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**COMBINING ABILITY STUDIES FOR SWEETNESS AND YIELD
IMPROVEMENT IN MAIZE (*Zea mays* L.)**

By
J. JAGAN MOHAN REDDY

**THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE
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March, 1998

CERTIFICATE

Mr. J. Jagan Mohan Reddy has satisfactorily prosecuted the course of research and that the thesis entitled "COMBINING ABILITY STUDIES FOR SWEETNESS AND YIELD IMPROVEMENT IN MAIZE (*Zea mays* L.)" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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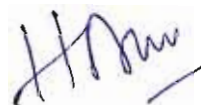
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CERTIFICATE

This is to certify that the thesis entitled "COMBINING ABILITY STUDIES FOR SWEETNESS AND YIELD IMPROVEMENT IN MAIZE (*Zea mays* L.)" submitted in partial fulfillment of the requirements for the degree of 'Master of Science in Agriculture' of Acharya N. G. Ranga Agricultural University, Hyderabad is a record of bonafide research work carried out by Mr. J. Jagan Mohan Reddy under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations has been duly acknowledged by the author of the thesis.



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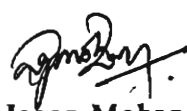
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Date : 16 - 04 - 1998.


(J. JAGAN MOHAN REDDY)

DECLARATION

I, J. Jagan Mohan Reddy, hereby declare that the thesis entitled "COMBINING ABILITY STUDIES FOR SWEETNESS AND YIELD IMPROVEMENT IN MAIZE (*Zea mays* L.)" is a result of the original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.



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ABSTRACT

The present investigation on "Combining ability studies for sweetness and yield improvement in maize (*Zea mays* L.)" was undertaken with six sweet corn lines and four testers. These were crossed in a line x tester design for the production of 24 hybrids at Maize Research Station, Amberpet, during *khari*f 1996. Further, the parents and F₁ hybrids were evaluated for heterosis and combining ability at the College Farm, College of Agriculture, Rajendranagar during *rabi* 1996-97 in a randomized block design with three replications. Character associations and path coefficients were also studied for yield, yield component characters and the quality parameters viz., total sugars, protein and carbohydrates.

The analysis of variance revealed significant differences among the genotypes for all traits studied. Further, non-additive gene action was found to be pre-ponderant for yield, yield component traits and the quality parameters studied in the present investigation, favoring a hybrid breeding program. High levels of heterosis were also noticed for grain yield per plot and several yield component characters.

The study of *per se* performance, heterosis and *sca* effects revealed the superiority of the hybrids, ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208 for yield and majority of yield component characters studied, while the crosses, ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1 were found superior for total sugars. However, the cross, ASCC III-2-1-1 x NSCC-6-1-1 alone exhibited superior performance for both yield and total sugars in addition to protein content and majority of the yield component characters. Further, these crosses involved either both or atleast one good general combiner parent and hence, advance generations of these crosses may also be obtained for isolation of homozygous lines or transgressive segregants, respectively.

Studies on character associations and path analysis emphasized the need for selection based on plant type with bold seed and superior ear characteristics for grain yield, while for total sugars, plant types with high protein content and moderate grain yields were found desirable. Hence, while breeding for both grain yield and increased sweetness, optimum yielding hybrids with moderately high protein and sugar contents (ASCC III-2-1-1 x NSCC-6-1-1) were found more desirable.

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CD	Critical difference
cm	Centimeter
g	Grams
<i>gca</i>	General combining ability
ha	Hectare
Kg	Kilogram
%	Per cent
ml	Millilitre
mg	Milligram
nm	Nanometer
SE	Standard error
<i>sca</i>	Specific combining ability



INTRODUCTION

CHAPTER I

INTRODUCTION

Maize occupies a prominent position in global agriculture and is an important cereal crop of India. It has been traditionally cultivated as a food crop, but is now also being extensively used for poultry feed, livestock, manufacture of bakery items, biscuits and as a rich source of starch in several industries. Sweet corn is a speciality corn that has become extremely popular in the U.S and Canada, and its consumption is increasing rapidly in eastern Asia and parts of Europe (Tracy, 1994). In India, it is primarily used as a table variety. However, it is gaining importance, particularly in the star hotels of urban areas for the production of special soups, sweets, jams, cream pastes and other delicacies. Increasing cultivation of sweet corn in areas surrounding big towns and cities of different states of India, including Andhra Pradesh, has also been reported in recent studies (Satyanarayana, 1996).

The primary difference between field corn and sweet corn is the presence of the sugary allele. However, it is also distinguished from other types of corn by many genes, both major and minor, that affect all phases of plant growth. Sweet corn has more sucrose than starch and is unique in accumulating phytyglycogen, a water soluble α -1, 4-glucan, that is more highly branched than the amylopectin components of maize starch (Gonzales *et al.*, 1976).

Origin of sweet corn dates back to 1779, when a member of the Sullivan expedition against the Six Nations brought back a few ears of sweet corn, which was called Papoon Corn (Erwin, 1934). The first sweet corn breeder was Noyes Darling, a lawyer living in New Haven, Connecticut, U.S.A, who crossed a very early yellow strain with a sweet type in 1836, by detasseling the yellow variety (Singleton, 1944). The first hybrid to be grown

extensively was developed by D.F. Jones and released by the Connecticut Station in 1924. Further, the most popular and widely grown sweet corn hybrid, Golden Cross Bantam was developed by Glenn Smith in 1933 (Smith, 1933). Open pollinated varieties, such as Stowell's Evergreen, Golden Bantam and Spanish Gold were also developed simultaneously. However, most of the sweet corn in the United States at the present time is single cross hybrid. In India, the Maize Directorate had released the first sweet corn variety, "Madhuri", during 1990 for cultivation in Andhra Pradesh. It has also become extremely popular in several other states of the country. However, it is a poor yielder. Further, no major efforts have been made for development of high yielding, superior quality sweet corn hybrids.

Improvement of sweet corn yields, while retaining its quality, is one of the major challenges facing the sweet corn breeder (Hunsperger and Davis, 1987). Generally, sweet corn varieties have been derived from dent corns. However, some varieties such as Golden Bantam have been obtained from flint corns (Smith, 1955). The role of these corns in the improvement of sweet corn has been reported by several workers (Haber, 1945; Hunsperger, and Davis, 1987; Davis *et al.*, 1988a and b; Tracy, 1990). However, the dent and flint corns have been primarily bred for yield and not for quality. Hence, lines selected for flavor and texture were reported to be a more appropriate choice for sweet corn improvement (Tracy, 1994). Therefore, in the present investigation, dent and flint lines were also involved along with the sweet corn lines.

Combining ability and heterosis are valuable tools in determination of superior parents and hybrid combinations, for use in hybrid breeding programs. Further, complex quantitative characters such as yield and sugar content depend on various component characters. Therefore, a knowledge of their associations and cause and effect relationship would help in formulation of effective selection schemes (Talwar and Joshi, 1983). In this direction, the present

investigation was undertaken with the following objectives:

1. Identification of lines with high general combining ability and crosses with high specific combining ability for sweetness, yield and other quantitative characters.
2. Estimation of the magnitude of heterosis for sweetness, yield and other yield component characters.
3. Study of direct and indirect effects of various quantitative characters on sweetness and grain yield.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

A brief review of relevant literature on "Combining ability studies for sweetness and yield improvement in maize (*Zea mays* L.)" is presented here under:

2.1 SUGAR

The sugar content in maize kernels is generally low. However, several mutants are known to occur in maize, that alter the composition of endosperm carbohydrates (Gonzales *et al.*, 1976). Among these, the sugary (*su*) genotype, commonly used as sweet corn, has more sucrose than starchy maize. It has been reported to be a mutant from the field corn (Kempton, 1926; Lindstrom, 1929; Smith, 1955). The genetic composition of sweet corn kernel differs from dent corn in only one recessive gene. This gene prevents the conversion of some of the sugar into starch. The kernel has a translucent, horny appearance and is wrinkled when dry. The sugary gene, *su1* is the basis for large production of sweet corn. Further, Mangelsdorf (1947) reported duplicate genes that determine amylaceous-sugary endosperm. He discussed the possible use of these genes in sweet corn breeding. Andrew *et al.* (1944) reported that sweet corn, recessive for the waxy gene (*su/wx*) was superior to sweet corn that was dominant at the waxy locus.

Lindstrom and Gerhardt (1926 and 1927) studied the chemical composition of known endosperm genotypes from crosses of dent x sugary. An increase of sugars and a decrease of starches for each additional *su1* gene was obtained in the recombinations resulting from reciprocal F₁ mating, back crosses or F₂ generation.

Cameron and Cole (1959) reported that the gene combinations, *su1du* and *su1su2*, as contrasted to *su1* alone, slowed the accumulation of starch in developing kernels on several inbred and hybrid backgrounds. Sugar and water-soluble polysaccharides were not always

affected but improved eating quality was often recognized.

The effect of the *sh2* factor on carbohydrate reserves in the mature endosperm of corn was utilized by Laughnan (1953 and 1954). He introduced the shrunken gene into standard sweet corn inbred lines. Through his efforts at the University of Illinois along with the staff of the Illinois Foundation Seeds, Champaign, Illinois extremely desirable super sweet corn hybrids were produced. "Illini Xtra-sweet corn" is twice as sweet as normal sweet corn at harvest. It is four times as sweet as normal sweet corn, even 48 hours later at room temperatures. This is because the sugar does not change to starch as rapidly as in normal sweet corn. The harvest period is prolonged by the slow conversion of sugar to starch. Illinois super sweet corns are generally yellow in color. They are admirably adapted for the home garden, market garden, freezing, and canning and are single cross hybrids. Further, the seed is lighter in weight than ordinary sweet corn.

Sweet corn is commonly used as a canning or frozen vegetable throughout the world and as a fresh market or green garden vegetable in regions favoring its cultivation. The main region of sweet corn production is the northern half of the United States and Southern Canada. There are several reasons for this restricted distribution. One of the main reason, being the short period during which sweet corn kernels remain sweet after picking. Further, the sugars are rapidly converted to starch at higher temperatures. The corn worm is also less injurious to sweet corn in latitudes with low winter temperatures as it prevents winter pupation of the larvae.

The history of sweet corn has been reviewed in detail by Smith (1955). The origin of this crop dates back to 1779 (Erwin, 1934). A Connecticut lawyer, Noyes Darling, was the first sweet corn breeder, who crossed a very early yellow strain with a sweet type in 1836 by detasseling the yellow variety (Singleton, 1944). However, the first hybrid to be grown extensively was developed by Jones and released by the Connecticut Experimental Station in

1924. Later on, Glenn Smith developed Golden Cross Bantam, a single cross hybrid, by crossing P39 and P51 inbreds, derived from the variety, Golden Bantam, during 1933. The hybrid became extremely popular and was widely cultivated. The popularity of the hybrid was mainly due to its excellent yielding ability, canning qualities, uniformity and resistance to bacterial wilt. Further research resulted in the development of several other hybrids and open pollinated varieties.

In 1934, Tapley *et al.* listed approximately 850 open-pollinated sweet corn varieties. Many of these were synonyms and the total number of different varieties was approximately 300. The contributions of these varieties to modern germplasm is highly variable, with Golden Bantam and its derivatives having the greatest contribution followed by Evergreen and Country Gentlemen types. These three varieties were the initial source material for inbreeding at the State Experiment Stations, with programs interested in yellow fresh market corns emphasizing Golden Bantam types, while those concentrating on processing corn, extracted inbreds from Evergreen and Country Gentleman (Smith, 1933).

The general objectives of sweet corn breeders have been:

1. Production of high yielding and uniform hybrids with good quality and
2. Extension of the range of adaptation.

The major problems, generally faced by sweet corn breeders have been discussed in detail by Smith (1955). Improvement of sweet corn yields, while retaining its quality is one of the major challenges facing the sweet corn breeder (Hunsperger and Davis, 1987). The role of field corns (flint and dent) in the improvement of sweet corn has been reported by several workers (Haber, 1945; Hunsperger and Davis, 1987; Davis *et al.*, 1988 a and b; Tracy, 1990). The development of Stowell's Evergreen, and Golden Bantam, along with many other examples indicate the success of this strategy. One of the last developed open-pollinated varieties for the temperate zone was Spanish Gold, a new variety of yellow sweet corn, which was released in

1931 by Jones and Singleton. It was developed by crossing Cinquantino, an early flint corn from the Pyrenees region of northern Spain, with a number of sweet corn varieties, including Golden Bantam. Spanish Gold became the source population from which the very early-maturing inbreds, C2A, C3, C4, and C5, were derived. Some of these inbreds, which were developed in the 1930s, are still used commercially today (Tracy, 1994). Further, the Spanish Gold derivatives were important in extending the range of sweet corn hybrids into regions with cooler, shorter growing seasons (Galinat, 1971).

