COMBINING ABILITY AND HETEROSIS OF POPCORN
(*Zea mays* var. *everta*)

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DHAKA-1207

DECEMBER, 2014

COMBINING ABILITY AND HETEROSIS OF POPCORN (*Zea mays* var. *everta*)

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REGISTRATION NO. 08-02846

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

IN

GENETICS AND PLANT BREEDING

SEMESTER: JULY-DECEMBER, 2014

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CERTIFICATE

This is to certify that thesis entitled, "COMBINING ABILITY AND HETEROSIS OF POPCORN (Zea mays var. everta)"submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCE in GENETICS AND PLANT BREEDING,*** *embodies the result of a piece of bona fide research work carried out by TOWHIDI ALMAS MUJAHIDI, Registration No. 08-02846 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: December, 2014
Place: Dhaka, Bangladesh

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Prof. Dr. Md. Sarowar Hossain

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, Who has enabled me to complete the research work and to prepare this thesis for the degree of Master of Science (M.S.) in Genetics and Plant Breeding.

I should express my heartfelt respect, deepest sense of gratitude and immense indebtedness to my esteemed Supervisor Dr. Md. Sarowar Hossain, Professor, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

I should also express my profound gratitude and indebtedness to my honorable Co-supervisor Dr. Md. Amiruzzaman, Chief Scientific Officer and Head of Plant Breeding Division, Bangladesh Agricultural Research Institute, Gazipur for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

I should expresses my sincere gratitude towards my colleague, Asgar Ahmed, Scientific Officer, Plant Breeding Division, Bangladesh Agricultural Research Institute, Gazipur for his valuable suggestions and cooperation during the experimental period.

I am also thankful to all the field staff of Plant Breeding Division, BARI, Gazipur for their help and cooperation during the experimental period.

December, 1014 ***The Author***

SAU, Dhaka

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ABSTRACT

The study was conducted to assess on combining ability and heterosis in popcorn produced through Line × Tester matting design. Eight S_5 lines of popcorn used as female and four as male were crossed in a Line × Tester to produce F_1 hybrid at the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during *Rabi* 2012-13. The produced 32 F_1s, 8 lines and 4 testers were evaluated along with two commercial check in the following year at the same station to determine the general combining ability (GCA) and specific combining ability (SCA) effects for 16 parameters on growth, yield and yield contributing traits and popping quality traits. Highly significant genotypic differences were observed which indicated wide range of variability present among the genotypes. Parents PCB/S5-12 and PCB/S5-13 were found promising and could be used for obtaining higher yield as well as popping quality. The crosses with high SCA effect for grain yield evolved from high × low general combiner parents were revealed additive × dominance types of gene action. The cross combinations PCB/S5-13×T17, PCB/S5-13×Thai, PCB/S5-13×T8, PCB/S5-25×T2 PCB/S5-15×T2, PCB/S5-16×Thai, PCB/S5-30×T17, PCB/S5-39×T8, PCB/S5-39×T17 and PCB/S5-39×Thai possessed high means for quality traits heterotic for yield and SCA values could be used for obtaining high yielding quality popcorn hybrids. The information on the nature of gene action with respective genotype and characters might be used as donor depending on the breeding objectives.

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SOME COMMONLY USED ABBREVIATION

Abbreviation	Full name
%	Percent
^0C	Degree celsius
σ^2 p	Phenotypic variance
σ^2 g	Genotypic variance
h^2b	Heritability in broad sense
AVM	Average moisture content
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BD	Bangladesh
CD	Critical difference
cm	Centimeter
CV%	Percentage of Coefficient of Variation
COV	Covariance
df	Degrees of freedom
et al.	And others
etc.	Etcetera
F_1	The first generation of a cross between two dissimilar homozygous parents
gm	Gram
G	Genotype
GCA	General combining ability
GCV	Genotypic coefficient of variation
ha	hectare
J.	Journal
Kg	Kilogram
m	Meter
MSS	Mean sum of square
M^2	Square meter
PCB	Popcorn burst
PCV	Phenotypic coefficient of variation
SAU	Sher-e-Bangla Agricultural University
SCA	Specific combing ability
SE	Standard error
t	Ton

CHAPTER I

INTRODUCTION

In the recent years considerable emphasis has been given for the development of high yielding single cross and hybrids in maize especially in popcorn. The main aim of the breeder is to develop high yielding genotypes. The breeding programme can efficiently be planned with prior knowledge of the genetic makeup of complex quantitative character like yield and its attributes. So there is a need to examine the genetic architecture of various quantitative characters in relation to breeding behaviour of the genetic material available.

Now the use of popcorn as a snack food has been increasing continuously throughout the world. In Bangladesh it is much popular as a street food. Cheap price, attractive colour and good storage period earns it great popularity among every age of people. Most of the popcorns in Bangladesh are imported from foreign countries as seed. This is due to unavailability of high yielding varieties. Bangladesh Agricultural Research Institute released an ‘open-pollinated’ variety of popcorn few years ago. But it is not sufficient to meet the growing demand of the market. Having a large market demand and very suitable growing condition in Bangladesh, a high yielding hybrid variety of popcorn has a huge scope. In Bangladesh popcorn is mainly cultivated in northern parts. The region has a lot of char lands and the cultivation is increasing day by day.

Generally, popcorn germplasm has a narrow genetic basis. Due to the higer yield and popping volume, new popcorn hybrids have almost completly replaced local varieties. (Sakin *et al*. 2005) compared yield and some quality characteristics of single-cross, three-way cross genotypes and open-pollinated popcorn cultivars are replaced. They found significant differences among genotypes for yield, popping volume, and percentage of unpopped kernels. They also found high popping volume in hybrid genotypes than open-pollinated cultivars whereas the percentage of unpopped kernels was 50% lower in hybrids. Popcorn is not only limited in germplasm quantity, but also is generally inferior to dent maize in yield and other

agronomic traits (Dofing *etal*. 1991); (Zeigler and Ashman 1994). The most important factor affecting yield in popcorn is genotype (Pajic 1990; Pajic and Babic 1991). Dent/flint germplasm could be introduced to improve grain yield and yield components through backcrossing with popcorn germplasm but due to negative correlation between popping characteristics and yield traits traditional breeding is not an efficient method to improve grain yield while maintaining popping characteristics. Higher popping volume was recorded for low- or medium-yielding cultivars whereas high-yielding cultivars had lower popping volume (Pajic 1990).
Exploitation of heterosis or hybrid vigour is an important method of crop improvement adopted in many of the crops especially in cross pollinated crops. This phenomenon of heterosis was attracted the attention of plant breeders due to its conspicuous effect on economic characters especially grain yield and this heterosis has been successfully exploited in many cross pollinated crops among which maize is the major one.

In order to exploit hybrid vigour/heterosis the choice of suitable parents is an important step. The selection of parents depends on factors like mean performance of the parents and their combining ability. The concept of general and specific combining ability (Sprague and Tatum, 1942) helps the breeder in assessing many of the lines to be used as parents in the production of hybrids and also in identifying the superior hybrids having additive and non-additive genes. It is therefore necessary to assess the genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining ability which are due to additive and non-additive gene actions. Thus, the information regarding heterosis, combining ability and nature of gene action are the basic requirements for a thorough understanding of genetic architecture of yield and its components. The available literature on maize indicated the possibility of exploiting heterosis for realizing higher yield potentiality; being monoecious in nature it provides an ample scope to exploit heterosis commercially.

The potential of heterosis is just beginning to be exploited in developing countries through expansion of hybrid seeds. It has the highest potential of per day carbohydrate productivity. Thus, the father of green revolution, the renowned Nobel

Laureate, Dr. Norman E. Borlaug, believes that "after the last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era"

The invention of heterosis phenomenon, the development of hybrid breeding technology and successful commercial exploitation of heterosis in maize are considered to be significant achievements and land marks in the history of biological sciences during the present century. A number of genotypes e.g., single crosses, three way crosses, double crosses, varietal hybrids, multiple hybrids, composites, synthetics, pools, populations etc. are feasible to maize growing farmers for commercial cultivation by virtue of the crop being a highly cross-pollinated species.
Shull (1908 and 1911) gave the original concept for production and growing of single-cross hybrids, but the cost of seed production has limited its utility. Jones (1918) suggested that double cross hybrids can be produced from two single cross hybrids to reduce the cost of seed production subsequently with the improvement in vigour and yield potential of inbred lines and development of better cultural practices, single crosses were adapted for commercial cultivation in the advanced countries. The recent trends even in the developing and under developed countries single cross hybrids are more popular due to their higher yield levels under favourable environment and uniformity in expression. Hence, there is a greater scope for the exploitation of heterosis through single cross hybrids, than double cross.

The hybrid development programme in maize involves development and evaluation of inbred lines, crossing of selected inbreds based on their combining ability and production of hybrids. In this context, a programme on development of inbred lines of popcorn was initiated by using inbreeding system utilizing commercial hybrid Pop Corn Burst (PCB) as base population at the Bnagladesh Agricultural Rresearch Institute, Gazipur. The experimental hybrids developed from S_5 popcorn lines derived from PCB and crossed with four testers by line × tester method were evaluated to assess their crossbred performance, combining ability and nature of inheritance heterosis for different qualitative and qualitative traits.
In heterosis breeding programme, the selection of parents/inbreds based on their morphological diversity with good combining ability is very important in producing superior hybrids. The analysis of general combining ability and specific combining ability helps in identifying potential parents/inbreds for the production of superior

hybrids. The line × tester analysis (Kempthorne, 1957) is one of the simplest and efficient methods of evaluating large number of inbreds/parents for their combining ability.

With this in view, an attempt was made to evaluate 32 single cross popcorn hybrids, 8 S_5 popcorn lines, 4 testers and 2 popcorn checks with the following objectives.

1. To evaluate the performance of single cross popcorn hybrids for grain and quality parameters.
2. To estimate the gca effects of parent and sca effects of cross combinations in respect to growth, yield and quality parameters.
3. To Assess the heterotic effect of hybrids

CHAPTER II

REVIEW OF LITERATURE

The research carried out in the past on maize to study the gene action, heterosis, combining ability, correlation and path analysis in respect of qualitative and quantitative characters relevant to the present study is reviewed below.

Study of the behaviour of quantitative traits in maize is important because traits like maturity, plant height, ear length, ear circumference, number of kernel rows per cob, number of kernels per row, 100-grain weight, and grain yield are under polygenic control. The available literature on these aspects is reviewed under the following headings:

2.1 Evaluation of lines by hybrid and mean inbred performance

Rangel *et al.* (2008); evaluated that 15 hybrids, resulting from circulant diallel of 10 parents, for grain yield and popping expansion. They concluded that intrapopulation breeding for poping expansion may offer superior genetic gains, but for grain yield, interpopulation breeding is required. Viana and Matta (2003); evaluated diallel crosses among five popcorn varieties to select parents for an intra and interpopulation breeding and determine two open-pollinated cultivars with highest potential as parents. Three popcorn inbred lines were evaluated as possible sources of favorable alleles for grain yield and popping volume improvement of an elite pop corn hybrid Babic *et al.* (1996); obtained on utilization of the best enhancer of grain yield show serious reduction of popping volume and therefore the improvement should be done using the donor ranked the second fo grain yield and the first for the popping volume

Jones (1922); reported on the relative performance of top crosses. Davis (1927); used top crosses to estimate the combining ability of S2 lines. Lindstorm (1931); suggested the commercial use of top crosses. He found that certain inbred lines were very preponderant for ear type, disease resistance, stability and uniformity in maturity. Jha and Khehra (1992); in their study on evaluation of maize inbred lines derived from two heterotic populations by using factorial mating analysis with eighty crosses of maize produced by crossing five females with sixteen pollen parents in two different locations for combining ability noticed that specific combining ability (sca) and sca x environmental components were of higher magnitude than general combining ability (gca) and gca x environmental components for grain yield indicating greater contribution of nonadditive gene action and its pronounced interactions with the environments.

Menkir *et al*. (2004); reported that the classification of maize inbred lines into heterotic groups is an important undertaking in hybrid breeding. Thirty-eight tropical mid-altitude maize inbred lines were crossed to two inbred line testers representing the flint and dent heterotic pattern, respectively. The resulting testcrosses were evaluated in a trial at three locations for 2 years. Significant general combining ability (GCA) and specific combining ability (SCA) effects for grain yield were detected among the inbred lines. The tester inbred lines classified 23 of the 38 tested inbred lines into two heterotic groups based on SCA effects and testcross mean grain yields.

Kumari *et al.* (2007); evaluated that six sweet corn inbreds, three each of sugary (P1, P2 and P3) and shrunken2 (P4, P5 and P6) types derived from different source populations were crossed in half diallel mating design. The mean sums of square due to G x E interaction were highly significant for all the traits except number of kernel rows and 100-grain weight, which implied the importance of carrying out trials in different environments. Significance of both GCA and SCA variance for most of the characters implied that both additive as well as non-additive components are important. The estimates of GCA effect indicated inbred P5 as the most promising parent since it was observed as a good general combiner for plant height, kernel rows, 100-grain weight, yield per plant, whereas P1 and P3 reflected significant GCA effect for early maturity and plant height, respectively. The SCA effect revealed P2 x P6 as the best specific combiner for grain yield per plant, followed by P2 x P5 and P3 x P4.

Kadubiec *et al*. (2007); reported that eight parental lines and the 28 hybrids obtained by crossing the parents in a diallel crossing design were investigated for relationship of some traits in Poland during 2001 and 2002. Six traits were evaluated: length and diameter of ear, ear row number, grain yield/ear, plant height and ear height. All traits except grain row number were highly and significantly correlated with grain yield in both years. Direct effects of ear length and diameter on grain yield were observed in both years; as well as ear height in 2001; and grain row per ear in 2002.

2.2 Heterosis

Heterosis of varying magnitude has been observed in almost all the crop plants. Heterosis breeding has received more attention than other branches of plant breeding in several crop plants and maize is one such cross fertilized crop in which has an array of hybrids have been realized over decades. Heterosis is the deviation of F1 from the reference for the particular character.

Shull (1908); coined the term heterosis to provide a term to describe the phenomenon but it did not include a description of genetic mechanism involved in its expression. Bruce (1910) and Keeble and Pellow (1910); put-forth the support for dominance hypothesis, which suggested that increase in vigour after crossing resulted from the combination of various dominant alleles by each parent. Shull (1911), East and Hayes (1912); objected the dominance theory and proposed overdominance hypothesis indicating heterosis as the result of heterozygosis. Ash by (1930 and 1932); suggested that heterosis resulted from the maintenance of the initial advantage in embryo size and not from an acceleration of metabolic process. East (1936); concluded that seed size or the size of any part of the seed cannot be the cause of heterosis. Hull (1945, 1946 and 1948); reported the evidence of overdominance in the expression of heterosis. The degree of geographical separation and the degree of ancestral relationship can be used as an indication of genetic diversity. The greater genetic diversity of the parents is associated with greater heterosis in the F1 (Moll *et al*., 1962, Paternani and Lonnquist, 1964; Wellhausen, 1965; Heidrich Sobrinho and Cordeiro, 1975; Vasal *et al*., 1992). Moll *et al*. (1967); reported that heterosis increased with increased divergence within certain limits and extremely divergent crosses in maize resulted in decrease in heterosis.

Griffing and Zsiros (1971); viewed heterosis as not entirely the result of genetic stimuli but rather as a result of the interaction between genetic and environmental stimuli and implicated that the environment was a significant factor in the manifestation of heterosis. Karvencheko *et al*. (1971); reported on heterosis for ear length, plant height, 100-grain weight, number of kernel rows and yield. Annenkova (1973); stated that selecting suitable pollen parents with 21.8 to 41.2 per cent higher yield than standard check could produce hybrids with superior heterotic vigour. Mukherjee and Saha (1984); observed positive heterosis for grains per ear in seven crosses, ear length in ten crosses and 100-grain weight in eight cross combinations. Muthiah (1989); obtained significant positive heterosis for grain yield per plant and other 15 yield related characters in several cross combinations from 9 × 9 diallel analysis. Bhatnagar *et al*. (1993); observed that high heterotic effects for early silking and grain yield per plant in early maize inbred lines. High heterotic effects for grain yield per plant and time to silk was reported by Vasal *et al.* (1993) based on the combining ability analysis of maize germplasm lines Kumar (1995); observed high degree of heterosis for grain yield per plant and earliness in eight hybrids. Nagda *et al*. (1995); obtained significant positive heterosis for grain yield per plant over the best check in 15 crosses and significant relative heterosis for days to silking, plant height and ear height in 14 hybrid combinations.

Ling *et al.* (1996); noticed that mean heterotic effects were highest for grain yield per plant followed by grain weight and ear thickness. Saha and Mukherjee (1996); observed significant positive heterosis for grains per ear and the crosses with highest heterosis for 100- grain weight and grain yield per plant and negative heterosis for percentage grain conversion. Verma and Singh (1996); reported that dominance × dominance gene interactions were important for improving heterosis for yield. Yurankova *et al*. (1996); obtained that considerable instability in heterosis for ear width, ear length and number of grains per row. Heterosis was slight or absent for number of rows per ear. Dass and Arora (1999); reported that negative heterosis will be considered as desirable for the phenological traits as it contributed favourable genes for earliness. Rosa *et al.* (2000); noticed the highest values of heterosis over the mid-parental value in the hybrid PP-9539 × AN-453 (11.35%) and PP-9603 × PP-9539 (11.13%). Geetha (2001); obtained maximum heterosis for grain yield per plant, ear weight and number of grains per ear. They also reported that significant positive heterosis in grain yield which was associated with the heterosis for plant height, number of grains per row, 100grain weight and number of rows per ear.

Nigussie *et al.* (2001); reported that the crossing maize (*Zea mays* L.) genotypes obtained from different sources could result in better utilization of hybrid vigour. This study was conducted to determine the heterosis and combining ability of eight elite maize genotypes. The eight parents were selected based on per se and top-cross performance. Jha *et al.* (2002); reported the heterosis and gene action for number of days to 50% silking, plant height, basal stem girth, number of leaves per plant, leaf:stem ratio, green fodder yield and dry matter yield were studied using 30 crosses and 12 parental genotypes. Standard heterosis was up to 23.42% in APFM-22 x African Tall for green fodder yield, and up to 20.94% in GBM-84-2 x African Tall for dry matter yield. This heterosis can be exploited for the improvement of green fodder yield in maize. Saleh *et al.* (2002); reported high estimates of heterosis for grain yield, ear weight, grain weight per ear, moderate estimates for plant and ear height, shelling percentage, ear circumference, number of kernel rows per ear, number of kernels per ear row and grain weight.

Singh *et al.* (2002); reported that the eight diverse inbreds were crossed in a half diallel to estimate heterosis and combining ability. Based on the per se performance, GCA effect and heterosis, P1 x P7 was the best hybrid, yielding 14.30% more grain yield per plant followed by P4 x P7 (13.07%) over the superior control: CM-400 x CM-300. Crosses between high x high and high x low GCA parents exhibited greater heterosis. Heterosis for yield was generally accompanied by heterosis for yield components. Srivastava *et al.* (2003); studied heterosis and combining ability for yield and maturity by using exotic and indigenous inbred lines of maize. Eighty single crosses along with parental lines were evaluated in three environments viz., Uttaranchal, Uttarpradesh and Punjab, during kharif 2000. The mean square due to interaction of lines and lines x testers with environments were significant for all characters, while testers with environments was significant for days to 50 per cent silking. Li-Jizhu (2004); reported that highest heterosis for ear grain weight and lowest for ear row number. All characters studied were controlled by additive gene action. Ear length had significant additive and dominance effects, whereas, ear row number and ear grain weight had dominant and epistatic effects, respectively.

