Variability, Character Association and Path Analysis of F_4 Populations of White Maize (*Zea mays* L.)

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Variability, Character Association and Path Analysis of F_4 Populations of White Maize (*Zea mays* L.)

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CERTIFICATE

*This is to certify that thesis entitled, " Variability, Character Association and Path Analysis of F_4 Populations of White Maize (Zea mays L.)" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **MD.MOSHIUR RAHMAN**, Registration No. 14-05938 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, 2021 *(Dr. Md. Sarowar Hossain)*

Place: Dhaka, Bangladesh *Supervisor*

Dedicated To

My Beloved Family

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SOME COMMONLY USED ABREVIATIONS

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 Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Base diameter	BD
By way of	Via
Centimeter	cm
Cob diameter	CD
Cob height	CH
Cob length	CL
Cultivars	cv.
Days after Sowing	DAS
Days to 50% Silking	DS
Days to 50% tasseling	DT
Days to Maturity	DM
Degree Celsius	^{0}C
Degrees of Freedom	Df

SOME COMMONLY USED ABREVIATIONS (cont'd)

Full word	Abbreviation
Environmental variance	σ^2e
Etcetera	Etc.
Food and Agricultural Organization	FAO
Genetic Advance	GA
Genotype	G
Genotypic coefficient of variation	GCV
Genotypic variance	σ^2g
Gram	g
Harvest Index	HI
Heritability in broad sense	h^2b
Journal	J.
Kilogram	Kg
Leaf Length	LL
Leaf Width	LW
Mean sum of square	MSS
Meter	m
Ministry of Agriculture	MOA
Muriate of Potash	MP
Namely	Viz.
Number	No.
Number grains per row	GPR

SOME COMMONLY USED ABREVIATIONS (cont'd)

Full word	Abbreviation
Percent	%
Percentage of Coefficient of Variation	CV%
Phenotypic variance	σ^2p
Randomized Complete Block Design	RCBD
Residual Effect	R
Science	Sci.
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
Standard deviation	SD
Standard Error	SE
The fourth generation of a cross between two dissimilar homozygous parents	F_4
Triple Super Phosphate	TSP
University	Uni.
Variety	var
Yield per plant	YYP

Variability, Character Association and Path Analysis of F_4 Populations of White Maize (Zea *mays* L.)

Abstract

Maize produced the highest grain yield among the cereal crops and contributed about 39% in total cereal production, where the white grained type maize is additionally consumed as human food throughout the world. The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during kharif-1 in 2018-2019 to determine the mean performance, genetic variability, correlation, and path coefficient of 25 F_4 populations of white maize. Among the populations, the shortest plant height was found in the population Youngnuo-7-R_3-S_1-3 (86.98 cm), Youngnuo-7-R_3-S_1-2 was the early maturing line (103.67 days) and Youngnuo-7-R_3-S_1-1 produced the highest grain yield per plant (111.67 g). Higher genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) values were observed for cob height (18.17 and 24.78), the number of branches of tassels (22.95 and 28.56), and yield per plant (15.38 and 27.95). Higher heritability with higher genetic advance percent mean was observed in the number of branches of tassels (65% and 37.98). The correlation studies revealed a significant positive relation of yield per plant with base diameter, leaf length, leaf width, cob length, cob diameter, number of rows per cob, number of grains per row, and 100-grains weight. The path analysis showed a very high and high positive direct effect on yield through days to 50% tasselling, cob height, number of total leaves per plant, leaf width, cob diameter, number of rows per cob, and 100-grains weight. Considering the mean performance, Youngnuo-7-R_3-S_1-3, Changnuo-6-R_3-S_3, Youngnuo-7-R_3-S_1-2, and Changnuo-6-R_3-S_2-1, 2 were selected for cob height, plant height, and additionally short duration. On the other hand, Changnuo-1-R_3-S_1-1 and Youngnuo-7-R_3-S_1-1 were selected for the yield potentiality. Thus, the generation advance and selection work in progress.

Keywords: White maize, human food, variability, heritability, days to maturity, yield

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) produced the highest grain production among the cereal crops and the share of cereal production was 39% (FAOstat, 2021). Maize is used for human consumption in various forms, from specialized foods in developed countries (Poneleit, 2001), to a staple food in developing and undeveloped countries (Hotz and Gibson, 2001) and also used for livestock (Guruprasad *et al.*, 2016; Dogan *et al.*, 2015) thus maize is known as the "queen of cereal". The interest of consumers is increasing, notably in those regions wherever maize is the main cereal for food (Malvar, 2008). Among the cereal crops, maize is a relatively new crop in Bangladesh. It had been incepted during 1960 through testing some varieties provided by the CIMMYT substantially for research purposes (Karim, 1992), and thus the crop has gained rapid popularity since the 2000s (Ullah *et al.*, 2017). In Bangladesh, maize production enthralled the 2nd position next to rice (DAE, 2020). A study indicated that maize production is profitable to growers that the average net return was 32,392 BDT/acre and the BCR (Benefit Cost Ratio) was further than 2 (Adnan *et al.*, 2021).

The important industrial use of maize includes the manufacture of starch and different products like glucose, high fructose sugar, maize oil, alcohols, baby foods, and breakfast cereals (Kaul, 1985). Maize grain features a high nutritive value containing 66.2% starch, 11.1% protein, 7.12% oil, and 1.5% minerals. Moreover, 100 g maize grains contain 90 mg of carotene, 1.8 mg niacin, 0.8 mg thiamin, and 0.1 mg riboflavin (Chowdhury and Islam, 1993). Maize oil is used as one of the best quality edible oil. Green plants and grain are used as the feed of livestock and poultry. Stover and dry leaves are used as good fuel. Yellow maize is the most popular for feeding animals because it contains carotenoids (Troyer, 1999). In general, white maize is taken into account as a crop of human food. Market prices for white maize are generally higher than yellow type. White maize is preferred for human consumption because the degradation of carotenoids during baking or frying causes a robust aroma and flavor. There are health-related reasons to advise the use of maize bread and related products, particularly gluten intolerance (Ylimaki *et al*., 1989) and diabetes (Van der Merwe *et al*., 2001). Moreover, white maize features a medium GI (Glycemic Index) which helps to reduce obesity (Hasan *et al*., 2021).

The United States, China, Brazil, and Mexico regard for 70% and India contributes 2% of the global production of maize (Shompa, 2018). Globally 67% of maize is used for livestock feed, 25% human consumption, industrial functions, and balance is used as seed, and demand for grain is increasing worldwide (Reddy *et al.*, 2013). Due to the expansion of the poultry industry since 2004 the popularity of growing maize got momentum among farmers raising the area of maize from 0.07 million hectares to 4.72 million hectares in 2019-20 season with the entire production of 4.02 million Metric tons (BBS, 2020) of that the foremost of the quantum is getting used as poultry feed.

The maize is additionally consumed as human food throughout the world utmost of that is of white-grained type. Bangladesh produced 36.391 Million tons annually rice food grains for its 180 million people (BBS, 2020). However, such an amount of rice grains can't be guaranteed in all the times particularly within the times when natural calamities like floods, cyclones, and drought happen. Also after 2050 when the population has been projected to be 202 million (UN, 2015; Timsina *et al*., 2016) posing an increased demand for foods for Bangladesh departure uncertainty in sustaining food security. Being a C_4 plant and thanks to its relatively higher adaptive capability at the unfavorable growth conditions, maize is taken into account to be a grain crop having higher yield productivity compared to other cereals *e.g.* rice and wheat (Ullah *et al.,* 2019) thus to face this challenge cultivation of high productive crops like maize breeding may be a necessity.

Maize is cultivated mainly in Rabi season and partially in kharif season in Bangladesh. In Kharif, maize yield is comparatively lower than that of the Rabi season due to the unfavorable climate of the kharif season (summer and rainy) like sturdy wind, heavy rainfall, interrupted sunshine due to cloud cover, thunderstorms also some spells of drought in the growing period (Shompa *et al.,* 2020). To mitigate the continuing global climate change challenges and sustain generating climate-resilient crops through breeding efforts incorporating novel key options *viz*., early maturity, dwarf stature, drought, salinity tolerance, *etc.* is that the sole option to grow crops such harsh unfavorable growth environments (Shompa *et al.*, 2020). Most of the available commercial maize varieties found in Bangladesh are tall-type (*e.g.* plant height >200cm), long-period (*e.g.* mature at >130-140 days), *etc.* (BARI, 2018), and hence, the varieties aren't appropriate for cultivation in the Kharif season. If we can develop short duration variety which can complete its life cycle within a shorter period and in the case of dwarf stature variety, it becomes less affected by the wind or storm. As a result, the yield may increase as well as the cropping intensity of Bangladesh. Therefore, to accomplish this target maize breeding is an inevitable need.

Previously sporadic attempts were taken to accelerate yellow maize production. However, few attempts were taken to develop the improved and adapted a variety of white maize. White-maize breeding programs usually use well-established white-maize populations and inbreeds as base germplasm as a result of the event of recent varieties is complicated owing to the strict quality requirements and therefore the complex genetic regulation of white endosperm. Indeed, crosses among white and yellow varieties usually turn out new white varieties with undesirable pigmentation (Poneleit, 2001). Therefore, yellow-maize germplasm ought to be avoided as a source of new white maize varieties. Hybrid development of white maize has lagged far behind yellow maize because of the smaller market demand.

The success of the breeding activities depends in the main on the choice of promising lines from the early segregating generations. To attain this goal, the breeder has the choice of selecting fascinating genotypes in early generations or delaying intense selection till advanced generations, when progenies are nearly homozygous (Savitha, 2015). In the subsequent generations, the lines are further advanced through self-fertilization to achieve the homozygosity of the lines which are used as parental inbred lines within the hybrid breeding program (Kumar *et al.*, 2017).

Genetic variability, marked as a monogenic distinction among cultivars, is needed at an optimal level among a population. Progress from selection has been reported to be directly associated with the magnitude of genetic variance within the population (Helm *et al*., 1989; Hallauer and Miranda, 1995; Tabanao and Bernardo, 2005). Information on the genetics of yield and other associated characters is a prerequisite for breeding purposes concerning developing high-yielding varieties (Agrawal, 2002). Grain yield is that the most significant and complicated quantitative attribute in maize controlled by varied genes (Zdunic *et al.*, 2008). Yield achievement can be improved by selection for grain yield, plant height, and ear height (Prodhan, 1997). Larger genetic variability has been found within the segregating population that represents completely different environmental conditions, geographical regions (Ilarslan *et al.*, 2002). Abayi *et al*. (2004) signified the genetic variation in important agronomic traits like earliness, cob height, and yield per plant to sufficiently justify the initiation of a selection program. Usually, desirable breeding lines are chosen through assessment of their genetic variability, heritability, genetic advance, etc. (Mishra *et al.*, 2015). Also, correlation and path coefficient analyses are applied for the selection of yield contributory traits and so these techniques facilitate within the understanding of effective selection criteria for yield improvement (Hossain *et al.*, 2015).

Therefore, considering the above scheme and discussion in mind, the study was conducted to determine the genetic variability, heritability, and character associations among 25 F_4 populations of white maize to meet the following objectives:

OBJECTIVES:

i. To study genetic variability and heritability among the 25 F_4 populations of white maize.

ii. To study the correlation and path coefficient analysis among the yield contributing traits.

iii. To select the best short stature promising lines and advances them from F_4 to F_5 level through self-fertilization.

CHAPTER II
REVIEW OF LITERATURE

Maize being an important cereal crop which has received much attention from research workers regarding the improvement of maize through manipulations of qualitative and quantitative characters all over the world. Various researchers at home and abroad worked with different maize lines and studied their performance regarding the characterization and diversity of maize. Many studies on the growth, yield, variability, correlation, heritability, and genetic advance have been carried out in many countries of the world. The work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter under the following headings:

2.1 Biology of Maize

Maize is a tall, determinate and annual plant. It produced large, narrow, opposite leaves, borne as an alternative on the length of the stem. All maize varieties follow the same general pattern of development, though specific time and the interval between stages and a total number of leaves developed might vary between totally different hybrids, seasons, time of planting, and placement.

The vegetative stage includes the seedling stage that comes about one week after sowing and the plants have about 2-4 leaves at this stage, the knee height stage of the plant that arrives about 35-45 days after sowing, and then the flower initiation stage. Generally, the maize plant would have attained its full height by this stage.

Silking stages involving the formation of the feminine flowers or cobs is that the first reproductive stage and happen 2-3 days once tasselling stage. This stage begins once any silks are visible outside the husk. These are auxiliary flowers, unlike tassels that are terminal ones. Fertilization happens when these new wet silks catch the falling spore grains. Maize is a monoecious plant that is the sexes are partitioned off into separate pistillate (ear), the feminine flower, male (tassel), and the male flower. It’s a determinate growth habit and therefore the shoot terminates into the inflorescences bearing staminate or pistillate flowers (Dhillon and Prasanna, 2001).

Fertilization occurs after the pollen grain is caught by the silk and germinates by the growth of the pollen tube down the silk channel within minutes of coming in contact with 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 (Hasan, 2017).

The soft-dough stage is the second stage under the reproductive stage that commences after pollination and fertilization are 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 and harvesting is done (Shompa, 2018).

2.2 Mean Performance

Breeders have an interest in screening and developing the open-pollinated population in any crop. In maize, vary of any attribute is that the major indicator of additional genetic variation. When the range is higher, then it is attainable to select the best genotype for any breeding purpose.

Ear length is a very important yield component for maize and had a right away impact on grain yield (Subramanian *et al.*, l98l). BARI (1990) reported that cv. Barnali gave additional ear per plant than Khaibhutta.

Hossain (2015) experimented at Sher-e-Bangla Agricultural University in 2015 with white maize. The results revealed that the highest grains per row ((33.98) and rows per cob ((13.67) were recorded from variety PSC-121. KS-510 showed a 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).

Shompa *et al.* (2020) experimented at Sher-e-Bangla Agricultural University with F_3 population of white maize and found that the population of KS-510-F_3-S_2 showed maximum mean performance in plant height (220.61cm), days to maturity (135.17

days) and yield per plant (91.82) whereas the population Youngnuo-7-F_3-S_1 showed minimum mean performance in plant height (122.33 cm), days to maturity (107.83 days) and yield per plant (46.94g).

Hasan *et al.* (2021) experimented 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).

2.3 Genetic Variability

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

Maize displays an orderly sequence of development of yield components specifically the number of ear per plant, number of grain per row, number of rows per ear, and hundred-grain weights reported by Viola *et al*. (2004).

An experiment was conducted by Sola *et al.* (2004) under the field conditions using a two-factor factorial arrangement in RCBD with four replications. Significant variations in plant height, ear height, stalk diameter, days to 50% silking and tasselling, maturity, percentage of barren plants, percent ear fill, ear length, ear diameter, and 1000-seed weight was attributed to the independent effects of different level of generation. Ihsan *et al*. (2005) also reported significant genetic variation for the morphological parameter for maize genotypes.

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

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

Shanthi *et al*. (2011) found that grain yield and its component characters viz., total anthers dehiscence period, the total period of silk appearance, active pollination period, number of grains per cob, cob weight, protein yield, and oil yield had expressed high estimates of GCV and PCV and high heritability (more than 85%) plus high genetic advance, indicating the factor tic variances for these traits in all probability because of their high additive gene effects. Hence, it had been inferred that direct selection was a more robust scope for the improvement of those traits.

Farhan *et al*. (2012) revealed that test crosses differed significantly for all the studied characters except days to 50% anthesis, days to 50% silking, and ASI. The genotype x environment interaction was also significant for all the traits except for cob length.

Hepziba *et al*. (2013) and Nayaka *et al*. (2015) found significant differences in grain yield plant^{-1}, grains row^{-1}, plant height, cob height, and cob length in maize

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.

Matin *et al.* (2017) conducted an experiment with twenty-one locally developed maize hybrids for ten characters to access variability and found that a 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.

Bartaula *et al.* (2019) found that when the difference between PCV and GCV is higher that indicates that characters are highly influenced by the environment and in that case, the direct selection would not be effective for crop improvement. Assessment of phenotypic variation alone is not an effective way for selection of elite lines from the breeding populations (Beulah *et al*., 2018).

Shompa *et al.* (2020) studied genetic variability in F_3 generation of white maize (*Zea mays* L.) revealed that high genotypic and phenotypic coefficient of variation for cob height (20.99, 21.55), leaf blade area (19.20, 20.31), and yield per plant (19.04, 22.59).

Hasan *et al.* (2021) studied genetic variability in F_2 generation of white maize (*Zea mays* L.) revealed that high genotypic and phenotypic coefficient of variation was cob height (19.64, 21.58), the number of branches of tassel (20.12, 25.41), leaf blade area (17.3, 20.87) and yield per plant (18.25, 22.98).

2.4 Heritability and Genetic Advance

Presterl *et al*. (2003) administered 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%.

Amer and Mosa (2004) revealed that heritability estimates in a narrow sense were 44% for days to 50% silking, 39% for plant height, 44% for ear height, 27% for ear length, 31% for ear circumference, 29% for the number of rows per cob, 23% for the number of grain per row and 36% for grain yield.

