base diameter (cm), LPP = no. of leaves per plant, BT = no. of branches of tassel, CBN = no. of cob bearing node, LBA (cm^2) = leaf blade area (cm^2), CL (cm) = cob length (cm), CB (cm) = cob breadth (cm), RPC = no. of rows per cob, GPR = no. of grains per row, 100GW (g) = 100 grains weight (g).

4.4.5 Cob height (cm)

Path coefficient analysis revealed that cob height had negative direct effect (-0.010) on grain yield per plant (Table 8). It showed high positive indirect effect through grains per row (0.542) and 100 grains weight (0.211). It showed negative indirect effect through days to 50% tasseling (-0.066), days to maturity (-0.166), leaves per plant (-0.011) and no. of cob bearing node (-0.045). 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 negative direct effect (-0.212) on grain yield per plant (Table 8). It showed more positive indirect effect through grain per row (0.575) and 100 grains weight (0.285) and it was negligible positive effect through days to 50% silking (0.061), base diameter (0.038), branches of tasseling (0.055), leaf blade area (0.068), cob length (0.055), cob diameter (0.034) and rows per cob (0.072).On the other hand, days to maturity represented negative indirect effect via days to 6th leaf stage (-0.014), days to 50% tasseling (-0.069), cob height (-0.008), leaves per plant (-0.008) and no. of cob bearing node (-0.041).

4.4.7 Base diameter (cm)

Path analysis revealed that base diameter had positive direct effect (0.051) on grain yield per plant (Table 8). It showed high positive indirect effect through grains per row (0.403) and 100 grain weight (0.341) and negligible positive indirect effect through days to 50% silking (0.049), branches of tasseling (0.032), leaf blade area (0.049), cob length (0.037), cob diameter (0.025) and number of rows per cob (0.089).On the other hand, base diameter represented negative indirect effect via days to 50% tasselimg (-0.063), cob height (-0.008), days to maturity (-0.159), number of leaves per plant (-0.007), number of cob bearing node (-0.038).

4.4.8 Number of leaves per plant

Number of leaves per plant had negative direct effect (-0.017) on grain yield. It was found that number of leaves per plant had high positive indirect effect on grain yield through grains per row (0.371), whereas negligible positive indirect effect via days to 50% silking (0.057), base diameter (0.020), leaf blade area (0.025) and 100 grains weight (0.098) (Table 8). Number of leaves per plant showed negative indirect effect via days to 6^{th} leaf stage (-0.015), days to 50% tasseling (-0.062), cob height (-0.006), days to maturity (-0.096), no. of cob bearing node (-0.035) and no. of rows per cob (-0.048).

4.4.9 Number of branches of tassel

Number of branches of tassel had positive direct effect (0.066) on grain yield. It was found that number of branches of tassel had high positive indirect effect on grain yield through grains per row (0.575) and 100 grains weight (0.190), whereas negligible positive indirect effect via days to 50% silking (0.073), base diameter (0.025), leaf blade area (0.033), cob length (0.060), cob diameter (0.026) and no. of rows per cob (0.060) (Table 8). Number of branches of tassel showed negative indirect effect via days to 6^{th} leaf stage (-0.019), days to 50% tasseling (-0.059), days to maturity (-0.178), leaves per plant (-0.013) and no. of cob bearing node (-0.045).

4.4.10 Number of cob bearing node

Number of cob bearing node had negative direct effect (-0.050) on grain yield. It was found that number of leaves per plant had high positive indirect effect on grain yield through grains per row (0.553) and 100 grains weight (0.243), whereas negligible positive indirect effect via days to 50% silking (0.079), base diameter (0.039), branches of tasseling (0.059), leaf blade area (0.045), cob length (0.053), cob diameter (0.022) and rows per cob (0.060) (Table 8).

4.4.11 Leaf blade area (cm^2)

Leaf blade area had positive direct effect (0.081) on grain yield. It was found that leaf blade area had high positive indirect effect on grain yield through grains per row (0.523) and 100 grains weight (0.207), whereas negligible positive indirect effect via days to 50% silking (0.037), base diameter (0.031), branches of tassel (0.027), cob length (0.041), cob diameter (0.031) and number of rows per cob (0.052) (Table 8).

4.4.12 Cob length (cm)

Cob length had positive direct effect (0.062) on grain yield. It was found that cob length had positive indirect effect on grain yield through grains per row (0.578) and 100 days to 50% tasseling (0.190) (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). It was negative indirect effect via days to 6^{th} leaf stage (-0.021), days to 50% tasseling (-0.062), days to maturity (-0.189) and no. of cob bearing node (-0.043). Its indirect effects via plant height and number of leaves per plant also negative (Parh *et al.*, 1986).