2.3 Combining ability and gene action

In relation to single cross of corn, Sprague and Tatum (1942) formulated the concept of combining abilities. General combining ability is the average performance of a strain in a series of cross combinations, estimated from the performance of F1s from the crosses, whereas specific combining ability is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of lines involved. Griffing (1956); has shown relationship between various heritable variance components and GCA and SCA variances. GCA variance is due to additive variance and additive × additive interaction variance while, SCA variance is due to dominance variance, additive × additive variance, additive × dominance variance and dominance × dominance variance components. Estimates of the variances due to GCA and SCA provide an appropriate diagnosis of the predominant role of additive or non-additive variances of gene.

Ratio of additive to non additive gene action is to be considered in order to decide the predominance of the kind of genetic variation for a given character. The ratio of additive to nonadditive gene action is more than unity it indicates the major role of additive variance in controlling the expression of a character, whereas, less than unity indicates the importance of non-additive variance (Gardner, 1963). According to Dhillon and Singh (1976), general combining ability was more important than specific combining ability for the inheritance of days to 50 per cent silking, grain moisture, plant height, ear height, ear length, ear circumference and kernel row number but not for grain yield. Bhalla and Khehra (1977); reported significant general combining ability for yield per plant, ear length and plant height. Ramamurthy (1980); reported the predominance of additive gene effects for plant height, 100-grain weight, while non-additive effects were important for ear height and grain yield per plant. Murthy *et al.* (1981); observed that predominance of additive gene action for days to silking and non-additive gene action for grain yield per plant. Ali and Topara (1986); noticed that the additive gene action was more important than non-additive gene action for days to silking and plant height, whereas non-additive gene action was more important for ear circumference, number of grain rows per ear, grains per ear and grain yield. Singh *et al.* (1983); in their study on combining ability in maize noticed that additive genetic variance was relatively more important for days to 75% silk and plant height but yield per plant was controlled by non additive genetic variance. Significant maternal effects were reported by Melchinger *et al*. (1986) for yield and plant height. Muthiah (1989); reported that the proportion of GCA variance was higher than the SCA variance showing preponderance of additive genetic effects for all the characters studied.

Prasad *et al.* (1988); studied combining ability analysis in an 8 x 8 maize diallel for days to silk, plant height, cob placement, kernel rows per cob, kernels per row, cob length, cob girth, test weight, grain yield per plant and stover yield per plant by using different inbreds in the crossing program. According to Debnath and Sarkar (1990), non-additive gene action was preponderant in the inheritance of grain yield, ear circumference, whereas equal importances of both additive and non additive effects were observed for ear length, kernel rows per ear and kernels per row. Zargar and Singh (1990); suggested that additive components of variance with dominance played a major role in the inheritance of grain yield, plant height, ear height, ear length, kernel rows per ear and 100 kernel weight exhibited importance of variance with dominance in a partial to negligible range. Quadri *et al.* (1993); in their study on combining ability predominance of additive genetic variation was observed for all the ear character and identified composite Rutherford was the best general combiner for all the ear character.

Alika (1994); observed highly significant variation due to gca for ear length, ear circumference,ear weight and 100-kernel weight and sca fo ear circumference. According to Packiaraj (1995), GCA variance was greater in magnitude than SCA for shelling percentage, number of leaves, leaf breadth, 100-grain weight, days to 50 per cent silking, number of grains per row and plant height. SCA variance was high for ear weight, grain weight per plant and number of grain rows per ear indicating that dominance and epistatic played a major role in the expression of these traits. Dass *et al.* (1997); reported that non-additive gene action played major role in the inheritance of grain yield and majority of ear traits, but, Geetha (1997) observed that additive gene effects controlled the inheritance of grain yield per plant and also added that proportion of GCA variance was higher than the SCA variance having preponderance of additive genetic effects for characters such as plant height, number of grain rows per cob, number of grains per row, ear weight, days to 50 per cent silking, 100-grain weight and starch content. According to Altinbos and Tosum (1998) GCA and SCA variances for grain yield per plant and other yield components indicated that screening the parental lines and crosses based on combining ability effects for 100-grain weight and ear length should be effective. Yang *et al.* (1998); concluded that most plant and ear characters were improved with additive and dominance effects of the female parents. According to Singh and Singh (1998), GCA variance was more important for ear length, number or kernel rows per ear, but SCA variance was important for other characters like grain yield per plot, ear circumference, number of kernels per ear row, 100-kernel weight, days to 50 per cent silking, plant height and ear height.

Paul and Debnath (1999); obtained significant gca and sca effects for all characters studied viz., days to silking, plant height and ear height. Combining ability analysis indicated that additive gene action was more important than non-additive gene action and the best general and specific combiners were selected. Talleei and Kochaksaraei (1999); observed significant gca effects for plant height, ear height, kernel length and yield per plant. Choudhary *et al.* (2000); estimated the combining ability of early generation inbred lines derived from two maize populations aimed at forming a heterotic group Fen 81 line were derived from two maize populations namely jogia local and DH 8644.showing that better performing crosses usually had at least one parent with high general combining ability but for ear length inter population crosses were usually superior to intrapopulation crosses.

Kadlubiec *et al*. (2000); obtained that higher GCA values than those of SCA for majority of traits suggesting the importance of additive gene action. Non-additive gene action effects were responsible for the inheritance of lodging resistance only. Rameeh *et al.* (2000); observed greater ratios of GCA to SCA mean squares for all traits, except for number of seed rows per ear, indicating importance of non- additive gene effects in their genetic control. Suneetha *et al.* (2000); noticed significant variances for GCA and SCA for days to 50 per cent tasseling, plant height and neutral detergent fiber content. Zelleke (2000); had derived an information from data on grain yield, plant height, ear length, days to maturity and 1000-grain weight from a diallel mating that both gca and sca effects were significant for all traits. Geetha and Jayaraman (2000); reported that additive and dominance components were significant for plant height, number of kernel rows per cob, number of kernels per row, ear weight, 100-grain weight and grain yield. Desai and Singh (2001); reported significant difference in gca and sca effects for the traits viz., days to 50 per cent tasselling, days to 50 per cent silking, anthesis, silking interval, plant height, ear height, number of leaves per plant. Kalla *et al.* (2001); reported that both additive and non-additive gene actions were significant for 1000-grain weight, grains per ear, ear girth and ear length. The non-additive gene action was predominant for ear length and 1000-grain weight, and significant for grain yield per plant. The additive (D) component was significant for grain yield per plant, grains per ear and 1000-grain weight.

Kara (2001); observed significant gca effects for all the traits and significant sca effects for ear circumference, ear height and grain yield per unit area. Konak *et al.* (2001); obtained non-additive gene effects for ear length and number of kernel rows on ear and additive gene effect for yield, 1000-kernel weight, plant height, ear height and days to silking. Mandal *et al*. (2001); noticed significant GCA and SCA variances for most of the traits studied. Mahto ad Ganguly (2001); observed that both additive and non-additive genetic components for 100-grain weight and shelling percentage in CML 85 and CML 79. The crosses showed positive and highly significant specific combining ability effect for grain yield. Shieh-Guang Jauh and Thseng-FuSheng (2001); they suggests that early testing was effective for predicting the combining abilities expressed at later inbreeding generations. In addition, the additive effects of inbred lines may be a main contributor to the relationships between the S to S generation hybrids for ear dry weight and grain dry weight.

Vacaro *et al*. (2002); reported that mean sum of square for gca effects was greater than that for sca effects for the traits like plant height, point of insertion of the first ear, number of ears per plant, number of grains per ear, root and stalk lodging and grain yield indicating the predominance of additive effects. Alamnie *et al*. (2003); reported that a high magnitude of specific combining ability (sca) than general combining ability (gca) for all the characters indicate the predominance of non-additive gene action. The variance components of gca and sca were significant indicating the role of both additive and non-additive gene actions in the inheritance of the characteristics.

Dodiya and Joshi (2003); conducted line x tester analysis by using 20 lines and 3 testers in maize (*Zea mays*) along with their F1 hybrids was carried out in three environments to asses combining ability and heterosis with respect to quality and yield attributes and the observed that combining ability analysis showed the predominant role of non-additive type of genetic component in the inheritance of all the characters. Wu-Guang Cheng *et al.* (2003); reported that the kernel weight percentage, growth period, plant height, rows/cob, cob length, seed-bearing cob length, kernels/row and cob position should be selected during early generations of maize breeding, while the other 4 traits should be selected in later generations. El-Moula *et al.* (2004); indicated that magnitude of delta 2-GCA was greater for days to 50 per cent silking, plant and ear heights, while delta 2SCA was greater for number of ears per 100 plant and grain yield. Interaction of delta 2SCA × L was higher than that of delta 2GCA × L for all traits indicating that the non-additive type of gene action was more affected by environmental conditions than the additive type. Malik et al. (2004); reported that temperate material gave high gca effects for striking characters contributing towards high grain yield i.e., plant and ear height, leaf area, ears per plant, ear weight and kernels per row. Surya Prakash and Ganguli (2004); revealed that gene action appeared to be non-additive for all traits except for number of days to 50 per cent tasseling, ear height and number of kernel rows per ear, which are characterized by additive gene action.

Welcker *et al.* (2005); reported that heterosis and combining ability for maize adaptation to tropical acid soils in five different environments and observed significant genotype x soil condition interactions grain yield. Mid parent heterosis for yield was significantly higher in acid soils (32%) than non acid soils (20%) and suggested that the development of variety crosses between acid soil-tolerant populations could be used to increase maize yields in acid soil cropping pattern. Amit Dadheech *et al.* (2007); reported that the ratio of non additive/additive gene effect revealed that there was preponderance of non additive gene action in the expression of all the traits under study. Jumbo *et al.* (2008); reported that the general combining ability (GCA) effects were on average larger than specific combining ability (SCA) effects. Maternal effects (ME) and reciprocal effects (RE) were not significant for all traits, except for ear height.

CHAPTER III

MATERIALS AND METHOD

The present investigation was carried out at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The base population was raised and crossing programme was conducted at experimental field of BARI during *Rabi* of 2012-13. In the following year 2013-14 during *Rabi* season the evaluation of parents and F_1s was conducted at the same place.

3.1 Geographical location and weather condition

Geographically Joydebpur, Gazipur is situated at 23 °59'N latitude and 90°24'E longitude and at an altitude of 2 m above sea level. Soil of the experimental field was clay loam with pH ranging from 5.0-6.5. Temperature varied between 13°C to 34°C during growing season.

3.2 Experimental material

The experimental material comprised of eight S_5 generation of popcorn lines (used as female parent) and four testers (male parents) with diverse genetic base. The produced 32 F_1 (8×4) cross combinations were recovered through Line (8) × Tester (4) mating design during *Rabi* of 2012-13 at BARI, Joydebpur. The 32 F_1's and 8 parental lines and four testers were grown in an alpha lattice design with two replications spaced of 60 x 20 cm(between rows and hills) at the same location during *rabi* 2013-14. One border row was used at each end of the replication to minimize the border effect. The length of each rows were 4 m. All the recommended package of practices was followed and the observations were recorded on ten randomly selected plants for both growth parameters, yield contributing charecters and quality parameters. Data on days to pollen shedding, silking and grain yield was taken on plot basis. After harvesting, shelling and drying seeds were popped and data on popping quality characters were recorded. The general view of field is presented in Plate 1, 2 and 3.

3.3 Crossing programme

The crossing programme was done at BARI, Joydebpur during *Rabi* of 2012-13. Sowing was done on 13th November 2012 with a spacing of 75 x 20 cm. The recommended fertilizer doses were applied and proper agronomic management practices were followed with good care. The male parents were sown on 19th

Plate 1. General view of the experimental field

Plate 2. A female parent **Plate 3. A selected popcorn hybrid**

November, 2012 with four rows of each for synchronization of flowering. The crossing programme was started on 19th February 2013 and it includes same times silk cutting for emergence, bagging and pollination.

3.3.1 Silk covering

Each cob covered with white-creamy coloured tracing paper with water proof glue 3 to 4 days before silk emergence.

3.3.2 Tassel bagging

Bagging was done a day before the pollination according to tassel bag method. Tassel bag method involves the covering the tassel with bag made of heavy craft paper with water proof glue. The bag was placed over the tassel and fastened with a paper clip 24 houres before pollen collection. Pollens were collected 24 hours after bagging the tassel and care had been taken to prevent contamination and to avoid spilling the pollen.

3.3.3 Pollination

The collected pollens were applied to the selected plants silk in such a way that, silk bag is removed without touching or exposing the silks. Bottom of the tassel bag is flipped upwards, causing the pollen to fall upon the silk.

3.4 Materials used

3.4.1 Materials used for line × tester analysis

Sl. No.	**Lines (females)**		
1	PCB/ S5-12		
2	PCB/ S5- 13		
3	PCB/ S5-15		
4	PCB/ S5- 16		
5	PCB/ S5-17		
6	PCB/ S5-25		
7	PCB/ S5-30		
8	PCB/ S5-39		
Testers (male)			
1	T2		
2	T8		
3	T17		
4	Thai		
Experimental Hybrids		Experimental Hybrids	
1	PCB/S5-12 × T2	17	PCB/ S5- 17 × T2
2	PCB/ S5- 12× T8	18	PCB/ S5- 17 × T8
3	PCB/ S5- 12 × T17	19	PCB/ S5- 17 × T17
4	PCB/ S5-12 × Thai	20	PCB/ S5- 17 × Thai
5	PCB/ S5- 13 × T2	21	PCB/ S5- 25 × T2
6	PCB/ S5- 13 × T8	22	PCB/ S5-25 × T8
7	PCB/ S5- 13 × T17	23	PCB/ S5- 25 × T17
8	PCB/ S5- 13 × Thai	24	PCB/ S5-25 × Thai
9	PCB/ S5- 15 × T2	25	PCB/ S5-30 × T2
10	PCB/ S5- 15 × T8	26	PCB/ S5-30 × T8
11	PCB/ S5- 15 × T17	27	PCB/ S5-30 × T17
12	PCB/ S5- 15 × Thai	28	PCB/ S5-30 × Thai
13	PCB/ S5- 16 × T2	29	PCB/ S5-39 × T2
14	PCB/ S5- 16 × T8	30	PCB/ S5- 39 × T8
15	PCB/ S5- 16 × T17	31	PCB/ S5-39 × T17
16	PCB/ S5- 16 × Thai	32	PCB/ S5- 39 × Thai
Commercial Checks			
1	BARI Khoi bhutta-1		
2	Thai Popcorn		

3.5 Recording of observations

Observations on 16 different characters of three group viz. growth parameters, yield and yield contributing characters and popping quality characters were recorded on ten competitive randomly selected plants. The average was taken as the mean of the treatment. The way in which observations were recorded is described below.

3.5.1 Growth Parameters/Characters

3.5.1.1 Days to 50 percent pollen shedding

The number of days taken from the date of sowing to the day on which 50 percent of plants in a treatment starts shedding pollen was recorded as days to 50 percent pollen shedding.

3.5.1.2 Days to 50 per cent silking

The number of days taken from the date of sowing to the day on which 50 per cent of the plants in a treatment showed complete silk emergence was recorded as days to 50 percent of silking.

3.5.1.3 Plant height (cm)

Height of the plant from ground level upto the base of fully opened flag leaf was recorded in centimetres as plant height when plants were matured.

3.5.1.4 Ear height (cm)

Height of the plant from ground level upto the base of leaf adjacent to the primary ear was recorded in centimetres as ear height when plants were matured.

3.5.2 Yield and Yield contributing characters

3.5.2.1 Grain yield ton per hectare

At physiological maturity, the cobs were dehusked and harvested in each plot. The harvested cobs are air dried, shelled, cleaned and weighed. Grain yield per ha was calculated by using the formula given below and expressed in ton per ha.

$$Grain\ yield\ ton\ per\ ha = \frac{Fresh\ ear\ weight \times (100 - AVM) \times 10 \times k}{Stand\ harvest \times 1000}$$

$$K = 10000 \times 0.9412 \times \frac{(100-AVM)}{100 \times plot\ area}$$

Where,

AVM = Average moisture content

3.5.2.2 Number of kernels per row

Number of kernels in each kernel row was counted and average was recorded as number of kernels per row

3.5.2.3 Number of kernel rows per ear

The number of kernel rows per cob was counted and recorded.

3.5.2.4 Number of kernels per ear

Number of kernel per row and kernel rows per ear were counted and multiplied to obtain the total kernel number in a ear and recorded.

3.5.2.5 Ear length (cm)

Cob length was measured from bottom to the top of the cob and recorded in centimetres.

3.5.2.6 Ear diameter (cm)

Ear diameter was measured and recorded in centimetres as the thickness of the ear i.e., at the middle of the cob.

3.5.2.7 1000-grain weight (g)

Weight of 1000 grain drawn from a random sun dried sample from each plot was recorded in grams at 15 per cent moisture content.

3.5.2.8 Shelling percentage

Average pith weight and average grain weight of the randomly selected plants per plot were used to compute the shelling percentage by using the following formula.

$$Shelleing\ \% = Grain\ weight \times \frac{100}{Total\ weight(grain\ weight + pith\ weight)}$$

3.5.3 Quality parameters

3.5.3.1 Popping percentage

200 random kernels from each plot were counted and popped. After popping number of unpopped seed were counted. Then popping percentage is computed by using following formula.

$$Popping\ \% = \frac{Number\ of\ popped\ karnel}{Total\ number\ of\ karnel} \times 100$$

3.5.3.2 Popping volume

Popping volume was measured after popping of random 200 kernels by using volumetric flask as shown in Plate 4.

3.5.3.3 Popping expansion

For measuring popping expansion first taken the weight of 200 kernel in gram. After popping the kernels, volume of popped kernel was measured to obtain the popping expansion cc^3/gm.

3.5.3.4 Taste score

Grains from each plot from both replication was popped separately and taste of quality (taste, softness and attractiveness) were measured by 15 individuals in 1-5 scale (1=very good, 2=good, 3=moderate, 4=poor & 5=very poor). Data were then averaged and recorded for each plot. (See plate 5)

3.6 Statistical analysis

Mean values of the plants selected at random in each treatment and replication were subjected to statistical analysis. The following statistical methods were adapted.

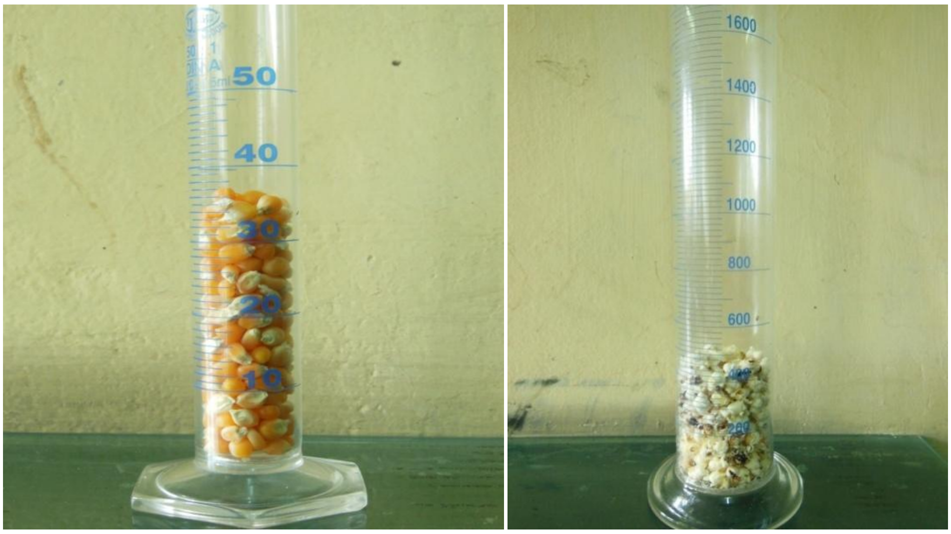

Plate 4: Measuring popping volume and popping expansion

Plate 5: Evaluation of taste of quality

3.6.1 Analysis of variance (ANOVA) for parents and hybrids

Mean values of the 12 quantitative characters recorded for the hybrids and parents were subjected for statistical analysis and variances according to Panse and Sukhatme (1961).