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 50% 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.

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% tasselling, 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).

Wannows *et al*. (2010) obtained that all estimates of additive (VA) and dominance (VD) variance were vital for all characteristics with exception of additive variance for specific leaf weight, and dominance variance for leaf area index, plant and cob height, cob length and the number of grain per row. However, the magnitude of VA was systematically larger than that of VD for all characteristics with exception of specific leaf weight, silk emergence date, stay green, 100-grain weight, and grain yield where VD values were larger than VA values.

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

Praveen *et al*. (2014) revealed that traits yield per plant, plant height, ear height, number of seeds per row, 100-seed weight were shown high heritability accompanied with a genetic advance which indicates that most likely the heritability is due to additive gene effects and selection may be effective in early generations for these traits. Whereas high to moderate heritability along with low estimates of genetic advance were observed for days to 50% tasselling, days to 50% silk emerge, shelling percentage, ear length and days to maturity ear girth, and the number of seed rows per cob.

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

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

The best heritability (H^2b) 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 a high potential for selection (Matin *et al.*, 2017).

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

Roy (2018) studied seventeen maize genotypes for 13 characters to access their heritability. The highest heritability (H^2b) was observed for 100-grains weight (99.91 %). Higher heritability and higher genetic advance in percent of means were observed in distance between plant height and cob height, number of grains per row, 100-grains weight and yield per plant.

Estimations of heritability coupled with genetic advance (GA) have been considered as an important index in selection purposes. High heritability coupled with high GA is considered as good selection criteria (Bartaula *et al*., 2019).

Shompa *et al.* (2020) studied twenty-four maize genotypes for 17 characters to access their heritability. The highest heritability (H^2b) was observed for cob height (94.92). Higher genetic advance in percent of means were observed in leaf blade area (37.39) followed by cob height (42.13).

Hasan *et al.* (2021) studied on heritability and genetic advance in F_2 generation of white maize (*Zea mays* L.) and revealed that high heritability alone with high genetic advances in percent of 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.

2.5 Correlation Coefficient

Genotypic and phenotypic correlation determination is that the basic step within the formulation and implementation of assorted breeding programs. The correlation among traits is additionally necessary for successful selections to be conducted in breeding activities. Again, analysis of correlation coefficient is that the most generally used one of many strategies (Yagdi and Sozen, 2009).

When major yield characters are positively associated then breeding would be effective. However, once these characters are negatively associated, it might be tough to observe coincident choice for them in developing a variety (Nemati *et al*., 2009).

Al-Ahmad (2004), Aydin *et al*. (2007) and Najeeb *et al*. (2009) found the positive and significant correlation between grain yields and each plant height, number of rows per cob, number of grains per row, and 100-grain weight and emphasized the role of those traits in the selection of high grain yield in corn additionally indicated that the correlation values were positive and significant between grain yield and each of ear circumference, ear length and number of grains per row. It also revealed that sources of variation in plant yield were the direct effects on both numbers of grains per row and ear circumference.

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

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

Bikal and Deepika (2015) showed that attributes viz. plant height, cob height, cob length, cob girth, cob weight, number of grain rows per cob, number of grains per row exhibited a positive and highly significant correlation with grain yield per hectare and 500-grains weight. The analysis also indicated that days to 50% tasselling and days to 50% silk emergence explained a negative and highly significant correlation with grain yield per hectare. Similarly, days to maturity showed a negative and insignificant correlation with grain yield per hectare.

Barua *et al.* (2017) studied on correlation in maize genotypes for grain yield and yield contributing traits. Grain yield showed a highly significant positive genotypic correlation with plant height (0.767) and ear height (0.823) indicating these characters, can be strategically used to improve the grain yield of 21 (twenty one) maize. Thus, selection can be exercised on these traits in improving the maize population for high grain yield.

Roy (2018) studied seventeen maize genotypes for 13 characters to access their genotypic correlation among different pairs of yield and yield contributing characters and found that positive correlation of base diameter, leaf length, leaf width, cob length, cob diameter, number of rows per cob, number of grains per row and 100-grains weight.

Shompa *et al.* (2020) found that yield plant^{-1} showed highly significant difference among the tested lines which had positive correlation with plant height (0.790), cob height (0.756), days to maturity (0.827), cob length (0.729), cob breadth (0.904), number of rows cob^{-1} (0.543), number of grains row^{-1} (0.776), 100 grain weight (0.677), 50% tasseling (0.676) and base diameter (0.753).

Hasan *et al.* (2021) stated a positive correlation of yield per plant with plant height, days to maturity, number of leaves per plant, cob length, cob diameter, and number of grains per row at both genotypic and phenotypic levels.

2.6 Path Analysis

Simple correlation does not contemplate the complex relationships between the various traits associated with a variable quantity. Correlation coefficients show relationships among independent variables and therefore the linear relationship between these variables, however, it’s not sufficient to explain these relationships when the causal relationship among variables is required. A clear image of the interrelationship between seed yield and other yield tributary characters, direct and indirect effects of them may be worked out by victimization path analysis.

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

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

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

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

Venugopal *et al*. (2003) reported that days to 50% tasselling and the number of seed rows per cob showed negative indirect association with all traits towards grain yield. The study disclosed that direct selection for these traits would be effective. Days to 50% silk exhibited a negative direct effect on grain yield indicated that choice for top yield may be done by indirect choice through yield parts.

Bello *et al*. (2010) studied path analysis and revealed that days to 50% silk emergence, ear weight, and the number of grains per cob had the highest direct effect on grain yield whereas the 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 may be the necessary selection criteria for the improvement of open-pollinated maize varieties and hybrids in terms of high grain yield.

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

The study carried out by Selvaraj and Nagarajan (2011) disclosed that direct selection for ear length and numbers of rows per cob is effective for yield improvement. The same author expressed that, the positive direct and indirect effects of an attribute on grain yield make it attainable for its exploitation in the selection below specific conditions.

Days to 50% tasselling and the number of rows per cob showed a negative indirect association with all traits towards grain yield. The study revealed that direct selection for these traits would be effective. Days to 50% silk exhibited a negative direct effect on grain yield indicated that selection for top yield may be done by indirect selection through yield elements (Pavan *et al*., 2011).

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

Mustafa *et al.* (2014) disclosed that the fresh shoot length had a 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 24 seedlings. These traits had reasonable heritability estimations. Thus selection may be created for top-yielding maize genotypes on the premise of those traits.

An experiment was conducted and stated that direct effect of days to silking on grain yield, the number of kernels per row, thousands seed weight and cob diameter (Reddy and Jabeen, 2016).

Alhussein and Idris (2017) studied to investigate the path analysis of grain yield elements on yield and found that ear length and diameter and hundred kernel weight had high positive direct effects on grain yield. The flowering day such as days to tasselling had a high negative direct effect on yield. These results portrayed that ear length and diameter is also used as reliable criteria for rising grain yield.

Barua *et al.* (2017) studied path analysis in maize genotypes for grain yield and yield contributing traits. Path analysis unconcealed that days to 50% silking (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 the number of kernels per row (0.600) indicating these characters, maybe strategically accustomed improving grain yield of maize. Thus, selection may be exercised on these traits in improving the maize population for high grain yield.

Jakhar *et al.* (2017) studied the path analysis on maize and revealed that it provides an effective measure of direct and indirect causes of association and depicts the relative importance of each factor involved in contributing to the ultimate 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, whereas direct and negative effects were exhibited by days to 50% silking and ear height indicating the effectiveness of indirect selection.

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

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

Pandey *et al.* (2017) studied maize by 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).

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

Shompa *et al.* (2020) performed path analysis within the F_3 generation of white maize at Sher-e-Bangla Agricultural University and revealed that direct selection based on plant height, days to maturity, cob height, number of row per cob, and number of grains per row could be reliable for yield improvement in white maize.

Hasan *et al.* (2021) studied within the F_2 generation of white maize by path analysis at Sher-e-Bangla Agricultural University and revealed that direct selection based on plant height, days to maturity, cob height, number of leaves per plant, cob length, number of rows per cob and number of grains per row could be reliable for yield improvement in white maize.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted to study the genetic variability, heritability, correlation, and path coefficient analysis for yield and its tributary characters of twenty-five (25) white maize inbred lines which lines were collected from the Department of Genetics and Plant Breeding, SAU, Dhaka-1207. The small print of the materials and strategies i.e. description of the experimental site, soil and climatic condition of the plot, materials were used within the experiment, data collection, and data analysis procedure utilized in the experiment are conferred below underneath the subsequent points.

3.1 Description of the Experimental Site

3.1.1 Experimental period-

The field experiment was conducted during the period of October/2018 to March/2019.

3.1.2 Location of the experiment-

The experiment was laid out in the research field of SAU, Dhaka-1207. The placement belongs to the sub-tropical climate and AEZ No. 28 called: Madhupur Tract, it's settled at 23^0 41 N latitude associated 90^0 22 E longitudes with an elevation of 8.6 meters from the ocean level.

3.1.3 Climate and soil

The geographical scenario of the experimental site was underneath the subtropical climate, characterized by three distinct seasons, the winter season from October to February and the pre-monsoon season from March to April and the monsoon period from May to October (Edris *et al.*, 1979) and also characterized by heavy precipitation during the period from July to August and scarcity precipitation from October to March. The record of air, temperature, humidity and rainfall throughout the amount of the experimental site during the period of October, 2018 to March, 2019 were recorded from the Bangladesh Metrological Department, Agargaon, Dhaka and were conferred in Appendix II. The experimental 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 0.86%. The physical and chemical characteristics of the soil are conferred in Appendix III.

3.2 Experimental Material

In this experiment, 25 (Twenty-five) F_4 population of hybrid white maize seed was collected from the Department of Genetics and Plant Breeding, SAU, Dhaka-1207. The elaborate pedigree of F_4 populations of hybrid white maize was bestowed in Table 1.

3.3 Details of the Experiment

The experiment was set up following Randomized complete block design (RCBD) with 3 replications were performed during this experiment. 2.0m × 2.5m unit plot size assigned for each genotype for conducting this experiment. Plot-plot distance was 0.5 m and replication-replication distance was 1.5 m. Each replication area was 157.5 m^2 and also the total land area was 472.5 m^2. The plant spacing provided was 0.6 m between rows and 0.25 m between plants of the same row. Within the experimental field, the seeds were seeded on 22nd November 2019 in the randomized organization among the plot.

3.4 Cultural Practices

3.4.1 Land preparation

The chosen experimental field for growing white maize was initial tilt with a power tiller and was exposed to the sun for seven days. Then the land was prepared to obtain good tilt by several tilling, cross tilling, and laddering. Weeds and stubbles were removed; massive clods were broken into little particles, and finally, get fascinating tilts to ensure the best growing conditions. The plot was painted into the small unit blocks according to the experimental design as mentioned earlier. The suggested dose of cow dung, organic manure and chemical fertilizers were applied and mixed well with the soil of each block. Proper irrigation and drainage channels were additionally ready around the blocks. The bed soil was created friable and also the surface of the bed was leveled.

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

Sl. No.	Given Name	Pedigree	Sources
01	V_1	Youngnuo-3000-R_1-S_2	Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207
02	V_2	Youngnuo-3000-R_2-S_2	
03	V3	Youngnuo-3000-R_3-S_1	
04	V_4	PSC-121-R_2-S_2	
05	V_5	Plough-201-R_1-S_2	
06	V_6	Plough-201-R_1-S_3	
07	V_7	Plough-201-R_2-S_3	
08	V_8	Changnuo-1-R_3-S_1-1	
09	V_9	Changnuo-1-R_3-S_1-2	
10	V_{10}	Changnuo-1-R_3-S_1-3	
11	V_{11}	Youngnuo-7-R_3-S_1-1	
12	V_{12}	Youngnuo-7-R_3-S_1-2	
13	V_{13}	Youngnuo-7-R_3-S_1-3	
14	V_{14}	Changnuo-6-R_3-S_2-1, 2	
15	V_{15}	Changnuo-6-R_3-S_2-3, 4	
16	V_{16}	Changnuo-6-R_2-S_3	
17	V_{17}	Changnuo-6-R_3-S_3	
18	V_{18}	Q- Xiangnuo-R_1-S_2-1, 2	
19	V_{19}	Q- Xiangnuo-R_1-S_2-3, 4	
20	V_{20}	Q-Xiangnuo-R_2-S_2	
21	V_{21}	Q-Xiangnuo-R_2-S_3	
22	V_{22}	Q-Xiangnuo-R_3-S_3	
23	V_{23}	KS-510-R_1-S_3	
24	V_{24}	KS-510-R_2-S_2	
25	V_{25}	KS-510-R_3-S_2	

3.4.2 Manure and chemical fertilizer application

Generally, cow dung, urea, TSP (Triple superphosphate), MP (Muriate of potash), gypsum, zinc sulfate, and boron are needed for maize cultivation. The field was fertilized with 03-ton manure per ha and also fertilized with 650,250,200,120,20 and 6 kg urea, TSP, MP, gypsum, zinc sulfate, and boric acid per hectare recommended for hybrid Maize production (BARC, 2018). In the experimental field, the amount of 200 kg cow dung, 33 kg urea, 12.5 kg TSP, 10 kg MP, 6 kg gypsum, 1 kg zinc sulfate, and 0.3 kg boric acid were applied. The whole quantity of cow dung was applied seven days before sowing. TSP, MP, Gypsum, Zinc sulfate, and Boric acid were applied throughout the final land preparation and incorporated with the soil. The overall quantity of urea was divided by three splits. One-third was applied during land preparation, one third was applied after 35 DAS (Days after sowing) and another one-third was applied after 60 DAS (before flowering) (Table 2).

Table 2. Fertilizer doses for conducting experiment on maize

Sl. No.	Fertilizer	Required dose (Kg/ha)	Applied fertilizer (Kg)
01	Cow dung	3000	200
02	Urea	650	33
03	TSP	250	12.5
04	MP	200	10
05	Gypsum	120	6
06	Zink sulfate	20	1
07	Boric acid	6	0.3

3.4.3 Thinning of excess seedlings

The weak seedlings were first thinned from all of the plots at 18 days after sowing (DAS). Second thinning was carried out after seven days of 1st thinning for maintaining the proper spacing of the experimental plots. In 10 DAS gap filling was done.

3.4.4 Irrigation

Irrigation was provided at the sapling stage, knee stage, flowering stage, and milking stage at 20, 40, 65, and 78 DAS four times for proper growth and development of the plants.

3.4.5 Weeding

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

3.4.6 Earthling up

Earthling up was done twice during the growing period. The first earthling up was done at 45 DAS and the second earthling up was done after 65 DAS.

3.4.7 Plant protection

Adult and larva of the many insects were found within the crop throughout the vegetative and flowering stages of the plant. To control such insects Malathion-57 EC @2ml/liter and Diazinion 60 EC @2 ml/liter of water was sprayed at 70 and 90 DAS respectively. The insecticide was applied in the afternoon. Ridomil gold 2g per liter of water was sprayed three times within the plants as a protection measure against plant fungal disease.

3.4.8 Harvesting

Different genotype matured at different times. The crops were harvested once the husk cover was utterly dried and straw color was formed of the husk of the mature cob. The five randomly chosen plants of every line were separately harvested. Border plants were discarded to avoid the border impact.

3.5 Data Recording

3.5.1 Days to 50% tasseling

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

3.5.2 Days to 50% silking

Days to silking were recorded as the range of days from planting to the time 50% of plants had completely extruded silks.

3.5.3 Plant height (cm)

Plant height was measured in centimeters from the bottom of the plants up to the tassel base from wherever the tassel branching started at every of five randomly selected plants from each line (Figure 1).

3.5.4 Cob height (cm)

The heights of cob from ground level to the cob node from randomly selected plants were measured from each unit plot in cm with a measuring scale. Cob height was taken from the ground level to the node bearing the topmost cob node. Cob heights were measured from the identical plant from that plant heights were recorded (Figure 1).

3.5.5 Days to maturity

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

3.5.6 Base diameter (cm)

The base of plant diameter was calculated with calipers and therefore the average was done in centimeters.

3.5.7 Leaves per plant

The number of leaves per plant was recorded by counting all the leaves from the chosen plants of each unit plot and therefore the mean was calculated.

3.5.8 Branches of tassel

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

3.5.9 Leaf length (cm)

It was measured on a centimeter-scale from the joining point of the leaf and to the tipping point of each of the five randomly selected plants in each line of the leaf.