Haber (1945) was a strong proponent of using Corn Belt Dent inbreds in the improvement of sweet corn. He thought that plant health and vigor could be improved by doing so. An inspection of the pedigrees of sweet corn inbreds released by Haber's program at Iowa State University revealed that a number of field corn lines were used and in most cases, they constituted 25 to 50 per cent of the background of the new sweet corn inbreds. One of the most important publicly developed inbreds is Ia2132, which is one of the parents of Iobelle. A *sh2* conversion of Ia2132, is a parent of Florida Stay sweet. Other *sh2* versions of Ia2132 are used in other currently available *sh2* hybrids. Twenty five per cent of Ia2132 is derived from the inbred TSR, and although the origin of TSR is unclear, its designation fits the pattern of the other field corn inbreds used by Haber. Haber (1945) also emphasized the importance of rigorous selection for table quality traits during the inbreeding process and warned that without it, quality could be lost when using field corn germplasm in sweet corn improvement.

In developing sweet corn for the tropics, Brewbaker (1971) emphasized the use of tropical germplasm sources because most North American sweet corn germplasm lacked the pest resistance and stress tolerance traits needed for survival under tropical conditions with minimal inputs.

Recent studies by several other workers have also examined the potential contributions and methods of incorporation of both Corn Belt Dent and tropical germplasm in

sweet corn improvement. In a study using a factorial mating design with four *su* versions of field corn inbreds as males and several sweet corn inbreds as females, Tracy (1990) found that the field corn lines not only increased all the vigor related traits, such as yield, number of ears, ear weight, ear size and plant height but also improved ear appearance traits, such as ear shape, tip fill and row configuration, relative to sweet x sweet checks. The results of taste tests, however, indicated that the sweet by dent hybrids had unacceptable flavor and tenderness (Tracy, 1994). The studies of Cartea *et al.* (1996) also indicated similar results. Further, European flint sweet corn populations such as Tuy and Oroso were observed to have a less detrimental effect on grain quality than the U.S. dent populations.

The potential contributions of five Latin American populations adapted to the north temperate region were examined in a separate study by Tracy (1990). The populations were NTZ Mexican Dent, NTZ Caribbean Flint, NTZ Cuzco, NTZ Cateto and NTZ Coroico. The top crosses with the Mexican Dent population had the best agronomic qualities, such as yield, and root and stalk quality, as well as the best ear appearance traits. Those top crosses having either the Coroico or Cuzco populations as parents were generally poor in all respects. The results of the study suggested the potential of Mexican dent and Caribbean flint populations in sweet corn improvement.

Davis *et al.* (1988b) developed two populations in an attempt to capitalize on the well-known Lancaster/Stalk heterotic pools of Corn Belt Dent. NE-HY-13A was developed by crossing a sweet corn pool with seven lancaster-type inbreds and NE-HY-13B resulted from the cross of a different sweet corn pool with Stiff Stalk Synthetic/Reid-type inbreds. They also developed the composite IR by crossing 11 sweet corn inbreds to 17 tropical parents. The tropical parents were chosen because they were all consumed by humans as fresh (green) corn since long periods and thus may have been selected for desirable flavor traits. The composite IR

was developed as a source of diversity for desirable traits for sweet corn improvement. Tracy (1994), also reported that though corn belt dent germplasm was a good source of genes for improved plant type, pest resistance and stress resistance, many of the tropical corns, consumed directly by humans, have been selected for flavor and texture, unlike the corn belt dents, and hence, may be a better choice for sweet corn improvement. Puskarie and Carrigan (1988) also reported the successful development of a Pioneer sweet corn hybrid, 3TD by crossing of sweet corn inbred lines. The hybrid exhibited superior yields and grain quality, in addition to cold tolerance.

Sweet corn breeders at various experiment stations are producing and releasing hybrids in increasing numbers and it is now possible for a grower to select a variety suited to his needs. The Maize Directorate at India had released the first sweet corn variety, "Madhuri", during 1990 for commercial cultivation in Andhra Pradesh. It has 33 per cent sugar on green fresh grain weight basis. However, it is a poor yielder. Much research efforts are needed for sweet corn improvement in India, particularly in the direction of production of high yielding superior quality hybrids, and the present investigation is a humble attempt in this direction.

2.2 PROTEIN

Protein is a scarce, expensive, but necessary constituent of food and feed. Quality of protein is also as important as quantity. The corn kernel contains several types of protein, the major one, being Zein. It is however, deficient in tryptophan and lysine which are essential amino acids particularly for monogastric animals.

Starting in 1896, the University of Illinois, USA gave the first evidence that protein content in corn could be greatly increased or lowered by breeding. In this direction, Hayes and Garber (1919) isolated two strains from Minnesota 13 that possessed 15 per cent

protein on average, compared to 10.2 per cent of the parent variety.

Earle *et al.* (1946) discussed the composition of the component parts of the corn kernel. About 20 per cent of the protein was reported to be present in the embryo while 80 per cent of it was located in the endosperm. F_1 kernels borne on a high-protein plant were usually high in protein content, while F_1 kernels borne on a low-protein parent were low. The male parent had little or no immediate effect on protein content.

Woodworth and Jugenheimer (1948) also demonstrated that the protein content of inbred lines could be substantially increased by backcrossing, selfing and selection. Further, Dobbins *et al.* (1950) concluded that the protein of a low-protein corn had a higher biological value than high-protein corn.

Hamilton *et al.* (1951) reported that kernels of corn grown on soils of low fertility were 26 per cent smaller than from the fertilized plots and the germ made up 17 per cent less of the kernel. Grain on the unfertilized plots was below normal in phosphorus, oil and protein. Further, Jugenheimer (1958) reported that protein content was significantly correlated with maturity, plant and ear heights, grain yield and certain diseases and insects.

Mertz *et al.* (1964) reported that the substitution of the normal allele with the O_2 allele in maize resulted in an enhancement of the endosperm nutritive value of corn. Similarly, Nelson *et al.* (1965) reported that the floury-2 (fl_2) gene, when homozygous, caused an increase in lysine and tryptophan amino acid contents of corn protein.

Lambert *et al.* (1969) studied the relative performance of normal and modified protein (Opaque-2) corn hybrids. They reported that Opaque-2 hybrids were lower in grain yield and weight per 100 kernels but higher in grain moisture, cracked kernels and total oil content.

Dudley and Lambert (1969) reported significant genetic variability for both oil and protein contents after 65 generations of selection in Illinois High Oil (IHO), Illinois Low Oil

(ILO), Illinois High Protein (IHP) and Illinois Low Protein (ILP) strains. Correlated responses between oil and protein over the 65 generations of selection were however, small.

Genter and King (1971) investigated the nutritive value of protein in high-oil selections in corn. They developed inbred lines by continuous selfing and simultaneous selection for high protein and high oil content. Grain of the sixth generation inbred lines was analyzed and then composited to represent the four possible combinations of high and low oil and protein. They found that the protein digestibility of all four composites was lower than that of a field corn sample included as standard.

Palii *et al.* (1983) reported that appreciable differences in protein yield/ha were not only due to protein content but also due to the effects of environment and genotype x environment interaction. Hybrid grain was concluded to have an increased crude protein content when the maternal parent had a high crude protein content. High crude protein in the F_1 would therefore be achieved by crossing high crude protein, low yielding lines. While, high yields would be obtained by crossing high yielding, low crude protein lines. Further, Proksza and Harmati (1988) reported that hybrids with a relatively short vegetative period had high protein contents. Hybrids with moderate protein content but high yielding capacity produced high protein yields.

2.3 STARCH

Starch is one of the major components of the carbohydrate fraction in normal corn. Starch and its derivatives are widely used in the manufacture of ice creams and other frozen fruits, soft drinks etc. Several new uses of corn starch are in the manufacture of water absorbents, plastics, compounds that remove metals from water, etc. Starch from high amylose corns is valuable in the manufacture of plastics, cellophane and films.

Wagner (1946) pointed out that wet millers desire corn with high percentages of starch, oil and protein. However, most dry millers prefer a kernel of semi hard, vitreous starch type that does not have too much soft starch on either the tip or the dent end.

The standard corn-starch granule is usually a mixture of two polysaccharides, amylopectin and amylose (Greenwood, 1956; Whelan, 1961). Amylopectin is the major component ranging from 75 to 85 per cent and is of high molecular weight. Cracius and Ciofu (1970) also reported that the carbohydrate composition of hybrids is influenced by the genotype, in particular, by the length of the growth period. The hybrids in general have higher contents of starch and amylose.

Penning de Vries *et al.* (1974) stated that starch is a relatively energy efficient storage product compared with oil and protein. Further, Tymchuk (1979) reported that starch content in the opaque-2 forms tended to be lower than in the normal counterparts, whereas oil content tended to be higher in opaque-2 forms.

Proksza and Harmati (1988) reported that starch content was favored under dense planting, while oil and protein contents were favored under less dense plantings. Tsyganash *et al.* (1989) also reported that the double mutant O_2SU_2 had a higher oil and lower starch content than its normal (+ +) and opaque-2 ($O_2 O_2$) versions and was equal to the O_2O_2 counterpart in *in vitro* digestibility.

Doehlert and Lambert (1991) reported that starch concentration is closely correlated with mature kernel dry weight and most of the starch is found in the endosperm. Further, genotypes with either increased protein or oil concentrations had lower starch concentrations.

2.4 HETEROSIS

The term "heterosis" was coined by Shull (1914) to refer to the phenomenon in

which F_1 obtained by crossing of two genetically dissimilar individuals showed an increase or decrease in vigor over the mid-parent value. The term, heterobeltiosis, was proposed later (Fonesca and Patterson 1968) to denote the expression of heterosis over better parent.

In cross-pollinated crops, exploitation of heterosis has proved to be a boon for high yields (Singh *et al.*, 1978). In maize, heterosis was reported by many workers for several economic characters (Singh and Sagar, 1971; Galal *et al.*, 1978; Nawar *et al.*, 1979). Ravi (1986) in his study on 45 hybrids derived from 10 inbred lines reported that all hybrids showed heterobeltiosis for yield while, two crosses showed heterobeltiosis for more than one character. Debnath (1987) in his study of nine inbreds and 36 F_1 s reported significant and positive heterosis over mid-parental values and better parental values. Highest heterosis was recorded for number of grains per row, followed by ear length and 1000-grain weight.

Abdul (1988) evaluated 56 single crosses and reported heterosis over better parent ranging from 40.98 to 120.43 per cent for stover yield. Ulger and Becker (1989) in an analysis of 16 inbred lines and 16 hybrids with three N levels for 17 different traits reported that heterosis occurred for all traits, except grain protein content. Generally heterosis was higher in unfavorable environment.

Beck *et al.* (1990) reported that average heterosis was significant for grain yield, plant height and ear height, though heterosis over the better parent was low in most crosses. Heterosis was also generally low for plant height, ear height and days to silk. The results were obtained from a 10 parental diallel study carried out to determine combining ability and heterotic patterns in maize.

Yurenkova and Tsitok (1989) in a study of heterosis of 20 reciprocal hybrids from 5 x 5 diallel for six yield components, reported stable heterosis for grain weight per ear and ear weight for the three year period of experiment, while instability was noticed in respect of ear

length, ear width and number of grains per row.

Poskannaya and Kapusta (1991) in a study of heterotic expression of 28 F_1 s, obtained from eight early line crosses, revealed high heterosis for plant height and length of ear and low heterosis for number of grains per row and number of grain rows per ear.

Jha and Khehra (1992) in their studies on a 16 line x 5 tester cross, reported heterosis in 16 crosses over the best hybrid control. Further, non-additive genetic action was found to be predominant for grain yield.

Vasal *et al.* (1993) in a diallel cross of 10 parents reported that crosses among dents x flints yielded higher than flint x flint crosses, but flints had better endosperm modification than dents.

Bhalla and Sharma (1993) in a study of 13 composites, nine inbred lines from USA, seven Indian composites and their hybrids from crosses with 3 testers, reported highest heterosis in crosses between Indian and foreign material.

Widstrom and Mc Millan (1993) in a study of 66 crosses obtained from 12 adapted maize populations (USA) for seven traits, reported significant heterosis for all traits except, insect damage. Average heterosis relative to mid-parental values varied from 2.2 per cent to 22.5 per cent for yield.

2.5 COMBINING ABILITY STUDIES

The concepts of general and specific combining abilities were coined by Sprague and Tatum (1942). General combining ability was defined as the average performance of a line in hybrid combinations, while specific combining ability referred to those crosses, wherein certain hybrid combinations did relatively better or worse than was expected, on the basis of average performance of the lines involved.

Griffing (1956) pointed out the usefulness of information on the relative magnitude of additive and non-additive gene effects in designing an efficient breeding program. The information could be obtained through the study of combining ability, as variance due to GCA involved mostly additive gene action while that due to SCA involved dominance and epistatic components.

In maize, combining ability and gene action have been widely studied for yield and yield component traits. A summary of the nature of gene action for various traits as reported by different workers, is presented in Table 1.

Different methods have been developed to estimate the *gca* and *sca*. The most popular among them are (1) top cross, (2) poly cross, (3) line x tester and (4) diallel. Singh and Joshi (1966) in their study on a line x tester analysis found non-additive effects to be of greater importance in maize. They suggested the use of single or double crosses as testers involving inbreds with high *gca*. Further, it was also indicated that parental performance was not necessarily a guarantee of its usefulness in breeding programs. Mel'nik (1979) reported that in order to achieve an accurate evaluation of inbred lines for *gca* and *sca*, the number of testers used should be no fewer than four, regardless of the crossing system or the statistical analysis adopted.