ANOVA for parents and hybrids

Sl.. No.	Sources of variation	Degrees of freedom	Mean sum of squares	Variance ratio
1.	Replication	(r-1)	Mr	Mr/Me
2.	Treatments	(t-1)	Mt	Mt/Me
a.	Parents	(f + m-1)	Mp	Mp/Me
i.	Females	(f-1)	Mf	Mf/Me
ii.	Males	(m-1)	Mm	Mm/Me
iii.	Females Vs Males	1	Mf Vs Mm	Mf Vs Mm/Me
b.	Hybrids	(fm-1)	Mh	Mh/Me
c.	Parents Vs Hybrids	1	Mp Vs Mh	Mp Vs Mh/M
3.	Error	(t-1) (r-1)	Me	-
4.	Total	(mfr-1)	-	-

Where,

r = Number of replications

t = Number of treatments

f = Number of females (lines)

m = Number of males (testers)

p = Parents

h = Hybrids

e = Error

M = Mean sum of squares

3.6.2 Combining ability analysis

3.6.2.1 Analysis of variance

The mean of each character for each entry were subjected to line × tester analysis and the variance of general combining ability of different cross combinations were estimated by the procedure developed by Kempthorne (1957). The form of analysis is given in the table below.

Sources of variation	Degrees of freedom	Mean sum of squares	Expected mean sum of squares
Replication	(r-1)		
Hybrids	(fm-1)		
Females	(f-1)	M1	σe^2 + r[COV (FS) – 2 COV (HS)] + [mr COV (HS)]
Males	(m-1)	M2	σe^2 + r[COV (FS) – 2 COV (HS)] + [fr COV (HS)]
Females × Males	(f-1) (m-1)	M3	σe^2+ r[COV (FS) – 2 COV (HS)]
Error	(r-1) (fm-1)	M4	σe^2

Where,

r = Number of replications

f = Number of females (lines)

m = Number of males (testers)

COV (FS) = Covariance of full sibs

COV (HS) = Covariance of half sibs

M1 = Mean sum of squares due to females (lines)

M2 = Mean sum of squares due to males (testers)

M3 = Mean sum of squares due to females × males

M4 = Mean sum of squares due to error

3.6.2.2 Estimation of variance components

From the expectation of mean squares, the covariance between half sibs (COV HS) and covariance between full sibs (COV FS) were estimated as detailed below

$$COV\ HS = \frac{M1+M2-2M3}{r(f+m)}$$

$$COV\ FS = \frac{[(M1 + M2 + M3 + M4) + 2r\ COV\ HS - r(f + m)COV\ HS]}{3r}$$

The estimates of COV HS and COV FS were used to estimate the variance due to general combining ability (GCA) and variance due to specific combining ability (SCA) as below.

σ^2 GCA = COV HS

σ^2 SCA = COV FS - 2COV HS

The estimates of variance component due to females, males and hybrids were obtained as shown below.

$$\sigma^2 f = \text{COV HS (lines)} = \frac{M1 - M3}{rm}$$

$$\sigma^2 m = \text{COV HS (testers)} = \frac{M2 - M3}{rf}$$

$$\text{Covariance (HS) average} = \frac{M1 + M2 - 2M3}{r(f + m)}$$

$$\sigma^2 mf = \sigma^2\ SCA = \frac{M3 - M4}{r}$$

After estimating the GCA and SCA variances as mentioned above, the GCA/SCA ratio was computed to predict the type of gene action involved.

3.6.2.3 Proportional contribution of lines, testers and line × tester

a. Contribution of lines (%) $= \frac{SS(f)}{SS(c)} \times 100$

b. Contribution of testers (%) $= \frac{SS(m)}{SS(c)} \times 100$

c. Contribution of lines × testers $= \frac{SS(f \times m)}{SS(c)} \times 100$

Where,

SS (c) = Sum of squares due to crosses

SS (f) = Sum of squares due to lines

SS (m) = Sum of squares due to testers

SS (f × m) = Sum of squares due to crosses

3.6.2.4 Estimation of combining ability effects

The models used to estimate gca and sca effect of ijk observations was as follows.

$$Xij = \mu + gi + gj + sij + eijk$$

Where,

µ = population

gi = gca effects of the ith female parent

gj = gca effects of the jth female parent

sij = sca effects of the ijth cross combination

i = number of female parents involved

j = number of male parents involved

k = number of replications

eijk = error associated with the observation Xijk

The individual effects were estimated as follows.

3.6.2.4.1 General combining ability (gca) effects

a) lines (gi) $= \frac{Xi...}{mr} - \frac{X...}{mfr}$

Where,

Xi… = total of i female parent over all male (m) parents and replications (r).

X... = total of all the hybrids over all male parents (m), female parents (f) and replications (r).

b) Testers (gj) $(Xj\ ...)/mr - (X\ ...)/mfr$

where,

Xj… = total of the j male parent over all female parents (f) and replication(r).

3.6.2.4.2 Specific combining ability (sca) effects

Xij $= \frac{(Xij)}{r} - \frac{Xi}{mr} - \frac{Xj}{fr} + \frac{X}{mfr}$

Where, Xij = jith combination total over all replications (r).

3.6.2.4.3 Standard error for combining ability effects

The standard error (SE) pertaining to gca effects of males and females and sca effects of different combinations were calculated as under.

a) SE for gca effects of lines SE gi = $(M_4 / rm)^{1/2}$

b) SE for gca effects of testers SE gj = $(M_4 / rf)^{1/2}$

c) SE for sca effects SE gij = $(M_4 / r)^{1/2}$

3.6.2.4.4 Critical difference (CD)

The critical difference values in each case were computed by multiplying their corresponding SE values with Table 't' value at error degrees of freedom at 5 and 1 per cent level of significance.

3.6.3 Estimation of heterosis

Heterosis expressed as per cent increase or decrease of F1 hybrid over mid-parent (average or relative heterosis), better parent (heterobeltiosis) and the best commercial check (standard heterosis) were computed for each character using the following formulae (Turner, 1953 and Hayes et al., 1955). Out of three checks, the mean performance of the best check in a given character was considered to work out the standard heterosis.

a. Heterosis over mid parent (relative heterosis) $= \frac{(\overline{F1}-\overline{MP})}{\overline{MP}} \times 100$

b. Heterosis over better parent (heterobeltiosis) $= \frac{\overline{F1}-\overline{BP}}{\overline{BP}} \times 100$

c. Heterosis over check (standard heterosis) $= \frac{\overline{F1}-\overline{CC}}{\overline{CC}} \times 100$

Where,

F1 = Mean performance of F1

MP = Mean mid-parental value = (P1 + P2)/2

P1 = Mean performance of parent one

P2 = Mean performance of parent two

BP = Performance of better parent

CC = Performance of the best commercial check

The differences in the magnitude of heterosis were tested following the procedure given by Panse and Sukhatme (1961).

a. Critical difference for mid-parent heterosis = $(3Me/2r)^{1/2} \times t$

b. Critical difference for better parent heterosis = $(2Me/2r)^{1/2} \times t$

c. Critical difference for commercial check = $(2Me/2r)^{1/2} \times t$

Where,

r = Number of replications

Me = Error mean sum of square from analysis of variance table

T = Table value of 't' test at error degrees of freedom corresponding to 5% or 1% level of significance.

3.6.4 Association analysis between yield and its components

3.6.4.1 Genotypic and phenotypic correlation coefficients

Analysis of covariance was done similar to that of analysis of variance taking two characters at a time. The genotypic and phenotypic co- variances were derived as detailed for genotypic variance.

$$\sqrt{\frac{COV.g.1.2}{(\sigma 2\ \ g1)\times(\sigma 2\ \ g2)}} \quad \sqrt{\frac{COV.p.1.2}{(\sigma 2\ \ p1)\times(\sigma 2\ \ p2)}}$$

Where,

Cov.g.1.2 - Genotypic covariance between two traits (1 and 2)

Cov.p.1.2 – Phenotypic covariance between two traits (1 and 2)

$\sigma^2 g_1$ - Genotypic covariance for first trait

$\sigma^2 p_1$ - Phenotypic covariance for first trait

$\sigma^2 g_2$ - Genotypic covariance for second trait

$\sigma^2 p_2$ - Phenotypic covariance for second trait

Referring to correlation table of Snedecor and Cochran (1967), the significance of correlation coefficient was tested

CHAPTER IV

RESULTS

A line x tester experiment consisting of 8 lines and 4 testers and their 32 F_1 hybrids, were evaluated along with the two commercial checks during *Rabi* 2013-14 at the Bangladesh Agricultural research Institute, Joydebpur, Gazipur. The recorded data on 16 characters viz., days to 50 per cent pollen shedding, days to 50 per cent silking, plant height (cm), ear height (cm), ear length(cm), ear diameter (cm), number of kernel rows per ear, number of kernels per row, number of kernel per ear, 1000-grain weight (g), shelling percentage, grain yield (t/ha), popping percentage, popping volume, popping expansion and taste of quality are presented under the following headings.

4.1 Analysis of variance

Analysis of variance for all entries including parent hybrids and checks for 16 characters are presented in Table 1.1 to 1.3.The treatment varience was highly significant for all characters except number of kernel rows per ear and taste score indicates the presence of variability among them.

4.2 Mean sum of squares for parent and hybrids

Mean sum of square for 16 traits of parents and hybrids are presented in Table 2.1 to 2.3. The mean sum square of parents was highly significant for all characters except number of kernel rows per ear and popping percentage. Highly significant mean sum of square were observed in females for all characters except grain yield, number of kernel rows per ear, number of kernel per ear, ear diameter and popping percentage. Highly significant mean sum of square were observed in males for all characters except days to 50 percent silking, number of kernel row per ear, ear diameter and taste score.The mean sum of square of female versus male were highly significant for all characters except days to 50 percent pollen shedding, days to 50 percent silking, ear length, shelling percentage and taste score. Highly significant mean sum of square was observed in hybrids for 7 characters viz. days to 50 percent pollen shedding, ear height, grain yield, number of kernel per row, ear length, ear diameter and 1000 kernel weight. The mean sum of square of parent versus hybrid was highly

Table 1.1: Analysis of variance of growth characters

Sl.No	Sources of variation	Replication	Treatments	Error
1	Degrees of freedom	1	43	43
2	Days to 50% pollen shedding	61	16**	2
3	Days to 50% silking	62	21**	4
4	Plant height	88	1966**	261
5	Ear height	219	708**	98

Table 1.2: Analysis of variance of yield and yield contributing characters

Sl.No	Sources of variation	Replication	Treatments	Error
1	Degrees of freedom	1	43	43
2	Grain yield	0.6	5**	0.5
3	No of Kernels/row	5	47**	4
4	No of kernel rows/ear	6	5	5
5	No of Kernels/ear	12576	1606**	5507
6	Ear length	0.03	7**	0.86
7	Ear diameter	0.0014	1.19**	0.36
8	1000 kernel weight	19	1070**	66
9	Shelling%	28	17**	6

Table 1.3: Analysis of variance of quality parameters

Sl.No	Sources of variation	Replication	Treatments	Error
1	Degrees of freedom	1	43	43
2	Popping %	29	11*	8
3	Popping volume	0.3	19**	8
4	Taste score	1	0.9	0.8
5	Popping expansion	0.3	19**	8

*significant at 5% level ** significant at 1% level

Table 2.1: Mean sum of squares for parents and hybrids in respect of growth characters in popcorn

Source of variation	Degrees of freedom	Days to 50% pollen shedding	Days to 50% silking	Plant hight	Ear hight
Replication	1	61	62	88	219
Parents	11	9**	12**	1938**	650**
Females(lines)	7	10**	15**	1346**	140
Males (tasteers)	3	7*	8	856*	319**
Female V Males	1	3	2	9324**	5212**
Hybrids	31	4*	6	372	303**
Parents V Hybrids	1	444	572**	51694**	13923**
Error	43	2	4	262	98

Table 2.2: Mean sum of squares for parents and hybrids in respect of yield and yield contributing characters in popcorn

Source of variation	Degrees of freedom	Grain Yield ton/ha	No. of Kernel/ row	No. of kernel Row/ ear	No. of Kernel/ ear	Ear length	Ear diameter	1000 kernel weight	Shelling %
Replication	1	0.56	5	5.7	12576	0.03	0.0014	19	28.4
Parents	11	2.16**	34**	3.5	11954*	4**	1.3**	512**	50.48**
Females (lines)	7	0.4	27**	1.9	6575	4**	0.7	561**	66.2**
Males (tasters)	3	4.82**	55**	0.87	16825*	5.6**	0.15	449**	28.12**
Female V Males	1	6.47**	20.6**	22.96*	34992*	2.3	8.5**	359*	7.52
Hybrids	31	0.76*	21*	5.24	8780	3**	0.7*	369**	4.19
Parents V Hybrids	1	172**	976**	12.95	287023**	168**	16**	28973**	56**
Error	43	0.45	4	4.6	5506	0.85	0.4	66	6.47

Table 2.3: Mean sum of squares for parents and hybrids in respect popping quality characters

Source of variation	Degrees of freedom	Popping volume	Popping expansion	Popping %	Taste score
Replication	1	0.39	0.3	29	1.14
Parents	11	38.9**	38.35**	14.2	1.8*
Females (lines)	7	44.2**	43.6**	5.2	2.1*
Males (tasters)	3	25.9*	26*	20.7*	1
Female V Males	1	4.55*	38.68*	57.42**	2
Hybrids	31	12.17	12.3	10.68	0.46
Parents V Hybrids	1	1.27	1.74	0.001	3.18*
Error	43	8.4	8.42	7.8	0.76

*significant at 5% level and ** significant at 1% level significant for all characters except days to 50 percent pollen shedding, number of kernel rows per ear, popping volume, popping expansion and popping percentage.

The mean sum of squares of males were highly significant for 12 traits viz days to 50 percent pollenshedding, plant height, ear height, grain yield, number of kernel per row, number of kernels per ear, ear length, 1000 kernel weight, shelling percentage,popping volume, popping expansion and popping percentage which signifies that males were diverse for these 12 traits. The mean sum of squares of females versus male were significant for 11 traits viz., plant height, ear height, grain yield, number of kernel per row, number of kernel rows per ear, number of kernels per ear, ear diameter, 1000 kernel weight, popping volume, popping expansion and popping percentage. This implies that the divergence of testers from lines with respect to these 11 characters.

The mean sum of squares for hybrids were highly significant for 7 characters viz. days to 50 percent pollen shedding, ear height, grain yield, number of kernel per row, ear length, ear diameter and 1000 kernel weight including the diverse performance of different cross combinations for remaining 9 traits. The parents versus hybrids mean sum of squares were highly significant for all the traits except days to 50 percent pollen shedding, number of kernel rows per ear, popping volume, popping expansion and popping percentage revealing the presence of almost average heterosis due to the significant differences in the mean performances of hybrids and parents.

4.3 Proportional contribution of lines, testers and their interaction to total hybrid variance

The proportional contribution of lines, testers and their interaction to total hybrid variance for sixteen characters are presented in Table (3.1 to 3.3). In this study it was clear that contribution towards total hybrid variance was found to be higher from females than males except for Plant height, ear length and popping percentage. The contribution of the female × male interaction for the total variance was higher than that of males for all characters except plant height and ear length. On the other hand, the contribution of the female × male interaction was higher than that of females for all characters except days to 50 percent pollen shedding and ear length.

Table 3.1 Proportional contribution of line, testers and their interaction to total hybrid variance for growth characters

Sl. No.	Characters	Contribution of females (%)	Contribution of males (%)	Contribution of females × males (%)
1	Days to 50% pollen shedding	44	23	32
2	Days to 50% silking	38	22	40
3	Plant height	30	36	34
4	Ear height	29	29	43

Table 3.2: Proportional contribution of line, testers and their interaction to total hybrid variance for yield and yield contributing characters

Sl. No.	Characters	Contribution of females (%)	Contribution of males (%)	Contribution of females × males (%)
1	Grain yield	41	16	42
2	No of Kernels/row	33	10	57
3	No of kernel rows/ear	25	12	63
4	No of kernels/ear	36	0.5	64
5	Ear length	32	40	28
6	Ear diameter	38	8	54
7	1000 kernel weight	34	31	34
8	Shelling%	42	10	48

Table 3.3: Proportional contribution of line, testers and their interaction to total hybrid variance for quality parameters

Sl. No.	Characters	Contribution of females (%)	Contribution of males (%)	Contribution of females × males (%)
1	Popping %	12	14	74
2	Popping volume	31	5	63
3	Taste score	34	21	45
4	Popping expansion	31	6	63

The contribution to total hybrid variances was found to be higher from females than males for all characters except plant height, ear length and popping percentage as females were genetically diverse than males the contribution of the females x males interaction for the total hybrid was also higher than that of males for all characters except plant height and ear length. On the other hand, the contribution of the interaction of female x male was higher than that of females for all the characters except days to 50 percent pollen shedding and ear length, revealing the importance of either female or male parents for the expression of other traits in hybrids.

4.4 Mean performance of lines, testers, hybrids

Mean performance of lines, testers, hybrids and checks are presented in Table 4.1 to 4.3.

4.4.1 Growth characters

4.4.1.1 Days to 50% pollen shedding

The mean varied from 90 (PCB/S5-39) to 97.5 days (PCB/S5-13) in females, 89.5 (T2) to 93.5 (T17) in males and 83.5 (PCB/S5-25 × T8) to 91 days (PCB/S5-13 × Thai) in hybrids. Line PCB/S5-39 showed early pollen shedding while no tester showed earliness. All hybrids except PCB/ S5- 13 × Thai showed early pollen shedding.

4.4.1.2 Days to 50% silking

The trait days to 50% silking ranged from 88.5 (PCB/ S5-39) to 98.5 days (PCB/ S5-13) in females, 90.5 (Thai) to 94.5 (T17) days in males and 83.5 (PCB/S5-25 × T8) to 91 (PCB/ S5- 13 × Thai) days in hybrids. Line PCB/S5-39 showed earliness in silking that no tester showed in the study. 25 hybrids showed earliness in silking.

4.4.1.3 Plant height (cm)

The range of plant height was from 58.3 (PCB/ S5- 13) to 141.8 (PCB/ S5-39)cm in females, 136.8 (T_{17}) to 185.5 (thai) cm in males and 153.7 (PCB/S5-12 × Thai)to 209.8 (PCB/S5-17 × T_8) cm in hybrids. Nine hybrids exhibited lower plant height.

4.4.1.4 Ear length (cm)

The range of ear length was from 37.5 (PCB/ S5-25) to 58 (PCB/ S5-17) cm in females, 64.9 (T_{17}) to 90.3 cm (Thai) and 60.1 (PCB/S5-12 × T_2) to 106.9 (PCB/S5-17 × T_8) cm in hybrids. 18 hybrids showed lower ear length.