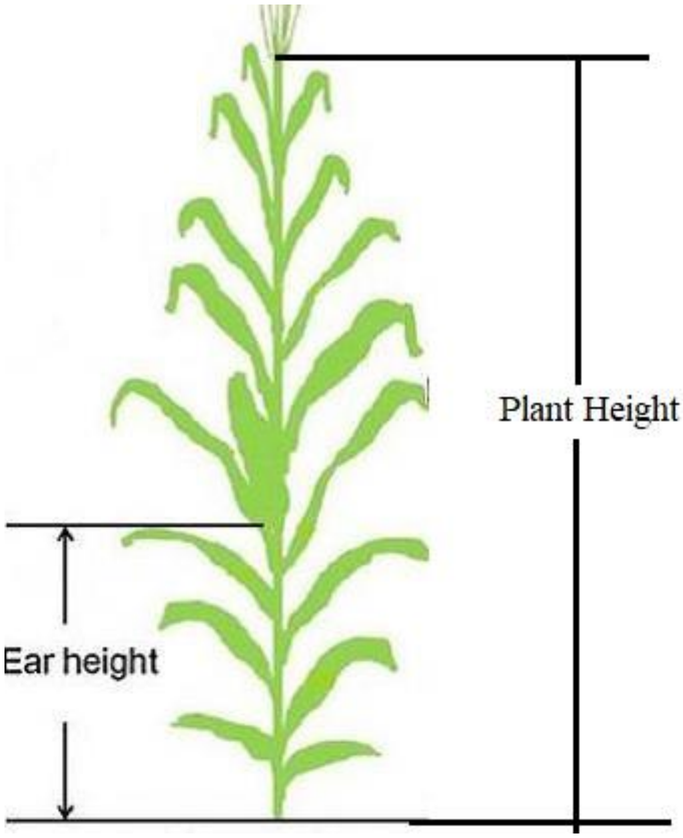

Figure 1. Plant and cob height measurement

3.5.10 Leaf width (cm)

The width of a leaf was measured in centimeters employing a scale at the center of the leaf from the randomly selected five plants and averages the results.

3.5.11 Cob length (cm)

The lengths of cobs were measured from the cob base to the apex in centimeters by using the measuring scale.

3.5.12 Cob diameter (cm)

The diameter of cobs at the top, basal and central part was measured in centimeters by employing a measuring tape and therefore the average was recorded. Cob length and diameter measurement was shown on the (Figure 2) and (Plate 1).

3.5.13 Number of rows per cob

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

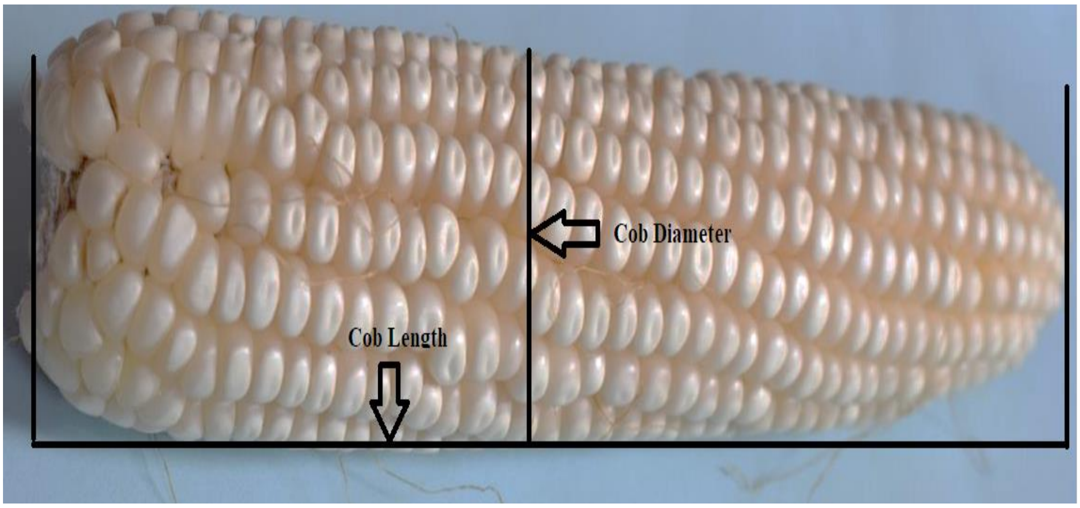

Figure 2 . Cob length and cob diameter measurement

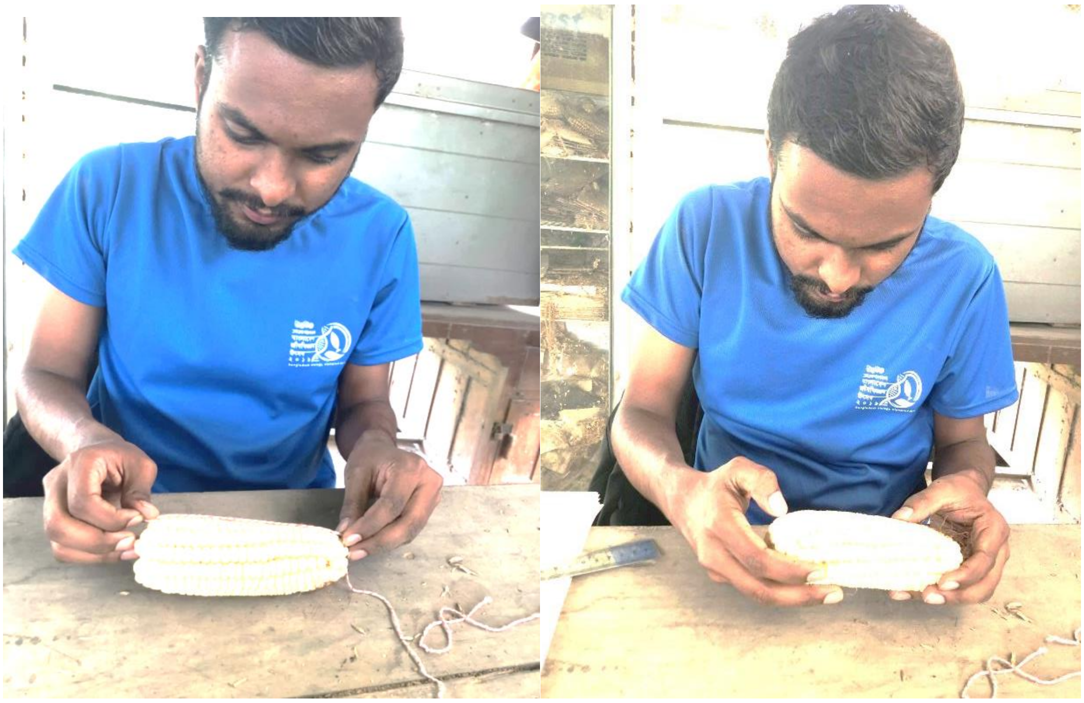

Plate 1: Measurement of cob length and counting the rows per cob

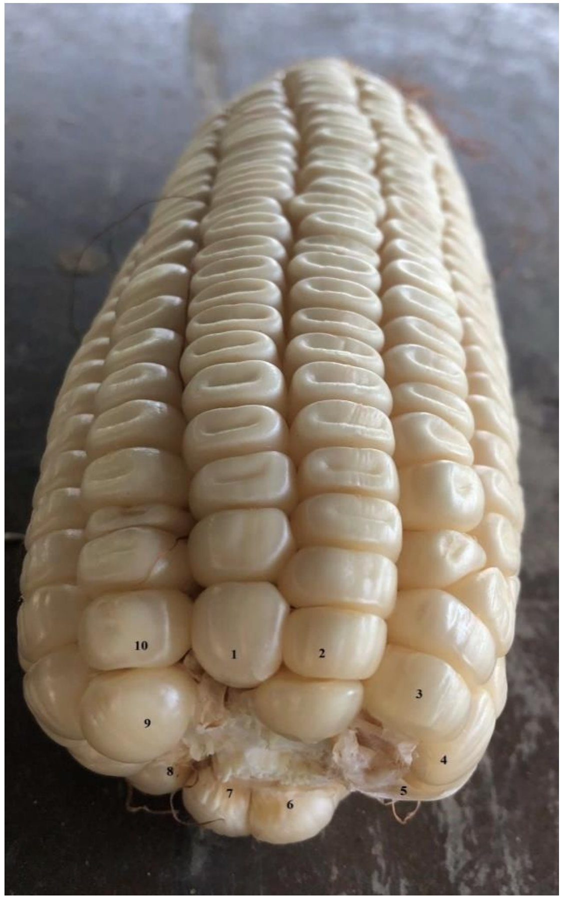

Figure 3. Number of rows per cob

Figure 4. Number of grains per row

3.5.14 Number of grains per row

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

3.5.15 100-grain weight (g)

A sample of seeds was taken randomly and weighed in grams.

3.5.16 Grain yield per plant (g)

All cobs were shelled from chosen plants and yield was measured as a bulk weight than the average was calculated by dividing the number of selected plants by the closest (gram). The yield was measure as gram (g) per plant.

Selfing was performed in the required number of plants of F_4 generation for the production of the inbred line of the F_5 generation.

3.6 Statistical Analysis

The mean of the three replicated data collected on 25 genotypes on 16 attributes mentioned above was subjected to biometrical analysis following appropriate biometrical procedures.

3.6.1 Analysis of Variance

Analysis of variance was administered as per the procedure given by Panse and Sukhatme (1985). The structure of analysis of variance is as follows (Table-3).

Data on the 16 (sixteen) characters, namely Days to 50% tasseling, 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 a tassel, leaf length (cm), leaf breadth (cm), 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.

Table 3. Analysis of variance

Source of variation	Degrees of freedom (df)	Sum of squares (SS)	Expected mean sum of square (MSS)
Replication	r-1	M_1	$\delta^2e + t\delta^2r$
Treatment	t-1	M_2	$\delta^2e + r\delta^2g$
Error	(r-1) (t-1)	M_3	δ^2e
Total	rt-1	$(M_1 + M_2 + M_3)$	

Where,

r = Number of replications

t = Number of treatments (genotypes)

δ^2e = Error variance

δ^2g= Genotypic variance

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

3.6.2 Genotypic and phenotypic variances

Genotypic and phenotypic variances were calculable in keeping with the formula given by Johnson *et al.* (1955).

Genotypic variance (δ^2g) = $\frac{GMS-EMS}{r}$

Where,

GMS = Genotypic mean sum of square

EMS = Error mean sum of square

r = number of replications

Phenotypic variance (δ^2p) = $\delta^2g + \delta^2e$

Where,

δ^2g = Genotypic variance

EMS = Error mean sum of square

δ^2e = Error variance

3.6.3 Genotypic and phenotypic co-efficient of variation

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

Genotypic co-efficient of variation (GCV %) = $\sqrt{\frac{\delta^2 g}{\bar{x}}} x\ 100$

Where,

δ^2g = Genotypic variance

$\bar{x}$ = Population mean

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

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

δ^2ph= 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%

3.6.4 Heritability

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

Heritability, $h^2b = \frac{\delta^2 g}{\delta^2 p} x\ 100$

Where,

h^2b = Heritability in broad sense

δ^2g = Genotypic variance

δ^2p= 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%

3.6.5 Genetic advance

The expected genetic advance for various characters underneath selection was estimable victimization the formula introduced by Lush (1943) and Johnson *et al.* (1955).

Genetic advance, GA = K. h^2. δ_p

Or Genetic advance, GA = $K.\frac{\delta^2 g}{\delta^2 p}.\delta p$

Where,

K = Selection intensity, the worth that is 2.06 at 5% selection intensity

δ_{p} = Phenotypic standard deviation

h^2b = Heritability in broad sense

δ^2g = Genotypic variance

δ^2p= Phenotypic variance

3.6.6 Genetic advance mean's proportion

Genetic advance as the proportion of mean was calculated from the subsequent formula as planned by Comstock and Robinson (1952):

Genetic advance (% of mean) = $\frac{Genetic\ advance}{Population\ mean}\ X\ 100$

Genetic advance as per cent mean was categorized into following groups as suggested by Johnson *et al.* (1955).

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

3.6.7 Genotypic and phenotypic correlation co-efficient

The calculation of genotypic and phenotypic correlation coefficient for all potential mixers through the formula advised 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 element was derived within the same approach as for the corresponding variance elements. The co-variance elements were the accustomed reason the genotypic and phenotypic correlation between the pairs of characters as follows:

Genotypic correlation, $r_{gxy} = \frac{GCOVxy}{\sqrt{(GVx.GVy}} = \frac{\delta_{gxy}}{\sqrt{\delta^2{}_{gx}.\delta^2 gy}}$

Where,

δ_{gxy} = Genotypic co-variance between the attributes x and y

$\delta^2{}_{gx}$ = Genotypic variance of the attribute x

$\delta^2{}_{gy}$ = Genotypic variance of the attribute y

Phenotypic correlation, $r_{pxy} = \frac{PCOVxy}{\sqrt{(PVx.PVy}} = \frac{\delta_{pxy}}{\sqrt{\delta^2{}_{px}.\delta^2 py}}$

Where,

δ_{pxy} = Phenotypic co-variance between the attributes x and y

$\delta^2{}_{px}$ = Phenotypic variance of the attribute x

$\delta^2{}_{py}$ = Phenotypic variance of the attribute y

3.6.8 Path coefficient analysis

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

The second step in path analysis was to organize a path diagram that supported the cause and effect relationship. In the present study, the path diagram was ready by taking yield because the impact i.e. function of assorted elements like X_1, X_2, X_3, and these elements showed the subsequent form of association with one another.

In the path diagram, the yield is that the results of X_1, X_2, X_3…..X_n and a few other undefined factors designated by R. The double arrow lines indicated mutual association as measured by the parametric statistic. The single arrow showed direct influence as measured by path coefficient P_{ij}.

Path coefficients were obtained by finding a bunch of the synchronous equation of the shape as per Dewey and Lu (1959).

$r_{ny} = P_{ny} + r_n^2 P_{2y} + r_n^3 P_{3y} +$ …………….

Where,

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

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

r_n^2 = represents the correlation between that character and every one of the opposite components successively.

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

Plate 2. Supervisor visiting the experimental field and giving instruction

Plate 3. Co-supervisor visiting the experimental field and giving instruction

CHAPTER IV
RESULTS AND DISCUSSION

This experiment was conducted to select the short duration and dwarf stature populations by comparing the performance of 25 F_4 populations on 16 (sixteen) characters of white maize and to advance the F_4 lines to F_5 -stage by self-fertilization. This study was conducted to find out the phenotypic and genotypic variability, coefficient of variance, heritability, genetic advance, correlation, and path analysis to estimate the direct and indirect effect of yield contributing traits on yield. The data were recorded on 16 (sixteen) different parameters such as days to 50% tasseling, days to 50% silking, plant height, cob height, days to maturity, base diameter, no. of total leaves per plant, no. of branches per tassel, leaf length, leaf width, cob length, cob diameter, no. of rows per cob, no. of grains per row, 100 grains weight and yield per plant. The data were statistically analyzed by Stastix-10 and R studio (2020). Level of significance at 5% was used to compare mean differences among the treatments (Gomez and Gomez, 1984). Thus obtained results are described below under the following headings:

4.1 Mean Performance

The analysis of variance and mean performance are presented in (Table 4 and Table 5). ‘F’ test revealed highly significant variation among promising 25 F_4 populations of white maize in terms of all the yield contributing characters and yield.

4.1.1 Days to 50% tasseling

Data revealed that the average days to 50% tasseling was recorded around 72.79. The highest (77.67) days to 50% tasseling was found in the population KS-510-R_3-S_2 which was followed by KS-510-R_1-S_3 whereas the lowest (65.00) days was found from the population of Youngnuo-7-R_3-S_1-2 followed by Youngnuo-7-R_3-S_1-1 (65.67) and Youngnuo-7-R_3-S_1-3 (66.33). Data revealed that different promising populations required different days to 50% male flowering and it might be due to genetic factors of the genotype. It was also found that populations Youngnuo-7-R_3-S_1-2 and Youngnuo-7-R_3-S_1-1 were the early male flowering. Huda (2015) reported that the minimum and maximum duration for 50% tasseling was observed in the genotype G5 (55.33 days) and G14 (63.33 days), which were less than these findings. .