Pakudin (1977) evaluated the combining ability of maize inbred lines in diallel crosses and came to a conclusion that yield of single cross hybrids was controlled to a great extent by non-additive genes. Debnath and Sarkar (1981) analyzed data from a half diallel cross of nine inbreds and reported non-additive gene effects to be important in the inheritance of grain yield, ear diameter and 1000 grain weight. Additive and non-additive gene effects were equally important for ear length, grain rows/ear and number of grains/row. Similarly, Manmohan (1984) reported the pre-dominance of non-additive gene action for all characters studied in a maize

Table 1 Summary of references on nature of gene action for yield, yield component traits and quality parameters in maize.

Character	Nature of gene action	Worker(s)
Days to 50 per cent silking	<i>gca</i> or additive	Sharma (1989)
	<i>sca</i> or non-additive	Reddy (1989b); Vasal <i>et al.</i> (1993)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Rao (1986); Khalifa and Drolson (1988); Prakash (1996)
Plant height	<i>gca</i> or additive	Singhanian (1980); Khamis (1983)
	<i>sca</i> or non-additive	Pajic (1986); Anuradha (1988); Reddy (1989b); Vasal <i>et al.</i> (1993)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Rao (1986); Khalifa and Drolson (1988); Ravindranath (1989); Prakash (1996)
Ear length	<i>gca</i> or additive	Liao <i>et al.</i> (1987); Sharma (1989)
	<i>sca</i> or non-additive	Pajic (1986); Reddy (1989a); Reddy (1989b)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Shen and Lai (1987) ; Prakash (1996)
Ear height	<i>gca</i> or additive	Singh <i>et al.</i> (1974); Singh (1979); Khamis (1983); Sharma (1989)
	<i>sca</i> or non-additive	Thompson <i>et al.</i> (1971); Bhalla and Khehra (1989); Reddy (1989a); Reddy (1989b)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Singh (1980); Rao (1986); Ravindranath (1989)
100-seed weight or 500-seed weight	<i>gca</i> or additive	Shahi and Singh (1986); Sharma (1989)
	<i>sca</i> or non-additive	Wu (1987); Anuradha (1988); Reddy (1989a); Reddy (1989b)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Rao (1986); Prakash (1996)
Grain yield	<i>gca</i> or additive	Zambezi <i>et al.</i> (1986); Catherine and Pollak (1988); Sharma (1989); Cosmin and Bice (1991); Vasal <i>et al.</i> (1993)
	<i>sca</i> or non-additive	Pajic (1986); Anuradha (1988); Reddy (1989a) Han <i>et al.</i> (1991); Jha and Khehra (1992)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Rao (1986); Muthaiah <i>et al.</i> (1989); Reddy (1989b); Prakash (1996)
Sugars	<i>gca</i> or additive	Raghupathireddy (1989); Satyanarayana (1990)
Protein	<i>gca</i> or additive	Robinson <i>et al.</i> (1949); Lindsey <i>et al.</i> (1962); Maggiore <i>et al.</i> (1980); Russell and Pierre (1980); Song <i>et al.</i> (1986); Satyanarayana (1990)
	<i>sca</i> or non-additive	Tasanasuwan (1976); Kharistova and Kharistova (1985); Vedeneev <i>et al.</i> (1986); Raghupathireddy (1989)
	<i>gca</i> and <i>sca</i> or additive and non-additive	Bauman (1970); Sreeramulu and Bauman (1970); Dracea <i>et al.</i> (1976); Kuhn (1977); Pollmer <i>et al.</i> (1978)
Carbohydrat	<i>gca</i> or additive	Raghupathireddy (1989); Satyanarayana (1990)

diallel, though both *gca* and *sca* variances were significant. The highest ratio of *gca* to *sca* variance was observed in grain yield per plot, followed by grains per row and the lowest was noticed for number of rows per ear. All characters, except yield per plot, showed high narrow sense heritability (h^2) estimates.

Satyanarayana and Kumar (1995) also reported the pre-dominant role of non-additive (dominant x dominant) gene action in the inheritance of yield and its components, in sweet corn. Further, duplicate type of epistasis was noticed for most of the yield traits. Hence, crossing systems such as hybridization or reciprocal recurrent selection which exploit both additive and non additive gene effects simultaneously, were suggested for the genetic improvement of yield and its component characters in sweet corn.

2.6 CORRELATION STUDIES

A knowledge of character associations would be of great help in formulation of effective selection criteria. Further, correlation forms the basis of selection index and thus aids the breeder in systematic crop improvement.

Robinson *et al.* (1951) computed genotypic and phenotypic correlations from biparental crosses made within each of three F_2 populations and reported that ears per plant had highest positive correlation with yield. The other characters having more genetic association with yield were plant height and ear height. However, Murthy and Ray (1957) reported low correlation between yield and plant height in maize.

Patil *et al.* (1969) reported that grain yield was positively and significantly correlated with ear height. Further, Singh and Sagar (1971) reported that grain yield was significantly associated with ear girth, ear length and 100 seed weight. A close resemblance between phenotypic and genotypic correlations was observed, although genotypic correlations

were slightly higher than phenotypic correlations. Similarly, Tomaszewski and Idzhowaska (1972) reported significant and positive association of ear girth, ear height, plant height and time to tasselling and silking with total yields in maize.

Subramanian and Mahboob Ali (1974) reported that though ear length, ear diameter and kernel rows per ear showed positive correlations with yield, only ear diameter was significantly and positively correlated with yield. Further, Sakhov (1975) reported a close association between ear height, ear diameter and number of grains per row.

Panchanadhan *et al.* (1978) reported that the three yield attributes viz., grains per ear, length of ear and 1000 grain weight exhibited positive and highly significant correlation with grain yield. Ahmed *et al.* (1978) also found both ear length and ear diameter to be positively correlated with both 100 grain weight and grain yield.

Rupak *et al.* (1979) found significant association of grain yield with plant height, ear length, ear girth and 1000 kernel weight in eight pop corn varieties and twenty eight crosses. Laptev (1981) also reported that yield was positively correlated with plant height, ear height and number of ears per plot in maize. Further, Singh *et al.* (1981) also reported positive and significant correlations for ear height with days to silking.

Godawat (1982) also reported significant positive correlation of grain yield per plant with ear diameter, plant height and 100 grain weight. Similarly, Sharma *et al.* (1982) reported positive correlation between grain yield and plant height. Further, Kang *et al.* (1983) concluded that selection for increased plant height would result in higher grain yields.

Bhole and Patil (1984) reported that the genotypic correlations were relatively higher than phenotypic ones, indicating a strong inherent association of the characters under study with a probable influence of environment on their expression. Plant height had highly significant genotypic correlation with ear length. Further, highly significant and positive

genotypic correlations were also noticed for ear length and dry weight of ears with grain yield. In contrast, negative association was reported for days to tasselling and silking with grain yield (Lee ^{and Shi:et,} 1986). However, positive correlation of grain yield with plant height and ear height was observed by Malhotra and Khehra (1986) and Nawar (1986). Similar results were also noticed by Rao (1986).

Djisbar and Brewbaker (1987) reported that grain yield was highly correlated with plant and ear heights in both normal maize and hybrids. Lindaski *et al.* (1987) observed correlation of higher magnitude in hybrids than in parents. Further, Sharma and Kumar (1987) stated that grain yield was positively associated with plant height. Similarly, Tyagi *et al.* (1988) observed significant positive correlation between grain yield and ear weight, ear length, plant height and 100 seed weight.

Correlation studies by Annapurna (1989) indicated that grain yield was positively and significantly correlated with plant height, ear length, ear girth, number of seeds per ear and 100 seed weight. Further, correlation coefficient studies reported by Sharma (1989) indicated that the most important components of yield were ear girth and 100 grain weight. Similarly, Singh *et al.* (1995) observed positive and highly significant correlations with seeds per row, plant height and days to maturity. Zuping and Kezhu (1995) also reported significant correlations of plant height and ear length with grain yield. Similarly, Tusuz and Balabanli (1997) observed significant correlations of days to 50 per cent silking, plant height and ear height with grain yield of maize.

Studies on character associations between grain yield and the quality characters, in maize are limited. Raghupathireddy (1989) had reported a positive association for grain yield with sugar content and non-significant association with protein content in maize inbreds. However, the correlation of grain yield with protein content of the hybrids was observed to be significant and negative. Satyanarayana (1990) also analyzed the character associations in parents

and hybrids of a 10 x 10 diallel. Protein content was noticed to be negatively correlated with grain yield in parents alone. Further, carbohydrates and total sugars had exhibited non-significant associations with grain yield in both parents and hybrids. Umakanth (1993) also reported similar non-significant association of protein and starch with grain yield, in his studies on high oil lines of maize. In contrast, Reddy (1996) reported a strong negative association of grain yield with total sugars and protein content. However, total sugars and protein content were observed to be positively associated with each other.

2.7 PATH COEFFICIENT STUDIES

The technique of path analysis was outlined by Wright (1921) for partition of the observed correlation into direct and indirect effects. It was applied in plant breeding for the first time by Dewey and Lu (1959).

In maize, Panchanadhan *et al.* (1978) reported that, of the three characters viz., grain number per ear, ear length and 1000 grain weight, the latter had the maximum direct effect, while ear length and grain number per ear had their influence on yield through 1000 grain weight. Path coefficient studies of Rupak *et al.* (1979) however, revealed maximum direct effect of plant height on yield followed by 100 seed weight, ear girth and ear length.

Subramanian *et al.* (1981) reported direct effect of grain weight per ear on grain yield, thus indicating the importance of greater emphasis on this character for any increase in grain yield. Kang *et al.* (1983) also reported relatively large and positive direct effect of ear weight on grain yield at both the phenotypic and genotypic levels. The direct effect of plant height on grain yield was also reported to be positive and highly desirable.

The path coefficient analysis of Ganga Hybrid 5 revealed the importance of 1000 grain weight, number of grains per ear and weight of grains per ear (high positive direct influence) on grain yield (Singh *et al.*, 1987). In another study, involving 24 genotypes of

popcorn, Sharma and Kumar (1987) showed that grain yield of maize was directly influenced by number of grains per row, plant height, ear width, leaf area and 1000 grain weight. Further, among the positive traits influencing the yield, the role of number of grains per row was prominent. The path coefficient studies by Swarnalatha Devi (1990) also indicated maximum direct effect of 100 seed weight and total number of seeds per ear on grain yield. Similarly, Reddy (1995) in his studies on high oil lines in maize reported maximum direct effect of number of seeds per row on grain yield. Further, the sequential path analysis of five yield components of maize by Agrama (1996) revealed the largest direct effect of ears per plant, followed by number of grains per ear. It was also inferred that greater number of grains per ear and grain size were potential characters in the development of superior lines.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present investigation was carried out with an objective of identifying high yielding lines and hybrids coupled with high sugar content. The studies were taken up with six sweet corn lines and four testers. These were involved in a line x tester mating during *kharif* 1996 at Maize Research Station, Amberpet. Further, the parents and hybrids were evaluated during *rabi* 1996-97 at College Farm, College of Agriculture, Rajendranagar, Hyderabad.

3.1 MATERIALS

The experimental material for the present investigation comprised of six sweet corn lines viz., NSCC II-2-1-1, ASCC I-1-2-1, NSCC I-3-1-1, ASCC II-3-2-1, ASCC III-2-1-1 and ASCC III-3-2-1, and four testers including two sweet corn lines, ASCC II-2-2-1, NSCC-6-1-1, a flint line, CM 120 and a dent line, CM 208. These were obtained from Maize Research Station, Amberpet, Hyderabad. The lines were crossed to the testers in a 6 x 4 line x tester fashion to produce 24 hybrids during *kharif* 1996. The details of the single crosses are given in Table 2.

3.2 METHODS

The crosses made during *kharif* 1996 at Maize Research Station, Amberpet, Hyderabad were evaluated during *rabi* 1996-97 at College Farm, College of Agriculture, Rajendranagar, Hyderabad along with the parents and two checks viz., Madhuri (Sweet corn) and Trishulatha (Dent corn). These were laid out in a randomized block design with three replications. Each plot consisted of two rows, each of 3m length. A spacing of 60 x 25cm was

Table 2 Details of the single crosses produced by mating of
six lines and four testers.

Lines/Testers	ASCC II-2-2-1	NSCC-6-1-1	CM 120	CM 208
NSCC II-2-1-1	X	X	X	X
ASCC I-1-2-1	X	X	X	X
NSCC I-3-1-1	X	X	X	X
ASCC II-3-2-1	X	X	X	X
ASCC III-2-1-1	X	X	X	X
ASCC III-3-2-1	X	X	X	X

X-Cross made

adopted. All recommended package of practices were adopted to raise a successful crop. Observations on yield, yield components and quality parameters viz., total sugars, protein and carbohydrates were recorded from ten competitive plants, selected at random from each plot. However, observations on days to 50 per cent silking, days to 50 per cent maturity and grain yield were recorded on plot basis.

The details of the characters studied are presented hereunder :

Day to 50 per cent silking : Number of days from sowing to when 50 per cent of the plants have silk.

Days to 50 per cent maturity : Number of days from sowing to when 50 per cent of the plants in the plot were ready for harvest.

Plant height : Height of the plant from ground level to base of the tassel, measured in cm.