4.4.2 Yield and yield contributing characters

4.4.2.1 Grain yield (ton/hectare)

The grain yield per hectare ranged from 1.5 (PCB/ S5-12) to 2.8 (PCB/ S5-16) ton per hectare in females, 1.8 (T8) to 5.5 (Thai) ton per hectare and 4.5 (PCB/ S5- 15 × Thai, PCB/ S5- 17 × Thai) to 7.3 (PCB/ S5- 13 × T17) ton per hectare in hybrids. 11 hybrids showed higher grain yield per hectare.

4.4.2.2 Number of kernels per row

Number of kernel per row varied from 16.5 (PCB/ S5- 13) to 29 (PCB/ S5-17) in females, 20.5 (T8) to 32.6 (Thai) in males and 27.1 (PCB/ S5- 15 × Thai) to 39 (PCB/ S5-25 × T8) in hybrids. 18 hybrids showed higher number of kernel per row.

4.4.2.3 Number of kernel rows per ear

Number of kernel rows per ear varied from 11.8 (PCB/ S5- 13) to 14.6 (PCB/ S5-25) in females, 14.2 (T8) to 15.6 (Thai and T17) in males and 12.6 (PCB/ S5- 39 × T8) to 22.6 (PCB/ S5- 13 × Thai) in hybrids. Eleven hybrids showed higher kernel rows per ear

4.4.2.4 Number of kernel per ear

Number of kernel per ear varied from 201 (PCB/ S5- 13) to 377.5 (PCB/ S5-25) in females, 291 (T_8) to 508.5 (Thai) in males and 347.5 (PCB/ S5- 39 × T8) to 692.5 (PCB/ S5- 13 × Thai) in hybrids. Twenty one hybrids showed higher number of kernel per ear.

4.4.2.5 Ear length

The ear length varied from 9.8 (PCB/ S5- 13) to 14.2 (PCB/ S5-39) in females, 10.8 (T_8) to 14.4 (T_2) in males and 14.1 (PCB/ S5- 15 × Thai) to 18.8 (PCB/ S5- 12 ×

Table 4.1: Mean performance of Growth characters of lines, testers, single cross experimental hybrids of popcorn

Sl.No.	Entries	Days to 50% pollen shedding	Days to 50% silking	Plant height (cm)	Ear height (cm)
Lines (Females)					
1	PCB/ S5-12	92	93	107.7	41.2
2	PCB/ S5- 13	97.5	98.5	58.3	40.3
3	PCB/ S5-15	92.5	94	110.8	42
4	PCB/ S5- 16	92.5	94	124	57.3
5	PCB/ S5-17	91.5	92.5	138.6	58
6	PCB/ S5-25	91	92.5	112	37.5
7	PCB/ S5-30	91	92.5	122.8	45.7
8	PCB/ S5-39	90	88.5	141.8	55.2
Testers (males)					
1	T2	89.5	91	150.2	70.45
2	T8	92.5	94	152.7	88
3	T17	93.5	94.5	136.8	64.9
4	Thai	90.5	90.5	185.5	90.3
Hybrids					
1	PCB/S5-12 × T2	85.5	87.5	174.6	60.1
2	PCB/ S5- 12× T8	85.5	87	181.3	86
3	PCB/ S5- 12 × T17	88	89	166.3	75.2
4	PCB/ S5-12 × Thai	87.5	90	153.7	76.9
5	PCB/ S5- 13 × T2	88.5	89	184.9	78.7
6	PCB/ S5- 13 × T8	86.5	87	194.3	99.3
7	PCB/ S5- 13 × T17	89.5	88.5	181.7	75.2
8	PCB/ S5- 13 × Thai	91	91	172.1	76
9	PCB/ S5- 15 × T2	84	82.5	182.2	88.2
10	PCB/ S5- 15 × T8	86.5	87	186.7	87.5
11	PCB/ S5- 15 × T17	86.5	86.5	169.5	72.5
12	PCB/ S5- 15 × Thai	87.5	88	157.0	79.9
13	PCB/ S5- 16 × T2	88.5	88	186.8	99.1
14	PCB/ S5- 16 × T8	87	86.5	194.2	102.3
15	PCB/ S5- 16 × T17	87.5	87	158.7	76.9
16	PCB/ S5- 16 × Thai.	87.5	88.5	194.5	92.8
17	PCB/ S5- 17 × T2	87.5	87.5	203.8	106.1
18	PCB/ S5- 17 × T8	86	85	209.8	106.9
19	PCB/ S5- 17 × T17	87.5	88	174	88.6
20	PCB/ S5- 17 × Thai	87.5	85.5	185.8	79.8
21	PCB/ S5- 25 × T2	86	86	174.6	60.2
22	PCB/ S5-25 × T8	83.5	83.5	198.3	95.4
23	PCB/ S5- 25 × T17	86	85	185.3	90.7

Table 4.1 (continued)

24	PCB/ S5-25 × Thai	86.5	88	196.6	93.2
25	PCB/ S5-30 × T2	86	86.5	184	88.0
26	PCB/ S5-30 × T8	87.5	86.5	192.6	102
27	PCB/ S5-30 × T17	86	87	187.9	95.8
28	PCB/ S5-30 × Thai	87.5	88	184.5	81.0
29	PCB/ S5-39 × T2	86.5	86	191	91.0
30	PCB/ S5- 39 × T8	86	88	202.3	95.7
31	PCB/ S5-39 × T17	88	90	171	69.2
32	PCB/ S5- 39 × Thai	87.5	88	171.3	76.3
33	BARI Khoi Bhutta-1	90.5	90.5	188	86.5
34	Thai popcorn	90.5	90.5	171.2	91.45
	Mean(lines)	92.25	93.19	114.5	47.14
	Mean(testers)	91.5	92.5	156.3	78.4
	Mean (hybrids)	86.95	87.23	182.8	85.8
	General mean	88.33	88.8	167.98	78.1
	SE	1.05	1.5	11.44	7.01
	CD at 5%	2.97	4.26	32.53	19.94
	CD at 1%	3.96	5.67	43.37	26.58
	CV%	1.67	2.38	9.63	12.7

Table 4.2. Mean performance of yield and yield contributing characters of lines

Sl. No.	Entries	Grain yield	No of Kernel/ rows	No of kernel row/ear	No of Kernel/ ear	Ear length	Ear diameter	1000 kernel weight	Shelling%
Lines									
1	PCB/ S5-12	1.5	23.8	13.2	314	11.6	9.9	101.53	81.5
2	PCB/ S5- 13	2	16.5	11.8	201	9.8	8.8	121.1	71
3	PCB/ S5-15	1.9	24.1	13.8	332	13.7	9.9	122.1	85.5
4	PCB/ S5- 16	2.8	25.5	12.2	310	12.8	9.9	141.8	82
5	PCB/ S5-17	2.2	29	12.8	371.5	13.5	9.9	112.1	77
6	PCB/ S5-25	2.3	25.8	14.6	377.5	11.9	9.9	106.8	74
7	PCB/ S5-30	2.6	26	12.2	316.5	12.8	10.1	121	74
8	PCB/ S5-39	2.6	27	13.8	372.5	14.2	11	150.7	86.5
Testers									
1	T2	3.1	29	15.1	438	14.4	11	134.6	80.5
2	T8	1.8	20.5	14.2	291	10.8	11.1	128.5	79
3	T17	2.9	24.6	15.6	384	13.3	11.1	111.1	76
4	Thai	5.5	32.6	15.6	508.5	14.3	11.6	147.2	85
Hybrids									
1	PCB/S5-12 × T2	5.9	31.1	14.2	442	15.3	11	150.6	81
2	PCB/ S5- 12× T8	6.1	34.7	13.6	471	16	10.8	155.2	81.5
3	PCB/ S5- 12 × T17	6.1	37.8	14	529.5	18.8	11.2	165.6	80.5
4	PCB/ S5-12 × Thai	5.7	33.2	13.3	441.5	15.7	9.9	144.6	81.5
5	PCB/ S5- 13 × T2	6.2	34.6	15.8	546.5	16.1	12.1	156	81.5
6	PCB/ S5- 13 × T8	6.4	36.3	13.2	479	16.8	11.8	168.3	80
7	PCB/ S5- 13 × T17	7.3	34.3	14.5	497.5	18.4	11.3	212	82

Table 4.2. (continued)

8	PCB/ S5- 13 × Thai	6.1	30.2	22.6	692.5	15.7	11	171.2	81
9	PCB/ S5- 15 × T2	6.3	29	14.2	411	14.9	11.4	164.5	80.5
10	PCB/ S5- 15 × T8	5.3	33.1	14.4	476.5	16.1	12	182.7	81.5
11	PCB/ S5- 15 × T17	6	37	14.6	539.5	16.6	11.1	175	84.5
12	PCB/ S5- 15 × Thai	4.5	27.1	14.9	404	14.1	10.6	166	80
13	PCB/ S5- 16 × T2	5.4	28.2	14.8	418	14.4	11.2	170	79.5
14	PCB/ S5- 16 × T8	5.6	29.4	14.3	420.5	14.6	11	172.5	78.5
15	PCB/ S5- 16 × T17	5.6	30	14.2	424.5	14.2	10.5	189.9	78
16	PCB/ S5- 16 × Thai	5.9	27.2	14.4	391.5	14.7	10.9	150.1	81.5
17	PCB/ S5- 17 × T2	5.2	34.3	15.6	536	16.1	11.7	154.7	80
18	PCB/ S5- 17 × T8	5.1	36.1	15.5	560	15.4	11.6	158.2	80.5
19	PCB/ S5- 17 × T17	5.6	31.7	13.2	418	17.2	11.3	173.3	82
20	PCB/ S5- 17 × Thai	4.5	32	14.3	457.5	16	11.1	160.1	79.5
21	PCB/ S5- 25 × T2	5.5	35.7	14.4	514	15	11.6	158.4	80.5
22	PCB/ S5-25 × T8	5.6	39	14.2	553.5	15.9	12.5	154.3	80.5
23	PCB/ S5- 25 × T17	6.5	33.1	15.2	503	17.3	11.4	167.3	81
24	PCB/ S5-25 × Thai	5.6	31.9	15.1	481.5	15.6	12.1	152.4	82.5
25	PCB/ S5-30 × T2	4.8	29.7	13.8	409.5	14.1	11.2	145.8	79
26	PCB/ S5-30 × T8	5.9	34.9	14.2	495	15.2	11.3	158.4	81.5
27	PCB/ S5-30 × T17	6.2	33.6	14.2	477	17.1	12.1	171	82
28	PCB/ S5-30 × Thai	4.8	34.8	15	524	15	11.5	161.6	82.5
29	PCB/ S5-39 × T2	5.9	36.4	14.4	523.5	16.3	12	177.9	82.5
30	PCB/ S5- 39 × T8	6.6	27.4	12.6	347.5	14.3	10.1	175.8	83
31	PCB/ S5-39 × T17	5.3	32	14.4	461	17.9	11.3	168.1	84
32	PCB/ S5- 39 × Thai	6.2	35.3	14.2	501	16.8	11.5	168.4	82
33	BARI Khoi Bhutta-1	4.69	29.3	12.6	369.2	14	11.2	133.43	82.8

Table 4.2. (continued)

34	Thai popcorn	5.48	35.6	14.6	519.76	15.3	12	147.15	86.5
	Mean(lines)	2.23	24.71	13.05	324.38	12.54	9.93	122.13	78.9
	Mean(testers)	3.33	26.68	15.13	405.38	13.2	11.19	130.3	80.13
	Mean (hybrids)	5.74	32.84	14.6	479.61	15.86	11.32	165.6	81.13
	General mean	4.88	30.8	14.37	444.64				
	SE	0.48	1.45	1.52	52.47	15.01	11.05	154.5	80.64
	CD at 5%	1.36	4.13	4.32	149.16	0.66	0.43	5.7	1.8
	CD at 1%	1.81	5.5	5.75	198.88	1.86	1.21	16.3	5.12
	CV%	13.82	6.66	14.94	16.69	2.48	1.61	21.77	6.82

Table 4.3: Mean performance of quality parameters of lines, testers and crosses of popcorn

	Entry	Popping %	Popping volume	Taste score	Popping expansion
Lines(fermales)					
1	PCB/ S5-12	98	28.7	2.5	27.4
2	PCB/ S5- 13	94.5	19.8	4	18.4
3	PCB/ S5-15	97.8	28.2	2	26.9
4	PCB/ S5- 16	96.3	25.2	1	23.8
5	PCB/ S5-17	96	34.8	1	33.3
6	PCB/ S5-25	93.5	21.5	2	20.2
7	PCB/ S5-30	97.5	26.4	1.5	25
8	PCB/ S5-39	95.3	29.1	1	27.7
Testers (males)					
1	T2	93.3	27.4	1.5	26.1
2	T8	95.8	24.5	3	23.1
3	T17	94	25	3	23.7
4	Thai	88.3	18.9	2.5	17.6
Hybrids					
1	PCB/S5-12 × T2	95.5	28.2	2.5	26.9
2	PCB/ S5- 12× T8	98.3	27	2	25.7
3	PCB/ S5- 12 × T17	94.8	27.4	1.5	26.1
4	PCB/ S5-12 × Thai	93.5	25.2	2.5	23.9
5	PCB/ S5- 13 × T2	92.5	20	3	18.7
6	PCB/ S5- 13 × T8	96	30.2	1.5	28.8
7	PCB/ S5- 13 × T17	91.3	21.9	1.5	20.5
8	PCB/ S5- 13 × Thai	95.3	25.1	1.5	23.8
9	PCB/ S5- 15 × T2	93.3	24.5	1.5	23.2
10	PCB/ S5- 15 × T8	93.3	24.4	1	23.1
11	PCB/ S5- 15 × T17	94.8	24.3	1	23.1
12	PCB/ S5- 15 × Thai	98.3	27	1.5	25.8
13	PCB/ S5- 16 × T2	97.3	27.3	1	26.1
14	PCB/ S5- 16 × T8	96.5	27.6	1.5	26.4
15	PCB/ S5- 16 × T17	98.5	28.6	1	27.3
16	PCB/ S5- 16 × Thai	93	27.1	1.5	25.9
17	PCB/ S5- 17 × T2	96	26.5	1.5	25.2
18	PCB/ S5- 17 × T8	96.8	27.3	2	26.1
19	PCB/ S5- 17 × T17	95.5	26.7	1.5	25.4
20	PCB/ S5- 17 × Thai	92	22.6	2	21.3
21	PCB/ S5- 25 × T2	96	29	1.5	27.8
22	PCB/ S5-25 × T8	97.3	25.8	1.5	24.5
23	PCB/ S5- 25 × T17	93.8	24.5	1.5	23.2
24	PCB/ S5-25 × Thai	88.8	21.3	2	20
25	PCB/ S5-30 × T2	97.3	29.3	1.5	28.1
26	PCB/ S5-30 × T8	97.8	29.2	2	28

Table 4.3. (continued)

27	PCB/ S5-30 × T17	92.8	27.8	1.5	26.5
28	PCB/ S5-30 × Thai	93.5	27.2	1.5	26
29	PCB/ S5-39 × T2	93	23.2	2.5	21.9
30	PCB/ S5- 39 × T8	94.3	24.3	1.5	23.0
31	PCB/ S5-39 × T17	97	25.5	1	24.1
32	PCB/ S5- 39 × Thai	96.5	27.8	2	26.5
33	BARI Khoi Bhutta-1	81.75	37.5	3	17.42
34	Thai popcorn	96.25	18.9	2.5	21.65
	Mean (lines)	96.09	26.7	1.87	25.36
	Mean (testers)	92.81	23.95	2.5	22.66
	Mean (hybrids)	94.99	26.06	1.66	24.78
	General mean	94.99	25.98	1.77	24.69
	SE	1.98	2.05	0.62	2.05
	CD at 5%	5.62	5.83	1.76	5.83
	CD at 1%	7.5	7.77	2.34	7.78
	CV%	2.94	11.16	49.3	11.76

T17) in hybrids. Twenty four hybrids showed higher ear length.

4.4.2.6 Ear diameter

Ear diameter varied from 8.8 (PCB/ S5- 13) to 11 (PCB/ S5-39) in females, 11 (T_2) to 11.6 (Thai) in males and 9.9 (PCB/ S5-12 × Thai) to 12.5 (PCB/ S5-25 × T8) in hybrids. Nine hybrids showed higher ear length.

4.4.2.7 1000 kernel weight

1000 kernel weight varied from 101.53 (PCB/ S5- 12) to 150.7 (PCB/ S5-39) in females, 111.1 (T_{17}) to 147.2 (Thai) in males and 144.6 (PCB/ S5-12 × Thai) to 212 (PCB/ S5- 13 × T17) in hybrids. Seventeen hybrids showed higher 1000 kernel weight.

4.4.2.8 Shelling percentage

Shelling percentage varied from 71 (PCB/ S5- 13) to 86.5 (PCB/ S5-39) in females, 76 (T_{17}) to 85 (Thai) in males and 78 (PCB/ S5- 16 × T17) to 84 (PCB/ S5-39 × T17) in hybrids. Sixteen hybrids showed higher shelling percentage.

4.4.3 Quality parameters

4.4.3.1 Popping percentage

Popping percentage varied from 93.5 (PCB/ S5-25) to 98 (PCB/ S5-12) in females, 88.3 (Thai) to 95.8 (T_8) in males and 88.8 (PCB/ S5-25 × Thai) to 97.8 (PCB/ S5-30 × T8) in hybrids. Seventeen hybrids showed higher popping percentage.

4.4.3.2 Popping volume

Popping volume varied from 19.8 (PCB/ S5- 13) to 34.8 (PCB/ S5- 17) in females, 18.9 (Thai) to 27.4 (T2) in males and 20 (PCB/ S5- 13 × T2) to 30.2 (PCB/ S5- 13 × T8) in hybrids. Sixteen hybrids showed higher 17 hybrids showed higher popping volume.

4.4.3.3 Taste score

Taste score varied from 1 (PCB/ S5- 16, PCB/ S5- 17 and PCB/ S5- 39) to 4 (PCB/ S5- 13) in females, 1.5 (T_2) to 3 (T_{17} and T_8) in males and 1 (PCB/ S5- 15 × T2, PCB/ S5- 15 × T8, PCB/ S5- 16 × T17 and PCB/ S5-39 × T17) to 3 (PCB/ S5- 13 × T2) in hybrids. Twenty two hybrids among 32 showed very good taste score.

4.4.3.4 Popping expansion (cc^3/gm)

Popping expansion varied from 18.4 (PCB/ S5- 13) to 33.3 (PCB/ S5- 17) in females, 17.6 (Thai) to 26.1 (T_2) in males and 18.7 (PCB/ S5- 13 × T2) to 28.8 (PCB/ S5- 13 × T8) in hybrids. Nineteen hybrids showed higher popping expansion.

4.5 ANOVA of combining ability

4.5.1 Variance due to females, males and female × male interaction

Variance due to females, males and female × male interaction in respect of 16 characters are presented in Table (5.1 to 5.3). The variance due to female was highly significant for all characters except for number of kernel rows per ear, popping percentage and taste score. Variance due to male were highly significant for all characters except number of kernel rows per ear, number of kernel per ear, shelling percentage, popping volume, popping percentage, taste score and popping expansion. The female × male interaction variance were highly significant for ear height, number of kernel per row, ear diameter, 1000 kernel weight, popping volume, popping expansion and popping percentage.