Table 4. Analysis of variance for different characters of 25 F_4 populations of white maize

Source of variation	Degrees of Freedom (df)	Days to 50% tasselling	Days to 50% silking	Plant height	Cob height	Days to maturity	Base diameter	No. of leaves per plant	Branches of tassel	Leaf length	Leaf width	Cob length	Cob diameter	No. of rows per cob	No. of grains per row	100-grains weight	Grain yield per plant
Replication	2	2.30	0.37	837.41	344.46	0.84	0.10	2.33	2.45	9.63	0.90	1.38	0.03	2.07	14.05	22.98	334.54
Genotype	24	36.19 **	36.32 **	872.60 **	473.68 **	215.34 **	0.12 **	5.17 **	23.42 **	137.81 **	1.18 **	6.55 **	0.26 **	4.99 **	28.99 **	47.26 **	826.26 **
Error	48	0.78	0.65	177.63	105.52	1.06	0.05	1.03	3.62	59.98	0.37	2.53	0.10	1.79	17.35	12.18	358.72

** = Significant at 1%, * = Significant at 5%

Table 5. Mean performance of different characters of 25 F_4 populations of white maize

Genotypes	Days to 50% tasselling	Days to 50% silking	Plant height (cm)	Cob height (cm)	Days to maturity	Base diameter (cm)	Leaves per plant	Branches of tassel
V_1 (Youngnuo 3000 R_1S_2)	75.3cd	79.00bc	107.75e-j	51.70d-g	122.67d	1.47gh	10.92ef	9.58e-i
V_2(Youngnuo-3000 R_2S_2)	76.00bc	79.33b	114.53e-h	54.60c-g	120.33e	1.54fgh	10.67f	10.18e-i
V_3(Youngnuo- 3000 R_3S_1)	76.33abc	79.00bc	117.32d-g	60.20c-f	124.67c	1.79b-g	11.08def	11.36c-g
V_4 (PSC 121 R_2S_2)	75.67cd	79.33b	108.93e-i	44.02efg	133.00b	2.01abc	10.87ef	6.37j
V_5 (Plough- 201 R_1S_2)	70.33jk	74.00ij	118.60d-g	66.57a-d	115.00gh	1.65d-h	11.53c-f	9.73e-i
V_6 (Plough-201 R_1S_3)	72.67fgh	77.33ef	110.32e-i	70.93abc	115.33gh	1.43h	12.68bcd	7.30ij
V_7 (Plough-201 R_2S_3)	71.67g-j	75.33gh	109.38e-i	67.87a-d	114.33hi	1.57e-h	11.72b-f	10.73d-h
V_8 (Changnuo-1 R_3S_1 -1)	75.33cd	78.67bcd	124.73b-e	68.20a-d	116.33g	1.80b-g	11.53c-f	8.07hij
V_9 (Changnuo-1 R_3S_1 -2)	75.67cd	79.00bc	99.53g-j	53.40d-g	115.33gh	1.75b-h	10.97ef	11.05d-h
V_{10} (Changnuo-1 R_3S_1 -3)	75.67cd	78.33b-e	122.87c-f	60.07c-f	115.67gh	1.90a-e	11.67b-f	12.47b-f
V_{11} (Youngnuo-7 R_3S_1-1)	65.67l	69.33l	129.33a-e	68.33a-d	106.33j	1.99a-d	12.87bc	14.20abc
V_{12} (Youngnuo-7 R_3S_1-2)	65.00l	68.33l	93.50hij	47.72efg	103.67k	1.82b-f	8.95g	9.83e-i
V_{13} (Youngnuo-7 R_3S_1-3)	66.33l	70.67k	86.98j	38.92g	105.00jk	1.55e-h	8.36g	8.82g-j
V_{14} (Changnuo-6 R_3S_2 -1,2)	71.33hij	75.33gh	95.43hij	53.22d-g	121.33de	1.85a-f	10.80ef	9.43f-j
V_{15} (Changnuo-6 R_3S_2 -3,4)	69.67k	73.33j	102.84f-j	47.28efg	118.33f	1.86a-f	11.67b-f	11.48c-g
V_{16} (Changnuo-6 R_2S_3)	71.00ijk	75.33gh	101.42f-j	53.42d-g	115.33gh	1.67c-h	12.22b-f	10.02e-i
V_{17} (Changnuo-6 R_3S_3)	70.67jk	74.67hi	89.50ij	43.42fg	115.00gh	1.99a-d	12.33b-f	7.25ij
V_{18} (Q- Xiangnuo R_1S_2-1,2)	73.33ef	77.33ef	111.85e-h	60.80b-e	116.33g	1.61e-h	10.78ef	12.47b-f
V_{19} (Q- Xiangnuo R_1S_2-3,4)	74.33de	77.67de	101.23f-j	57.58c-f	113.00i	1.79b-g	11.53c-f	11.12c-h
V_{20} (Q-Xiangnuo R_2S_2)	73.00efg	77.33ef	127.42a-e	79.03a	120.67e	2.05ab	13.10abc	13.35a-d
V_{21} (Q-Xiangnuo R_2S_3)	73.67ef	78.00cde	144.92ab	78.83a	116.33g	2.03ab	14.55a	16.07a
V_{22} (Q-Xiangnuo R_3S_3)	72.33f-i	76.33fg	102.80f-j	58.50c-f	115.00gh	1.76b-h	12.13b-f	12.70b-e
V_{23} (KS-510 R_1S_3)	77.33ab	82.33a	140.64abc	82.60a	134.33ab	1.66d-h	12.89abc	14.67ab
V_{24} (KS-510 R_2S_2)	73.67ef	78.00cde	146.62a	77.55ab	133.33b	2.18a	12.40b-e	16.45a
V_{25} (KS-510 R_3S_2)	77.67a	82.00a	139.10a-d	79.73a	135.33a	1.62e-h	13.27ab	16.13a
Mean	72.79	76.61	113.90	60.98	118.48	1.77	11.66	11.23
CV (%)	1.21	1.05	11.70	16.85	0.87	12.12	8.71	17.00
SD	3.47	3.48	17.06	12.57	8.47	0.20	1.31	2.81
$LSD_{0.05}$	1.45	1.33	21.88	16.86	1.69	0.35	1.67	3.12

Table 5. (Cont'd)

Genotypes	Leaf length (cm)	Leaf width (cm)	Cob length (cm)	Cob diameter (cm)	No. of rows per cob	No. of grains per row	100-grains weight (g)	Grain yield per plant (g)
V_1 (Youngnuo 3000 R_1S_2)	69.50b-f	6.24e-i	11.62ghi	4.27c-h	13.42bc	21.17cde	29.20d-j	85.22a-g
V_2(Youngnuo-3000 R_2S_2)	73.50a-e	5.37i	11.70f-i	4.58a-d	13.05bcd	16.43e	33.80a-f	71.57c-h
V_3(Youngnuo- 3000 R_3S_1)	70.94a-f	6.80b-h	14.31a-f	4.52a-e	12.17b-f	22.72b-e	37.58a	90.55a-f
V_4 (PSC 121 R_2S_2)	78.83abc	8.12a	14.33a-e	5.01a	13.20bc	26.17abc	31.63b-h	98.90a-d
V_5 (Plough- 201 R_1S_2)	69.27b-f	7.15a-e	15.17abc	4.52a-e	11.73c-g	21.40cde	35.73abc	79.17b-h
V_6 (Plough-201 R_1S_3)	68.12b-f	5.87hi	11.48ghi	4.45b-f	13.02bcd	21.07cde	23.54j	58.03gh
V_7 (Plough-201 R_2S_3)	63.95efg	6.05ghi	10.81i	4.39b-g	10.17fg	21.67cde	27.87g-j	57.40gh
V_8 (Changnuo-1 R_3S_1 -1)	72.20a-e	6.70b-h	13.15b-i	4.86ab	12.78b-e	30.88a	29.00e-j	100.70abc
V_9 (Changnuo-1 R_3S_1 -2)	71.13a-f	5.99ghi	12.73c-i	4.27c-h	12.83b-e	23.28bcd	25.57ij	73.10b-h
V_{10} (Changnuo-1 R_3S_1 -3)	72.87a-e	6.76b-h	12.45d-i	4.34c-g	12.53b-e	22.80b-e	27.03g-j	68.33d-h
V_{11} (Youngnuo-7 R_3S_1-1)	74.80a-e	7.47ab	15.71ab	4.69abc	13.93ab	27.20abc	32.11a-h	111.67a
V_{12} (Youngnuo-7 R_3S_1-2)	63.65fg	7.07b-f	12.53d-i	4.49b-e	15.67a	26.20abc	27.73g-j	103.33ab
V_{13} (Youngnuo-7 R_3S_1-3)	64.92d-g	6.43c-h	11.44hi	4.55a-d	12.56b-e	18.80de	31.89a-h	77.53b-h
V_{14} (Changnuo-6 R_3S_2 -1,2)	68.53b-f	7.42abc	14.00a-h	4.41b-g	12.97bcd	23.93bcd	36.47ab	101.23abc
V_{15} (Changnuo-6 R_3S_2 -3,4)	69.23b-f	6.84b-h	14.35a-e	4.14d-h	10.73efg	24.87a-d	23.96j	53.93h
V_{16} (Changnuo-6 R_2S_3)	67.08c-f	6.30d-i	14.07a-g	4.76abc	13.22bc	21.68cde	36.97ab	95.87a-e
V_{17} (Changnuo-6 R_3S_3)	62.67efg	6.18e-i	12.32e-i	4.15d-h	10.92d-g	20.40cde	32.53a-g	67.63e-h
V_{18} (Q- Xiangnuo R_1S_2-1,2)	58.62fg	6.89b-g	12.76c-i	3.96fgh	10.96d-g	22.64b-e	28.90e-j	60.17fgh
V_{19} (Q- Xiangnuo R_1S_2-3,4)	68.32b-f	6.66b-h	15.23abc	3.82h	11.30c-g	24.82a-d	32.20a-g	81.13a-h
V_{20} (Q-Xiangnuo R_2S_2)	74.17a-e	6.68b-h	13.82a-h	4.42b-g	12.95bcd	22.72b-e	34.73a-d	93.00a-e
V_{21} (Q-Xiangnuo R_2S_3)	78.57abc	6.61b-h	14.95a-d	4.75abc	12.57b-e	24.48a-d	30.33c-i	81.83a-h
V_{22} (Q-Xiangnuo R_3S_3)	53.93g	6.08f-i	13.03c-i	3.92gh	9.87g	20.53cde	31.37b-h	59.37gh
V_{23} (KS-510 R_1S_3)	80.50ab	7.26a-d	16.350a	4.03e-h	12.40b-e	28.53ab	26.43hij	82.70a-h
V_{24} (KS-510 R_2S_2)	82.75a	7.53ab	14.67a-e	4.52a-e	12.50b-e	25.15a-d	33.93a-e	99.37a-d
V_{25} (KS-510 R_3S_2)	76.98a-d	7.34abc	13.96a-h	4.44b-f	14.017ab	21.87b-e	28.20f-j	77.30b-h
Mean	70.20	6.71	13.48	4.41	12.46	23.26	30.75	81.16
CV (%)	11.03	9.04	11.79	7.09	10.75	17.91	11.35	20.45
SD	6.78	0.63	1.48	0.30	1.30	3.11	3.97	16.60
$LSD_{0.05}$	12.72	1.00	2.61	0.51	2.20	6.84	5.73	31.09

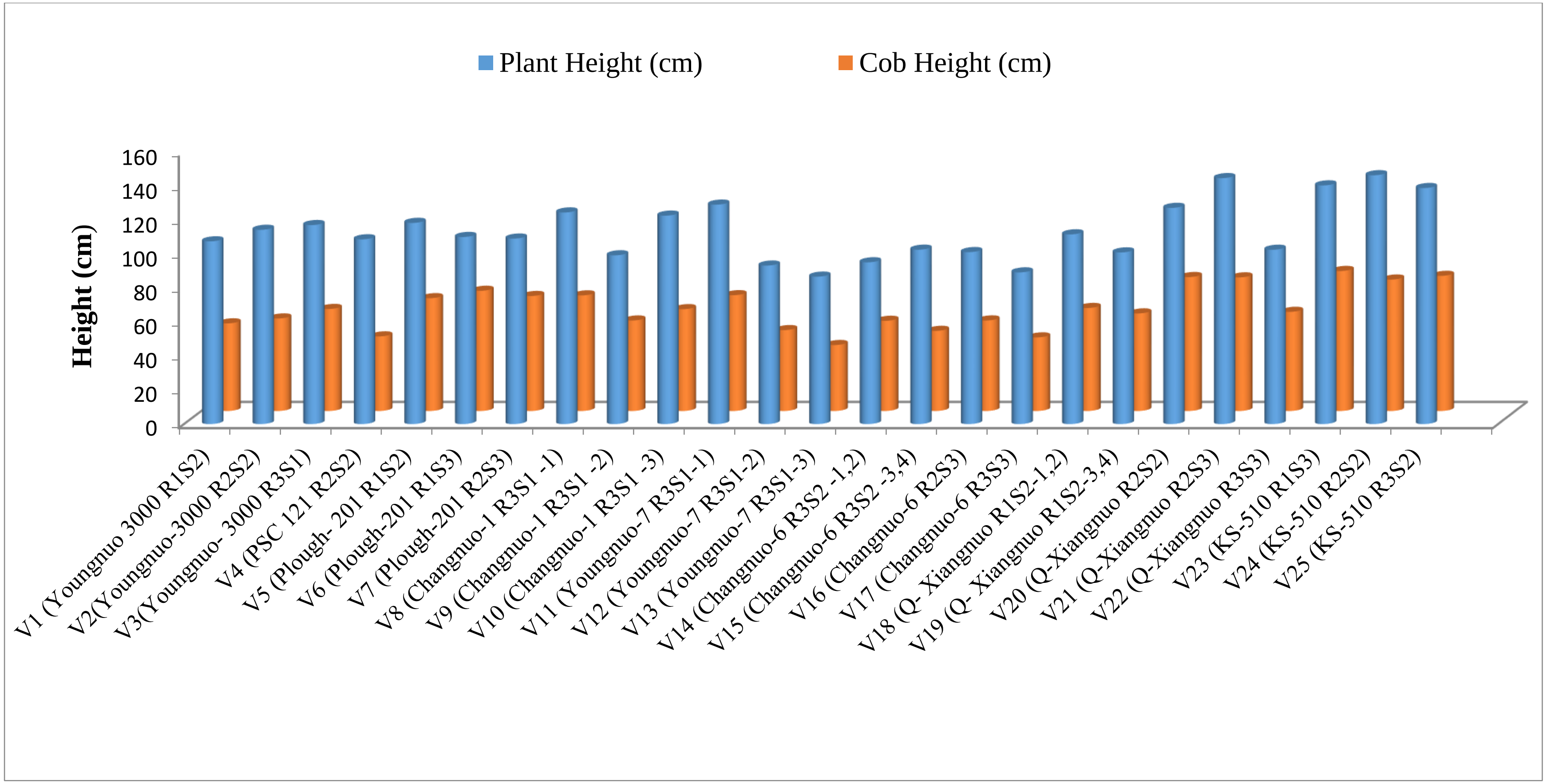

Figure 5. Variation of plant height and cob height in 25 F_4 populations of white maize

4.1.2 Days to 50% silking

Statistically significant variation was observed for days to 50% silking among white maize F_4 populations under the investigation (Table 4). The average days to 50% silking among white maize was recorded around 76.61 days. The maximum days to 50% silking was found in the population KS-510-R_1-S_3 (82.33) was followed by KS-510-R_3-S_2 (82.00). The minimum days to 50% silking was found in the population Youngnuo-7-R_3S_1-2 (68.33) followed by Youngnuo-7-R_3S_1-1 (69.33) (Table 5). According to Hasan *et al*. (2021) minimum days to silking were 72.33 days and maximum days to silking were 85.67 days for white maize, thus results supporting results of this experiment.

4.1.3 Plant height (cm)

Plant height was varied significantly due to different F_4 populations indicating considerable differences exist among the populations studied (Table 4). The lowest was observed in Youngnuo-7-R_3-S_1-3 (86.98 cm) was followed by Changnuo-6-R_3-S_3 (89.50 cm). On contrary, the highest was seen in KS-510-R_2-S_2 (146.62 cm) was followed by Q-Xiangnuo-R_2-S_3 (144.92 cm). It was observed that the short plant has been benefited against heavy storms and wind. So, short plant structures were found in this experiment was Youngnuo-7-R_3-S_1-3 (86.98 cm), Changnuo-6-R_3-S_3 (89.50 cm), and Youngnuo-7-R_3-S_1-2 (93.50 cm) and the average plant height was recorded 113.90 cm (Table 5). Plant height is an important agronomic character for selecting desirable genotypes for the breeding program (Ali *et al*., 2012). Plant height is a genetically as well as environmentally controlled trait and different segregating generations of white maize represent different plant heights. These results are also following the results of Ali (1994) who reported differences in plant height in different maize hybrids.

4.1.4 Cob height (cm)

Cob height varied significantly due to different selected white maize F_4 populations (Table 4). The average cob height was recorded as 60.98 cm, therefore the highest cob height was seen in KS-510-R_1-S_3 (82.6 cm) were followed by KS-510-R_3-S_2 (79.73 cm) and Q-Xiangnuo-R_2-S_2 (79.03 cm). The lowest was seen in Youngnuo-7-R_3-S_1-3 (38.92 cm). Cob height is an indicator for dwarf variety selection. The population of Youngnuo-7-R_3-S_1-3 and Changnuo-6-R_3-S_3 was showed the minimum height of cob (Table 5). These populations might be resistant to storms and heavy wind. Maximum difference between plant height and cob height is effective for dwarf plant selection (Roy, 2018). In Figure 5, plant height and cob height of 25 F_4 populations of white maize were presented.