Ear length : Length of ear as measured from butt end to tip of the ear, in cm.

Ear weight : Fresh weight of the ear recorded in grams.

Ear height : Height of the plant from ground level to base of the lower most ear, measured in cm.

100 seed-weight : Weight of one hundred seeds sampled randomly from the shelled ears, in grams.

Grain yield per plot : All the ears in a plot were harvested and fresh weight was recorded in kg. Moisture per cent of the grain was determined and the yield was computed at 15 per cent moisture.

3.3 CHEMICAL ANALYSIS

3.3.1 Total Sugars

The procedure described by Dubois *et al.* (1956) was followed for estimation of total sugars in the grain. One gram of seed powder was sampled and placed in 100 ml beaker

containing 15 ml of 80 per cent ethyl alcohol and kept in water bath at 60°C for about 10 minutes. Afterwards, the seed powder was placed in a clean mortar and ground further to a fine powder and then transferred to a 25 ml volumetric flask through Wattman No. 42 filter paper along with 80 per cent alcohol. The pulp retained on the filter paper was once again transferred to mortar, ground and filtered. This was repeated 2-3 times to ensure complete extraction of sugars. Every time care was taken to rinse the mortar and walls of the funnel to ensure that all the sugars were collected. One ml of ethanol extract was taken into 100 ml volumetric flask and 0.25 ml of 80 per cent phenol was added. 25 ml of concentrated H_2SO_4 was further added to the above solution rapidly and the volume was made up. After 30 minutes the optical density was recorded at 490 nm. Samples were analyzed in duplicate and read against blank. Standard curve with glucose was used to calculate the total sugars (AOAC, 1980).

3.3.2 Protein

The fresh seed was thoroughly dried for 48 hours at 60°C and powdered. Thereafter, the nitrogen percentage in the grain was estimated by taking 0.1 g of powdered seed sample following the Micro-Kjeldhal procedure as given in AOAC (1980). The crude protein percentage was estimated later by multiplying the nitrogen percentage with the factor, 6.25.

3.3.3 Carbohydrates

The carbohydrate content was estimated by hydrolysing the sample with glucose-*amylase* (Sigma) and the resultant glucose released was measured by phenol-sulphuric acid reaction (Dubois *et al.*, 1956). 75 g of corn flour was weighed into a conical flask and 10 ml of distilled water was added slowly. The flask was then sealed and autoclaved for 1.25 hours at 19 lbs pressure. After cooling, 1 ml of 2M acetate buffer (pH 4.8) and 25 mg of glucose *amylase* were added and the volume was made up to 25 ml. The flasks were then incubated in a water bath at 55°C for 24 hours, and the volume was made up to 250 ml. After appropriate

dilution, 1 ml of the aliquot was treated with 1 ml of 5 per cent phenol and 5 ml of 96 per cent H_2SO_4 . The mixture was then kept in a water bath for half an hour for color development and the resultant color was read at 490 nm. An appropriate standard was run simultaneously with dextroglucose and a calibration curve was used to convert optical density to mg of glucose. After correcting with dilution factor, per cent glucose was multiplied with 0.93 to give total carbohydrate per cent.

3.4 STATISTICAL ANALYSIS

The data recorded was analyzed through the following statistical procedures :

3.4.1 Analysis of variance

Analysis of variance for the randomized block design, including parents and F_1 s was carried out as per the model given by Singh and Chaudhary (1977).

Source	d.f	m.s.s
Replication	$r-1$	
Genotypes	$a-1$	M_g
Parents (p)	$p-1$	
parents vs crosses	1	
Crosses (C)	$c-1$	
Lines (l)	$l-1$	M_l
Testers (t)	$t-1$	M_t
L x T	$(l-1)(t-1)$	$M_{l \times t}$
Error	$(r-1)(a-1)$	M_e

Where, r , a , p , c , l and t are number of replications, genotypes, parents, crosses, lines and testers, respectively and M_l , M_t , $M_{l \times t}$ and M_e are the mean sum of squares of lines, testers, lines x testers and error.

3.4.2 Heterosis estimation and testing

The magnitude of heterosis for yield component characters was worked out over mid and better parents as follows :

$$\text{Heterosis over mid-parent} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Heterosis over better parent} = \frac{F_1 - BP}{BP} \times 100$$

Where,

F_1 = Mean value of hybrid

MP = Mid parental value

BP = Better parent value

Heterosis for grain yield, sugar content and the other quality parameters viz., protein and carbohydrate content was also estimated over the standard checks viz., Madhuri and Trishulatha, as follows :

$$\text{Standard heterosis} = \frac{F_1 - SV}{SV} \times 100$$

Where,

F_1 = Mean value of the hybrid

SV = Mean value of the standard variety, Madhuri or Trishulatha

Heterosis was considered significant if the difference between F_1 mean value and the mid-parent or better parent or standard variety used for comparison was found significant. The formula suggested by Arunachalam (1980) was used for the purpose and is given below :

$$t \text{ cal} = \frac{F_1 - MP}{\sqrt{1.5 \text{ EMS}/r}} \text{ and } \frac{F_1 - BP/SV}{\sqrt{2 \text{ EMS}/r}}$$

Where,

$\sqrt{\text{EMS}/r}$ = is the standard error

The calculated "t" value was further compared with t-table value at error degrees of

freedom, at 5 per cent and 1 per cent levels of significance, for testing of heterosis.

3.4.3 Estimation of combining ability

For estimation of combining ability of various characters, the line x tester model suggested by Kempthorne (1957) was used.

3.4.4 Phenotypic and Genotypic correlations

The phenotypic and genotypic correlation coefficients were calculated for yield, yield components and quality characters by working out the variance components for each character and the covariance components for each pair of character using the formulae suggested by Al-Jibouri *et al.* (1958). The significance of correlation coefficients was obtained by comparing the estimated values with the table values (Fischer and Yates, 1967) at 5 per cent and 1 per cent levels of significance, at $(n-2)$ degrees of freedom.

3.4.5 Path coefficient analysis

The direct and indirect effects were estimated taking grain yield and total sugars as dependent variables and the yield component characters as independent variables. The procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959) was adopted.

RESULTS

CHAPTER - IV

RESULTS

The results of the present investigation on "Combining ability studies for sweetness and yield improvement in maize" are presented here under:

4.1 ANALYSIS OF VARIANCE

The analysis of variance of parents and hybrids for grain yield, yield component characters and the quality parameters viz., total sugars, protein content and carbohydrate content are presented in Table 3. The mean sum of squares due to genotypes were highly significant for all characters studied. On further partitioning, the parents and hybrids were also found significant for the various traits studied, except ear height, wherein the parents were non-significant. Further, the parents vs. hybrids component was found to be significant for days to 50 per cent silking, plant height, ear length, ear weight, ear height, 100-seed weight, grain yield per plot and carbohydrate content.

4.2 MEAN PERFORMANCE OF PARENTS AND HYBRIDS

The *per se* performance of parents and hybrids for grain yield, yield component characters and quality parameters are presented in Tables 4 and 5. Madhuri, a sweet corn variety and Trishulatha, a high yielding three-way hybrid were used as the standard checks.

4.2.1 Days to 50 per cent silking:

Hybrids recorded less number of days to 50 per cent silking (59.49) compared to testers (64.00). However, the lines were in general early for days to 50 per cent silking (56.67) compared to both testers and hybrids. The range was however, greater in hybrids (56.33 to

Table 3 Analysis of variance (mean squares) for grain yield, yield component characters and quality parameters in sweet corn

Source	df	Days to 50 per cent silking	Days to 50 per cent maturity	Plant height (cm)	Ear length (cm)	Ear weight (g)	Ear height (cm)	100- seed weight (g)	Grain yield per plot (kg)	Total Sugars (%)	Protein (%)	Carbohyd- rates (%)
Replications	2	2.32	150.89	2868.28	2.77	417.05	14.21	0.53	0.20	0.16	0.07	2.06
Genotypes	33	117.38	80.92	568.46	8.15	2681.59	198.08	38.96	1.05	40.17	1.49	354.69
Parents	9	146.98	101.05	221.05	6.76	3558.74	75.07	44.85	1.42	86.31	2.72	661.07
Hybrids	23	107.95	76.44	687.99	5.45	1544.75	213.12	35.75	0.60	31.64	1.27	297.97
Parents vs. Hybrids	1	67.97	3.18	946.04	82.71	20934.51	959.25	59.78	8.22	0.05	0.02	92.98
Error	66	6.70	8.65	17.59	2.25	146.78	113.98	8.39	0.06	0.06	0.03	0.73

**Significant at 1 per cent level

*Significant at 5 per cent level

Table 4 Mean performance of parents for grain yield, yield component characters and quality parameters in sweet corn

Parent	Days to 50% silking	Days to 50% maturity	Plant height (cm)	Ear length (cm)	Ear weight (g)	Ear height (cm)	100- seed weight (g)	Grain yield per plot (kg)	Total sugars (%)	Protein (%)	Carbohyd- rates (%)
Female parent (Line)											
NSCC II-2-1-1	58.67	93.00	134.89	12.71	69.42	45.11	15.26	1.40	9.83	14.96	28.66
ASCC I-1-2-1	56.67	89.33	126.39	14.02	74.87	43.79	14.93	1.51	10.42	14.83	32.08
NSCC I-3-1-1	57.33	92.00	165.16	14.37	76.86	52.64	14.60	1.55	10.26	13.26	35.27
ASCC II-3-2-1	55.00	90.33	159.43	15.07	83.31	60.40	16.38	1.68	9.65	14.47	24.98
ASCC III-2-1-1	56.00	94.67	169.07	15.93	91.24	65.91	18.17	1.84	9.55	13.60	33.03
ASCC III-3-2-1	56.33	90.67	152.31	14.95	79.34	50.06	14.89	1.60	9.26	13.83	36.39
Mean	56.67	91.67	151.20	14.51	79.17	52.99	15.71	1.60	9.83	14.15	31.74
Range	55.00	89.33	126.31	12.71	69.42	43.79	14.60	1.40	9.26	13.26	24.98
Maximum	58.67	94.67	169.07	15.93	91.24	65.91	18.17	1.84	10.42	14.96	36.39
Male parent (Tester)											
ASCC II-2-2-1	62.00	97.33	172.30	15.12	86.78	67.91	11.55	1.75	8.87	14.30	31.40
NSCC-6-1-1	63.67	98.00	175.07	13.93	74.88	90.36	16.26	1.51	8.67	14.62	35.79
CM 120	64.33	97.67	170.16	16.02	93.22	70.68	22.24	1.88	4.21	9.18	56.08
CM 208	66.00	101.33	175.00	15.87	83.31	68.41	24.70	1.67	3.95	9.34	54.29
Mean	64.00	98.58	173.38	15.24	84.55	74.34	18.69	1.71	6.43	11.86	44.39
Range	62.00	97.33	170.16	13.93	74.88	67.91	11.55	1.51	3.95	9.18	31.40
Maximum	66.00	101.33	176.07	16.02	93.22	90.36	24.70	1.88	8.87	14.62	56.08
Checks											
Madhuri	55.00	94.33	192.14	12.80	93.17	72.23	18.20	1.93	10.24	14.71	26.15
Trishulatha	67.33	105.00	235.67	17.69	118.50	105.63	33.36	2.37	4.13	10.25	68.34
SEM	1.49	1.71	2.42	0.87	6.99	6.16	1.67	0.14	0.14	0.10	0.49
CD (5%)	4.22	4.80	6.84	2.44	19.78	17.44	4.74	0.40	0.40	0.28	1.40

64.33) compared to lines (55.00 to 58.67) and testers (62.00 to 66.00). Among the lines, ASCC II-3-2-1 was early, while NSCC II-2-1-1 was late for the trait. However, among the testers, ASCC II-2-2-1 and CM 208 were earlier and late, respectively. Among the hybrids, the cross combinations, ASCC I-1-2-1 x NSCC 6-1-1, ASCC II-3-2-1 x ASCC II-2-2-1 and ASCC III-3-2-1 x ASCC II-2-2-1 were earliest, while ten other cross combinations were at par with these earliest hybrids. Further, lines, testers and hybrids were in general observed to be late, compared to Madhuri and early, compared to Trishulatha.

4.2.2 Days to 50 per cent maturity:

The hybrids recorded greater number of days to 50 per cent maturity (94.78) in comparison to lines (91.67). However, they were early, compared to testers (98.58). The range was also greater for hybrids (90.33 to 99.00), in comparison to lines (89.33 to 94.67) and testers (97.33 to 101.33). The line, ASCC I-1-2-1 (89.33) and the tester, ASCC II-2-2-1 (97.33) were observed to be early, compared to others, while among the hybrids, ASCC III-2-1-1 x ASCC II-2-2-1 and NSCC I-3-1-1 x ASCC II-2-2-1 (90.33) were early. However, the crosses, NSCC II-2-1-1 x CM 120, ASCC I-1-2-1 x CM 208 and NSCC I-3-1-1 x CM 208 (99.00) were late. Sweet corn lines were observed to be early, in general, compared to the checks, Madhuri and Trishulatha. However, the testers and hybrids were early, compared to Trishulatha.