4.5.2 Estimates of gene actions

The variances σ^2g (line), σ^2g (tester), σ^2gca, σ^2sca and σ^2gca/σ^2sca are presented in Table (6.1 to 6.3). The analysis of variance revealed highest magnitude of SCA than GCA for most of the characters and the ratio GCA to the SCA variance of all characters less than unity. The analysis of variance revealed highest magnitude of dominance than additive for most of the characters. The ratio of additive to dominance was lesser than unity for all characters.

Table 5.1: Mean sum of squares of female, males and female × male interaction in respect of growth characters in popcorn

Source of variation	Degrees of freedom	Days to 50% pollen shedding	Days to 50% silking	Plant hight	Ear hight
Replication	1	47	54	378	198
Females (lines)	7	8**	11*	501*	384**
Males (tasteers)	3	10**	14*	1384**	901**
Females × Males	21	2	4	184	190*
Error	31	2	5	173	108

Table 5.2: Mean sum of squares of female, males and female × male interaction in respect of yield and yield contributing characters in popcorn

Source of variation	Degrees of freedom	Grain Yield ton/ha	No. Of Kernel/ row	No. Of kernel Row/ ear	No. Of Kernel/ ear	Ear length	Ear diameter	1000 kernel weight	Shelling %
Replication	1	1	4	11	16933	0.08	0.07	83	14
Females (lines)	7	1.38*	31**	6	13918*	4**	1.11**	560**	8*
Males (tasters)	3	1.28*	21**	7	489	13**	0.58*	1184**	4
Females× Males	21	0.47	18**	5	8252	1	0.53*	188**	3
Error	31	0.5	3	6	6747	0.85	0.23	39.5	3

Table 5.3: Mean sum of squares of female, males and female × male interaction in respect of quality parameters in popcorn

Source of variation	Degrees of freedom	Popping volume	Popping expansion	Popping %	Taste score
Replication	1	25	25	65	0.6
Females (lines)	7	16.82**	17.07**	5.5	0.7
Males (tasters)	3	6.84	7.03	16	1
Females × Males	21	11.37*	11.45*	12*	0.3
Error	31	5	5	6	0.8

* significant at 5% ** significant at 1%

Table 6.1: Estimates of variance components as reference to the prevailing gene action in popcorn for growth characters

Sl. No.	Characters	σ^2g (Line)	σ^2g (Taster)	σ^2gca	σ^2sca	σ^2gca/ σ^2sca
1	Days to 50% pollen shedding	0.8	0.5	0.06	0.3	0.2
2	Days to 50% silking	0.8	0.6	0.07	-0.5	-0.1
3	Plant height	39.6	74.9	5.4	5.5	0.98
4	Ear height	24	44	3.3	41	0.08

Table 6.2: Estimates of variance components as reference to the prevailing gene action in popcorn for yield and yield contributing characters

Sl. No.	Characters	σ^2g (Line)	σ^2g (Taster)	σ^2gca	σ^2sca	σ^2gca/ σ^2sca
1	Grain yield	0.1	0.05	0.008	-0.03	0.2
2	No of kernel/rows	1.6	0.2	0.09	7.5	0.01
3	No of kernel row/ear	0.1	0.1	0.01	-0.5	-0.02
4	No of kernel/ear	708	-485	15.7	752	0.02
5	Ear length	0.4	0.7	0.05	0.2	0.25
6	Ear diameter	0.07	0.003	0.004	0.14	0.03
7	1000 kernel weight	46	62	5.4	74.5	0.07
8	Shelling%	0.6	0.08	0.03	-0.2	-0.15

Table 6.3: Estimates of variance components as reference to the prevailing gene action in popcorn for quality characters

Sl. No.	Characters	σ^2g (Line)	σ^2g (Taster)	σ^2gca	σ^2sca	σ^2gca/ σ^2sca
1	Popping %	-0.7	0.2	-0.03	2.5	-0.01
2	Popping volume	0.7	-0.3	0.02	3.1	0.006
3	Taste score	0.05	0.04	0.004	-0.2	-0.002
4	Popping expansion	0.7	-0.2	0.02	3.1	0.006

4.6 General combining ability effects

The gca effects of 8 female parants (line) and 4 male parents (tester) for different traits are given in Table 7.1 to 7.3. Parents with best gca value are presented in plate 6. Harvested cob of selected parents are shown in plate 7.

4.6.1 Growth characters

4.6.1.1 Days to 50 percent pollen shedding

The gca effect for days to 50% pollen shedding varied from-0.8 to 1.9 in females. Out of 8 female lines, as many as 4 exhibited negative gca effects where as remaining 4 lines had positive gca effects. Line PCB/ S5-25 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5- 13 exhibited highly significant positive gca effect. Two testers (T_{17} and Thai) showed positive gca effect and two testers (T_2 and T_8) showed negative gca effect, (T_8) being negatively significant and (Thai) being positively significant.

4.6.1.2 Days to 50 percent silking

The gca effect for days to 50% silking varied from -1.6 to 1.6 in females. Out of 8 female lines, as many as 4 exhibited negative gca effects where as remaining 4 lines had positive gca effects. Line PCB/ S5-25 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5- 13 exhibited highly significant positive gca effect. Two testers (T_{17} and Thai) showed positive gca effect and two testers (T_2 and T_8) showed negative gca effect, none of them being significant.

4.6.1.3 Plant height

The gca effect for plant height varied from -13.9 to 10.8 in females. Out of 8 female lines, as many as 2 exhibited negative gca effects where as remaining 6 lines had positive gca effects. Line PCB/ S5-12 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5-17 exhibited significant positive gca effect. Two testers (T_{17} and Thai) showed negative gca effect and two testers (T_2 and T_8) showed positive gca effect, (T_{17}) being negatively significant and (T_8) being positively high significant.

Plate 6: Parents with best GCA value

Plate 7: Harvested cob of some parents

4.6.1.4 Ear height

The gca effect for ear height varied from -11.3 to 9.5 in females. Out of 8 female lines, as many as 5 exhibited negative gca effects where as remaining 3 lines had positive gca effects. Line PCB/ S5-12 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5-17 exhibited significant positive gca effect. Three testers (T_2, T_{17} and Thai) showed negative gca effect and one tester (T_8) showed positive gca effect, (T_{17}) being negatively significant and (T_8) being positively high significant.

4.6.2 Yield and yield contributing characters

4.6.2.1 Grain yield (ton/hectare)

The gca effect for grain yield varied from -0.6 to 0.8 in females. Out of 8 female lines, as many as 4 exhibited negative gca effects where as remaining 4 lines had positive gca effects. Line PCB/ S5-17 exhibited significant gca effect in negative direction. On the other hand PCB/ S5-13 exhibited significantly high positive gca effect. Two testers (T_2 and Thai) showed negative gca effect and two testers (T_8 and T_{17}) showed positive gca effect, none of them being significant.

4.6.2.2 Number of kernels per row

The gca effect for number of kernels per row varied from -4.2 to 2.08 in females. Out of 8 female lines, as many as 3 exhibited negative gca effects where as remaining 5 lines had positive gca effects. Line PCB/ S5-16 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5-25 exhibited significantly high positive gca effect. Two testers (T_2 and Thai) showed negative gca effect and two testers (T_8 and T_{17}) showed positive gca effect, (Thai) being negatively high significant and (T_8) being positively significant.

4.6.2.3 Number of kernel rows per ear

The gca effect for number of kernels rows per ear varied from -0.8 to 1.9 in females. Out of 8 female lines, as many as 5 exhibited negative gca effects where as remaining 3 lines had positive gca effects. Line PCB/ S5-13 exhibited significant positive gca effect, while no significant gca effect observed in negative direction.

Two testers (T_8 and T_{17}) showed negative gca effect and two testers (T_2 and Thai) showed positive gca effect, none of them being significant.

4.6.2.4 Number of kernels per ear

The gca effect for number of kernels per ear varied from -65.98 to 74.3 in females. Out of 8 female lines, as many as 5 exhibited negative gca effects where as remaining 3 lines had positive gca effects. Line PCB/ S5-16 exhibited significant gca effect in negative direction. On the other hand PCB/ S5-13 exhibited significant positive gca effect. Two testers (T_2 and T_8) showed negative gca effect and two testers (T_{17} and Thai) showed positive gca effect, none of them being significant.

4.6.2.5 Ear length

The gca effect for ear length varied from -1.4 to 0.9 in females. Out of 8 female lines, as many as 3 exhibited negative gca effects where as remaining 5 lines had positive gca effects. Line PCB/ S5-16 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5-13 exhibited significantly high positive gca effect. Three testers (T2, T8 and Thai) showed negative gca effect and one tester (T17) showed positive gca effect, (T2) being negatively significant and (T17) being positively high significant.

4.6.2.6 Ear diameter

The gca effect for ear diameter varied from -0.6 to 0.6 in females. Out of 8 female lines, as many as 4 exhibited negative gca effects where as remaining 4 lines had positive gca effects. Line PCB/ S5-12 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5-25 exhibited significantly high positive gca effect. Two testers (T17 and Thai) showed negative gca effect and two tester (T2 and T8) showed positive gca effect, none of them being significant.

4.6.2.7 1000 kernel weight

The gca effect for 1000 kernel weight varied from -11.6 to 11.2 in females. Out of 8 female lines, as many as 4 exhibited negative gca effects where as remaining 4 lines had positive gca effects. Lines PCB/ S5-12, PCB/ S5-25 and PCB/ S5-30 exhibited significantly high gca effect in negative direction. On the other hand PCB/ S5-13, PCB/ S5-15 and PCB/ S5-39 exhibited significantly high positive gca effect.

Table 7.1 General combining ability (gca) effects of parents in respect of growth characters

Sl.No.	Entries	Days to 50% pollen shedding	Days to 50% silking	Plant height	Ear height
Lines (Females)					
1	PCB/ S5-12	-0.3	1.1	-13.9**	-11.3**
2	PCB/ S5- 13	1.9**	1.6*	0.38	-3.5
3	PCB/ S5-15	-0.8	-1.2	-9	-3.8
4	PCB/ S5- 16	0.7	0.3	0.7	6.9
5	PCB/ S5-17	0.2	-0.7	10.5*	9.5*
6	PCB/ S5-25	-1.5**	-1.6*	5.8	-0.96
7	PCB/ S5-30	-0.2	-0.2	4.4	5.9
8	PCB/ S5-39	0.1	1.1*	1.1	-2.8
Tasters (males)					
1	T2	-0.4	-0.6	2.38	-1.9
2	T8	-0.9*	-0.9	12.1**	11.1**
3	T17	0.4	0.4	-8.6*	-5.3*
4	Thai	0.9*	1.1	-5.9	-3.8
	CD at 5% Females	1.39	2.2	13.23	10.46
	CD at 1% Females	1.85	2.9	17.6	13.95
	S.E for line	0.49	0.77	4.6	3.68
	CD at 5% Males	0.98	1.54	9.35	7.4
	CD at 1% Male	1.3	2.06	12.47	9.86
	S.E for taster	0.34	0.54	3.3	2.6

Table 7.2 General combining ability (gca) effects of parents in respect of yield and yield contributing characters

Sl.No.	Entries	Grain yield	No of Kernels/row	No of kernel rows/ear	No of Kernels/ear	Ear length	Ear diameter	1000 kernel weight	Shelling%
Lines (Females)									
1	PCB/ S5-12	0.2	1.4*	-0.8	-8.6	0.6	-0.6**	-11.6**	0.00
2	PCB/ S5- 13	0.8**	1.01	1.9*	74.3*	0.9**	0.2	11.2**	0.00
3	PCB/ S5-15	-0.2	-1.3*	-0.08	-21.9	-0.4	-0.04	6.4**	0.5
4	PCB/ S5- 16	-0.1	-4.2**	-0.18	-65.98*	-1.4**	-0.4	5.05*	-1.8*
5	PCB/ S5-17	-0.6*	0.7	0.05	13.3	0.3	0.1	-4.05	-0.6
6	PCB/ S5-25	0.04	2.08**	0.12	33.4	0.08	0.6**	-7.5**	0.00
7	PCB/ S5-30	-0.3	0.4	-0.3	-3.11	-0.5	0.2	-6.43**	0.13
8	PCB/ S5-39	0.3	-0.07	-0.7	-21.4	0.5	-0.09	6.9**	1.8*
Tasters (males)									
1	T2	-0.09	-0.5	0.05	-4.6	-0.6*	0.2	-5.87**	-0.56
2	T8	0.09	1.02*	-0.6	-4.2	-0.3	0.07	0.05	-0.25
3	T17	0.33	0.83*	-0.3	1.7	1.3**	-0.04	12.15**	0.63
4	Thai	-0.33	-1.4**	0.9	7.1	-0.4	-0.2	-6.33**	0.19
	CD at 5% Females	0.74	1.66	2.45	82.5	0.92	0.48	6.32	1.86
	CD at 1% Females	0.98	2.2	3.26	110	1.23	0.64	8.42	2.5
	S.E for line	0.26	0.58	0.86	29	0.33	0.17	2.22	0.65
	CD at 5% Males	0.52	1.17	1.73	58.4	0.66	0.34	4.46	1.3
	CD at 1% Male	0.69	1.56	2.31	77.8	0.87	0.46	5.96	1.75
	S.E for taster	0.18	0.41	0.61	20.5	0.23	0.12	1.57	0.46

Table 7.3: General combining ability (gca) effects of parents in respect of quality parameters

Sl. no	Entry	Popping %	Popping volume	Taste score	Popping expansion
Lines					
1	PCB/ S5-12	0.5	0.9	0.5	0.9
2	PCB/ S5- 13	-1.2	-1.8*	0.2	-1.8*
3	PCB/ S5-15	-0.1	-1.02	-0.4	-1
4	PCB/ S5- 16	1.3	1.6*	-0.4	1.6*
5	PCB/ S5-17	0.07	-0.3	0.09	-0.3
6	PCB/ S5-25	-1.05	-0.9	-0.03	-0.9
7	PCB/ S5-30	0.3	2.3**	-0.03	2.4**
8	PCB/ S5-39	0.2	-0.9	0.09	-0.9
Tasters					
1	T2	0.1	-0.05	0.22	-0.05
2	T8	1.26	0.9	-0.03	0.9
3	T17	-0.2	-0.2	-0.3	-0.3
4	Thai	-1.2	-0.6	0.2	-0.6
	CD at 5% Females	2.6	2.28	0.87	2.27
	CD at 1% Females	3.45	3.04	1.16	3.03
	S.E for line	0.91	0.8	0.3	0.8
	CD at 5% Males	1.83	1.6	0.62	1.6
	CD at 1% Male	2.4	2.14	0.82	2.14
	S.E for taster	0.64	0.57	0.23	0.56

Two testers (T_2 and Thai) showed highly significant negative gca effect while two tester (T_8 and T_{17}) showed positive gca effect among them (T_{17}) was highly significance.

4.6.2.8 Shelling percentage

The gca effect for shelling percentage varied from -1.8 to 1.8 in females. Out of 8 female lines, as many as 2 exhibited negative gca effects where as among remaining 6 lines, 2 had positive gca effects and 3 lines showed null effect. Line PCB/ S5-16 exhibited significant gca effect in negative direction. On the other hand PCB/ S5-30 and PCB/ S5-30 exhibited positive gca effect, none of them being significant. Two testers (T_2 and T_8) showed negative gca effect and two tester (T_{17} and Thai) showed positive gca effect, none of them being significant.

4.6.3 Quality parameters

4.6.3.1 Popping percentage

The gca effect for popping percentage varied from -1.2 to 1.3 in females. Out of 8 female lines, as many as 3 exhibited negative gca effects where as remaining 5 lines had positive gca effects, none of them being significant. Two testers (T_{17} and Thai) showed negative gca effect and two tester (T_2 and T_8) showed positive gca effect, none of them being significant.

4.6.3.2 Popping volume

The gca effect for popping volume varied from -1.8 to 2.3 in females. Out of 8 female lines, as many as 5 exhibited negative gca effects where as remaining 3 lines had positive gca effects. Lines PCB/ S5-13 exhibited significant gca effect in negative direction. On the other hand PCB/ S5-30 and PCB/S5-16 exhibited significantly high positive gca effect. Three testers (T_2, T_{17} and Thai) showed negative gca effect while one tester (T_8) showed positive gca effect, none of them being significant.

4.6.3.3 Taste score

The gca effect for taste score varied from -0.4 to 0.5 in females. Out of 8 female lines, as many as 4 exhibited negative gca effects where as remaining 4 lines had positive gca effects, none of them being significant. Two testers (T_8 and T_{17}) showed negative gca effect while two testers (T_2 and Thai) showed positive gca effect, none of them being significant.

4.6.3.4 Popping expansion

The gca effect for popping expansion varied from -1.8 to 2.4 in females. Out of 8 female lines, as many as 5 exhibited negative gca effects where as remaining 3 lines had positive gca effects. Lines PCB/ S5-13 exhibited significant gca effect in negative direction. On the other hand PCB/ S5-30 and PCB/S5-16 exhibited significantly high positive gca effect. Three testers (T2, T17 and Thai) showed negative gca effect while one tester (T8) showed positive gca effect, none of them being significant.

4.7 Specific combing ability effect

The Specific combing ability effects of 32 hybrids are presented in Table 8.1 to 8.3. Picture of some promising hybrids and their hervested cob are presented in plate 8 and 9 respectively

4.7.1 Growth characters

4.7.1.1 Days to 50 percent pollen shedding

The sca effect for days to 50% pollen shedding varied from -1.73 (PCB/ S5- 15 × T2) to 1.64 (PCB/S5-30× T8). Out of 32 hybrids 17 hybrids manifested negative sca effects where as remaining 15 hybrids manifested positive sca effects. None of them are significant.

4.7.1.2 Days to 50 percent silking

The sca effect for days to 50% silking varied from -2.89 (PCB/ S5- 15 × T2) to 1.92 (PCB/S5-15× T8). Out of 32 hybrids 16 hybrids manifested negative sca effects where as remaining 16 hybrids manifested positive sca effects, none of them being significant.

Plate 8: Some promising hybrids

Plate 9: Harvesterd cob of some promising hybrids

4.7.1.3 Plant height

The sca effect for plant height varied from -16.49 (PCB/ S5-25 × T2) to 16.89 (PCB/S5-16× Thai). Out of 32 hybrids 15 hybrids manifested negative sca effects where as remaining 17 hybrids manifested positive sca effects, none of them being significant.

4.7.1.4 Ear height

The sca effect for plant height varied from -22.74 (PCB/ S5-25 × T2) to 12.61 (PCB/S5-17× T2). Out of 32 hybrids 17 hybrids manifested negative sca effects where as remaining 15 hybrids manifested positive sca effects, none of them being significant.

4.7.2 Yield and yield contributing characters

4.7.2.1 Grain yield

The sca effect for grain yield varied from -0.67 (PCB/ S5-15 × Thai) to 0.87 (PCB/S5-15× T2). Out of 32 hybrids 16 hybrids manifested negative sca effects where as remaining 16 hybrids manifested positive sca effects. Among 16 hybrids significant negative sca effects were observed in PCB/ S5- 15 × Thai, PCB/ S5-30 × T2 and PCB/ S5-39 × T17. On the other hand among 16 hybrids that exhibited positive sca effects (PCB/ S5- 13 × T17, PCB/ S5-30 × T17, PCB/ S5- 39 × Thai) and (PCB/ S5-15 × T2, PCB/ S5- 16 × Thai, PCB/ S5- 39 × T8) were significant and highly significant respectively.