4.1.5 Days to maturity

Statistically, significant variation was recorded for days to maturity for different white maize F_4 populations (Table 4). The average days to maturity were recorded 118.48 days. The highest (135.33) days to maturity was found in the population of KS-510-R_3-S_2 followed by KS-510-R_1-S_3 (134.33). The minimum (103.67) was observed in Youngnuo-7-R_3-S_1-2 followed by Youngnuo-7-R_3-S_1-3 (105.00) and Youngnuo-7-R_3-S_1-1 (106.33) (Table 5). In case of unfavorable condition likes heavy wind and storm in late time maize cultivation so it was needed to harvest early from the field. That's why an early maturating genotype from segregating population needs to be selected. For this reason, Youngnuo-7-R_3-S_1-2, Youngnuo-7-R_3-S_1-3, and Youngnuo-7-R_3-S_1-1 might be selected for further evaluation. Hasan *et al.,* (2021) found the average day to maturity was 119.67 with a range from 106.00 to 135.00, which almost similar with this experiment result.

4.1.6 Base diameter (cm)

The base diameter was represented significant variation among white maize F_4 populations (Table 4). The average value of base diameter was observed at 1.77 cm and the maximum base diameter was found in the F_4 populations of KS-510-R_2-S_2 (2.18) followed by Q-Xiangnuo-R_2-S_2 (2.05) and Q-Xiangnuo-R_2-S_3 (2.03) (Table 5). On the contrary, the minimum value was observed in Plough-201-R_1-S_3 (1.43) followed by Youngnuo-3000-R_1-S_2 (1.47) (Table 5). Base diameter is an important trait because it maintains the plant under unfavorable weather conditions like a hail storm and heavy wind. If the base diameter is higher, then the plants become strong and still stand without breaking in unfavorable condition. So, under this study populations of KS-510-R_2-S_2, Q-Xiangnuo-R_2-S_2 and Q-Xiangnuo-R_2-S_3 might be selected for this character.

4.1.7 Leaves per plant

Significant variation was observed for the number of leaves per plant among different white maize populations (Table 4). The average number of leaves per plant was recorded at 11.66. The highest (14.55) number of leaves per plant was recorded in the population of Q-Xiangnuo-R_2-S_3 which was followed by KS-510-R_3-S_2 (13.27) and Q-

Xiangnuo-R_2-S_2 (13.10). Whereas the least (8.36) was observed in the population of Youngnuo-7-R_3-S_1-3 followed by Youngnuo-7-R_3-S_1-2 (8.95) (Table 5). These findings are almost similar with Hasan *et al.* (2021) who observed significant differences for this trait while evaluating maize genotypes.

4.1.8 Number of branches of tassel

The number of branches of tassel was showed significant variation among different white maize F_4 populations (Table 4). The mean value of number of branches of tassel was 11.19. The highest number of branches of tassel was observed in the populations of KS-510-R_2-S_2 (16.45) which was followed by KS-510-R_3-S_2 (16.13) and Q-Xiangnuo-R_2-S_3 (16.07) and the least number (6.37) of branches of tassels was observed in the populations of PSC-121- R_2-S_2 (Table 5). Hasan *et al.* (2021) found the average value of number of branches of tassels was 12.47 that almost similar findings of this experiment.

4.1.9 Leaf length (cm)

The leaf length was showed significant variation among different white maize F_4 populations (Table 4). The average leaf length was observed at 70.20 cm. The longest leaf was found in KS-510-R_2-S_2 (82.75) followed by KS-510-R_1-S_3 (80.50). The lowest leaf length was observed in Q-Xiangnuo-R_3-S_3 (53.93) and Q- Xiangnuo-R_1-S_2-1, 2 (58.62) (Table 5). The grain yield and yield-related traits are positively associated with flag leaf area (Ashrafuzzaman *et al.*, 2009) and leaf length is an important content for chlorophyll and photosynthesis that is important in grain and total biomass production.

4.1.10 Leaf width (cm)

Leaf width is also an important factor for higher grain yield. Leaf width was significantly different among the studied populations (Table 4). The average leaf width was 6.71 cm. The highest (8.12 cm) leaf width was observed in PSC-121-R_2-S_2 followed by KS-510-R_2-S_2 (7.53 cm) and Youngnuo-7-R_3-S_1-1 (7.47 cm). The lowest leaf width was found in the population of Youngnuo-3000-R_2-S_2 (5.37 cm) followed by Plough-201-R_1-S_3 (5.87 cm) (Table 5).

4.1.11 Cob length (cm)

Significant variation was exhibited in respect of cob length among different F_4 populations (Table 4).The average cob length was 13.48 cm. The longest (16.35 cm) cob length was found in KS-510-R_1-S_3 was followed by Youngnuo-7-R_3-S_1-1 (15.71 cm). Cob length (10.81 cm) was the shortest in the genotype Plough-201-R_2-S_3 (Table 5). Naushad *et al.* (2007) was observed significant difference in maize genotypes for cob length.

4.1.12 Cob diameter (cm)

Cob diameter varied insignificantly in different white maize populations (Table 4). The average cob diameter was recorded at 4.41 cm with a range from 3.41 cm to 5.65 cm. The highest (5.01 cm) cob diameter was recorded in the population of PSC-121-R_2-S_2 followed by Changnuo-1-R_3-S_1-1 (4.86 cm), whereas the lowest (3.82 cm) cob diameter was observed in Q- Xiangnuo-R_1-S_2-3, 4 (Table 5). Similar findings were reported by Hasan *et al.* (2021).

4.1.13 Number of rows per cob

The number of rows per cob is a genetically controlled factor but the 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 populations (Table 4). The average row per cob was recorded at 12.46. The highest (15.67) row per cob was recorded in the population of Youngnuo-7-R_3-S_1-2 and it was followed by the KS-510-R_3-S_2 (14.02) and Youngnuo-7-R_3-S_1-1 (13.93), while the lowest (9.87) number of rows per cob was observed from Q-Xiangnuo-R_3-S_3 (Table 5). This result was almost similar with Shompa *et al.* (2020) in white maize.

4.1.14 Number of grains per row

The number of grains per row varied significantly due to different maize populations (Table 4). The average number of grains per row was recorded around 23.26 with a range from 11.20 to 39.25. The highest (30.88) number of grains per row was recorded in Changnuo-1-R_3-S_1-1 which was followed by KS-510-R_1-S_3 (28.53), whereas the lowest (16.43) number was observed from the population of Youngnuo-3000-R_2-S_2 (Table 5). The average number of grains per row was recorded around 25.70 by Hasan *et al.* (2021) and 26.38 by Shompa *et al.* (2020) for white maize.

4.1.15 100-grains weight (g)

100-grain weight is an important factor directly contributing to final grain yield. There was a prominent effect of different segregating populations on 100-grain weight. This was due to the genetically controlled factor that 100-grain weights of different populations were different. As for the effect of environmental factors on 100-grain weight concerned it could not be neglected but the selection of suitable population can manage the influence of the environment. Data indicated that highly significant variation present due to 100-grain weight among different maize populations (Table 4). The average 100-grain weight was 30.75 g with a range from 22.00 g to 40.00 g. The highest (37.58a g) 100-grain weight was recorded in the population of Youngnuo-3000-R_3-S_1 which was followed by Changnuo-6-R_2-S_3 (36.97 g) and Changnuo-6-R_3-S_2-1, 2 (36.47 g) while the lowest (23.54 g) weight of 100-grain was observed in Plough-201-R_1-S_3 (Table 5). Similar results were also reported by Jing *et al.* (2003) and Ali (1994).

4.1.16 Grain yield per plant (g)

Grain yield was varied significantly in different maize populations under the present study (Table 4). Data revealed that the average grain yield per plant was recorded at 81.16 g with a range from 35.20 g to 134.40 g. The highest (111.67 g) grain yield per plant was recorded in the population of Youngnuo-7-R_3-S_1-1 which was followed by Youngnuo-7-R_3-S_1-2 (103.33 g), Changnuo-6-R_3-S_2 -1,2 (101.23 g), and Changnuo-1-R_3-S_1-1 (100.70 g).The lowest (53.93 g) grain yield was observed from the population of Changnuo-6-R_3-S_2-3, 4 (Table 5). Tahir *et al. (*2008) reported that the maximum grain yield was obtained from HG-3740. The lowest (43.42 g) grain yield was observed from the genotype Yungnuo 7 which was statistically similar with Changnuo 6 (54.01 g). Hasan *et al.* (2021) found 73.02 g yield per plant in the genotype Yungnuo-30 and average yield per plant was 65.13 g.

Plate 4. Variation in cob of 25 F_4 populations of white maize

Plate 4. (cont'd)

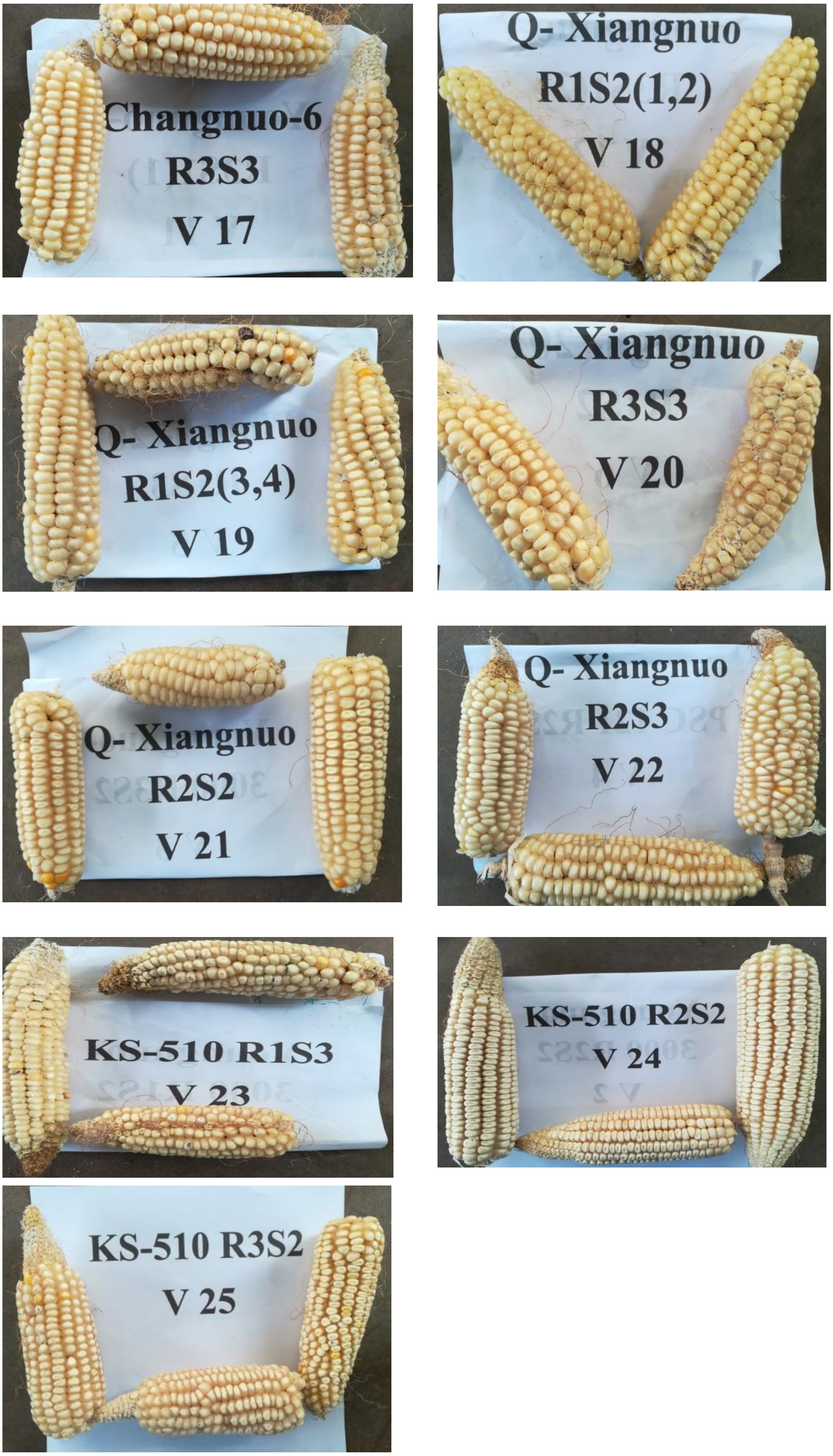

Plate 4. (cont'd) Variation in cob of 25 F_4 populations of white maize

Plate 5. Variation in grains of different 25 F_4 populations of white maize

Plate 5. (cont'd) Variation in grains of different 25 F_4 populations of white maize

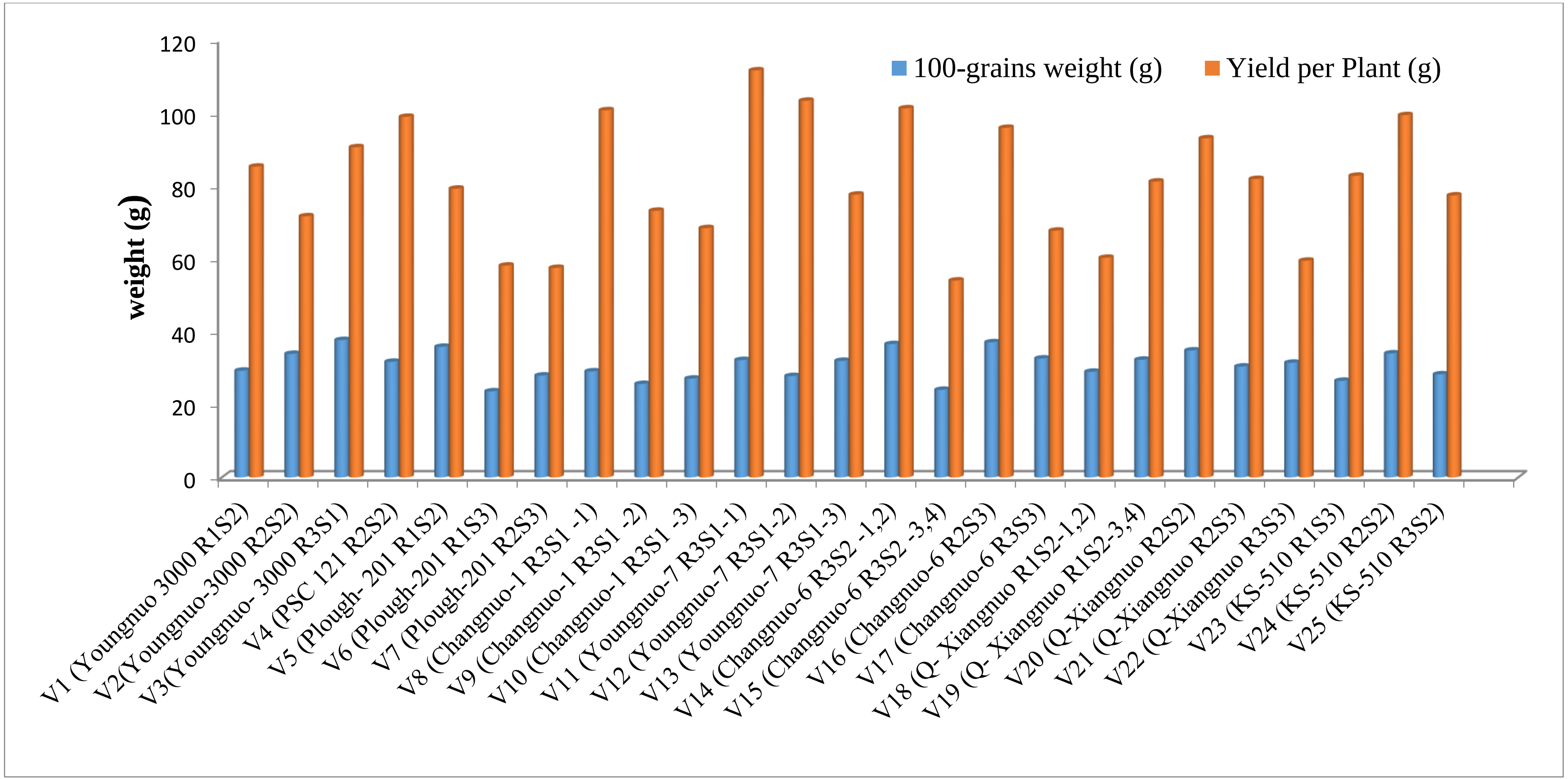

Figure 6. Variation in 100-grains weight and yield per plant of 25 F_4 populations of white maize

4.2 Variability

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

Genotypic variance, phenotypic variance, environmental variance, genotypic coefficient variance, phenotypic coefficient variance, environmental coefficient variance, heritability, genetic advance, and genetic advance percent mean were estimated for 16 traits in 25 populations of white maize presented in Table 6.

4.2.1 Days to 50% tasselling

For days to 50% tasselling; phenotypic variance (12.58) was higher than the genotypic variance (11.80) that indicating the environmental influence on these characters is low which was supported by a narrow difference between phenotypic (4.87%) and genotypic (4.72%) co-efficient of variation with (1.21%) environmental coefficient of variation. High heritability (94%) in days to 50% tasselling attached with a low genetic advance in the percentage of the mean (9.42%) (Table 6). This character was controlled by non-additive gene action and heterosis breeding would be rewarding.