4.2.3 Plant height:

The hybrids recorded greater average plant height (172.21) in comparison to the lines (151.20). However, the testers (173.38) were in general, taller compared to the hybrids. Further, the range was greater among the hybrids (157.16 to 200.73) in comparison to lines (126.31 to 169.07), compared to the testers (170.16 to 176.07). The inbred, ASCC III-2-1-1 recorded maximum plant height (169.07) and the inbred, NSCC I-3-1-1 (165.16) was observed

to be on par with it, while the inbred, ASCC I-1-2-1 recorded minimum value (126.31) among the lines. However, among the testers, the inbreds, CM 120 (170.16) and NSCC-6-1-1 (176.07) recorded the minimum and maximum values, respectively. Further, among the hybrids, the cross, NSCC I-3-1-1 x NSCC-6-1-1 recorded the maximum value (200.73), while ASCC II-3-2-1 x CM 208 recorded minimum value (157.16). The lines, testers and hybrids were in general, observed to be dwarf, compared to the checks, Madhuri (192.14) and Trishulatha (235.67).

4.2.4 Ear length:

Average ear length was higher in hybrids (18.12), in comparison to lines (14.51) and testers (15.24). The range was also greater in hybrids, compared to lines and testers. The hybrids were also in general superior to the checks, Madhuri (12.80) and Trishulatha (17.69). The inbreds, ASCC III-2-1-1 and NSCC II-2-1-1 recorded maximum (15.93) and minimum (12.71) values among the lines. While the inbreds, NSCC 6-1-1 and CM 120 recorded minimum (13.93) and maximum (16.02) values among the testers, respectively. Further, among the 24 hybrids, ASCC III-3-2-1 x CM 120 (20.35) recorded maximum value, while the cross, ASCC III-3-2-1 x NSCC-6-1-1 (16.07) recorded the minimum value. Eleven hybrids exhibited *per se* performance on par with the cross, ASCC III-3-2-1 x CM 120.

4.2.5 Ear weight:

Hybrids recorded greater average ear weight (123.90) in comparison to lines (79.17) and testers (84.55). Performance of the hybrids was also much higher, compared to the checks, Madhuri (93.17) and Trishulatha (118.50). A study of the range also revealed maximum variation for hybrids (104.63 to 144.30) in comparison to lines (69.42 to 91.24) and hybrids (74.88 to 93.22). The inbreds, NSCC II-2-1-1 and ASCC III-2-1-1 recorded the minimum (69.42) and maximum (91.24) values among the lines while the inbreds, NSCC-6-1-1 and CM

120 recorded the minimum (74.88) and maximum (93.22) values among the testers. Further, among the 24 hybrids, ASCC I-1-2-1 x ASCC II-2-2-1 and ASCC III-3-2-1 x CM 120 recorded the minimum (104.63) and maximum (144.30) values, respectively. Ten hybrids had also exhibited performance statistically on par with the superior hybrid, ASCC III-3-2-1 x CM 120.

4.2.6 Ear height:

Average ear height was higher in hybrids (68.79) in comparison to lines (52.99). However, it was lower, compared to the testers (74.34) and the checks, Madhuri (72.33) and Trishulatha (105.63). The range was also higher for hybrids in comparison to lines and testers. The inbreds, ASCC I-1-2-1 and ASCC III-2-1-1 recorded minimum (43.79) and maximum (65.91) values among the lines, while the inbreds, ASCC II-2-2-1 and NSCC-6-1-1 recorded the minimum (67.91) and maximum (90.36) values, among the testers. Further, among the 24 hybrids, NSCC II-2-1-1 x ASCC II-2-2-1 and ASCC II-3-2-1 x CM 208 recorded the minimum (50.23) and maximum (83.36) values, respectively. Further, sixteen hybrids had exhibited performance on par with the cross, ASCC II-3-2-1 x CM 208 for the character.

4.2.7 100-Seed Weight :

The average 100-seed weight was higher for the hybrids (20.78) followed by testers (18.69) in comparison to the lines (15.71). Further, the performance of the testers and hybrids was in general, superior to the check, Madhuri (18.20) and inferior, in comparison to the check, Trishulatha (33.36). A study of the range, revealed greater value for testers (11.55 to 24.70) in comparison to the lines (14.60 to 18.17) and the hybrids (18.31 to 24.28). The inbreds, NSCC I-3-1-1 and ASCC III-2-1-1 recorded the minimum and maximum values among the lines, while the inbreds, NSCC-6-1-1 and CM 208 recorded the minimum and maximum values, respectively among the testers. Further, among the 24 hybrids, NSCC II-2-1-1 x NSCC-

6-1-1 and ASCC III-3-2-1 x CM 208 recorded the minimum and maximum values, respectively. Fourteen hybrids had also exhibited on par performance with the superior hybrid (ASCC III-3-2-1 x CM 208) for the trait.

4.2.8 Grain yield per plot :

Average grain yield per plot was observed to be higher in hybrids (2.50) in comparison to the lines (1.60), testers (1.71) and the checks, Madhuri (1.93) and Trishulatha (2.37). The range was also noticed to be greater among the hybrids in comparison to the lines and testers. The inbreds, NSCC II-2-1-1 and ASCC III-2-1-1 recorded minimum (1.40) and maximum (1.84) values among the lines, while the inbreds, NSCC-6-1-1 and CM 120 recorded the minimum (1.51) and maximum (1.88) values among the testers. Further, among the 24 hybrids, ASCC I-1-2-1 x ASCC II-2-2-1 and ASCC III-3-2-1 x CM 120 recorded the minimum (2.11) and maximum (2.91) values, respectively. Eleven hybrids viz., NSCC II-2-1-1 x CM 208, ASCC I-1-2-1 x CM 120, ASCC I 1-2-1 x CM 208, NSCC I-3-1-1 x CM 120, NSCC I-3-1-1 x CM 208, ASCC II-3-2-1 x CM 120, ASCC II-3-2-1 x CM 208, ASCC III-2-1-1 x NSCC-6-1-1, ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208 and ASCC III-3-2-1 x CM 208, had also recorded on par performance with the hybrid, ASCC III-3-2-1 x CM 120 for the trait.

4.2.9 Total sugars:

Average total sugars was greater among the lines (9.83), followed by hybrids (8.29) in comparison to the testers (6.43). Performance of the lines, testers and hybrids was in general, superior over the check, Trishulatha (4.13). However, they were inferior to the check, Madhuri (10.24). The range was noticed to be greater for hybrids, in comparison to the lines and testers. The inbreds, ASCC III-3-2-1 and ASCC I-1-2-1 recorded the minimum (9.26) and maximum (10.42) values among the lines, while the inbreds, CM 208 and ASCC II-2-2-1 recorded the minimum (3.95) and maximum (8.87) values among the testers. The inbred, NSCC

I-3-1-1 among the lines and the inbred, NSCC-6-1-1 among the testers, recorded on par performance with the inbreds, ASCC I-1-2-1 and ASCC II-2-2-1, respectively. Further, among the 24 hybrids, NSCC II-2-1-1 x CM 208 and ASCC III-2-1-1 x NSCC-6-1-1 recorded the minimum (5.76) and maximum (11.66) values, respectively. Three hybrids (ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1) also recorded on par performance with the hybrid, ASCC III-2-1-1 x NSCC-6-1-1 for total sugars.

4.2.10 Protein content :

Average protein content was observed to be higher in lines (14.15) and hybrids (14.03), compared to testers (11.86) and the check, Trishulatha (10.25). However, Madhuri (14.71) recorded greater protein content in comparison to lines, testers and hybrids. The range was noticed to be greater for testers in comparison to lines and hybrids. The inbreds, NSCC II-2-1-1 and NSCC I-3-1-1 recorded maximum (14.96) and minimum (13.26) values among the lines, while the inbreds, CM 120 and NSCC-6-1-1 recorded the minimum (9.18) and maximum (14.62) values among the testers. The inbred, ASCC I-1-2-1 was observed to be on par with the superior inbred, NSCC II-2-1-1. Further, among the 24 hybrids, NSCC II-2-1-1 x CM 120 and ASCC II-3-2-1 x ASCC II-2-2-1 recorded the minimum (12.64) and maximum (15.22) values, respectively. The hybrids, ASCC I-1-2-1 x ASCC II-2-2-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x ASCC II-2-2-1 and ASCC III-2-1-1 x NSCC-6-1-1 also exhibited, statistically on par performance with the hybrid, ASCC II-3-2-1 x ASCC II-2-2-1.

4.2.11 Carbohydrates:

The testers (44.39) recorded greater average carbohydrate content in comparison to the lines (31.74) and hybrids (44.39). However, the average carbohydrate content of lines, testers and hybrids was lower, compared to the check, Trishulatha (68.34) and higher compared to the check, Madhuri (26.15). Range for the trait was higher among the testers, in comparison

to lines and hybrids. The inbreds, ASCC II-3-2-1 and ASCC III-3-2-1 recorded the minimum (24.98) and maximum (36.39) values among the lines, while the inbreds, ASCC II-2-2-1 and CM 120 recorded the minimum (31.40) and maximum (56.08) values among the testers. Further, among the hybrids, the crosses, ASCC I-1-2-1 x ASCC II-2-2-1 and ASCC III-3-2-1 x CM 208 recorded the minimum (31.30) and maximum (48.69) values, respectively.

4.3 HETEROSIS

Heterosis for grain yield, yield component characters and the quality parameters was studied over the mid and better parents and the results are presented in Tables 6-8. Further, standard heterosis over Madhuri, and Trishulatha, was also analyzed and the results are presented in Table 9.

4.3.1 Days to 50 per cent silking:

Eleven hybrids exhibited significant and negative heterosis over the mid-parent, while the hybrid, NSCC I-3-1-1 x CM 208 alone, recorded significant and negative heterosis over better parent. Significant and negative heterosis over both the mid and better parents was also noticed for the hybrid, NSCC I-3-1-1 x CM 208. Heterosis over mid-parent ranged from -11.89 (NSCC I 3-1-1 x CM 208) to 5.59 (ASCC II-3-2-1 x CM 120), while heterosis over better parent ranged between -5.23 (NSCC I-3-1-1 x CM 208) and 14.55 (ASCC II-3-2-1 x CM 120).

4.3.2 Days to 50 per cent maturity:

Significant and negative heterosis, desirable for the trait was noticed in the hybrids, NSCC II 2-1-1 x ASCC II-2-2-1 and NSCC I-3-1-1 x ASCC II-2-2-1, over mid parent. However, none of the hybrids studied had recorded significant and negative heterosis over the

Table 6 Per cent heterosis over mid-parent (MP) and better parent (BP) for days to 50 per cent silking, maturity and plant height in sweet corn

Hybrid	Days to 50% silking		Days to 50% maturity		Plant height	
	over MP	over BP	over MP	over BP	over MP	over BP
NSSC II-2-1-1 X ASSC II-2-2-1	-3.32	-0.58	-5.06	-2.85	2.76	-8.40'
NSSC II-2-1-1 X NSSC 6-1-1	-6.82	-2.85	-2.96	-0.35	29.08	13.99
NSSC II-2-1-1 X CM 120	0.81	5.68	3.84	6.45	13.48	1.72
NSSC II-2-1-1 X CM 208	2.14	8.52	-1.54	2.87	11.03	-1.70
ASSC I-1-2-1 X ASSC II-2-2-1	-1.69	2.93	-0.35	4.11	18.11	2.35
ASSC I-1-2-1 X NSSC 6-1-1	-6.38	-0.60	-2.85	1.87	13.69	-2.37
ASSC I-1-2-1 X CM 120	0.28	7.06	3.03	7.84	11.92	-2.50
ASSC I-1-2-1 X CM 208	1.08	9.41	3.85	10.83	17.90	1.50
NSSC I-3-1-1 X ASSC II-2-2-1	-5.02	-1.15	-4.58	-1.82	-6.58	-8.52
NSSC I-3-1-1 X NSSC 6-1-1	-6.33	-1.15	-0.35	2.90	17.65	14.01
NSSC I-3-1-1 X CM 120	1.92	8.15	2.63	5.79	-5.14	-6.54
NSSC I-3-1-1 X CM 208	-11.89	-5.23	2.42	7.61	1.16	-1.68
ASSC II-3-2-1 X ASSC II-2-2-1	-3.71	2.42	0.18	4.06	2.28	-1.54
ASSC II-3-2-1 X NSSC 6-1-1	-3.94	3.64	-1.95	2.21	-6.42	-10.84
ASSC II-3-2-1 X CM 120	5.59	14.55	4.97	9.23	-0.93	-4.05
ASSC II-3-2-1 X CM 208	1.93	12.13	-1.57	4.43	-6.01	-10.19
ASSC III-2-1-1 X ASSC II-2-2-1	-3.95	1.20	-4.17	-2.82	0.67	-0.27
ASSC III-2-1-1 X NSSC 6-1-1	-3.62	2.98	-2.08	-0.36	13.16	10.91
ASSC III-2-1-1 X CM 120	0.84	8.34	1.21	2.81	15.47	15.10
ASSC III-2-1-1 X CM 208	2.18	11.30	0.00	3.52	-2.57	-4.22
ASSC III-3-2-1 X ASSC II-2-2-1	-4.79	0.00	-3.19	0.36	-1.36	-7.09
ASSC III-3-2-1 X NSSC 6-1-1	-5.55	0.60	-1.07	2.93	3.73	-3.27
ASSC III-3-2-1 X CM 120	0.56	7.70	3.01	6.98	6.51	0.92
ASSC III-3-2-1 X CM 208	-10.62	-2.95	-2.08	3.67	19.56	11.81
Range	-11.89	-5.23	-5.06	-2.85	-6.58	-10.84
Maximum	5.59	14.55	4.97	10.83	29.08	15.10
SEm	1.49	1.49	1.71	1.71	2.42	2.42