4.7.2.2 Number of kernel per row

The sca effect for Number of kernel per row varied from -6.40 (PCB/ S5-39 × T8) to 4.63 (PCB/S5-15× T17). Out of 32 hybrids 17 hybrids manifested negative sca effects where as remaining 15 hybrids manifested positive sca effects. Among 17 hybrids that exhibited negative sca effects (PCB/ S5- 12 × T2, PCB/ S5-17 × T17,PCB/ S5-30 × T2) and (PCB/ S5-39 × T8) were significant and highly significant respectively. On the other hand among 15 hybrids that exhibited positive sca effects (PCB/ S5- 25 × T8, PCB/ S5-30 × Thai) and (PCB/ S5-15 × T17, PCB/ S5- 25 × T8, PCB/ S5- 39 × T2, PCB/ S5- 39 × Thai) were significant and highly significant respectivel

Table 8.1 Specific combining ability (sca) effects of single cross hybrids of popcorn in respect of growth characters

Sl.No.	Entries	Days to 50% pollen sheding	Days to 50% silking	Plant height	Ear height
1	PCB/S5-12 × T2	-0.73	-0.27	3.27	-12.54
2	PCB/ S5- 12× T8	-0.23	-0.45	0.23	0.4
3	PCB/ S5- 12 × T17	0.95	0.23	5.9	5.94
4	PCB/ S5-12 × Thai	0.02	0.48	-9.39	6.2
5	PCB/ S5- 13 × T2	0.02	0.73	-0.74	-1.72
6	PCB/ S5- 13 × T8	-1.48	-0.95	-1.02	5.96
7	PCB/ S5- 13 × T17	0.2	-0.77	7	-1.8
8	PCB/ S5- 13 × Thai	1.27	0.98	-5.24	-2.44
9	PCB/ S5- 15 × T2	-1.73	-2.89	5.94	8.05
10	PCB/ S5- 15 × T8	1.27	1.92	0.75	-5.56
11	PCB/ S5- 15 × T17	-0.05	0.11	4.22	-4.17
12	PCB/ S5- 15 × Thai	0.52	0.86	-10.91	1.68
13	PCB/ S5- 16 × T2	1.27	1.11	0.84	8.21
14	PCB/ S5- 16 × T8	0.27	-0.08	-1.45	-1.55
15	PCB/ S5- 16 × T17	-0.55	-0.89	-16.28	-10.56
16	PCB/ S5- 16 × Thai.	-0.98	-0.14	16.89	3.9
17	PCB/ S5- 17 × T2	0.77	1.61	8.09	12.61
18	PCB/ S5- 17 × T8	-0.23	-0.58	4.4	0.50
19	PCB/ S5- 17 × T17	-0.05	1.11	-10.8	-1.41
20	PCB/ S5- 17 × Thai	-0.48	-2.14	-1.66	-11.7
21	PCB/ S5- 25 × T2	0.89	0.98	-16.49	-22.74
22	PCB/ S5-25 × T8	-1.11	-1.2	-2.48	-0.55
23	PCB/ S5- 25 × T17	0.08	-1.02	5.14	11.14
24	PCB/ S5-25 × Thai	0.14	1.23	13.83	12.15
25	PCB/ S5-30 × T2	-0.36	0.11	-5.65	-1.77
26	PCB/ S5-30 × T8	1.64	0.42	-6.74	-0.79
27	PCB/ S5-30 × T17	-1.17	-0.39	9.18	9.4
28	PCB/ S5-30 × Thai	-0.11	-0.14	3.2	-6.84
29	PCB/ S5-39 × T2	-0.11	-1.39	4.74	9.89
30	PCB/ S5- 39 × T8	-0.11	0.92	6.3	1.58
31	PCB/ S5-39 × T17	0.58	1.61	-4.33	-8.54
32	PCB/ S5- 39 × Thai	-0.36	-1.14	-6.71	-2.93
	CD at 5%	2.78	4.38	26.46	20.9
	CD at 1%	3.7	5.83	35.28	27.9

Table 8.2 Specific combining ability (sca) effects of single cross hybrids of popcorn in respect of yield and yield contributing charecters

Sl. No.	Entries	Grain yield	No of kernel/rows	No of kernel row/ear	No of kernel/ear	Ear length	Ear diameter	1000 kernel weight	Shelling%
1	PCB/S5-12 × T2	0.06	-2.63*	0.38	-24.45	-0.56	0.06	2.5	0.44
2	PCB/ S5- 12× T8	0.06	-0.52	0.43	4.23	-0.13	-0.0	1.1	0.63
3	PCB/ S5- 12 × T17	-0.22	2.77	0.54	56.80	1.03	0.53	-0.6	-1.25
4	PCB/ S5-12 × Thai	0.10	0.38	-1.35	-36.58	-0.34	-0.59	-3.1	0.2
5	PCB/ S5- 13 × T2	-0.15	1.22	-0.77	-2.83	-0.06	0.34	-15**	0.94
6	PCB/ S5- 13 × T8	-0.21	1.43	-2.72	-70.64	0.37	0.18	-8.6	-0.88
7	PCB/ S5- 13 × T17	0.45 *	-0.38	-1.71	-58.08	0.33	-0.21	23**	0.25
8	PCB/ S5- 13 × Thai	-0.09	-2.27	5.20**	131.55*	-0.64	-0.31	0.7	-0.31
9	PCB/ S5- 15 × T2	0.87 **	-2.11	-0.37	-42.2	0.06	-0.08	-1.7	-0.56
10	PCB/ S5- 15 × T8	-0.32	0.54	0.48	23	1	0.65	10.6*	0.13
11	PCB/ S5- 15 × T17	0.12	4.63**	0.39	80	-0.15	-0.14	-9.2*	2.25
12	PCB/ S5- 15 × Thai	-0.67 **	-3.06*	-0.50	-60.8	-0.91	-0.43	0.3	-1.81
13	PCB/ S5- 16 × T2	-0.12	-0	0.33	8.9	0.51	0.09	5.4	0.69
14	PCB/ S5- 16 × T8	-0.10	-0.30	0.48	11.11	0.45	0.03	1.8	-0.63
15	PCB/ S5- 16 × T17	-0.35	0.39	0.09	9.2	-1.60*	-0.36	7.1	-2
16	PCB/ S5- 16 × Thai.	0.57 **	-0.10	-0.90	-29.2	0.64	0.24	-14.3**	1.94
17	PCB/ S5- 17 × T2	0.17	1.25	0.90	47.7	0.51	0.07	-1	0.06
18	PCB/ S5- 17 × T8	-0.07	1.55	1.45	71.4	-0.45	0.1	-3.4	0.25
19	PCB/ S5- 17 × T17	0.18	-2.66*	-1.13	-76.6	-0.30	-0.09	-0.5	0.88
20	PCB/ S5- 17 × Thai	-0.28	-0.15	-1.22	-42.5	0.24	-0.08	4.9	-1.2
21	PCB/ S5- 25 × T2	-0.17	1.25	-0.37	5.6	-0.35	-0.51	6.2	-0.06
22	PCB/ S5-25 × T8	-0.32	3.05*	0.08	44.7	0.29	0.53	-3.9	-0.38
23	PCB/ S5- 25 × T17	0.37	-2.66*	0.79	-11.7	-0.01	-0.46	-2.9	-0.75
24	PCB/ S5-25 × Thai	0.12	-1.65	-0.50	-38.6	0.07	0.44	0.6	1.19

Table 8.2 (continued)

25	PCB/ S5-30 × T2	-0.66 **	-3.08*	-0.55	-62.5	-0.66	-0.53	-7.6	-1.69
26	PCB/ S5-30 × T8	0.40	0.63	0.50	22.7	0.17	-0.3	-0.8	0.5
27	PCB/ S5-30 × T17	0.52 *	-0.48	0.22	-0.7	0.43	0.61	-0.4	0.13
28	PCB/ S5-30 × Thai	-0.25	2.93*	-0.17	40.4	0.06	0.22	8.8	1.06
29	PCB/ S5-39 × T2	0.01	4.10**	0.45	69.8	0.56	0.57	11.2	0.19
30	PCB/ S5- 39 × T8	0.56 **	-6.40**	0.70	-106.5	-1.70*	-1.2**	3.2	0.38
31	PCB/ S5-39 × T17	-1.07 **	-1.61	0.82	1.05	0.25	0.11	-16.6**	0.5
32	PCB/ S5- 39 × Thai	0.50 *	3.90**	-0.57	35.7	0.89	0.52	2.2	-1.06
	CD at 5%	1.48	3.32	4.9	165	1.85	0.97	12.64	3.7
	CD at 1%	1.97	4.43	6.5	220	2.47	1.3	16.85	4.98

Table 8.3 Specific combining ability (sca) effects of single cross hybrids of popcorn in respect of quality parameters

Sl. No.	Entries	Popping %	Popping volume	Taste score	Popping expansion
1	PCB/S5-12 × T2	-0.1	1.3	0.16	1.29
2	PCB/ S5- 12× T8	1.49	-0.91	-0.09	-0.9
3	PCB/ S5- 12 × T17	-0.54	0.71	-0.28	0.73
4	PCB/ S5-12 × Thai	-0.85	-1.10	0.22	-1.12
5	PCB/ S5- 13 × T2	-1.35	-4.23*	0.91	-4.22 *
6	PCB/ S5- 13 × T8	0.99	4.96*	-0.34	4.95 **
7	PCB/ S5- 13 × T17	-2.29	-2.2	-0.03	-2.19
8	PCB/ S5- 13 × Thai	2.65	1.47	-0.53	1.47
9	PCB/ S5- 15 × T2	-1.73	-0.49	0.03	-0.53
10	PCB/ S5- 15 × T8	-2.88	-1.58	-0.22	-1.61
11	PCB/ S5- 15 × T17	0.09	-0.48	0.09	-0.47
12	PCB/ S5- 15 × Thai	4.52 *	2.56	0.09	2.61
13	PCB/ S5- 16 × T2	0.84	-0.3	-0.47	-0.31
14	PCB/ S5- 16 × T8	-1.07	-1.01	0.28	-0.98
15	PCB/ S5- 16 × T17	2.4	1.18	0.09	1.17
16	PCB/ S5- 16 × Thai.	-2.16	0.13	0.09	0.12
17	PCB/ S5- 17 × T2	0.84	0.75	-0.47	0.78
18	PCB/ S5- 17 × T8	0.43	0.66	0.28	0.65
19	PCB/ S5- 17 × T17	0.65	1.14	0.09	1.14
20	PCB/ S5- 17 × Thai	-1.91	-2.55	0.09	-2.57
21	PCB/ S5- 25 × T2	1.96	3.93*	-0.34	3.94 *
22	PCB/ S5-25 × T8	2.05	-0.28	-0.09	-0.26
23	PCB/ S5- 25 × T17	0.02	-0.45	0.22	-0.47
24	PCB/ S5-25 × Thai	-4.04 *	-3.2	0.22	-3.22
25	PCB/ S5-30 × T2	1.84	1	-0.34	1
26	PCB/ S5-30 × T8	1.18	-0.07	0.41	-0.06
27	PCB/ S5-30 × T17	-2.35	-0.4	0.22	-0.4
28	PCB/ S5-30 × Thai	-0.66	-0.53	-0.28	-0.53
29	PCB/ S5-39 × T2	-2.29	-1.95	0.53	-1.94
30	PCB/ S5- 39 × T8	-2.2	-1.77	-0.22	-1.8
31	PCB/ S5-39 × T17	2.02	0.5	-0.41	0.49
32	PCB/ S5- 39 × Thai	2.46	3.22	0.09	3.25 *
	CD at 5%	5.19	4.56	1.75	4.55
	CD at 1%	6.92	6.08	2.33	6.07

4.7.2.3 Number of kernel rows per ear

The sca effect for number of kernel rows per ear varied from -2.72 (PCB/ S5-13 × T8) to 5.20 (PCB/S5-13 × Thai). Out of 32 hybrids 14 hybrids manifested negative sca effects where as remaining 18 hybrids manifested positive sca effects. Among all hybrids only PCB/S513×Thai exhibited highly positive significant sca effect while no negative significant effects were observed.

4.7.2.4 Number of kernels per ear

The sca effect for number of kernels per ear varied from -106.5 (PCB/ S5-39 × T8) to 131.55 (PCB/S5-13 × Thai). Out of 32 hybrids 15 hybrids manifested negative sca effects where as remaining 17 hybrids manifested positive sca effects. Among all hybrids only PCB/S513×Thai exhibited positive significant sca effect while no negative significant effects were observed.

4.7.2.5 Ear length

The sca effect for ear length varied from -1.7 (PCB/ S5-39 × T8) to 1.03 (PCB/S5-12 × T17). Out of 32 hybrids 14 hybrids manifested negative sca effects where as remaining 18 hybrids manifested positive sca effects. Among all hybrids PCB/ S5-39 × T8 and PCB/S5-16×T17 exhibited negative significant sca effect while no positive significant effects were observed.

4.7.2.6 Ear diameter

The sca effect for ear diameter varied from -1.2 (PCB/ S5-39 × T8) to 0.65 (PCB/S5-15 × T8). Out of 32 hybrids 15 hybrids manifested negative sca effects where as remaining 17 hybrids manifested positive sca effects. Among all hybrids only PCB/ S5-39 × T8 exhibited negative significant sca effect while no positive significant effects were observed.

4.7.2.7 1000 kernel weight

The sca effect for 1000 kernel weight varied from -16.60 (PCB/ S5-39 × T17) to 23.0 (PCB/S5-13× T17). Out of 32 hybrids 16 hybrids manifested negative sca effects where as remaining 16 hybrids manifested positive sca effects. Among 16 hybrids that exhibited negative sca effects (PCB/ S5- 15 × T17) and (PCB/ S5-13 × T2, PCB/ S5-16 × Thai, PCB/ S5-39 × T17) were significant and highly significant respectively. On the other hand among 16 hybrids that exhibited positive sca effects (PCB/ S5- 15 × T8) and (PCB/ S5- 13 × T2) were significant and highly significant respectively.

4.7.2.8 Shelling percentage

The sca effect for Shelling percentage varied from -1.81 (PCB/ S5-15 × Thai) to 2.25 (PCB/S5-15× T17). Out of 32 hybrids 13 hybrids manifested negative sca effects where as remaining 19 hybrids manifested positive sca effects, none of them being significant.

4.7.3 Quality parameters

4.7.3.1 Popping percentage

The sca effect for Popping percentage varied from -4.04 (PCB/ S5-25 × Thai) to 4.52 (PCB/S5-15 × Thai). Out of 32 hybrids 15 hybrids manifested negative sca effects where as remaining 17 hybrids manifested positive sca effects. Among all hybrids PCB/S5-15×Thai exhibited positive significant sca effect while PCB/ S5-25 × Thai showed negative significant sca effects.

4.7.3.2 Popping volume

The sca effect for Popping volume varied from -4.23 (PCB/ S5-13 × T2) to 3.93 (PCB/S5-25 × T2). Out of 32 hybrids 18 hybrids manifested negative sca effects where as remaining 14 hybrids manifested positive sca effects. Among all hybrids (PCB/S5-13×T8 and PCB/S5-25×T2) exhibited positive significant sca effect while (PCB/ S5-13 × T2) showed negative significant sca effects.

4.7.3.3 Taste score

The sca effect for taste score varied from -0.53 (PCB/ S5-13 × Thai) to 0.91 (PCB/S5-13× T2). Out of 32 hybrids 14 hybrids manifested negative sca effects where as remaining 18 hybrids manifested positive sca effects, none of them being significant.

4.7.3.4 Popping expansion

The sca effect for Popping expansion varied from -4.22 (PCB/ S5-13 × T2) to 4.95 (PCB/S5-13 × T8). Out of 32 hybrids 18 hybrids manifested negative sca effects where as remaining 14 hybrids manifested positive sca effects. Among 14 hybrids that exhibited positive sca effects (PCB/S5-25 × T2, PCB/S5-39 × Thai) and (PCB/S5-13 × T8) exhibited significant and highly significant sca effect respectively. On the other hand (PCB/ S5-13 × T2) showed negative significant sca effects.

4.8 Heterosis over mid parent, better parent and check varieties

The percentage of heterosis over mid parent (relative heterosis, RH), better parent (heterobaltosis, HB) and over best check (standard heterosis, SH) is presented in Table 9.1 to 9.3. (Thai popcorn) was the earliest to pollen shedding, silking, had higher plant height, ear diameter,1000 kernel weight, shelling percentage, grain yield, popping expansion, taste score and popping percentage than other check(Khoi bhutta), thus found to be best check and used to work out standard heterosis.

4.8.1 Growth characters

4.8.1.1 Days to 50 percent pollen shedding

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -8.99 (PCB/ S5-25 × T8) to -2.75 (PCB/ S5-16 × T2), -11.28 (PCB/ S5-13 × T8) to -3.31 (PCB/ S5-39 × Thai) and -53.6(PCB/ S5-25 × T8) to 0.55(PCB/ S5-13 × Thai) respectively. 31 hybrids exhibited significant negative heterosis over mid parent, 32 over better parent and one over the standard check. The highest significant standard heterosis was manifested by (PCB/ S5-25 × T8) in negative direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-13 × Thai) but was non significant.

4.8.1.2 Days to 50 percent silking

For this trait, heterosis over mid parent, better parent and commercial checks ranged from -10.81 (PCB/ S5-15 × T2) to -1.64 (PCB/ S5-39 × T17), -12.23 (PCB/ S5-15 × T2) to -2.27 (PCB/ S5-39 × Thai) and -54 (PCB/ S5-25 × T8) to 0.55(PCB/ S5-39 × T17) respectively. 25 hybrids exhibited significant negative heterosis over mid parent, 30 over better parent and one over the standard check. The highest significant standard heterosis was manifested by (PCB/ S5-25 × T8) in negative direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-39 × T17) but was non significant.

4.8.1.3 Plant height

The percentage of heterosis over mid parent, better parent and commercial checks ranged from 4.66 (PCB/ S5-39 × Thai) to 86.26 (PCB/ S5-13 × T17), -17.17 (PCB/ S5-12 × Thai) to 37.44 (PCB/ S5-17 × T8) and -10.3 (PCB/ S5-12 × Thai) to 22.51 (PCB/ S5-17 × Thai) respectively. 28 hybrids exhibited significant positive heterosis over mid parent, 19 over better parent and two over the standard check. The highest significant standard heterosis was manifested by (PCB/ S5-17 × T8) in positive direction, on the other hand highest negative standard heterosis was observed in (PCB/ S5-39 × T17) but was non significant.

4.8.1.4 Ear height

The percentage of heterosis over mid parent, better parent and commercial checks ranged from 4.88 (PCB/ S5-39 × Thai) to 65.12 (PCB/ S5-17 × T2), -15.79 (PCB/ S5-13 × Thai) to 50.53 (PCB/ S5-17 × T2) and -34.3 (PCB/ S5-12 × T2) to 16.89 (PCB/ S5-17 × T8) respectively. 21 hybrids exhibited significant positive heterosis over mid parent, 6 over better parent. Three hybrids exhibited significant negative standard heterosis. The highest significant standard heterosis was manifested by (PCB/ S5-12 × T2) in negative direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-17 × T8) but was non significant.

4.8.2 Yield and yield contributing characters

4.8.2.1 Grain yield

For grain yield, heterosis over mid parent, better parent and commercial checks ranged from 16.6 (PCB/ S5-17 × Thai) to 271.08 (PCB/ S5-12 × T8), -18.42 (PCB/ S5-17 × Thai) to 232.15 (PCB/ S5-12 × T8) and -17.97 (PCB/ S5-17 × Thai) to 32.94 (PCB/ S5-13 × T17) respectively. 29 hybrids exhibited significant positive heterosis over mid parent, 24 over better parent, and one over standard check. The highest significant standard heterosis was manifested by (PCB/ S5-13 × T17) in positive direction, on the other hand highest negative standard heterosis was observed in (PCB/ S5-16 × T2) but was non significant.