4.4.13 Cob diameter (cm)

Path analysis revealed that cob diameter had positive direct effect (0.040) on yield per plant (Table 8). It showed negligible positive indirect effect through grains per row (0.462), 100 grains weight (0.375) and row per cob (0.129), whereas cob diameter showed negative indirect effect through days to 50% tasseling (-0.052), days to maturity (-0.180) and no. of cob bearing node (-0.027). 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 (0.173) on grain yield per plant. It was positive indirect effect on grain yield through grains per row (0.249) and 100 grains weight (0.117). 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. No. of rows per cob showed negative indirect effect via days to 50% tasseling (-0.016), days to maturity (-0.088) and no. of cob bearing node (-0.017).

4.4.15 Number of grains per row

Path analysis revealed that number of grains per row had highest positive direct effect (0.669) on yield per plant (Table 8). It showed negligible positive indirect effect through 100 grains weight (0.133), base diameter (0.031), branches of tassel (0.056), leaf blade area (0.063), cob length (0.054), cob diameter (0.028) and row per cob (0.064), 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). 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 (g)

Path analysis revealed that weight of 100-grains had positive direct effect (0.502) on yield per plant (Table 8). It showed high positive indirect effect through grains per row (0.178). While in via days to maturity (-0.120), no. of cob bearing node (-0.024) and days to 50% tasseling (-0.045) were showed negative indirect effect on yield.

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 grains per row (0.669), 100 grains weight (0.502), row per cob (0.173), cob length (0.062), cob diameter (0.040), leaf blade area (0.081), days to 50% silking (0.084) and plant height (0.005) indicating the effectiveness of direct selection, where as direct and negative effects were exhibited by days to 6th leaf stage (-0.025), days to 50% tasseling (-0.088), cob height (-0.010), days to maturity (-0.212), leaves per plant (-0.017) and no. of cob bearing node (-0.050) indicating the effectiveness of indirect selection.

4.4.17 Residual effect

The magnitude of residual effect (0.0014) indicated that traits included in path analysis explained about 99.86% of the variation in plant yield. However, the remaining variation in plant yield (0.14%) can be attained by incorporating other yield related traits in the path analysis as far as studies involving association of traits is concerned. Hasan (2017) found residual effect 0.322 in case of yield per plant.

4.5 Selection of F_3 population

From the mean performance it was revealed that populations Youngnuo-7-F_3-S_1, Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3 showed dwarf plant stature among all the populations (Table 9). So, they might be selected for further investigation for dwarf plant progenies. These were also least cob height and least no. of cob bearing node. In the unfavorable weather like heavy rain and storm condition these might be tolerant and able to provide reasonable yield. For early maturity these three progenies viz. Youngnuo-7-F_3-S_1, Youngnuo-7-

F_3-S_2 and Youngnuo-7-F_3-S_3 also showed the lowest days to maturity (Table 9). So, on the basis of overall performance populations Youngnuo-7-F_3-S_1, Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3 might be selected as promising for both of the traits short duration and dwarf plant stature.

Table 9. Selected populations according to short stature plant and yield potential plant

Genotypes	Materials	Days to 50% Silking	Plant height (cm)	Cob height (cm)	Days to maturity	No. of cob bearing node	Yield per plant (g)
G10	Youngnuo-7-F_3-S_1	70.67	122.33	53.00	107.83	5.11	46.94
G11	Youngnuo-7-F_3-S_2	71.33	126.82	53.67	105.50	5.05	47.36
G12	Youngnuo-7-F_3-S_3	72.00	133.06	49.72	107.50	5.33	54.76
G9	Changnuo-6-F_3-S_3	75.00	148.72	68.11	117.83	6.44	50.67
G1	Plough-201- F_3-S_1	74.67	165.61	65.83	112.33	6.11	54.21
G14	PSC-121-F_3-S_2	78.67	181.72	75.94	131.17	6.95	97.67
G4	KS-510-F_3-S_1	80.67	204.01	111.33	133.17	8.05	91.82

The selected plants were arranged here in ascending order based on the plant height. Youngnuo-7-F_3-S_1, Youngnuo-7-F_3-S_2, Youngnuo-7-F_3-S_3, Changnuo-6-F_3-S_3 and Plough- 201-F_3-S_1 were selected considering the short stature type on the other hand PSC-121-F_3-S_2 and KS-510- F_3-S_1 were selected only the yield potentiality.