**Significant at 1 per cent level *Significant at 5 per cent level MP - Mid-parent BP - Better parent

Table 7 Per cent heterosis over mid-parent (MP) and better parent (BP) for ear length, ear weight, ear height and 100-seed weight in sweet corn

Hybrid	Ear length		Ear weight		Ear height		Test weight	
	over MP	over BP	over MP	over BP	over MP	over BP	over MP	over BP
NSSC II-2-1-1 X ASSC II-2-2-1	21.24"	11.57"	40.95"	26.85"	-11.11	-26.03"	42.48"	25.16"
NSSC II-2-1-1 X NSCC 6-1-1	29.05"	23.40"	58.75"	52.96"	4.27	-21.83"	16.18"	12.61"
NSSC II-2-1-1 X CM 120	21.13"	8.61"	46.35"	27.67"	17.99"	-3.35	16.00"	-2.20
NSSC II-2-1-1 X CM 208	31.21"	18.15"	72.72"	58.32"	35.71"	12.60	7.31"	-13.20"
ASSC I-1-2-1 X ASSC II-2-2-1	10.71"	6.68"	29.45"	20.57"	9.11	-10.26	50.23"	33.22"
ASSC I-1-2-1 X NSCC 6-1-1	21.07"	20.68"	45.70"	45.69"	12.10	-16.79	19.65"	14.76"
ASSC I-1-2-1 X CM 120	18.58"	11.17"	48.68"	34.05"	19.33"	-3.37	12.13"	-6.29"
ASSC I-1-2-1 X CM 208	28.54"	21.05"	69.91"	61.30"	-10.02	-26.21"	11.99"	-10.16"
NSSC I-3-1-1 X ASSC II-2-2-1	25.94"	22.82"	47.27"	38.86"	-3.18	-14.06	55.79"	39.52"
NSSC I-3-1-1 X NSCC 6-1-1	26.57"	24.63"	51.63"	49.67"	6.22	-16.74	22.81"	16.54"
NSSC I-3-1-1 X CM 120	24.51"	18.10"	51.60"	38.30"	22.38"	6.76	15.20"	-4.69
NSSC I-3-1-1 X CM 208	35.43"	18.93"	63.17"	60.70"	13.73	-0.36	13.63"	-4.36"
ASSC II-3-2-1 X ASSC II-2-2-1	13.61"	13.43"	33.52"	30.85"	10.47	4.36	38.13"	17.77"
ASSC II-3-2-1 X NSCC 6-1-1	20.90"	16.32"	46.70"	39.27"	6.63	-11.04	15.50"	15.08"
ASSC II-3-2-1 X CM 120	23.19"	19.54"	48.87"	40.96"	22.37"	13.47	20.51"	4.63
ASSC II-3-2-1 X CM 208	27.73"	24.51"	62.49"	62.49"	29.43"	21.85"	8.76"	-9.55"
ASSC III-2-1-1 X ASSC II-2-2-1	13.49"	10.61"	34.25"	30.97"	16.40	14.68	26.45"	3.41
ASSC III-2-1-1 X NSCC 6-1-1	22.64"	14.94"	53.43"	39.68"	-10.19	-22.34"	14.78"	8.75"
ASSC III-2-1-1 X CM 120	20.63"	20.29"	53.77"	52.13"	18.21"	14.22	10.91"	6.76
ASSC III-2-1-1 X CM 208	20.38"	20.15"	61.36"	54.35"	20.44"	18.24"	4.27"	-9.51"
ASSC III-3-2-1 X ASSC II-2-2-1	11.41"	10.78"	31.94"	26.28"	-11.05	-22.74"	41.45"	25.59"
ASSC III-3-2-1 X NSCC 6-1-1	11.29"	7.49"	36.32"	32.49"	-24.77"	-41.54"	24.94"	19.68"
ASSC III-3-2-1 X CM 120	31.42"	27.03"	67.25"	54.80"	29.58"	10.68	26.21"	5.35"
ASSC III-3-2-1 X CM 208	23.49"	19.91"	74.39"	70.23"	-7.89	-20.25"	22.66"	-1.70
Range	10.71	6.68	29.45	20.57	-24.77	-41.54	4.27	-13.20
Maximum	31.42	27.03	74.39	70.23	35.71	21.85	55.79	39.52
SEm	0.87	0.87	6.99	6.99	6.16	6.16	1.67	1.67

"Significant at 1 per cent level *Significant at 5 per cent level MP - Mid-parent BP - Better parent

Table 8 Per cent heterosis over mid-parent (MP) and better parent (BP) for grain yield and the quality parameters in sweet corn

Hybrid	Grain yield per plot (kg)		Total sugars (%)		Protein (%)		Carbohydrates (%)	
	MP	BP	MP	BP	MP	BP	MP	BP
NSCC II-2-1-1 X ASCC II-2-2-1	40.95"	26.86"	-3.96"	-8.65"	0.14	-2.07"	8.59"	3.85"
NSCC II-2-1-1 X NSCC 6-1-1	58.76"	52.98"	16.97"	10.07"	0.14	-1.00"	6.87"	-3.77"
NSCC II-2-1-1 X CM 120	46.34"	27.66"	-14.67"	-39.06"	4.72"	-15.51"	8.24"	-18.22"
NSCC II-2-1-1 X CM 208	72.73"	58.33"	-16.40"	-41.40"	4.69"	-14.97"	11.44"	-14.86"
ASCC I-1-2-1 X ASCC II-2-2-1	29.45"	20.57"	-0.36"	-7.77"	4.43"	2.56"	-1.39"	-2.43"
ASCC I-1-2-1 X NSCC 6-1-1	45.70"	45.70"	17.97"	8.06"	0.85"	0.13	5.05"	-0.39
ASCC I-1-2-1 X CM 120	48.67"	34.04"	-11.83"	-38.10"	10.54"	-10.52"	3.72"	-18.47"
ASCC I-1-2-1 X CM 208	69.91"	61.31"	-19.00"	-44.15"	10.30"	-10.11"	-9.85"	-28.29"
NSCC I-3-1-1 X ASCC II-2-2-1	47.27"	38.86"	2.88"	-4.09"	6.82"	2.94"	3.37"	-2.30"
NSCC I-3-1-1 X NSCC 6-1-1	51.63"	49.68"	12.73"	4.00"	6.53"	1.57"	-6.64"	-7.32"
NSCC I-3-1-1 X CM 120	51.60"	38.30"	-12.65"	-38.40"	14.44"	-3.17"	-14.96"	-30.74"
NSCC I-3-1-1 X CM 208	67.18"	60.71"	-13.02"	-39.77"	14.69"	-2.26"	-0.51	-17.94"
ASCC II-3-2-1 X ASCC II-2-2-1	33.53"	30.86"	5.29"	1.04"	5.80"	5.18"	0.46	-9.81"
ASCC II-3-2-1 X NSCC 6-1-1	46.71"	39.29"	25.98"	19.59"	4.43"	3.90"	5.78"	-10.20"
ASCC II-3-2-1 X CM 120	48.88"	40.96"	-9.52"	-35.03"	12.81"	-7.81"	-8.83"	-34.11"
ASCC II-3-2-1 X CM 208	62.50"	62.50"	-13.09"	-38.76"	13.06"	-6.98"	6.29"	-22.40"
ASCC III-2-1-1 X ASCC II-2-2-1	34.26"	30.98"	10.86"	6.91"	7.38"	4.76"	3.99"	1.42"
ASCC III-2-1-1 X NSCC 6-1-1	53.43"	39.67"	27.99"	22.09"	7.16"	3.42"	8.46"	4.27"
ASCC III-2-1-1 X CM 120	53.76"	52.13"	-10.17"	-35.29"	19.49"	0.07	0.15	-20.44"
ASCC III-2-1-1 X CM 208	61.36"	54.35"	-13.33"	-38.74"	19.70"	0.96"	5.66"	-15.03"
ASCC III-3-2-1 X ASCC II-2-2-1	31.94"	26.29"	12.74"	10.37"	-0.89"	-2.52"	5.27"	-1.95"
ASCC III-3-2-1 X NSCC 6-1-1	36.33"	32.50"	25.71"	21.71"	2.99"	0.21	5.90"	5.03"
ASCC III-3-2-1 X CM 120	67.24"	54.79"	-5.57"	-31.32"	20.21"	0.00	-7.30"	-23.57"
ASCC III-3-2-1 X CM 208	74.39"	70.24"	-9.61"	-35.53"	14.54"	-4.05"	7.39"	-10.31"
Range	29.45	20.57	-19.00	-44.15	-0.89	-15.51	-14.96	-34.11
Maximum	74.39	70.24	27.99	22.09	20.21	5.18	11.44	5.03
SEm	0.14	0.14	0.14	0.14	0.10	0.10	0.49	0.49

"Significant at 1 per cent level

*Significant at 5 per cent level MP - Mid-parent BP - Better parent

Table 9 Per cent heterosis over the standard checks, Madhuri and Trishulatha for grain yield and the quality parameters in sweet corn

Hybrid	Grain yield per plot (kg)		Total sugars (%)		Protein (%)		Carbohydrates (%)	
	Madhuri	Trishulatha	Madhuri	Trishulatha	Madhuri	Trishulatha	Madhuri	Trishulatha
NSCC II-2-1-1 X ASCC II-2-2-1	15.03	-6.33	-12.30	117.43	-0.41	42.93	24.70	-52.28
NSCC II-2-1-1 X NSCC 6-1-1	19.69	-2.53	5.66	161.99	0.68	44.49	31.70	-49.60
NSCC II-2-1-1 X CM 120	24.35	1.27	-41.50	45.04	-14.07	23.32	75.37	-32.89
NSCC II-2-1-1 X CM 208	37.82	12.24	-43.75	39.47	-13.53	24.10	76.75	-32.37
ASCC I-1-2-1 X ASCC II-2-2-1	9.33	-10.97	-6.15	132.69	3.40	48.39	19.69	-54.20
ASCC I-1-2-1 X NSCC 6-1-1	13.99	-7.17	9.96	172.64	0.95	44.88	36.33	-47.83
ASCC I-1-2-1 X CM 120	30.57	6.33	-37.01	56.17	-9.79	29.46	74.84	-33.10
ASCC I-1-2-1 X CM 208	40.41	14.35	-43.16	40.92	-9.38	30.05	48.87	-43.03
NSCC I-3-1-1 X ASCC II-2-2-1	25.91	2.53	-3.91	138.26	0.07	43.61	31.78	-49.58
NSCC I-3-1-1 X NSCC 6-1-1	20.21	-2.11	4.20	158.35	0.95	44.88	26.85	-51.46
NSCC I-3-1-1 X CM 120	34.72	9.70	-38.28	53.03	-12.71	25.27	48.53	-43.17
NSCC I-3-1-1 X CM 208	39.90	13.92	-39.66	49.64	-11.90	26.44	70.36	-34.81
ASCC II-3-2-1 X ASCC II-2-2-1	18.65	-3.38	-4.79	136.08	3.47	48.49	8.30	-58.56
ASCC II-3-2-1 X NSCC 6-1-1	21.24	-1.27	12.70	179.42	3.26	48.20	22.91	-52.97
ASCC II-3-2-1 X CM 120	37.31	11.81	-38.77	51.82	-9.31	30.15	41.30	-45.93
ASCC II-3-2-1 X CM 208	41.45	15.19	-42.29	43.10	-8.50	31.32	61.11	-38.35
ASCC III-2-1-1 X ASCC II-2-2-1	2.07	1.69	-0.29	147.22	1.84	46.15	28.11	-50.98
ASCC III-2-1-1 X NSCC 6-1-1	33.16	8.44	13.87	182.32	2.79	47.51	42.72	-45.39
ASCC III-2-1-1 X CM 120	48.19	20.68	-39.65	49.62	-7.48	32.78	70.63	-34.71
ASCC III-2-1-1 X CM 208	47.15	19.83	-42.87	41.65	-6.66	33.95	76.41	-32.50
ASCC III-3-2-1 X ASCC II-2-2-1	14.51	-6.75	-0.20	147.46	-5.23	36.00	36.44	-47.79
ASCC III-3-2-1 X NSCC 6-1-1	9.84	-10.55	10.06	172.88	-0.41	42.93	46.16	-44.07
ASCC III-3-2-1 X CM 120	50.78	22.78	-37.89	54.00	-5.98	34.93	63.90	-37.28
ASCC III-3-2-1 X CM 208	48.19	20.68	-41.70	44.55	-9.79	29.46	86.20	-28.75
Range	2.07	-10.97	-43.75	39.47	-14.07	23.32	8.30	-58.56
Maximum	50.78	22.78	13.87	182.32	3.47	48.49	86.20	-28.75
SEm	0.14	0.14	0.14	0.14	0.10	0.10	0.49	0.49

*Significant at 1 per cent level

*Significant at 5 per cent level

MP - Mid-parent BP - Better parent

better parent. Heterosis over mid-parent ranged from -5.06 (NSCC II-2-1-1 x ASCC II-2-2-1) to 4.97 (ASCC II-3-2-1 x CM 120) while heterosis over better parent ranged between -2.85 (NSCC II-2-1-1 x ASCC II-2-2-1) and 10.83 (ASCC I-1-2-1 x CM 208).