4.2.2 Days to 50% silking

Days to 50% silking showed higher phenotypic variance (12.54) than the genotypic variance (11.89) that indicating lower environmental influence (0.78) on these characters which was supported by a narrow difference between phenotypic (4.62%) and genotypic (4.50%) co-efficient of variation (Table 6). High heritability (95%) attached with a low genetic advance in the percentage of the mean (9.03%) revealed the major role of non-additive gene action in the transmission of this character from parents to offspring.

4.2.3 Plant height (cm)

Plant height exhibited higher phenotypic variance (409.29) was higher than the genotypic variance (231.66) indicating that considerable environmental influence (177.63) for expression of this character which was supported by the moderate difference between phenotypic (17.76%) and genotypic (13.36%) co-efficient of variation (Table 6). Moderate heritability (57%) along with high genetic advance (23.59%) and high genetic advance in percent of the mean (20.71%) (Table 6) revealed the possibility of the 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). The greater the heritability of a particular trait, the lesser will be the environmental effect on its expression.

4.2.4 Cob height (cm)

Cob height showed higher phenotypic variance (228.24) than the genotypic variance (122.72) indicating that considerable environmental influence (105.52) for expression of this character. The phenotypic coefficient of variation (24.78%) was also higher than the genotypic coefficient of variation (18.17%), which supported earlier statement, that the environmental effect for the expression of this trait was (16.85%). Moderate heritability (54%) coupled with high genetic advance as percent of the mean (27.44) was observed for this trait (Table 6). This trait was most probably controlled by additive gene action and selection based on this trait for dwarf plant stature would be effective.

4.2.5 Days to maturity

Days to maturity exhibited high phenotypic variance (72.49) than the genotypic variance (71.42) that indicating less environmental influence (1.06) on the expression of this character which was supported by a narrow difference between phenotypic (7.19%) and genotypic (7.13%) co-efficient of variation. High heritability (99%) along with moderate genetic advance in the percentage of means (14.59%) (Table 6) that this trait was controlled by non-additive gene action.

Table 6. Estimation of genetic parameters for different characters of 25 F_4 white maize populations

Parameters	GV	PV	EV	GCV	PCV	ECV	Heritability	GA	GA(%) mean
50% tasselling	11.80	12.58	0.78	4.72	4.87	1.21	0.94	6.85	9.42
50% silking	11.89	12.54	0.65	4.50	4.62	1.05	0.95	6.92	9.03
Plant height	231.66	409.29	177.63	13.36	17.76	11.70	0.57	23.59	20.71
Cob height	122.72	228.24	105.52	18.17	24.78	16.85	0.54	16.73	27.44
Days to maturity	71.42	72.49	1.06	7.13	7.19	0.87	0.99	17.28	14.59
Base diameter	0.02	0.07	0.05	8.72	14.93	12.12	0.34	0.19	10.49
Leaves per plant	1.38	2.41	1.03	10.07	13.32	8.71	0.57	1.83	15.70
Branches of tassels	6.59	10.22	3.62	22.95	28.56	16.99	0.65	4.25	37.98
Leaf length	25.94	85.93	59.98	7.26	13.20	11.03	0.30	5.77	8.21
Leaf width	0.27	0.64	0.37	7.75	11.91	9.04	0.42	0.69	10.40
Cob length	1.34	3.87	2.53	8.59	14.59	11.79	0.35	1.41	10.43
Cob diameter	0.05	0.15	0.09	5.28	8.84	7.09	0.36	0.29	6.48
Rows per cob	1.07	2.86	1.79	8.28	13.57	10.75	0.37	1.29	10.42
Grains per row	3.88	21.23	17.35	8.47	19.81	17.91	0.18	1.74	7.46
100-grains weight	11.69	23.87	12.18	11.12	15.89	11.35	0.49	4.93	16.03
Yield Per Plant	155.85	514.56	358.72	15.38	27.95	23.34	0.30	14.15	17.44

GV= Genotypic variance, PV= Phenotypic variance, EV= Environmental variance, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, ECV= Environmental coefficient of variation, GA= Genetic advance, GA (%) mean= Genetic advance percentage mean

4.2.6 Base diameter (cm)

A difference between a phenotypic variance (0.07) and genotypic variance (0.02) supported the speculation that environment (0.05) had an effect on base diameter under the present study. A difference between GCV (8.72) and PCV (14.93) indicates that this character was responsive to environmental factors for their phenotypic expression. Moderate heritability (34%) and moderate genetic advance in percent of mean (10.49%) (Table 6), respectively, indicating this trait was controlled by additive gene action.

4.2.7 Number of leaves per plant

The differences between phenotypic variances (2.41) and genotypic variances (1.38) for leaves per plant indicating environmental influence (1.03). The value of PCV and GCV were 13.32% and 10.07% respectively for this trait which indicates that moderate variation exists among different populations (Table 6). Leaves per plant showed moderate heritability (57%) along with low genetic advance (2.11%) and medium genetic advance in percent of the mean (15.70%) (Table 6) revealed the predominance of both additive and non-additive gene action in the inheritance of this trait.

4.2.8 Number of branches of tassel

The number of branches of tassel showed the phenotypic variance and genotypic variance were 10.22 and 6.59, respectively; with relatively lower differences indicating less environmental influences (3.62) on the expression of this character as well as PCV (28.56%) and GCV (22.95%) is indicating the presence of considerable high variability among the populations. Higher heritability (65%) with a higher genetic advance in percent of the mean (37.98%) but low genetic advance (4.25) (Table 6).

4.2.9 Leaf length (cm)

Leaf length showed the phenotypic variance (85.93) was higher than genotypic variance (25.94), which showed there were high environmental influences (59.98). The value of PCV and GCV were 13.20% and 7.26% respectively for this trait. Leaf length showed moderate heritability (30%) with low genetic advance (5.77) and low genetic advance percent mean (8.21%) (Table 6).

4.2.10 Leaf width (cm)

Leaf width showed the phenotypic variance (0.64) is relatively higher than genotypic variance (0.27) and environmental variance was 0.37 as well as PCV and GCV were 11.91 and 7.75 respectively which was low. Leaf width showed moderate heritability (42%) with a moderate genetic advance in the percent of the mean (10.40%) (Table 6).

4.2.11 Cob length (cm)

Cob length showed moderate differences between phenotypic variance (3.87) and genotypic variance (1.34) indicating moderate environmental influence (2.53) on this character and the relatively moderate difference between PCV (14.59%) and GCV (8.59%) value indicating the apparent variation not only due to genotypes, but also due to the moderate influence of the environment (11.79%). The moderate heritability estimates of 35% with an expected genetic advance as percent of mean of 10.43% (Table 6). Moderate heritability coupled with moderate genetic advance was observed for this character, indicating little scope for the selection.

4.2.12 Cob diameter (cm)

Cob diameter showed the higher phenotype variance (0.15) was found than the genotypic variance (0.05), which indicated that the influence of environmental was low on this character. Thus higher coefficient of variation was observed between the phenotype (8.84%) and genotype (5.28%) (Table 6). Moderate heritability (36%) along with low genetic advances in the percentage of the mean (6.48%) (Table 6) indicated little scope for the selection upon this character due to the non-additive gene action.

4.2.13 Number of rows per cob

Phenotypic and genotypic variance for rows per cob were observed at 2.86 and 1.07, respectively, with less differences between them, suggested less influence of the environment (1.79) on the expression of the genes controlling this trait. The phenotypic coefficient of variation (13.57%) was higher than the genotypic coefficient of variation (8.28%) (Table 6), that suggested that the environment had a significant role in the expressions of this trait. Moderate heritability (37%) coupled with moderate genetic advances in percent of the mean (10.42%) (Table 6) attributed non-additive gene action. Similar results were reported by Chen *et al*. (1996), Satyanarayan and Kumar (1995), and Ojo *et al*. (2006).

4.2.14 Number of grains per row

Grains per row showed 21.23 and 3.88, respectively the phenotypic and genotypic variance with large differences between them indicating large environmental influences (17.35) on the expression of this character as well as PCV (19.81%) and GCV (8.47%) indicating the presence of considerable variability among the populations of white maize (Table 6). Low heritability (18%) coupled with a low genetic advance in percent of the mean (7.46%) (Table 6) attributed non-additive gene action. On the contrary results were reported by Abd El-Sattar (2003) that he found the high heritability and high genetic advance in the percent of the mean.

4.2.15 100-grains weight (g)

Hundred grains weight showed high phenotypic (23.87) and moderate genotypic (11.69) variance with high differences indicating that they were highly responsive to environmental factors (12.18) and the values of PCV and GCV were 15.89% and 11.12% indicating that the genotype has a considerable variation for this (Table 6). Similar results of PCV and GCV values for this trait were reported by Abirami *et al*. (2005). Moderate heritability (49%) along with low genetic advances (4.93) and moderate genetic advance percentage of the mean (16.03%) (Table 6) revealed the possibility of the predominance of both additive and non-additive gene action in the inheritance of this trait. Contrary results were reported by Anshuman *et al.* (2013). They found high heritability and high genetic advance in the percent of the mean.

4.2.16 Grain yield per plant (g)

The phenotypic variance (514.56) appeared high difference from the genotypic variance (155.85), suggesting a high influence of the environment (358.72) on the expression of the genes controlling this trait. The phenotypic coefficient of variation (27.95%) was higher than the genotypic coefficient of variation (15.38%) which suggested that the environment has an influence (23.34%) on the expression of this trait (Table 6). Moderate heritability (30%) coupled with moderate genetic advance as percent of the mean (17.44%) (Table 6) were observed indicating that this trait is controlled by additive gene action which is very useful in selection. The higher value of variance for grain yield per plant indicates that this character can be used as the generic parameter for the improvement and selection of higher-yielding genotypes. Improvement of the crop may be easy by simple selection because high heritability along with high genotypic variation disclosed the presence of an additive gene effect.

4.3 Correlation Coefficient

Yield is the result of the combined effect of the environment and several yield contributing characters. Understanding the interaction of characters among themselves and with the environment is beneficial in plant breeding. From this, it would be possible to bring about genetic up-gradation in one character by the selection of the other of a pair. Knowledge about character associations would surely help to identify the characters to make the selection for a higher yield. Hence, an attempt has been made to study the character association in the white maize F_4 segregating population at both genotypic and phenotypic levels.

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

4.3.1 Days to 50% tasseling

A highly significant positive association was recorded of days to 50% tasseling of maize genotypes with days to 50% silking (0.99 and 0.96), plant height (0.50 and 0.37), cob height (0.42 and 0.32), days to maturity (0.76 and 0.72), the number of leaves per plant (0.40 and 0.26) and leaf length (0.55 and 0.32) at both level and association with base diameter, branches of the tassel, leaf width, cob length, cob diameter, number of rows per cob, number of grains per row, 100-seed weight and grains yield per plant were non-significant (Table 7).

4.3.2 Days to 50% silking

Days to 50% silking was observed a highly significant positive association with plant height (0.55 and 0.40), cob height (0.49 and 0.37), days to maturity (0.80 and 0.77), number of leaves per plant (0.46 and 0.33), and leaf length (0.59 and 0.32) at both genotypic and phenotypic level and association with base diameter, branches of the tassel, leaf width, cob length, cob diameter, number of rows per cob, number of grains per row, 100-seed weight and grain yield per plant were non-significant (Table 7).

4.3.3 Plant height (cm)

Plant height had highly significant and positive correlation with cob height (0.90 and 0.86), days to maturity (0.61 and 0.46), base diameter (0.29 and 0.31), number of leaves per plant (0.78 and 0.59), number of branches of tassel (0.87 and 0.59), leaf length (0.80 and 0.70), leaf width (0.46 and 0.25), cob length (0.57 and 0.4), cob diameter (0.18 and 0.28) and number of grains per row (0.52 and 0.29) at both genotypic and phenotypic levels. Number of rows per cob (0.15 and 0.16), 100 grain weight (-0.04 and -0.01) and grain yield per plant (0.27 and 0.19) were non-significant (Table 7). Abou-Deif (2007); Ojo, *et al.* (2006); Sadek *et al.* (2006), and Mohammadi, *et al.* (2003) reported that plant height was significantly and positively correlated with each number of grains per row and cob diameter. On the contrary, Srekove *et al.* (2011) reported a 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). In this study, plant height was non-significant to grain yield.

4.3.4 Cob height (cm)

Cob height had a highly significant and positive correlation with days to maturity (0.46 and 0.33), base diameter (-0.02 and 0.23), number of leaves per plant (0.88 and 0.60), number of branches of tassel (0.83 and 0.54), leaf length (0.51 and 0.50), cob length (0.46 and 0.36) and number of grains per row (0.37 and 0.27) at both genotypic and phenotypic level and association with leaf width, cob length, cob diameter, number of rows per cob, 100-grain weight and grain yield per plant were non-significant (Table 7).

4.3.5 Days to maturity

A highly significant positive correlation was observed of days to maturity with the number of leaves per plant (0.40 and 0.33), the number of branches of tassel (0.34 and 0.28), leaf length (0.82 and 0.45), leaf width (0.48 and 0.31) and cob length (0.43 and 0.27) at both genotypic and phenotypic level and association with base diameter, cob diameter, number of rows per cob, number of grains per row, 100-grain weight and grain yield per plant were non-significant (Table 7).

Table 7. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for 25 F_4 populations of white maize

Traits		DT	DS	PH	CH	DM	BD	TL	BT	LL	LW	CL	CD	RPC	GPR	HGW	YPP
DT	G	1**															
	P	1**															
DS	G	0.99**	1**														
	P	0.96**	1**														
PH	G	0.50*	0.55**	1**													
	P	0.37**	0.40**	1**													
CH	G	0.42*	0.49*	0.90**	1**												
	P	0.32**	0.37**	0.86**	1**												
DM	G	0.76**	0.80**	0.61**	0.46*	1**											
	P	0.72**	0.77**	0.46**	0.33**	1**											
BD	G	-0.16ns	-0.16ns	0.29ns	-0.02ns	0.17ns	1**										
	P	-0.04ns	-0.07ns	0.31**	0.23*	0.10ns	1**										
TL	G	0.40*	0.46*	0.78**	0.88**	0.40*	0.49*	1**									
	P	0.26*	0.33**	0.59**	0.60**	0.33**	0.17ns	1**									
BT	G	0.22ns	0.25ns	0.87**	0.83**	0.34ns	0.42*	0.62**	1**								
	P	0.15ns	0.20ns	0.59**	0.54**	0.28*	0.24*	0.50**	1**								
LL	G	0.55**	0.59**	0.80**	0.51**	0.82**	0.41*	0.47*	0.50*	1**							
	P	0.32**	0.32**	0.70**	0.50**	0.45**	0.38**	0.37**	0.38**	1**							
LW	G	-0.09ns	-0.07ns	0.46*	0.18ns	0.48*	0.59**	0.14ns	0.34ns	0.68**	1**						
	P	-0.01ns	-0.01ns	0.25*	0.17ns	0.31**	0.47**	-0.01ns	0.14ns	0.31**	1**						
CL	G	0.11ns	0.16ns	0.57**	0.46*	0.43*	0.55**	0.55**	0.62**	0.55**	0.90**	1**					
	P	0.07ns	0.08ns	0.46**	0.36**	0.27*	0.47**	0.39**	0.38**	0.50**	0.48**	1**					
CD	G	-0.15ns	-0.13ns	0.18ns	-0.04ns	0.06ns	0.10ns	-0.05ns	-0.29ns	0.39ns	0.23ns	-0.29ns	1**				
	P	-0.03ns	-0.08ns	0.28*	0.09ns	0.05ns	0.29*	0.06ns	-0.06ns	0.53**	0.26*	0.27*	1**				
RPC	G	-0.12ns	-0.14ns	0.15ns	0.03ns	0.02ns	0.03ns	-0.34ns	-0.02ns	0.66**	0.38ns	-0.20ns	0.68**	1**			
	P	-0.10ns	-0.07ns	0.16ns	0.06ns	0.02ns	0.05ns	0.02ns	0.07ns	0.30*	0.21ns	0.26*	0.46**	1**			
GPR	G	0.02ns	0.04ns	0.52**	0.37*	0.22ns	0.51**	0.35ns	0.17ns	0.48*	0.96**	0.51**	-0.13ns	0.14ns	1**		
	P	0.04ns	0.01ns	0.29*	0.27*	0.11ns	0.45**	0.10ns	0.19ns	0.38**	0.46**	0.62**	0.32**	0.28*	1**		
HGW	G	-0.12ns	-0.12ns	-0.04ns	-0.14ns	0.06ns	0.32ns	-0.12ns	0.01ns	-0.03ns	0.17ns	0.23ns	0.27ns	-0.02ns	-0.54**	1**	
	P	-0.04ns	-0.08ns	-0.01ns	-0.02ns	0.05ns	0.24*	0.03ns	-0.04ns	0.07ns	0.14ns	0.32**	0.30**	0.05ns	-0.03ns	1**	
YPP	G	-0.24ns	-0.23ns	0.27ns	0.03ns	0.11ns	0.53**	-0.12ns	0.06ns	0.64**	0.76**	0.28ns	0.59**	0.73**	0.26ns	0.49*	1**
	P	-0.08ns	-0.11ns	0.19ns	0.13ns	0.07ns	0.41**	-0.01ns	0.09ns	0.36**	0.44**	0.57**	0.56**	0.64**	0.66**	0.52**	1**