CHAPTER V

SUMMARY AND CONCLUSION

Analysis of variance revealed highly significant difference among the F_3 segregating population for all the characters under study. The minimum days to 50% tasseling was recorded in the F_3 segregating population of Youngnuo-7-F_3-S_2 (66.00) and the maximum in PSC-121-F_3-S_3 (77.00). Days to 50% silking as the inimum were observed in Youngnuo-7-F_3-S_1 (70.67) and the maximum in Youngnuo-3000-F_3-S_3 (84.33). The minimum and the maximum plant height was observed in the F_3 segregating population of Youngnuo-7-F_3-S_1 (122.33 cm) and KS-510-F_3-S_2 (220.61 cm), respectively. The minimum cob height was noted in Youngnuo-7-F_3-S_3 (49.72 cm) while the maximum in KS-510-F_3-S_1 (111.33 cm). The minimum days to maturity were noted in Youngnuo-7-F_3-S_2 (105.50) while the maximum in KS-510-F_3-S_3 (137.33). The cob length was the maximum in KS-510-F_3-S_2 (19.65 cm) and the minimum in Youngnuo-7-F_3-S_1 (12.53 cm) observed. The highest number of rows per cob was observed in F_3 segregating population of Plough-201-F_3-S_3 (14.21) while lowest in PSC-121-F_3-S_3 (12.17). F_3 population of KS-510-F_3-S_3 (34.72) shown the highest number of grains per row and Youngnuo-7-F_3-S_1 (20.50) represented the lowest value. 100-grains weight ranged from 27.70 g to 42.77 g which was observed in Changnuo-6-F_3-S_3 and PSC-121-F_3-S_2, respectively. The highest grain yield per plant was observed in the genotype PSC-121-F_3-S_2 (97.67 g). The lowest grain yield per plant was observed in the genotype Youngnuo-7-F_3-S_1 (46.94 g).

Characters like cob height (21.55 and 20.99), leaf blade area (20.31 and 19.20) and yield per plant (22.59 and 19.04) 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 diameter, number of grains per rows 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 cob height (20.99), leaf blade area (19.20) and yield per plant (19.04). The maximum genotypic and phenotypic variations were 19.04and 22.59 respectively in yields per plant.

The highest estimated heritability amongst seventeen characters of maize was 92.18% for days to maturity and the lowest was 29.58% for no. of rows per cob. The highest genetic advance amongst seventeen characters was found in leaf blade area is 186.36 and the lowest genetic advance was carried out in cob diameter (0.24). The maximum genetic advance in percent of mean was observed for cob height (42.13), followed by leaf blade area (37.39), yield per plant (33.05), plant height (28.30) and no. of cob bearing node (22.48). In the present study, high heritability coupled with high genetic advance as per cent of mean was observed for plant height (92.15 and 28.30), cob height (94.92 and 42.13), number of cob bearing node (86.74 and 22.48), leaf blade area (89.36 and 37.39), no. of grains per row (70.87 and 21.30) and grain yield per plant (71.03 and 33.05). These traits are most probably controlled by additive gene action which is very useful in selection.

Again, considering both genotypic and phenotypic correlation co-efficient among seventeen yields contributing characters of 24 maize populations, yield per plant was positively and significantly correlated with days to 50% tasseling, 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% silking, plant height, base diameter, branches of tassel, leaf blade area, cob length, cob diameter, row per cob, grains per row and 100 grain weight showed positive direct effects on yield per plant indicating these traits effectiveness for direct selection. On the other hand days to 6^{th} leaf stage, days to 50% tasselling, cob height, days to maturity, leaves per plant and no. of cob bearing node showed negative direct effects on yield per plant indicating the effectiveness of indirect selection.

Results of the present studies indicated significant variation among the genotypes for all the characters studied. Plant height, cob height, days to maturity, number of cob bearing node, leaf blade area, no. of grains per row and grain yield per plant contributed maximum towards yield improvement. Considering yield and other agronomic performance the F_3 segregating population of Youngnuo-7-F_3-S_1, Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3 were selected for dwarf plant stature, least cob height and least no. of cob bearing node and in the unfavorable weather condition like heavy rain and storm weather they might be tolerant and able to provide yield. Lowest days to maturity were also shown by these three progenies like Youngnuo-7-F_3-S_1, Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3. Thus on the basis of overall performance populations Youngnuo-7-F_3-S_1, Youngnuo-7-F_3-S_2 and Youngnuo-7-F_3-S_3 were selected as promising for both of the traits of short duration and dwarf plant stature. PSC-121-F_3-S_2 was selected for highest value of grain yield per plant and followed by KS-510-F_3-S_1, KS-510-F_3-S_2 and KS-510-F_3-S_3. Thus populations mentioned above could be selected from advanced segregating generations for inbred line development and could be use as open pollinated variety for short duration, dwarf plant and high yield.

Recommendations:

The present F_3 populations have been selfed and the F_4 seeds were harvested to develop the homozygous inbred lines. Assuming that these populations of F_4 have reached approximate 93.73% homozygosity therefore these lines should further need to selfed for advancing them to F_5 generation where the homozygous will be reached at 96.874%.

Further the lines should be evaluated for the combining ability study through line-tester analysis to select the best combiner inbred lines for using them in future hybrid variety development program.