4.3.3 Plant height:

Significant and positive heterosis was noticed in 12 hybrids over mid-parent, while significant and negative heterosis was recorded in three hybrids. However, over better parent five hybrids had recorded significant and negative heterosis, while significant and positive heterosis desirable for the trait was noticed in five hybrids. Heterosis over mid-parent ranged between -6.58 (NSCC I-3-1-1 x ASCC II-2-2-1) and 29.08 (NSCC II-2-1-1 x NSCC-6-1-1), while heterosis over Trishulatha ranged from -10.84 (ASCC II-3-2-1 x NSCC-6-1-1) to 15.10 (ASCC III-2-1-1 x CM 120).

4.3.4 Ear length:

Significant and positive heterosis over the mid and better parents was noticed in all the 24 hybrids. Heterosis over mid-parent ranged from 10.71 (ASCC I-1-2-1 x ASCC II-2-2-1) to 31.42 (ASCC III-3-2-1 x CM 120), while heterosis over better parent ranged between 6.68 (ASCC I-1-2-1 x ASCC II-2-2-1) and 27.03 (ASCC III-3-2-1 x CM 120).

4.3.5 Ear weight:

All the hybrids had recorded positive and significant heterosis over both mid and better parents. Heterosis over mid-parent ranged from 29.45 (ASCC I-1-2-1 x ASCC II-2-2-1) to 74.39 (ASCC III-3-2-1 x CM 208), while heterosis over better parent ranged from 20.57 (ASCC I-1-2-1 x ASCC II-2-2-1) to 70.23 (ASCC III-3-2-1 x ASCC II-2-2-1).

4.3.6 Ear height:

Nine hybrids had exhibited significant and positive heterosis over the mid-parent,

while the hybrids, ASCC II-3-2-1 x CM 208 and ASCC III-3-2-1 x CM 208 exhibited positive and significant heterosis over the better parent. Heterosis over mid-parent ranged from -24.77 (ASCC III 3-2-1 x NSCC-6-1-1) to 35.71 (NSCC II 2-1-1 x CM 208), while heterosis over better parent ranged between -41.54 (ASCC III-3-2-1 x NSCC-6-1-1) and 21.85 (ASCC II-3-2-1 x CM 208).

4.3.7 100-seed weight :

All the hybrids studied had exhibited positive and significant heterosis over mid-parent, while 12 hybrids recorded significant and positive heterosis over the better parent. Heterosis over mid-parent ranged from 4.27 (ASCC III-2-1-1 x CM 208) to 55.79 (NSCC I-3-1-1 x ASCC II-2-2-1), while heterosis over better parent ranged between -13.20 (NSCC II-2-1-1 x CM 208) and 39.52 (NSCC I-3-1-1 x ASCC II-2-2-1).

4.3.8 Grain yield per plot:

Positive and significant heterosis over mid and better parents was noticed in all the hybrids studied, while over the sweet corn check, Madhuri, 15 hybrids had exhibited positive and significant heterosis. However, over Trishulatha, the high yielding three-way hybrid, desirable heterosis was noticed in four hybrids (ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208). The heterosis over mid-parent ranged between 29.45 (ASCC I-1-2-1 x ASCC II-2-2-1) and 74.39 (ASCC III-3-2-1 x CM 208), while heterosis over better parent ranged from 20.57 (ASCC I-1-2-1 x ASCC II-2-2-1) to 70.24 (ASCC III-3-2-1 x CM 208). Heterosis over Madhuri ranged between 2.07 (ASCC III-2-1-1 x ASCC II-2-2-1) to 50.78 (ASCC III-3-2-1 x CM 120). However, over Trishulatha, it ranged from -10.97 (ASCC I-1-2-1 x ASCC II-2-2-1) to 22.78 (ASCC III-3-2-1 x CM 120).

4.3.9 Total sugars :

Positive and significant heterosis was recorded in 10 hybrids over mid-parent, nine

hybrids over better parent, six hybrids over Madhuri, and all the 24 hybrids over Trishulatha. The hybrids with significant and positive heterosis over Madhuri (NSCC II-2-1-1 x NSCC-6-1-1, ASCC I-1-2-1 x NSCC-6-1-1, NSCC I-3-1-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1) also exhibited positive and significant heterosis over the mid-parent, better parent and the three-way check, Trishulatha. Heterosis over mid-parent ranged from -19.00 (ASCC I-1-2-1 x CM 208) to 27.99 (ASCC III-2-1-1 x NSCC-6-1-1), while heterosis over better parent ranged between -44.15 (ASCC I-1-2-1 x CM 208) and 22.09 (ASCC III-2-1-1 x NSCC-6-1-1). However, heterosis over Madhuri ranged between -43.75 (NSCC II-2-1-1 x CM 208) and 13.87 (ASCC III-2-1-1 x NSCC-6-1-1), while heterosis over Trishulatha ranged from 39.47 (NSCC II-2-1-1 x CM 208) to 182.32 (ASCC III-2-1-1 x NSCC-6-1-1).

4.3.10 Protein content :

Significant and positive heterosis was noticed in 21 hybrids over mid-parent and eight hybrids over the better parent. However, five hybrids over Madhuri and all the 24 hybrids studied, over Trishulatha had exhibited desirable heterosis for the trait. Hybrids exhibiting positive and significant heterosis, desirable for the trait over Madhuri (ASCC I-1-2-1 x ASCC II-2-2-1, ASCC II-3-2-1 x ASCC II-2-2-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x ASCC II-2-2-1 and ASCC III-2-1-1 x NSCC-6-1-1) also recorded desirable heterosis over the mid and better parents and Trishulatha. Heterosis over mid-parent ranged from -0.89 (ASCC III-3-2-1 x ASCC II-2-2-1) to 20.21 (ASCC III-3-2-1 x CM 120), while heterosis over better parent ranged between -15.51 (NSCC II-2-1-1 x CM 120) and 5.18 (ASCC II-3-2-1 x ASCC II-2-2-1). However, heterosis over Madhuri ranged from -14.07 (NSCC II-2-1-1 x CM 120) to 3.47 (ASCC II-3-2-1 x ASCC II-2-2-1), while heterosis over Trishulatha ranged from 23.32 (NSCC II-2-1-1 x CM 120) to 48.49 (ASCC II-3-2-1 x ASCC II-2-2-1).

4.3.11 Carbohydrates :

Positive and significant heterosis was noticed in 15 hybrids over mid parent, four hybrids over better parent and 24 hybrids over Madhuri, while negative and significant heterosis was noticed in six hybrids over mid-parent, 19 hybrids over better parent and in all the 24 hybrids studied over Trishulatha. Heterosis over mid-parent ranged from -14.96 (NSCC I-3-1-1 x ASCC II-2-2-1) to 11.44 (NSCC II-2-1-1 x CM 208); over better parent from -34.11 (ASCC II-3-2-1 x CM 120) to 5.03 (ASCC III-3-2-1 x NSCC-6-1-1); over Madhuri from 8.30 (ASCC II-3-2-1 x ASCC II-2-2-1) to 86.20 (ASCC III-3-2-1 x CM 208) and over Trishulatha from -58.56 (ASCC II-3-2-1 x ASCC II-2-2-1) to -28.75 (ASCC III-3-2-1 x CM 208).

4.4 COMBINING ABILITY ANALYSIS

4.4.1 Analysis of variance and variance components

The analysis of variance for combining ability (Table 10) revealed significant variation for all traits studied for the hybrids. The interaction mean square of lines and testers was also significant for grain yield, yield component characters and the quality parameters. However, the mean squares of lines and testers were not significant for any character. Observations on the components of genetic variation revealed that *sca* variance was high for all the characters studied.

4.4.2 General combining ability effects

The results on *gca* effects for the lines and testers involved in the present study are presented in Table 11.

For days to 50 per cent silking, the *gca* effects among the lines ranged from -3.38 (NSCC II-2-1-1) to 1.79 (ASCC III-3-2-1). Two inbreds recorded significant and negative *gca* effects (NSCC II-2-1-1 and ASCC III-2-1-1) among the lines. The *gca* effects for the testers

Table 10 Analysis of variance (mean squares) for combining ability, variance components and their ratios for grain yield, yield component characters and quality parameters in sweet corn

Source	df	Days to 50 per cent silking	Days to 50% maturity	Plant height (cm)	Ear length (cm)	Ear weight (g)	Ear height (cm)	100- seed weight (g)	Grain yield per plot (kg)	Total sugars (%)	Protein (%)	Carbohyd- rates (%)
Hybrids	23	107.95"	76.43"	687.99"	5.45"	1544.75"	213.12"	35.75"	0.59"	31.64"	1.27"	297.97"
Lines	5	52.72	26.92	521.03	3.01	849.31	104.08	24.36	0.15	15.45	0.62	145.52
Testers	3	148.68	91.66	772.91	6.48	1835.92	293.53	51.62	0.87	43.58	1.75	410.40
Lines x Testers	15	118.21"	89.88"	726.66"	6.06"	1718.33"	233.38"	36.37"	0.69"	34.65"	1.39"	326.30"
Error	66	6.70	8.65	17.59	2.25	146.78	113.98	8.39	0.06	0.06	0.03	0.73
<u>o'gca</u>		1.04	0.41	8.02	0.05	13.45	2.92	0.49	0.003	0.43	0.02	4.08
<u>o'sca</u>		37.17	27.08	236.36	1.27	523.85	39.80	9.33	0.21	11.53	0.45	108.52

"Significant at 1 per cent level

"Significant at 5 per cent level

Table 11 Estimates of general combining ability effects of various parents for grain yield, yield component characters and quality parameters in sweet corn

Parent	Days to 50% silking	Days to 50% maturity	Plant height (cm)	Ear length (cm)	Ear weight (g)	Ear height (cm)	100-seed weight (g)	Grain yield per plot (kg)	Total sugars (%)	Protein (%)	Carbohyd -rates (%)
Female parent (Line)											
NSCC II-2-1-1	-3.38 ^{**}	0.47	9.87 ^{**}	-0.39	-4.88	-0.71	0.57	-0.09	-1.39 ^{**}	0.17 ^{**}	-13.07 ^{**}
ASCC I-1-2-1	1.29	1.64	-0.18	-0.02	4.54	0.34	-2.74 ^{**}	0.10	3.86 ^{**}	-0.03	6.93 ^{**}
NSCC I-3-1-1	1.63 [*]	1.05	-9.85 ^{**}	-1.03 [*]	1.54	0.50	0.99	0.04	1.40 ^{**}	0.15 ^{**}	5.95 ^{**}
ASCC II-3-2-1	0.38	0.06	2.89 [*]	0.03	-6.04	-0.04	-1.30	-0.11	-3.38 ^{**}	-0.85 ^{**}	-4.55 ^{**}
ASCC III-2-1-1	-1.71 [*]	-2.61 ^{**}	0.92	0.87 ^{**}	9.21 [*]	-0.01	3.25 ^{**}	0.15 [*]	1.73 ^{**}	0.24 ^{**}	8.95 ^{**}
ASCC III-3-2-1	1.79 [*]	-0.61	-3.65 ^{**}	0.54	-4.37	-0.08	-0.77	-0.08	-2.22 ^{**}	0.32 ^{**}	-4.21 ^{**}
Range Minimum	-3.38	-2.61	-9.85	-1.03	-6.04	-0.71	-2.74	-0.11	-3.38	-0.85	-13.07
Maximum	0.79	1.64	9.87	0.87	9.21	0.50	3.25	0.15	3.86	0.32	8.95
SE (g.)	0.75	0.85	1.21	0.43	3.49	3.08	0.84	0.07	0.07	0.05	0.25
Male parent (Tester)											
ASCC II-2-2-1	4.21 ^{**}	2.83 ^{**}	1.47	-0.48	-6.54 [*]	0.92	0.36	-0.28 ^{**}	2.85 ^{**}	0.28 ^{**}	-3.43 ^{**}
NSCC-6-1-1	-2.07 ^{**}	-1.56 [*]	6.43 ^{**}	-1.38 ^{**}	-7.60 [*]	-0.61	-0.66	-0.05	0.58 ^{**}	0.34 ^{**}	3.78 ^{**}
CM 120	-0.57	0.78	-9.15 ^{**}	0.87 [*]	6.46 [*]	0.19	0.55	0.14 [*]	-2.02 ^{**}	-0.51 ^{**}	-7.78 ^{**}
CM 208	-1.57 [*]	-2.06 ^{**}	1.24	0.99 ^{**}	7.68 ^{**}	-0.50	-0.25	0.19 ^{**}	-1.41 ^{**}	-0.11	7.43 ^{**}
Range Minimum	-2.07	-2.06	-9.15	-1.38	-7.60	-0.61	-0.66	-0.28	-2.02	-0.51	-7.78
Maximum	4.21	2.83	1.47	0.99	7.68	0.92	0.55	0.19	2.85	0.34	7.43
SE (g.)	0.61	0.69	0.98	0.35	2.86	2.52	0.68	0.06	0.06	0.04	0.20

^{**}Significant at 1 per cent level

^{*}Significant at 5 per cent level

ranged between -2.07 (NSCC-6-1-1) and 4.21 (ASCC II-2-2-1). The inbreds, NSCC-6-1-1 and CM 208, had recorded significant and negative *gca* effects, while the inbred, ASCC II-2-2-1 recorded positive and significant effect for the trait.