DT=Days to 50% tasselling, DS = Days to 50% silking, PH = Plant height (cm), CH = Cob height (cm), DM = Days to maturity, BD = Base diameter (cm), TL = No. of leaves per plant, BT = No. of branches of tassel, LL= Leaf length (cm), LW= Leaf width (cm), CL = Cob length (cm), CD (cm) = Cob diameter (cm), RPC = No. of rows per cob, GPR = No. of grains per row, HGW = 100-grains weight (g), YPP= Yield per plant (g)

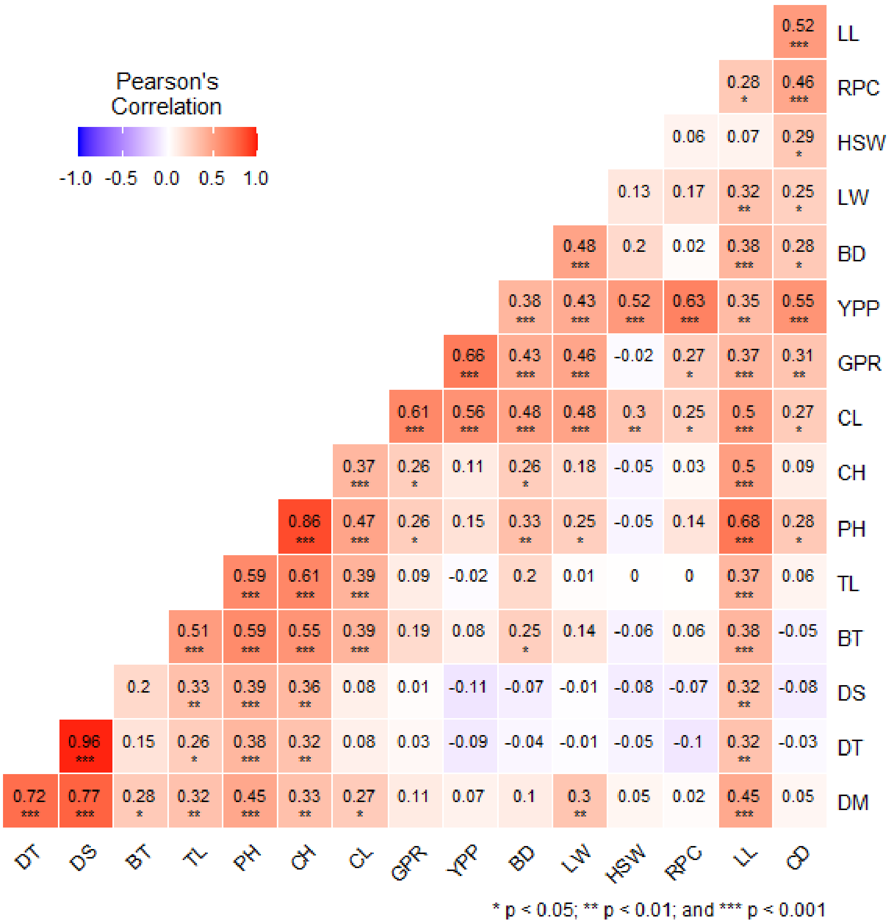

Figure 7. Correlation of sixteen characters in 25 F_4 populations of white maize

DT=Days to 50% tasselling, DS = Days to 50% silking, PH = Plant height (cm), CH = Cob height (cm), DM = Days to maturity, BD = Base diameter (cm), TL = No. of leaves per plant, BT = No. of branches of tassel, LL= Leaf length (cm), LW= Leaf width (cm), CL = Cob length (cm), CD (cm) = Cob diameter (cm), RPC = No. of rows per cob, GPR = No. of grains per row, HGW = 100-grains weight (g), YPP= Yield per plant (g)

4.3.6 Base diameter (cm)

A highly significant positive correlation was observed of base diameter with number of leaves per plant (0.49 and 0.17), number of branches of tassel (0.42 and 0.24), leaf length (0.41 and 0.38), leaf width (0.59 and 0.47), cob length (0.55 and 0.47), cob diameter (0.10 and 0.29), number of grain per row (0.51 and 0.45), hundred-grain weight (0.32 and 0.24) and yield per plant (0.53 and 0.41) at both genotypic and phenotypic level. Rows per cob (0.03 and 0.05) were non-significant (Table 7).

4.3.7 Number of leaves per plant

The number of leaves per plant showed positive significant interaction with the number of branches of tassel (0.62 and 0.50), leaf length (0.47 and 0.37), and cob length (0.55 and 0.39) at both genotypic and phenotypic levels and association with leaf width, cob diameter, number of rows per cob, number of grains per row, 100-seed weight and grain yield per plant were non-significant (Table 7). Triveni *et al*. (2014) found the number of leaves per plant of maize highly significantly and positively correlated with its grain yield where it is the opposite of the present findings.

4.3.8 Number of branches of tassel

The number of branches per tassel exhibited a positive significant correlation with leaf length (0.50 and 0.38) and cob length (0.62 and 0.38) at both genotypic and phenotypic levels. Association with leaf width, cob diameter, number of rows per cob, number of grains per row, 100 seed weight, and yield per plant were non-significant (Table 7).

4.3.9 Leaf length (cm)

Leaf length exhibited a significant positive association with leaf width (0.68 and 0.31), cob length (0.55 and 0.50), cob diameter (0.39 and 0.53), numbers of rows per cob (0.66 and 0.30), numbers of grain per row (0.48 and 0.38), and grain yield per plant (0.64 and 0.36) at both genotypic and phenotypic level and association with 100 seed weight was non-significant (Table 7). Results of this study imply that maize grain yield can be improved by considering leaf length.

4.3.10 Leaf width (cm)

Leaf width exhibited a significant positive association with cob length (0.90 and 0.48), cob diameter (0.23 and 0.26), numbers of grain per row (0.96 and 0.46), and grain yield per plant (0.76 and 0.44) at both genotypic and phenotypic level and association with numbers of rows per cob and 100 seed weight were non-significant (Table 7). Results of this study imply that maize grain yield can be improved by considering leaf width.

4.3.11 Cob length (cm)

Cob length showed a highly significant and positive correlation with cob diameter (0.27), the number of rows per cob (0.26), 100-grain weight (0.32), and grain yield per plant (0.57) at the phenotypic level in the genotypic level they were non-significant. Cob length showed a highly significant and positive correlation with the number of grains per row (0.51 and 0.62) at genotypic and phenotypic levels (Table 7). The result indicated that grain yield was positively and significantly associated with cob length (0.618) and plant height with cob length (0.471) reported by Pandey *et al.*, (2017).

4.3.12 Cob diameter (cm)

Cob diameter exhibited a significant and positive association with the number of rows per cob (0.68 and 0.46), the number of grains per row (-0.13 and 0.32), hundred-grain weight (0.27 and 0.30), and grain yield per plant (0.59 and 0.56) at both genotypic and phenotypic levels (Table 7). It was an important character that associated with grain yields so; selection based on this character was impactful.

4.3.13 Number of rows per cob

The number of rows per cob had a positive and significant correlation with the number of grains per row (0.14 and 0.28), and grain yield per plant (0.73 and 0.64) at both genotypic and phenotypic levels. A non-significant correlation was observed with the hundred seed weight at the genotypic and phenotypic levels (Table 7). On the contrary, Amin *et al.* (2003) and Mohammadi *et al.* (2003) reported that the number of rows per cob showed significant and negative correlations with 100-seed weights.

4.3.14 Number of grains per row

The number of grains per row had a negative and highly significant correlation with 100 grains weight (0.54) at the genotypic level and a positive and highly significant correlation with grain yield per plant (0.66) at phenotypic levels (Table 7). Amin *et al.* (2003) indicated that the number of grains per row was the highest contributor to variation in grain yield directly or indirectly. Grains per row (0.656) were positively and significantly associated with grain yield per plant reported by Pandey *et al.* (2017). This study also supported the notion.

4.3.15 100-grains weight (g)

A highly significant positive correlation was observed between 100-seed weight with grain yield per plant (0.49 and 0.52) at both genotypic and phenotypic levels (Table 7). Grain yield is considered to have a 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 relationship was negative, while Alvi *et al.* (2003) studied the relationship between these two traits established strong correlations between grain yield and 100-seed weight.

4.4 Path Coefficient Analysis

Association of character determined by correlation co-efficient might not provide an exact picture of the relative importance of the direct and indirect influence of each of yield components on total yield per plant. As a matter of fact, 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 the genotypic and phenotypic level which also measured the relative importance of each component. Grain yield per plant was considered as a dependent variable and 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 a tassel, leaf length (cm), leaf width (cm), cob length (cm), cob diameter (cm), no. of rows per cob, no. of grains per row and 100-grains weight (g) were casual (independent) variables. Estimation of the direct and indirect effect by path co-efficient analysis for maize was presented in (Table 8).

4.4.1 Days to 50% tasselling

Genotypic path analysis revealed that days to 50% tasselling had a positive direct effect (3.45) on grain yield per plant (Table 8). It showed negligible positive indirect effect through cob height (0.21), days to maturity (0.11), number of leaves per plant (0.14), number of branches of tassel (0.02), and cob length (0.02), whereas it showed negative indirect effect via days to 50% silking (3.25), plant height (0.37), base diameter (0.02), leaf length (0.30), leaf width (0.05), cob diameter (0.05), number of rows per cob (0.10) and hundred seed weight (0.04) (Table 8).

4.4.2 Days to 50% silking

Genotypic path analysis revealed that days to 50% silking had a negative direct effect (3.25) on grain yield per plant (Table 8) and it was contradictory by Pandey *et* *al.* (2017). It showed more positive indirect effect through days to tasselling (3.44) and negligible positive effect via cob height (0.25), days to maturity (0.11), number of leaves per plant (0.16), number of branches of tassel (0.02), and cob length (0.03), whereas negative indirect effects through plant height (0.40), base diameter (0.02), leaf length (0.32), leaf width (0.04), cob diameter (0.05) and number of rows per cob (0.12) and 100-seed weight (0.04) (Table 8).

4.4.3 Plant height (cm)

Plant height had a negative direct effect (0.73) on grain yield per plant (Table 8) and it was a similar finding with the results of Pandey *et al.* (2017) and who found a negative direct effect of plant height on grain yield. On the contrary, Shompa *et al.* (2020) found the positive effect of plant height on grain yield. Plant height is an important trait that affects grain yield. Taller plants need more plant nutrients to complete more vegetative growth than the reproductive phase that results in late maturation of cob. It showed a high positive indirect effect through days to tasselling (1.74), cob height (0.45), leaf width (0.24) and total leaves (0.27), negligible positive indirect effect via days to maturity (0.09), base diameter (0.03), number of branches of tassel (0.07), cob length (0.11), cob diameter (0.06), number of rows per cob (0.12) and grains per row (0.04) (Table 8). The plant height showed a highly positive indirect effect for cob height (0.1421) (Jakhar *et al.*, 2017). It showed a negative indirect effect through days to 50% silking (1.79), leaf length (0.43), and 100-seed weight (0.02). Emer (2011) and Mohan (2002) indicated that plant height had a negative direct effect (0.616) on yield because of its negative indirect effect through cob length and 100-grain weight.

4.4.4 Cob height (cm)

Path coefficient analysis revealed that cob height had a positive direct effect (0.50) on grain yield per plant (Table 8). On the contrary, Shompa *et al.* (2020) found that cob height had a negative direct effect on grain yield per plant. It showed a positive indirect effect through days to 50% tasselling (1.46), days to maturity (0.06), number of total leaves (0.31), number of branches of tassels (0.07), leaf width (0.09), cob length (0.09), rows per cob (0.03) and number of grains per row (0.03). It showed negative indirect effect through days to 50% silking (1.60), plant height (0.66), base diameter (0.01), leaf length (0.27), cob diameter (0.01) and 100-seed weight (0.05) (Table 8). The cob height showed a highly negative indirect effect for plant height (0.0852) reported by Jakhar *et al.* (2017) which was supported by this experiment.

4.4.5 Days to maturity

Path analysis revealed that days to maturity had a positive direct effect (0.14) on grain yield per plant (Table 8). It showed a positive indirect effect through days to 50% tasselling (2.62), cob height (0.23), base diameter (0.02), number of total leaves per plant (0.14), branches of tassels (0.03), leaf width (0.25), cob length (0.09), cob diameter (0.02), number of rows per cob (0.02), number of grains per row (0.02) and 100-seed weight (0.02). On the other hand, days to 50% silking (2.60), plant height (0.45) and leaf length (0.44) represented a negative indirect effect (Table 8).

4.4.6 Base diameter (cm)

Path analysis revealed that base diameter had a positive direct effect (0.12) on grain yield per plant (Table 8). Shompa (2018) also found the positive direct effect of base diameter on the grain yield per plant. It showed positive indirect effect via days to 50% silking (0.53), days to maturity (0.02), number of total leaves (0.17), number of branches of tassels (0.04), leaf width (0.31), cob length (0.11), cob diameter (0.04), number of rows per cob (0.03), number of grains per row (0.04) and 100-seed weight (0.12). On the other hand, negative indirect effect via days to 50% tasselling (0.56), plant height (0.21), cob height (0.01), and leaf length (0.22) (Table 8).

4.4.7 Number of leaves per plant

The number of leaves per plant had a positive direct effect (0.35) on grain yield. It was found that the number of leaves per plant had a positive indirect effect on grain yield per plant through days to 50% tasselling (1.37), cob height (0.44), days to maturity (0.06), base diameter (0.06), the number of branches of tassels (0.05), leaf width (0.07), cob length (0.11) and grains per row (0.03). The number of leaves per plant showed a negative indirect effect via days to 50% silking (1.49), plant height (0.57), leaf length (0.25), cob diameter (0.02), and rows per cob (0.28) (Table 8).

Table 8. Partitioning genotypic correlation coefficient into direct (bold) and indirect effects of 16 traits by path analysis of white maize

Parameter	DT	DS	PH	CH	DM	BD	TL	BT	LL	LW	CL	CD	RPC	GPR	HGW	YPP
DT	**3.45**	-3.25	-0.37	0.21	0.11	-0.02	0.14	0.02	-0.30	-0.05	0.02	-0.05	-0.10	0.00	-0.04	-0.24ns
DS	3.44	**-3.25**	-0.40	0.25	0.11	-0.02	0.16	0.02	-0.32	-0.04	0.03	-0.05	-0.12	0.00	-0.04	-0.23ns
PH	1.74	-1.79	**-0.73**	0.45	0.09	0.03	0.27	0.07	-0.43	0.24	0.11	0.06	0.12	0.04	-0.02	0.27ns
CH	1.46	-1.60	-0.66	**0.50**	0.06	-0.01	0.31	0.07	-0.27	0.09	0.09	-0.01	0.03	0.03	-0.05	0.03ns
DM	2.62	-2.60	-0.45	0.23	**0.14**	0.02	0.14	0.03	-0.44	0.25	0.09	0.02	0.02	0.02	0.02	0.11ns
BD	-0.56	0.53	-0.21	-0.01	0.02	**0.12**	0.17	0.04	-0.22	0.31	0.11	0.04	0.03	0.04	0.12	0.53**
TL	1.37	-1.49	-0.57	0.44	0.06	0.06	**0.35**	0.05	-0.25	0.07	0.11	-0.02	-0.28	0.03	-0.04	0.12ns
BT	0.77	-0.81	-0.64	0.41	0.05	0.05	0.21	**0.08**	-0.27	0.18	0.13	-0.10	-0.02	0.01	0.00	0.06ns
LL	1.90	-1.93	-0.59	0.25	0.11	0.05	0.16	0.04	**-0.54**	0.36	0.11	0.14	0.55	0.04	-0.01	0.64**
LW	-0.31	0.22	-0.34	0.09	0.07	0.07	0.05	0.03	-0.36	**0.53**	0.18	0.08	0.32	0.08	0.06	0.76**
CL	0.38	-0.51	-0.42	0.23	0.06	0.06	0.19	0.05	-0.30	0.48	**0.20**	-0.10	-0.17	0.04	0.09	0.28ns
CD	-0.52	0.42	-0.13	-0.02	0.01	0.01	-0.02	-0.02	-0.21	0.12	-0.06	**0.36**	0.56	-0.01	0.10	0.59**
RPC	-0.41	0.47	-0.11	0.01	0.00	0.01	-0.12	-0.01	-0.36	0.20	-0.04	0.24	**0.83**	0.01	-0.01	0.73**
GPR	0.06	-0.13	-0.38	0.18	0.03	0.06	0.12	0.01	-0.26	0.51	0.10	-0.04	0.11	**0.08**	-0.20	0.26ns
HGW	-0.42	0.40	0.03	-0.07	0.01	0.04	-0.04	0.00	0.02	0.09	0.05	0.10	-0.02	-0.04	**0.37**	0.49*

** = Significant at 1%, * = Significant at 5%,

Residual effect 0.085

DT=Days to 50% tasselling, DS = Days to 50% silking, PH = Plant height (cm), CH = Cob height (cm), DM = Days to maturity, BD = Base diameter (cm), TL = No. of leaves per plant, BT = No. of branches of tassel, LL= Leaf length (cm), LW= Leaf width (cm), CL = Cob length (cm), CD = cob diameter (cm), RPC = No. of rows per cob, GPR = No. of grains per row, HGW = 100-grains weight (g), YPP= Yield per plant (g)

4.4.8 Number of branches of tassel

The number of branches of tassel had a positive direct effect (0.08) on grain yield. It was found that the number of branches of tassel had a positive indirect effect on grain yield through days to 50% tasselling (0.77), cob height (0.41), days to maturity (0.05), base diameter (0.05), number of total leaves (0.21), leaf width (0.18), cob length (0.13) and grains per row (0.01). The number of branches of tassel showed a negative indirect effect via days to 50% silking (0.81), plant height (0.64), leaf length (0.27), cob diameter (0.10), and rows per cob (0.02) (table). Hasan *et al.* (2021) also indicated that the number of branches of tassel had a positive direct effect on grain yield.