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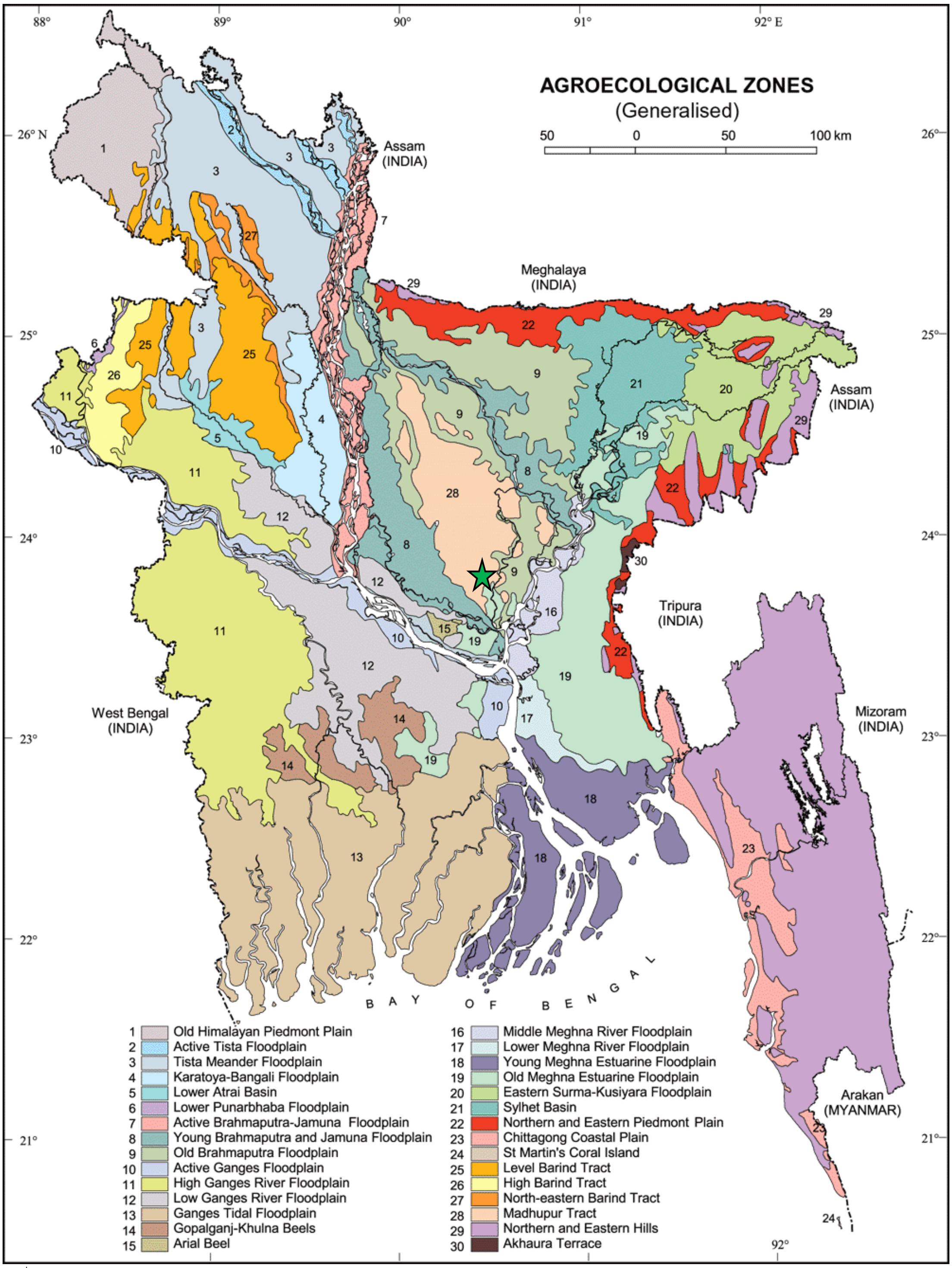
APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under the study

Appendix II: Morphological, Physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical composition of the soil

Soil separates	%	Methods employed
Sand	26	Hydrometer method (Day, 1915)
Silt	45	Do
Clay	29	Do
Texture class	Silty loam	Do

C. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.45	Walkley and Black, 1947
2	Total N (%)	0.03	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (ppm)	20.54	Olsen and Dean, 1965
7	Exchangeable K (me/100 g soil)	0.10	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.6	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly average temperature, average relative humidity and total rainfall and average sunshine of the experimental site during the period from October, 2017 to March, 2018.

Month	Average temperature (ºc)		Average RH (%)	Rainfall (mm) (total)	Average sunshine (hr)
	Minimum	Maximum			
October, 2017	25	32	79	175	6
Novenber, 2017	21	30	65	35	8
December, 2017	15	29	74	15	9
January, 2018	13	24	68	7	9
February, 2018	18	30	57	25	8
March, 2018	20	33	57	65	7

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