4.8.2.2 Number of kernel per row

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -6.29 (PCB/ S5-16 × Thai) to 96.22 (PCB/ S5-13 × T8), -16.87 (PCB/ S5-15 × Thai) to 77.07 (PCB/ S5-13 × T8) and -23.9 (PCB/ S5-15 × Thai) to 10.11 (PCB/ S5-39 × T17) respectively. 26 hybrids exhibited significant positive heterosis over mid parent, 17 over better parent. 10 hybrids exhibited significant heterosis over standard check in negative direction. The highest significant standard heterosis was manifested by (PCB/ S5-15 × Thai) in negative direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-39 × T17) but was non significant.

4.8.2.3 Number of kernel row per ear

The percentage of heterosis over mid parent, better parent and commercial for this trait checks ranged from -10 (PCB/ S5-39 × T8) to 64.96 (PCB/ S5-13 × Thai), -15.38 (PCB/ S5-17 × T17) to 44.87 (PCB/ S5-13 × Thai) and -13.7 (PCB/ S5-39 × T8) to 54.8 (PCB/ S5-13 × Thai) respectively. Only (PCB/ S5-13 × Thai) exhibited significant positive heterosis over mid parent, better parent and standard check.

4.8.2.4 Number of kernels per ear

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -4.34 (PCB/ S5-16 × Thai) to 95.21 (PCB/ S5-13 × Thai), -23.01 (PCB/ S5-16 × Thai) to 64.6 (PCB/ S5-13 × T8) and -33.5 (PCB/ S5-39 × T8) to 31.3 (PCB/ S5-13 × Thai) respectively. 12 hybrids exhibited significant positive heterosis over mid parent, 6 over better parent, and one over standard check. The highest significant standard heterosis was manifested by (PCB/ S5-13 × Thai) in positive direction, on the other hand highest negative standard heterosis was observed in (PCB/ S5-25 × T2) but was non significant.

Table 9.1 Percent relative heterosis (RH), heterobaltosis (HB) and standard heterosis (SH) for growth characters in popcorn.

Sl. No	Characters	Days to 50% pollen shedding			Days to 50% silking			Plant height			Ear height		
	Hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	PCB/S5-12 × T2	-5.79**	-7.07**	-5.52	-4.89*	-5.91*	-3.31	35.45**	16.28	1.96	7.71	-14.69	-34.3**
2	PCB/ S5- 12× T8	-7.32**	-7.57**	-5.52	-6.95**	-7.45**	-3.87	39.26**	18.74	5.84	33.18*	-2.27	-5.96
3	PCB/ S5- 12 × T17	-5.12**	-5.88**	-2.76	-5.07*	-5.82*	-1.66	36.06**	21.56	-2.89	41.73*	15.79	-17.81
4	PCB/ S5-12 × Thai	-4.11**	-4.89**	-3.31	-1.91	-3.23	-0.55	4.83	-17.17	-10.3	17.05	-14.79	-15.91
5	PCB/ S5- 13 × T2	-5.35**	-9.23**	-2.21	-6.07**	-9.64**	-1.66	77.39**	23.11*	7.94	42.03**	11.64	-14
6	PCB/ S5- 13 × T8	-8.95**	-11.28**	-4.42	-9.61**	-11.68**	-3.87	84.21**	27.25*	13.43	54.79**	12.84	8.57
7	PCB/ S5- 13 × T17	-6.28**	-8.21**	-1.10	-8.29**	-10.15**	-2.21	86.26**	32.79**	6.07	42.87*	15.79	-17.82
8	PCB/ S5- 13 × Thai	-3.19*	-6.67**	0.55	-3.70	-7.61**	0.55	41.17**	7.25	0.47	16.43	-15.79	-16.89
9	PCB/ S5- 15 × T2	-7.69**	-9.19**	-7.18	-10.81**	-12.23**	-8.84	39.63**	21.31	6.36	56.78**	25.12	-3.61
10	PCB/ S5- 15 × T8	-6.49**	-6.49**	-4.42	-7.45**	-7.45**	-3.87	41.72**	22.27*	9	34.62*	-0.57	-4.32
11	PCB/ S5- 15 × T17	-6.99**	-7.49**	-4.42	-8.22**	-8.47**	-4.42	36.94**	23.90*	-1.02	35.64*	11.71	-20.72
12	PCB/ S5- 15 × Thai	-4.37**	-5.41**	-3.31	-4.61*	-6.38**	-2.76	5.99	-15.36	-8.32	20.76	-11.52	-12.68
13	PCB/ S5- 16 × T2	-2.75	-4.32**	-2.21	-4.86*	-6.38**	-2.76	36.26**	24.38*	9.05	55.07**	40.60**	8.31
14	PCB/ S5- 16 × T8	-5.95**	-5.95**	-3.87	-7.98**	-7.98**	-4.42	40.38**	27.19*	13.37	40.74**	16.19	11.81

Table 9.1 (continued)

15	PCB/ S5- 16 × T17	-5.91**	-6.42**	-3.31	-7.69**	-7.94**	-3.87	21.73*	16.01	-7.33	25.78	18.41	-15.97
16	PCB/ S5- 16 × Thai.	-4.37**	-5.41**	-3.31	-4.07*	-5.85*	-2.21	25.71**	4.85	13.58	25.79	2.83	1.48
17	PCB/ S5- 17 × T2	-3.31*	-4.37**	-3.31	-4.63*	-5.41*	-3.31	41.16**	35.73**	19.01*	65.12**	50.53**	15.97
18	PCB/ S5- 17 × T8	-6.52**	-7.03**	-4.97	-8.85**	-9.57**	-6.08	44.07**	37.44**	22.51*	46.44**	21.48	16.89
19	PCB/ S5- 17 × T17	-5.41**	-6.42**	-3.31	-5.88**	-6.88**	-2.76	26.33**	25.51*	1.58	44.18**	36.52*	-3.12
20	PCB/ S5- 17 × Thai	-3.85**	-4.37**	-3.31	-6.56**	-7.57**	-5.52	14.63	0.13	8.47	7.66	-11.58	-12.74
21	PCB/ S5- 25 × T2	-4.71**	-5.49**	-4.97	-6.27**	-7.03**	-4.97	33.17**	16.25	1.93	11.63	-14.55	-34.2**
22	PCB/ S5-25 × T8	-8.99**	-9.73**	-53.6**	-10.46**	-11.17**	-54**	49.82**	29.87**	15.77	51.95**	8.35	4.26
23	PCB/ S5- 25 × T17	-6.78**	-8.02**	-4.97	-9.09**	-10.05**	-6.08	48.91**	35.42**	8.18	77.05**	39.68*	-0.87
24	PCB/ S5-25 × Thai	-4.68**	-4.95**	-4.42	-3.83	-4.86*	-2.76	32.15**	5.97	14.79	45.83**	3.21	1.86
25	PCB/ S5-30 × T2	-4.71**	-5.49**	-4.97	-5.72**	-6.49**	-4.42	34.81**	22.51*	7.42	51.53**	24.91	-3.77
26	PCB/ S5-30 × T8	-4.63**	-5.41**	-3.31	-7.24**	-7.98**	-4.42	39.83**	26.14*	12.44	52.51**	15.85	11.48
27	PCB/ S5-30 × T17	-6.78**	-8.02**	-4.97	-6.95**	-7.94**	-3.87	44.75**	37.32**	9.69	73.15**	47.53**	4.7
28	PCB/ S5-30 × Thai	-3.58*	-3.85*	-3.31	-3.83	-4.86*	-2.76	19.71*	-0.54	7.74	19.16	-10.25	-11.43
29	PCB/ S5-39 × T2	-3.62*	-3.89*	-4.42	-4.18*	-5.49*	-4.97	30.87**	27.21*	11.53	44.90**	29.17*	-0.49
30	PCB/ S5- 39 × T8	-5.75**	-7.03**	-4.97	-3.56	-6.38**	-2.76	37.40**	32.49**	18.1	33.64**	8.69	4.59
31	PCB/ S5-39 × T17	-4.09**	-5.88**	-2.76	-1.64	-4.27*	0.55	22.78*	20.63	-0.15	15.20	6.55	-24.38*
32	PCB/ S5- 39 × Thai	-3.05*	-3.31*	-3.31	-1.68	-2.27	-2.76	4.66	-7.68	0.00	4.88	-15.51	-16.62

Table 9.2 Percent relative heterosis (RH), heterobaltosis (HB) and standard heterosis (SH) for yield and yield contributing charecters in popcorn.

Sl. No	Characters	Grain yield			No of Kernels/row			No of karnel rows/era			No of karnels/ear		
	Hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	PCB/S5-12 × T2	159.60**	90.91**	7.3	17.80*	7.24	-12.64*	0.35	-5.96	-2.74	17.55	0.91	-15
2	PCB/ S5- 12× T8	271.08**	232.15**	11.22	56.66**	45.80**	-2.53	-0.73	-4.23	-6.85	55.70*	50.00*	-9.2
3	PCB/ S5- 12 × T17	179.17**	109.50**	10.68	56.20**	53.66**	6.18	-2.78	-10.26	-4.11	51.72**	37.89	1.82
4	PCB/ S5-12 × Thai	64.08**	3.63	4.2	17.73**	1.84	-6.74	-7.64	-14.74	-8.9	7.36	-13.18	-15
5	PCB/ S5- 13 × T2	146.09**	101.95**	13.5	52.09**	19.31**	-2.81	17.47	4.64	8.22	71.05**	24.77	5.2
6	PCB/ S5- 13 × T8	234.65**	222.78**	16.33	96.22**	77.07**	1.97	1.54	-7.04	-9.6	94.72**	64.60*	-7.8
7	PCB/ S5- 13 × T17	199.18**	151.64**	32.94*	66.91**	39.43**	-3.65	5.84	-7.05	-0.68	70.09**	29.56	-4.3
8	PCB/ S5- 13 × Thai	62.19**	10.16	10.77	23.01**	-7.36	-15.17*	64.96**	44.87**	54.8**	95.21**	36.18*	31.3**
9	PCB/ S5- 15 × T2	151.70**	103.90**	14.60	9.04	-0.17	-18.7**	-1.73	-5.96	-2.74	6.75	-6.16	-20.9
10	PCB/ S5- 15 × T8	182.51**	176.96**	-3.47	48.43**	37.34**	-7.02	2.86	1.41	-1.37	52.97*	43.52	-8.3
11	PCB/ S5- 15 × T17	148.70**	106.39**	9.03	51.95**	50.41**	3.93	-0.68	-6.41	0.00	50.70**	40.49*	3.9
12	PCB/ S5- 15 × Thai	21.70	-18.06	-17.61	-4.41	-16.87*	-23.9**	1.36	-4.49	2.25	-3.87	-20.55	-22.3
13	PCB/ S5- 16 × T2	84.17**	75.65**	-1.28	3.58	-2.76	-20.8**	8.42	-1.99	1.37	11.76	-4.57	-19.7
14	PCB/ S5- 16 × T8	143.63**	101.79**	2.92	27.97**	15.52	-17.4**	8.33	0.70	-2.05	39.93	35.65	-19
15	PCB/ S5- 16 × T17	97.72**	94.30**	2.65	19.48**	17.49*	-16**	2.16	-8.97	-2.74	22.33	10.55	-18.3

Table 9.2 (continued)

16	PCB/ S5- 16 × Thai.	41.48**	6.62	7.21	-6.29	-16.56*	-23.6**	3.60	-7.69	-1.37	-4.34	-23.01	-24.6
17	PCB/ S5- 17 × T2	96.21**	68.18**	-5.47	18.28**	18.28*	-3.65	11.83	3.31	6.85	32.43*	22.37	2.9
18	PCB/ S5- 17 × T8	154.77**	133.64**	-6.2	45.86**	24.48**	1.4	14.81	9.15	6.16	69.06**	50.74*	7.6*
19	PCB/ S5- 17 × T17	121.20**	94.65**	2.83	18.28**	9.31	-10.96	-7.04	-15.38	-9.6	10.66	8.85	-19.5
20	PCB/ S5- 17 × Thai	16.60	-18.42	-17.97	3.90	-1.84	-10.11	0.70	-8.33	-2.05	3.98	-10.03	-11.9
21	PCB/ S5- 25 × T2	105.99**	78.57**	0.36	30.29**	23.10**	0.28	-3.03	-4.64	-1.37	26.06	17.35	-1.09
22	PCB/ S5-25 × T8	171.55**	146.02**	1.46	68.47**	51.16**	9.55	-1.39	-2.74	-2.74	65.59**	46.62*	6.56*
23	PCB/ S5- 25 × T17	151.99**	124.35**	18.52	31.35**	28.29**	-7.02	0.66	-2.56	4.11	32.11	30.99	-3.2
24	PCB/ S5-25 × Thai	43.37**	1,09	1.64	9.25	-2.15	-10.39	0.00	-3.21	3.42	8.69	-5.31	-7.3
25	PCB/ S5-30 × T2	69.15**	56.66**	-11.95	8.00	2.41	-16.6**	1.10	-8.61	-5.48	8.55	-6.51	-21.1
26	PCB/ S5-30 × T8	163.23**	123.62**	7.12	50.11**	34.23**	-1.97	7.58	0.00	-2.74	62.96**	56.40*	-4.6
27	PCB/ S5-30 × T17	125.91**	115.37**	13.78	32.81**	29.23**	-5.62	2.16	-8.97	-2.74	36.33	24.35	-8.2
28	PCB/ S5-30 × Thai	17.76	-13.07	-12.59	18.77**	6.75	-2.25	7.91	-3.85	2.74	27.03	3.05	0.4
29	PCB/ S5-39 × T2	106.50**	90.91**	7.3	30.00**	25.52**	2.25	-0.35	-4.64	-1.37	29.18	19.52	0.84
30	PCB/ S5- 39 × T8	198.65**	154.11**	21.26	15.37*	1.48	-23**	-10.00	-11.27	-13.7	4.75	-6.71	-33.5
31	PCB/ S5-39 × T17	90.93**	81.69**	-4.01	24.03**	18.52*	10.11	-2.04	-7.69	-1.37	21.88	20.05	-11.3
32	PCB/ S5- 39 × Thai	52.49**	12.43	13.05	18.46**	8.28	-0.84	-3.40	-8.97	-2.74	13.73	-1.47	-3.5

Table 9.2 (continued)

Sl. No.	Characters	Ear length			Ear diameter			1000 kernel weight			Shelling%		
	Hybrids	RH	HB	SH	RH	BH	SH	RH	HB	SH	RH	HB	SH
1	PCB/S5-12 × T2	17.69**	6.25	0.00	5.26	0.00	-8.33	27.6**	11.9	2.3	0.00	-0.61	1.17
2	PCB/ S5- 12× T8	42.86**	37.93**	4.58	2.86	-2.70	-10	34.9**	20.8**	5.5	1.56	0.00	1.64
3	PCB/ S5- 12 × T17	51.00**	41.35**	22.9**	7.16	1.58	-6.46	55.7**	48.9**	12.5*	2.22	-1.23	0.43
4	PCB/ S5-12 × Thai	21.24**	9.79	2.61	-7.91	-14.6**	-17.5**	16.3**	-1.7	-1.7	-2.10	-4.12	1.87
5	PCB/ S5- 13 × T2	33.06**	11.81	5.23	22.22**	10.00	0.83	21.9**	15.9*	5.9	7.59*	1.24	1.73
6	PCB/ S5- 13 × T8	63.11**	55.56**	9.8	18.59**	6.31	-1.67	34.8**	30.9**	14.3*	6.67*	1.27	0.18
7	PCB/ S5- 13 × T17	59.31**	38.35**	20.26**	13.85*	2.26	-5.83	82.6**	75**	44.1**	11.56**	7.89*	2.44
8	PCB/ S5- 13 × Thai	30.29**	9.79	2.61	7.84	-5.17	-8.33	27.6**	16.3**	16.3**	3.85	-4.71	1.4
9	PCB/ S5- 15 × T2	6.05	3.47	-2.61	9.09	3.64	-5	28.1**	22.2**	11.8*	-3.01	-5.85	0.03
10	PCB/ S5- 15 × T8	31.43**	17.52*	5.23	14.29**	8.11	0.00	45.8**	42.2**	24.2**	-0,91	-4.68	2.24
11	PCB/ S5- 15 × T17	22.96**	21.17**	8.5	5.97	0.45	-7.5	50**	43.3**	18.9**	4.64	-1.17	5.4*
12	PCB/ S5- 15 × Thai	0.71	-1.40	-7.84	-1.40	-8.62	-11.67*	23.3**	12.8*	12.8*	-6.16*	-6.43	-0.2
13	PCB/ S5- 16 × T2	5.88	0.00	-5.88	7.18	1.82	-6.67	23.1**	20**	15.7**	-2.15	-3.05	-0.75
14	PCB/ S5- 16 × T8	23.73**	14.06	-4.58	4.76	-0.90	-8.33	27.7**	21.7**	17.2**	-2.48	-4.27	-2.34
15	PCB/ S5- 16 × T17	8.81	6.77	-7.19	0.24	-4.98	-12.5*	50**	33.9**	29.1**	-1.27	-4.88	-2.7
16	PCB/ S5- 16 × Thai.	8.49	2.80	-3.92	1.40	-6.03	-9.17	3.9	1.2	2	-2.40	-4.12	1.9
17	PCB/ S5- 17 × T2	15.41**	11.81	5.23	11.96*	6.36	-2.5	25.4**	14.9*	5.1	1.59	-0.62	-0.09

Table 9.2 (continued)

18	PCB/ S5- 17 × T8	26.75**	14.07*	0.65	10.48*	4.50	-3.33	31.6**	23.2**	7.5	3.21	1.90	0.56
19	PCB/ S5- 17 × T17	28.36**	27.41**	12.42*	7.88	2.26	-5.83	55.2**	54.6**	17.7**	7.19*	6.49	2.5
20	PCB/ S5- 17 × Thai	15.11*	11.89	4.58	3.26	-4.31	-7.5	23.5**	8.8	8.8	-1.85	-6.47*	-1.08
21	PCB/ S5- 25 × T2	14.07*	4.17	-1.96	11.00*	5.45	-3.33	31.3**	17.7**	7.7	4.21	0.00	0.62
22	PCB/ S5-25 × T8	40.09**	33.61**	3.92	19.05**	12.61*	4.2	31.1**	20.1**	4.8	5.23	1.90	0.77
23	PCB/ S5- 25 × T17	36.90**	29.70**	12.75*	8.83	3.17	-5	53.5**	50.6**	13.7*	8.00**	6.58	0.93
24	PCB/ S5-25 × Thai	19.08**	9.09	1.96	12.56*	4.31	0.83	20**	3.6	3.6	3.77	-2.94	3.4*
25	PCB/ S5-30 × T2	3.68	-2.08	-7.84	6.16	1.82	-6.67	14*	8.3	-0.95	2.27	-1.86	-1.5
26	PCB/ S5-30 × T8	28.81**	18.75*	-0.65	6.60	1.80	-5.83	27**	23.3**	7.7	6.54*	3.16	2.01
27	PCB/ S5-30 × T17	31.03**	28.57**	11.76*	14.42**	9.50	0.83	47**	41.3**	16.2**	9.33**	7.89*	2.46
28	PCB/ S5-30 × Thai	10.70	4.90	-1.94	5.99	-0.86	-4.17	20.5**	9.8	9.8	3.77	-2.94	3.4
29	PCB/ S5-39 × T2	13.99*	13.19*	6.54	9.09	9.09	0.00	24.7**	18.1**	20.9**	-1.20	-4.62	2.8
30	PCB/ S5- 39 × T8	14.40*	0.70	-6.54	-8.60	-9.01	-15.8**	25.9**	16.7**	19.5*	0.30	-4.05	3.5*
31	PCB/ S5-39 × T17	30.18**	26.06**	17**	2.49	2.26	-5.83	28.5**	11.6*	14.3*	3.38	-2.89	4.8*
32	PCB/ S5- 39 × Thai	17.89**	17.48**	9.8	1.77	-0.86	-4.17	13.1**	11.8*	14.4*	-4.37	-5.20	2.6

Table 9.3 Percent relative heterosis (RH), heterobaltosis (HB) and standard heterosis (SH) for quality parameters in popcorn.