4.4.9 Leaf length (cm)

Leaf length had a direct negative effect (0.54) on the grain yield per plant. It was found that leaf length had a positive indirect effect on grain yield per plant through days to 50% tasselling (1.90), cob height (0.25), days to maturity (0.11), base diameter (0.05), number of total leaves per plant (0.16), number of total branches of a tassel (0.04), leaf width (0.36), cob length (0.11), cob diameter (0.14), grains per row (0.04) and rows per cob (0.55). It had a negative indirect effect on grain yield via days to 50% silking (1.93) and plant height (0.59).

4.4.10 Leaf width (cm)

Leaf width had a direct positive effect (0.53) on the grain yield per plant. It was found that leaf width had a positive indirect effect on grain yield per plant through days to 50% silking (0.22), cob height (0.09), days to maturity (0.07), base diameter (0.07), number of total leaves per plant (0.05), number of total branches of a tassel (0.03), cob length (0.18), cob diameter (0.08), grains per row (0.08), rows per cob (0.32) and 100-seed weight (0.06). It had a negative indirect effect on grain yield via days to 50% tasselling (0.31) and plant height (0.34).

4.4.11 Cob length (cm)

Cob length had a positive direct effect (0.20) on grain yield. It was found that cob length had a positive indirect effect on grain yield through days to 50% tasselling (0.38), cob height (0.23), days to maturity (0.06), base diameter (0.06), number of total leaves per plant (0.19), number of branches per tassels (0.05), leaf width (0.48), grains per row (0.04) and 100-seed weight (0.09). Wannows *et al.* (2010) and Shompa *et al.* (2020) reported similar findings. It was a negative indirect effect on grain yield per plant via days to 50% silking (0.51), plant height (0.42), leaf length (0.30), cob diameter (0.10), and the number of rows per cob (0.17). Its indirect effects via plant height were negative (Parh *et al.*, 1986), which was similar to these findings.

4.4.12 Cob diameter (cm)

Path analysis revealed that cob diameter had a positive direct effect (0.36) on yield per plant (Table 8). It showed a positive indirect effect through days to 50% silking (0.42), days to maturity (0.01), base diameter (.01), leaf width (0.12), number of rows per cob (0.56), and 100-seed weight (0.10). Whereas cob diameter showed a negative indirect effect on grain yield through days to 50% tasselling (0.52), plant height (0.13), cob height (0.02), number of total leaves (0.02), leaf length (0.21), and cob length (0.06) (table). The cob diameter showed a highly positive indirect effect for cob height reported by Jakhar *et al.* (2017), Hasan *et al.* (2021), and Shompa *et al.* (2020) that was similar to this experiment.

4.4.13 Number of rows per cob

The number of rows per cob revealed a high positive direct effect (0.83) on grain yield per plant. It had a positive indirect effect on grain yield through days to 50% silking (0.47), leaf width (0.20), and cob diameter (0.24) (Table 8). These results were in agreement with the results which Ahmad and Saleem (2003), Najeeb *et al*. (2009), and Hasan *et al.* (2021) found in their research. No. of rows per cob showed negative indirect effect via days to 50% tasselling (0.41), plant height (0.11), number of total leaves (0.12), and leaf length (0.36) (Table 8).

4.4.14 Number of grains per row

Path analysis revealed that the number of grains per row had a positive direct effect (0.08) on yield per plant (Table 8). It showed a positive indirect effect through days to 50% tasselling (0.06), cob height (0.18), days to maturity (0.03), base diameter (0.06), the number of total leaves per plant (0.12), leaf width (0.51), cob length (0.10) and rows per cob (0.11), whereas the number of grains per row showed negative indirect effect through days to 50% silking (0.13), plant height (0.38), leaf length (0.26) and 100-seed weight (0.20). The number of grains per row showed a positive direct effect for grain yield reported by Hasan *et al.* (2021) and it was similar with this experiment.

4.4.15 100-grains weight (g)

Path analysis revealed that the weight of 100-grains had a positive direct effect (0.37) on yield per plant (Table 8). Shompa *et al.* (2020) also found a similar positive effect. It showed positive indirect effect through days to 50 % silking (0.40), plant height (0.03), days to maturity (0.01), base diameter (0.04), leaf width (0.09), leaf length (002), cob length (0.05) and cob diameter (0.10). 100- grain weight was showed a negative indirect effect on yield via days to 50% tasselling (0.42), cob height (0.07), total leaves per plant (0.04), number of rows per cob (0.02), and grains per row (0.04) (Table 8).

4.4.16 Grain yield per plant (g)

The estimation of correlation indicates only the extent and nature of the association between yield and its attributes but does not show the direct and indirect effects of different yield attributes on yield. 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 that are not revealed from the correlation studies. The highly positive and direct effect on yield was exhibited by days to 50% tasselling (3.45), cob height (0.50), number of total leaves per plant (0.35), leaf width (0.53), cob length (0.20) cob diameter (0.36), rows per cob (0.83) and 100-seed weight (0.37) indicating the effectiveness of direct selection, whereas direct and negative effects were exhibited days to 50% silking (3.25), plant height (0.73) and leaf length (0.54) indicating the effectiveness of indirect selection (Table 8).

4.5 Residual Effect

The magnitude of residual effect (0.085) indicated that traits included in path analysis explained about 99.92% of the variation in plant yield. However, the remaining variation in plant yield (0.08%) can be attained by incorporating other yield-related traits in the path analysis as far as studies involving the association of traits are concerned. Hasan *et al.* (2021) found a residual effect of 0.322 and Shompa *et al.* (2020) found a residual effect (0.0014) in the case of yield per plant for white maize study.

4.6 Selection of F_4 Population

From the mean performance, it was revealed that populations Youngnuo-7-R_3-S_1-3, Changnuo-6-R_3-S_3, Youngnuo-7-R_3-S_1-2 showed dwarf plant stature among all the 25 F_4 populations (Table 5). So, they might be selected for further investigation for dwarf plant progenies. These were also the least cob height which gives an advantage in the unfavorable weather like heavy rain and storm conditions these might be tolerant and able to provide reasonable yield. For early maturity, population of Youngnuo-7-R_3-S_1-2, Youngnuo-7-R_3-S_1-3, and Youngnuo-7-R_3-S_1-1 showed the lowest days to maturity (Table 5).

So, based on overall performance populations of Youngnuo-7-R_3-S_1-2, Youngnuo-7-R_3-S_1-3, and Youngnuo-7-R_3-S_1-1 might be selected as promising for both of the traits short duration and dwarf plant stature.

Table 9. F_4 populations selected based on short stature yield potentiality

Genotype	Plant height (cm)	Cob height cm)	Days to maturity	Yield per plant (g)
Youngnuo-7-R_3-S_1-3	86.98	38.92	105.00	77.53
Changnuo-6-R_3-S_3	89.50	43.42	115.00	67.63
Youngnuo-7-R_3-S_1-2	93.50	47.72	103.67	103.33
Changnuo-6-R_3-S_2 -1,2	95.43	53.22	121.33	101.23
Changnuo-1-R_3-S_1 -1	124.73	68.20	116.33	100.70
Youngnuo-7-R_3-S_1-1	129.33	68.33	106.33	111.67

The selected plants were arranged here in ascending order based on the plant height. Youngnuo-7-R_3-S_1-3, Changnuo-6-R_3-S_3, Youngnuo-7-R_3-S_1-2 and Changnuo-6-R_3-S_2-1, 2 were selected considering the short stature type on the other hand Changnuo-1 R_3-S_1 -1 and Youngnuo-7-R_3-S_1-1 were selected only the yield potentiality.

CHAPTER V
SUMMARY AND CONCLUSIONS

The wide genetic variability that exists in the available populations provides enormous scope for more improvement. Yield could be a complex quantitative character; direct selection for yield could also not result in successful improvement.

Analysis of variance revealed a highly significant difference among 25 populations of the F_4 population for all the characters. The minimum and maximum plant height was observed within the population of Youngnuo-7-R_3-S_1-3 (86.98 cm) and KS-510-R_2-S_2 (146.62 cm) respectively. Minimum cob height was found in the population of Youngnuo-7-R_3-S_1-3 (38.92) while maximum in the genotype KS 510-R_3-S_2 (107.22). Minimum days to maturity were noted within the Youngnuo-7-R_3-S_1-2 (103.67) and maximum days to maturity within the population of KS-510-R_3-S_2 (135.33). The highest grain yield per plant was observed in Youngnuo-7-R_3-S_1-1 (111.67 g) and also the lowest grain yield per plant was observed in the population of Changnuo-6-R_3-S_2-3, 4 (53.93 g). Characters like cob height (18.17 and 24.78) and the number of branches of tassel (22.95 and 28.56) exhibited high genotypic and phenotypic coefficient of variation. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all characters which indicated the greater influence of environment for the expression of these characters. The high differences between the phenotypic and genotypic coefficient of variation were found in yield per plant other characters had a moderate environmental coefficient of variation which indicated these traits were mostly dependent on the environmental condition. Amongst the characters, the maximum genotypic variations were observed (231.66) in plant height and maximum phenotypic variation (514.56) was found in the attribute yield per plant. The highest estimated heritability amongst 16 characters of maize was 99% for days to maturity and the lowest was 18% for grains per row. The highest genetic advance amongst 16 characters was found in plant height (23.59) and the lowest genetic advance was found in cob diameter (0.29). The maximum genetic advance in percent of mean was observed for branches of tassels (37.98), other high genetic advance percent mean was found in the attributes plant height (20.71) and cob height (27.44). In the present study, high heritability coupled with high genetic advance as percent of mean was observed for the number of branches per tassel (65% and 37.98). Moderate heritability with high genetic advance as percent of mean was found in plant height and cob height.

The result suggested that traits were likely controlled by additive gene action that was incredibly helpful in the selection of the fascinating traits for improving the traits.

Considering both genotypic and phenotypic correlation co-efficient among sixteen yield contributing characters of 25 F_4 populations of white maize, yield per plant was positively and significantly correlated with base diameter, leaf length, leaf width, and cob diameter, the number of rows per cob, and 100-grains weight. Phenotypic correlation co-efficient significant but genotypic correlation co-efficient non-significant were found within the attributes cob length and grains per row. Path analysis revealed that days to 50% tasselling, cob height, days to maturity, number of leaves per plant, number of branches of the tassel, leaf width, cob length, cob diameter, number of rows per cob, number of grains per row and 100-grains weight showed positive direct effects on yield per plant indicating these traits effectiveness for direct selection. On the other hand, days to 50% silking and plant height showed negative direct effects on yield per plant indicating the effectiveness of indirect selection. Results of the present studies indicated significant variation were existed among the populations for all the characters studied. Plant height, cob diameter, days to maturity, and the number of grains per row were strongly correlated with yield per plant suggesting these four traits could be the selection criteria in improving the yield per plant and additionally fulfills objectives for this experiment to select the dwarf stature short duration variety. Considering cob height and plant height and additionally early maturity Youngnuo-7-R_3-S_1-3, Changnuo-6-R_3-S_3, Youngnuo-7-R_3-S_1-2, and Changnuo-6-R_3-S_2-1, 2 were selected. On the other hand, Changnuo-1-R_3-S_1-1 and Youngnuo-7-R_3-S_1-1 were designated solely the yield potentiality.

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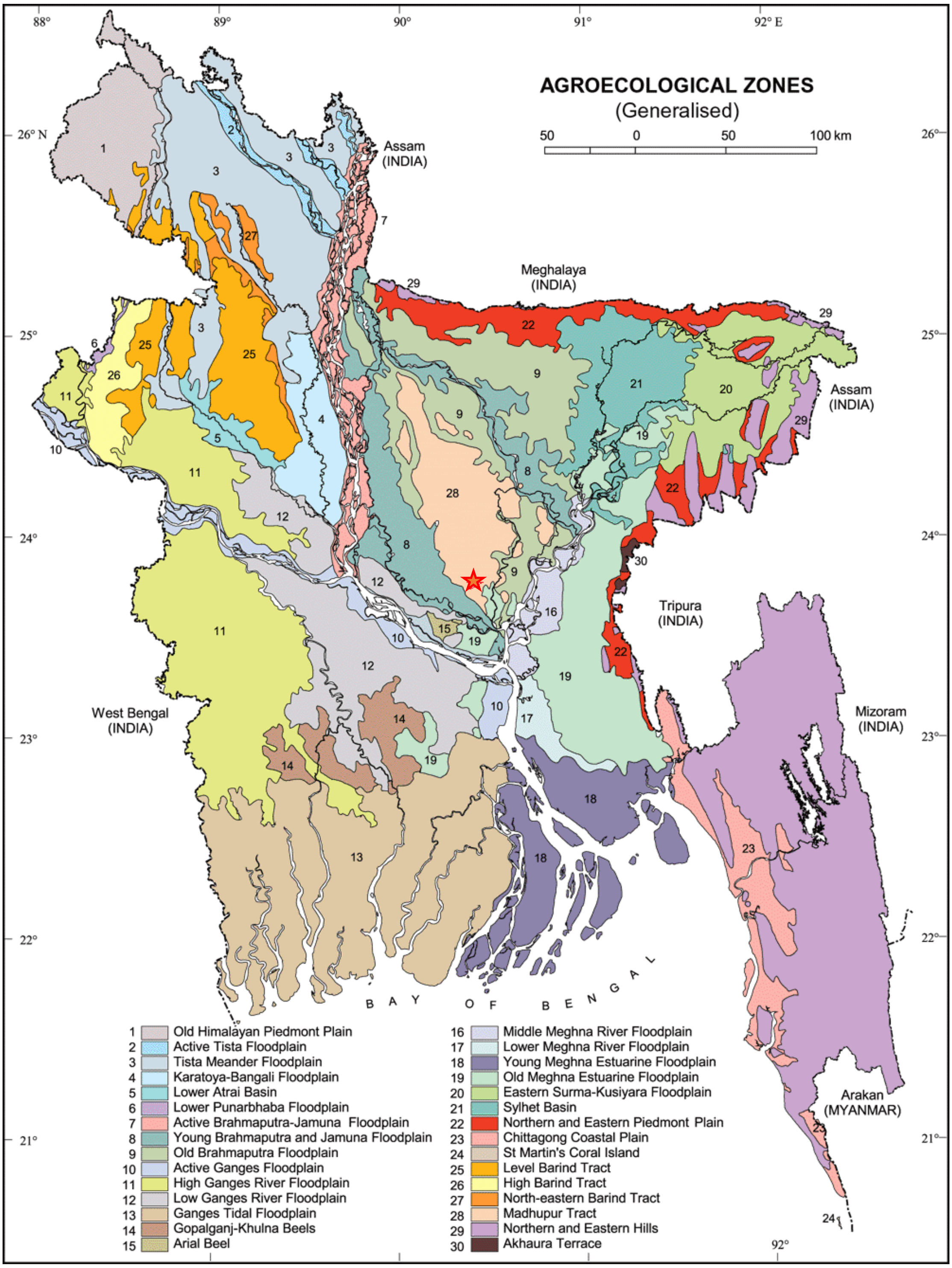
APPENDICES

Appendix I. Map showing the experimental site of the study



★ **Legend showing the research site**

Appendix II. Monthly average Temperature, Relative Humidity, Total Rainfall and Sunshine of the experimental site during the period of October, 2018 to March, 2019

Month	Air Temperature (^{0}c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2018	33.5	24	80	155	6
November, 2018	30.5	20	66	35	8
December, 2018	28	15	75	10	9
January, 2019	25.8	12.8	70	0	9
February, 2019	29.5	19.5	55	0	8
March, 2019	32.5	20	60	25	7

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

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

Soil Characteristics	Analytical Results
Agrological Zone	Madhupur Tract
pH	6.00-6.63
Organic matter	0.83
Available phosphorous	22 ppm
Exchangeable K	0.41meq/ 100 g soil

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