Sl. No.	Characters	Popping %			Popping volume			Taste score			Popping expansion		
	Hybrids	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	PCB/S5-12 × T2	-0.13	-2.55	-0.78	0.46	-1.7	22.92	25	0.0	0.00	0.5	-1.8	24.3
2	PCB/ S5- 12× T8	1.42	0.26	2.08	1.41	-6.1	17.45	27.3	-33.3	-20	1.57	-6.2	18.7
3	PCB/ S5- 12 × T17	-1.30	-3.32	-1.56	2.17	-4.4	19.55	-45	-50	-40	2.3	-4.6	20.7
4	PCB/ S5-12 × Thai	0.40	-4.59	-2.86	5.9	-12.2	9.89	0.0	0.0	0.00	6.3	-12.7	10.4
5	PCB/ S5- 13 × T2	-1.46	-2.12	-3.9	-15.3	-27.1*	-12.79	9.1	-25	20	-16.1	-28.4*	-13.6
6	PCB/ S5- 13 × T8	0.92	0.26	-0.26	36.29**	23.36	31.42*	-57.1*	-62**	-40	38.6**	24.4	33.23*
7	PCB/ S5- 13 × T17	-3.18	-3.44	-5.19	-2.38	-12.5	-4.71	-57.1*	-62**	-40	-2.6	-13.4	-5.2
8	PCB/ S5- 13 × Thai	4.24	0.79	-1.04	29.8*	26.9	9.52	-53.9*	-62**	-40	32.1*	29.2	9.97
9	PCB/ S5- 15 × T2	-2.36	-4.60	-3.12	-11.97	-13.1	6.76	-14.3	-25	-40	-12.4	-13.6	7.13
10	PCB/ S5- 15 × T8	-3.62	-4.60	-3.12	-7.46	-13.6	6.17	-60	-66.7*	-60	-7.7	-14	6.6
11	PCB/ S5- 15 × T17	-1.17	-3.07	-1.56	-8.56	-13.7	5.99	-60	-66.7*	-60	-8.8	-14.2	6.4
12	PCB/ S5- 15 × Thai	5.65*	0.51	2.08	14.43	-4.4	17.5	-33	-40	-40	15.8	-4.1	18.9
13	PCB/ S5- 16 × T2	2.64	1.04	1.04	3.87	-0.4	19.13	-20	-33.3	-60	4.1	-0.4	20.3
14	PCB/ S5- 16 × T8	0.52	0.26	0.26	11.17	9.5	20.24	-25	-50	-40	12.1	10.4	21.7
15	PCB/ S5- 16 × T17	3.55	2.34	2.34	14.15	13.7	24.82	-50	-66.7*	-60	14.9	14.6	26.2

Table 9.3 (continued)

16	PCB/ S5- 16 × Thai.	0,81	-3.38	-3.38	23.25*	7.9	18.46	-14.3	-40	-40	24.9*	8.6	19.6
17	PCB/ S5- 17 × T2	1.45	0.00	-0.26	-14.99	-24**	15.36	20	0.0	-40	-15.3	-24.4**	16.4
18	PCB/ S5- 17 × T8	0.91	0.78	0.52	-7.77	-21.5*	19.13	0.0	-33.3	-20	-7.8	-21.9*	20.3
19	PCB/ S5- 17 × T17	0.53	-0.52	-0.78	-10.8	-23.4**	16.26	-25	-50	-40	-11.1	-23.9**	17.1
20	PCB/ S5- 17 × Thai	-0.14	-4.17	-4.42	-15.9	-35.2 **	-1.57	14.3	-20	-20	-16.5	-36.2**	-1.8
21	PCB/ S5- 25 × T2	2.81	2.67	-0.26	18.6	5.81	26.56	-14.3	-25	-40	19.8	6.2	28.2
22	PCB/ S5-25 × T8	2.77	1.57	1.04	12.1	5.48	12.38	-40	-50	-40	13.1	5.8	13.4
23	PCB/ S5- 25 × T17	0.00	-0.27	-2.6	5.3	-2.1	6.67	-40	-50	-40	5.5	-2.3	6.9
24	PCB/ S5-25 × Thai	-2.34	-5.08	-7.79**	5.5	-0.88	-7.06	-11.1	-20	-20	5.9	-0.9	-7.5
25	PCB/ S5-30 × T2	1.97	-0.26	1.04	9	6.9	27.87*	0.00	0.0	-40	9.8	7.5	29.7*
26	PCB/ S5-30 × T8	1.16	0.26	1.56	15	10.9	27.39*	11.1	-33.3	-20	16.2	11.9	29.3*
27	PCB/ S5-30 × T17	-3.13	-4.87	-3.64	8.2	5.4	21.01	-33	-50	-40	8.7	5.8	22.3
28	PCB/ S5-30 × Thai	0.67	-4.10	-2.86	20.3	3.3	18.65	-25	-40	-40	21.9	3.8	19.9
29	PCB/ S5-39 × T2	-1.33	-2.36	-3.38	-17.9*	-20.2*	1.07	100	66.7	0.0	-18.7	-21	1.2
30	PCB/ S5- 39 × T8	-1.31	-1.57	-2.08	-9.06	-16.3	6.01	-25	-50	-40	-9.6	-16.9	6.4
31	PCB/ S5-39 × T17	2.51	1.84	0.78	-5.8	-12.4	10.92	-50	-66.7*	-60	-6.2	-12.9	11.5
32	PCB/ S5- 39 × Thai	5.18	1.31	0.26	15.79	-4.4	21.03	14.3	-20	-20	16.9	-4.4	22.5

4.8.2.5 Ear length

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -0.71 (PCB/ S5-15 × Thai) to 63.11 (PCB/ S5-13 × T8), -2.08 (PCB/ S5-30 × T2) to 55.56 (PCB/ S5-13 × T8) and -7.84 (PCB/ S5-15 × Thai) to 22.9 (PCB/ S5-12 × T17) respectively. 27 hybrids exhibited significant positive heterosis over mid parent, 15 over better parent, and 6 over standard check. The highest significant standard heterosis was manifested by (PCB/ S5-12 × T17) in positive direction, on the other hand highest negative standard heterosis was observed in (PCB/ S5-30 × T8) but was non significant.

4.8.2.6 Ear diameter

For ear diameter heterosis over mid parent, better parent and commercial checks ranged from -8.6 (PCB/ S5-39 × T8) to 22.22 (PCB/ S5-13 × T2), -14.6 (PCB/ S5-12× Thai) to 12.61 (PCB/ S5-25 × T8) and -17.5 (PCB/ S5-12 × Thai) to 4.2 (PCB/ S5-25 × T8) respectively. 10 hybrids exhibited significant positive heterosis over mid parent. One hybrid exhibited positive and another exhibited negative heterosis over better parent. 4 hybrids showed negative significant standard heterosis.The highest significant standard heterosis was manifested by (PCB/ S5-12 × Thai) in negative direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-25 × T8) but was non significant.

4.8.2.7 1000 kernel weight

The percentage of heterosis over mid parent, better parent and commercial checks ranged from 3.9 (PCB/ S5-16 × Thai) to 82.6 (PCB/ S5-13 × T17), -1.7 (PCB/ S5-12 × Thai) to 75 (PCB/ S5-13 × T17) and -0.95 (PCB/ S5-30 × T2) to 44.1 (PCB/ S5-13 × T17) respectively. Thirtythree hybrids exhibited significant positive heterosis over mid parent, 25 over better parent and 18 over the standard check. The highest significant standard heterosis was manifested by (PCB/ S5-13 × T17) in positive direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-30 × T2) but was non significant.

4.8.2.8 Shelling percentage

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -6.16 (PCB/ S5-15 × Thai) to 11.56 (PCB/ S5-13 × T17), -6.43 (PCB/

S5-12 × Thai) to 7.89 (PCB/ S5-13 × T17) and -2.34 (PCB/ S5-16 × T8) to 5.4 (PCB/ S5-15 × T17) respectively. 7 hybrids exhibited significant positive heterosis over mid parent, 2 over better parent and 4 over the standard check. One hybrid exhibited negative significant over mid parent and another over better parent. The highest significant standard heterosis was manifested by (PCB/ S5-15 × T17) in positive direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-16 × T8) but was non significant.

4.8.3 Qality parameters

4.8.3.1 Popping percentage

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -3.62 (PCB/ S5-15 × T8) to 5.65 (PCB/ S5-15 × Thai), -5.08(PCB/ S5-25 × Thai) to 2.67 (PCB/ S5-25 × T2) and -7.79 (PCB/ S5-25 × Thai) to 2.34 (PCB/ S5-16 × T17) respectively. One hybrids exhibited significant positive heterosis over mid parent. The highest significant standard heterosis was manifested by (PCB/ S5-25 × Thai) in negative direction, on the other hand highest positive standard heterosis was observed in (PCB/ S5-16 × T17) but was non significant.

4.8.3.2 Popping volume

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -17.9 (PCB/ S5-39 × T2) to 36.29 (PCB/ S5-13 × T8), -35.2 (PCB/ S5-17 × Thai) to 26.9 (PCB/ S5-13 × Thai) and -12.79 (PCB/ S5-13 × T2) to 31.42 (PCB/ S5-13 × T8) respectively. Three hybrids exhibited significant positive heterosis over mid parent and three over standard check. One hybrids exhibited significant negative heterosis over mid parent, 6 over better parent. The highest standard heterosis was manifested by (PCB/ S5-17 × Thai) in negative direction, but non significant, on the other hand highest positive significant standard heterosis was observed in (PCB/ S5-13 × T8).

4.8.3.3 Taste score

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -57.1 (PCB/ S5-13 × T8, PCB/ S5-13 × T17) to 100 (PCB/ S5-39 × T2), -66.7 (PCB/ S5-15 × T8, PCB/ S5-15 × T17, PCB/ S5-16 × T17 and PCB/ S5-39 ×

T17) to 66.7 (PCB/ S5-39 × T2) and -60 (PCB/ S5-15 × T8) to 20 (PCB/ S5-13 × T2) respectively. Three hybrids exhibited significant negative heterosis over mid parent and seven over better parent. No significant standard heterosis was observed.

4.8.3.4 Popping expansion

The percentage of heterosis over mid parent, better parent and commercial checks ranged from -18.7 (PCB/ S5-39 × T2) to 38.6 (PCB/ S5-13 × T8), -36.2 (PCB/ S5-17 × Thai) to 29.2 (PCB/ S5-13 × Thai) and -13.6 (PCB/ S5-13 × T2) to 33.23 (PCB/ S5-13 × T8) respectively. Three hybrids exhibited significant positive heterosis over mid parent and three over standard check. 5 hybrids exhibited negative heterosis over better parent. The highest significant standard heterosis was manifested by (PCB/ S5-13 × T8) in positive direction, on the other hand highest negative standard heterosis was observed in (PCB/ S5-13 × T2) but was non significant.

4.9 Genetic component of different characters

4.9.1 Growth characters

Growth is an important attribute of agiven genotype, which directly or indirectly affects economic yield. Growth itself expressed by several components such a days to 50 percent pollen shedding, days to 50 percent silking, plant height, ear height etc. Normally, in in maize it has been reported that the female inflorescence i.e., ear formation is very sensitive to environment fluctuation, plant density etc., where as male inflorescence i.e., tassel formation is less affected by such situations (Gieshercht, 1960). Therefore, the synchronization between male and female flowering is a very crucial phenomenon with direct bearing on yield.

4.9.1.1 Days to 50 percent pollen shedding

Days from planting to pollen shedding is one of the important growth character. One line and one tester (PCB/S5-25) and (T_8) exhibited significant negative GCA effect respectively that can be used for evolving earliness. Hussain *et al.* (2003) and Uddin *et al.* (2006) also observed similar phenomenon in their study.

4.9.1.2 Days to 50 percent silking

One line PCB/S5-25 showed significant negative GCA effect that indicates its usefulness for evolving earliness in future breeding.

4.9.1.3 Plant height

Plant height is another important trait, as breeding of maize is targeted to develop homogeneous dwarf hybrids to prevent lodging. One line (PCB/S5-12) and one tester (T_{17}) exhibited significant negative GCA effect that can be used for evolving shorter plant.

4.9.1.4 Ear height

One line (PCB/S5-12) and one tester (T_{17}) showed significant negative GCA effect, thus can be used for evolving lodging resistant plant.

4.9.2 Yield and yield contributing characters

Grain yield is a complex quantitative character, which is influenced by other ancillary and component characters, which may tend to counter balance each other giving in effect, homeostasis for yield. Hence all changes in the components would not be expressed as changes in yield but any changes in yield would be accompanied by changes in one or more components.

Johnson (1973); reported that genetic variability for grain yield in single ear attribute to additive and non-additive genetic variance expressed through yield components. Because of influence from various ancillary characters and environmental factors, comprehensive study is very difficult and it is the focal point about which plant breeding experiments are centered around.

4.9.2.1 Grain yield

One line (PCB/S5-13) exhibited significant positive GCA effect for yield indicated that this line could be used for exploiting higher yield.

In total six hybrids (PCB/S5-13×T17, PCB/S5-15×T2, PCB/S5-16×Thai, PCB/S5-30×T17, PCB/S5-39×T8 and PCB/S5-39×Thai) showed significant positive SCA effects that indicates their potential of being a high yielding hybrid.

4.9.2.2 Number of kernel per row

Two lines (PCB/S5-12 and PCB/S5-25) and two testers (T_8 and T_{17}) exhibited significant negative GCA effect, this can be used for evolving higher yield

Five hybrids (PCB/S5-15×T17, PCB/S5-25×T8, PCB/S5-30×Thai, PCB/S5-39×T2 and PCB/S5-39×Thai) showed significant positive SCA effect, so this are useful for attaining high yield.

4.9.2.3 Number of kernel rows per ear

One line PCB/S5-13 showed significant positive GCA effect. One hybrid (PCB/S5-13×Thai) showed significant positive SCA effect.

4.9.2.4 Number of kernel per ear

One line PCB/S5-13 showed significant positive GCA effect. One hybrid (PCB/S5-13×Thai) showed significant positive SCA effect.

4.9.2.5 Ear length

One line PCB/S5-13 and one tester T_{17} showed significant positive GCA effect.

4.9.2.6 Ear diameter

One line PCB/S5-25 showed significant positive GCA effect.

4.9.2.7 1000 kernel weight

Four lines (PCB/S5-13, PCB/S5-15, PCB/S5-16, PCB/S5-39) and one tester (T_{17}) showed significant positive GCA effect. Two hybrids (PCB/S5-13×T17 and PCB/S5-15×T8) showed significant positive SCA effect.

4.9.2.8 Shelling percentage

One line (PCB/S5-39) showed significant positive GCA effect. Nineteen hybrids also showed positive SCA effect, but none of them are significant.

4.9.3 Quality parameters

Quality is a very special consideration in case of popcorn. . Higher popping volume was recorded for low or medium-yielding cultivars whereas high-yielding cultivars had lower popping volume (Pajic 1990). It is very important to induce good popping characters viz. Popping percentage, popping volume, popping expansion and taste of popcorn along with higher yield.

4.9.3.1 Popping percentage

One hybrid (PCB/S5-15 × Thai) exhibited significant positive SCA effect.

4.9.3.2 Popping volume

Two lines (PCB/S5-16 and PCB/S5-30) exhibited significant positive GCA effect. Two hybrids (PCB/S5-13 × T8, PCB/S5-25 × T2) showed significant positive SCA effect

4.9.3.3 Taste score

Two lines and two testers showed negative GCA effects but no significant negative GCA effect observed among lines and testers. Fourteen hybrids also showed negative SCA effect, but none of them are significant

4.9.3.4 Popping expansion

Two lines (PCB/S5-16 and PCB/S5-30) exhibited significant positive GCA effect. Three hybrids (PCB/S5-13×T8, PCB/S5-25×T2 and PCB/S5-39×Thai) showed significant positive SCA effect.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted to evaluate single cross experimental hybrids of popcorn, which were obtained by crossing 8 lines with 4 testers in a line x tester fashion. An attempt was made to understand the genetic nature of 16 characters viz., days to 50 percent pollenshedding, days to 50 percent silking, plant height, ear height, grain yield, number of kernel per row, number of kernel rows per ear, number of kernels per ear, ear length, ear diameter, 1000 kernel weight, shelling percentage, popping volume, popping expansion, popping percentage, taste score. 32 F_1 s, 8 lines, 4 testers and 2 commercial checks viz., Thai popcorn and Khoi bhutta were evaluated in a alfa lattice design during *Rabi*, 2013 at the Banladesh Agricultural Research Institute, Gazipur.

The objectives of the study were

1. To evaluate the performance of single cross experimental popcorn hybrids for grain and quality parameters.
2. To estimate the gca effects of parent and sca effects of cross combinations in respect to growth, yield and quality parameters..
3. To assess the heterotic effect of hybrids.

The salient features of experimental finding are summarized below

Analysis of variance clearly indicated the presence of significant differences among the parents, hybrids and checks for all the traits indicating the presence of genetic variability in the materials used for the study. The analysis of variance revealed higher magnitude of SCA variance to GCA variance for maximum characters. The ratio of additive to dominance variance was lesser than unity for all traits, this indicated that all traits posses higher dominance variance than additive variance.

Among 8 lines PCB/S_5-13 was the best general combiner for grain yield, number of kernel rows per ear, numberof kernel per ear, ear length and 1000 kernel weight and PCB/S_5-12 for plant height, ear height and number of kernel per row.

Among the testers T_{17} was the best general combiner for plant height, ear height, number of kernels per row, ear length and 1000 kernel weight and T_8 for days to 50% pollen shedding, plant height and ear height.

The hybrids such as PCB/S5-13×T17, PCB/S5-13×Thai, PCB/S5-13×T8, PCB/S5-25×T2, PCB/S5-15×T2, PCB/S5-16×Thai, PCB/S5-30×T17, PCB/S5-39×T8, PCB/S5-39×T17 and PCB/S5-39×Thai were the best with higher sca effects.

From this investigation, it is suggested to evaluate best hybrids viz. PCB/S5-13×T17, PCB/S5-13×Thai, PCB/S5-13×T8, PCB/S5-25×T2 PCB/S5-15×T2, PCB/S5-16×Thai, PCB/S5-30×T17, PCB/S5-39×T8, PCB/S5-39×T17 and PCB/S5-39×Thai for grain yield as well as popping quality thus for commercial utilization. Further, the promising single cross experimental hybrids having parental combinations with low × low, high × high and low × high gca effects for yield may be used for improvement of parental lines by selection in advanced generation.

CHAPTER VI

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