For days to 50 per cent maturity, *gca* effects of the lines ranged from -2.61 (ASCC III-2-1-1) to 1.64 (ASCC I-1-2-1). Among the different lines evaluated, only ASCC III-2-1-1 showed significant and negative *gca* effects. Among the testers, *gca* effects ranged from -2.06 (CM 208) to 2.83 (ASCC II-2-2-1). Positive and significant *gca* effects were recorded by the inbred, ASCC II-2-2-1 alone, while NSCC-6-1-1 and CM 208 showed negative and significant *gca* effects among the various testers studied.

Gca effects for plant height ranged from -9.85 (NSSC I-3-1-1) to 9.87 (NSSC II-2-1-1) among the lines and from -9.15 (CM 120) to 6.43 (NSSC-6-1-1) among the testers. Further, the inbred, NSCC II-2-1-1, recorded significant and positive *gca* among the lines, while NSCC-6-1-1 recorded positive and significant *gca* among the testers.

The *gca* effects for ear length ranged from -1.03 (NSCC I-3-1-1) to 0.87 (ASCC III-2-1-1), among the lines and between -1.38 (NSCC-6-1-1) to 0.99 (CM 208) among the testers. ASCC III-2-1-1 had recorded significant and positive *gca* effects among the lines, while CM 120 and CM 208 recorded positive and significant *gca* effects among the testers.

For ear weight, *gca* effects of the lines ranged from -6.04 (ASCC II-3-2-1) to 9.21 (ASCC III-2-1-1), while for testers, they ranged between -7.60 (NSCC-6-1-1) and 7.68 (CM 208). Further, the inbred, ASCC III-2-1-1 exhibited positive and significant *gca* effects among the lines, while the inbreds, CM 120 and CM 208 had recorded significant and positive *gca* effects among the testers.

Gca effects for ear height ranged from -0.71 (NSCC II-2-1-1) to 0.50 (NSCC I-3-1-1) among the lines and from -0.61 (NSCC-6-1-1) to 0.92 (ASCC II-2-2-1) among the testers.

However, none of the lines/testers, studied had recorded significant *gca* effects for the trait.

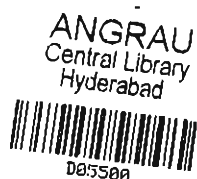
For 100-seed weight, the *gca* effects ranged from -2.74 (ASCC I-1-2-1) to 3.25 (ASCC III-2-1-1) among the lines and from -0.66 (NSCC-6-1-1) to 0.55 (CM 120) among the testers. Positive and significant *gca* effects were noticed for the inbred, ASCC III-2-1-1 among the lines, while none of the inbreds had recorded significant *gca* effects among the testers.

The *gca* effects for grain yield per plot ranged from -0.11 (ASCC II-3-2-1) to 0.15 (ASCC III-2-1-1) among the lines, and from -0.28 (ASCC II-2-2-1) to 0.19 (CM 208) among the testers. Significant and positive effects were recorded for the inbreds, ASCC III-2-1-1 among the lines, CM 120 and CM 208 inbreds among the testers for the trait.

For total sugars, the *gca* effects ranged from -3.38 (ASCC II-3-2-1) to 3.86 (ASCC I-1-2-1) among the lines and from -2.02 (CM 120) to 2.85 (ASCC II-2-2-1) among the testers. Significant and positive *gca* effects were exhibited by the inbreds, ASCC I-1-2-1, NSCC I-3-1-1 and ASCC III-2-1-1 among the lines, and ASCC II-2-2-1 and NSCC-6-1-1 among the testers.

The *gca* effects for protein content ranged from -0.85 (ASCC II-3-2-1) to 0.32 (ASCC III-3-2-1) among the lines and from -0.51 (CM 120) to 0.34 (NSCC-6-1-1) among the testers. Four inbreds had exhibited significant and positive effects for the trait among the lines, while two inbreds recorded significant and positive effects among the testers studied.

The *gca* effects for carbohydrates ranged from -13.07 (NSCC II-2-1-1) to 8.95 (ASCC III-2-1-1) among the lines and from -7.78 (CM 120) to 7.43 (CM 208) among the testers. Three inbreds had recorded significant and positive *gca* effect among the lines, while among the testers, the inbred, NSCC-6-1-1 and CM 208 exhibited significant and positive effects for the trait.



4.4.3 Specific combining ability effects

Specific combining ability effects of the 24 hybrids obtained from six lines and four testers are presented in Table 12.

Specific combining ability effects for days to 50 per cent silking ranged from -10.32 (NSCC II-2-1-1 x CM 208) to 7.24 (ASCC II 3-2-1 x CM 120). Nine hybrids had exhibited significant and negative *sca* effects, while seven hybrids exhibited significant and positive *sca* effects for the trait.

For days to 50 per cent maturity, the *sca* effects ranged from -9.18 (NSCC I -3-1-1 x ASCC II-2-2-1) to 7.98 (NSCC II-2-1-1 x CM 208). Nine hybrids had exhibited significant and negative *sca* effects, while seven hybrids recorded positive and significant *sca* effects for the trait.

The *sca* effects for plant height ranged from -26.61 (NSCC II-2-1-1 x NSCC-6-1-1) to 20.08 (ASCC III-3-2-1 x NSCC -6-1-1). Eight hybrids exhibited significant and negative *sca* effects, while nine hybrids, recorded positive and significant *sca* effects for the trait.

For ear length, the *sca* effects ranged from -6.55 (NSCC I-3-1-1 x NSCC-6-1-1) to 4.09 (ASCC II-3-2-1 x CM 208). Among the 24 hybrids studied, eight hybrids exhibited significant and negative effects, while ten hybrids exhibited positive and significant *sca* effects for the trait.

The *sca* effects for ear weight ranged from -37.76 (ASCC III-2-1-1 x ASCC II-2-2-1) to 38.84 (ASCC III-2-1-1 x CM 208). Nine hybrids had recorded significant and negative *sca* effects, while 12 hybrids recorded positive and significant *sca* effects for the trait.

For ear height, the *sca* effects ranged from -26.71 (ASCC III-3-2-1) to 17.79 (ASCC II-3-2-1 x ASCC II-2-2-1). Among the 24 hybrids studied, negative and significant *sca*

Table 12 Estimates of specific combining ability for grain yield, yield components and quality characters in sweet corn hybrids

Hybrids	Days to 50% silking	Days to 50% maturity	Plant height (cm)	Ear length (cm)	Ear weight (g)	Ear height (cm)	100-seed weight (g)	Grain yield per plot (kg)	Total sugars (%)	Protein (%)	Carbohydrates (%)
NSCC II-2-1-1 X ASCC II-2-2-1	-1.46	-3.71*	4.07	-1.34	-17.54*	-10.32	-6.21**	-0.98**	0.15	-0.12	0.56
NSCC II-2-1-1 X NSCC 6-1-1	-4.18**	-2.17	-26.61**	-2.75*	-24.07**	5.59	-5.19**	-0.49**	-0.12	0.05	0.28
NSCC II-2-1-1 X CM 120	-4.58**	-3.83*	15.99**	-2.86**	-11.21	6.50	4.50**	0.22	-0.99**	-0.01	-1.17*
NSCC II-2-1-1 X CM 208	-10.32**	7.98**	6.54**	2.27*	14.58*	0.43	4.90**	0.34*	0.14	-0.27*	-0.46
ASCC I-1-2-1 X ASCC II-2-2-1	-0.54	1.37	-11.32**	-2.38**	-10.98	-19.81**	4.85**	-0.84**	-0.19	1.04**	0.28
ASCC I-1-2-1 X NSCC 6-1-1	3.49*	2.16	9.27**	0.79	-21.35**	7.23	-1.07	-0.57**	0.43**	0.02	-0.07
ASCC I-1-2-1 X CM 120	-4.58**	-4.16*	-8.14**	3.59**	28.21**	11.39	5.75**	0.43**	-0.22	-0.17	-0.73
ASCC I-1-2-1 X CM 208	0.55	2.11	10.18**	2.69**	17.24*	-9.90	-6.54**	0.36*	0.23	-0.21*	-0.62
NSCC I-3-1-1 X ASCC II-2-2-1	-9.79**	-9.18**	-0.37	-2.20*	-28.38**	-14.50*	-0.27	-0.58**	-0.21	0.02	-0.72
NSCC I-3-1-1 X NSCC 6-1-1	1.32	3.27	4.41	-6.55**	-14.18*	2.61	-3.94*	-0.23	-0.18	-0.05	-0.09
NSCC I-3-1-1 X CM 120	2.65	4.15*	-8.34**	2.33**	14.21*	10.60	-6.09**	0.28*	-0.04	-0.20*	3.03**
NSCC I-3-1-1 X CM 208	5.32**	2.12	4.30	3.41**	25.30**	11.47	3.77*	0.54**	-0.14	-0.16	1.68**
ASCC II-3-2-1 X ASCC II-2-2-1	3.46*	4.18*	-1.09	-3.14**	-26.71**	17.79*	-6.53**	0.53**	-0.25	0.35**	0.88
ASCC II-3-2-1 X NSCC 6-1-1	-5.50**	-5.15**	-18.72**	-0.72	-19.57**	4.41	-0.71	-0.40**	0.33*	0.27*	-1.31**
ASCC II-3-2-1 X CM 120	7.24**	7.25**	3.15	2.51**	18.94*	3.78	-6.79**	0.28*	-0.26	-0.09	-0.16
ASCC II-3-2-1 X CM 208	-5.10**	-4.82**	16.64**	4.09**	19.18**	11.84	-5.46**	0.62**	-0.22	0.18	-2.15**
ASCC III-2-1-1 X ASCC II-2-2-1	2.71	4.12*	3.08	-3.35**	-37.76**	-23.74**	3.14	-0.37**	0.19	0.46**	-1.09*
ASCC III-2-1-1 X NSCC 6-1-1	6.65**	5.71**	11.56*	3.18**	31.37**	15.55*	5.34**	0.39**	0.42**	0.35**	4.59**
ASCC III-2-1-1 X CM 120	-1.45	-5.01**	7.72**	2.15*	16.29*	7.93	4.08*	0.61**	0.25	0.18	-2.21**
ASCC III-2-1-1 X CM 208	-7.51**	-3.86*	-22.37**	-0.02	38.34**	1.33	3.87*	0.76*	-0.04	-0.55**	-1.00*
ASCC III-3-2-1 X ASCC II-2-2-1	4.54**	4.68**	5.62*	-4.22**	-35.38**	-10.02	-5.30**	-0.69**	-0.08	-0.50**	-1.99**
ASCC III-3-2-1 X NSCC 6-1-1	-2.18	-2.18	20.08**	-1.39	-11.46	-12.68*	-0.68	-0.93**	0.35*	-0.70**	-0.08
ASCC III-3-2-1 X CM 120	3.32*	0.86	-10.40**	2.45*	16.46*	9.23	4.05*	0.36*	0.27	-0.49**	-0.05
ASCC III-3-2-1 X CM 208	-5.58**	-5.90**	-15.25**	1.96*	19.57**	-26.71**	10.53**	0.36*	0.18	0.60**	2.60**
Range	-10.32	-9.18	-26.61	-6.55	-37.76	-26.71	-6.79	-0.98	-0.99	-0.70	-2.21
Minimum	7.24	7.98	20.08	4.09	38.34	17.79	10.53	0.76	0.43	1.04	4.59
Maximum	1.49	1.70	2.42	0.37	6.93	6.16	1.67	0.14	0.14	0.10	0.49
SE (S ₀)											

*Significant at 1 per cent level

*Significant at 5 per cent level

effects were observed for five hybrids, while two hybrids (ASCC II-3-2-1 x ASCC II-2-2-1 and ASCC III-2-1-1 x NSCC-6-1-1) exhibited positive and significant *sca* effects for the trait.

The *sca* effects for 100-seed weight ranged from -6.79 (ASCC II-3-2-1 x CM 120) to 10.53 (ASCC III-3-2-1 x CM 208). Nine hybrids had exhibited significant and negative *sca* effects, while ten hybrids had recorded positive and significant *sca* effects for the trait.

For grain yield per plot, the *sca* effects ranged from -0.98 (NSCC II-2-1-1 x ASCC II-2-2-1) to 0.76 (ASCC III-2-1-1 x CM 208). Nine hybrids had exhibited significant and negative *sca* effects, while 13 hybrids exhibited positive and significant *sca* effects for the trait.

For total sugars, the *sca* effects ranged from -0.99 (NSCC II-2-1-1 x CM 120) to 0.43 (ASCC I-1-2-1 x NSCC-6-1-1). Positive and significant *sca* effects were noticed in four hybrids (ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1), while significant and negative effects were observed for NSCC II-2-1-1 x CM 120 hybrid.

The *sca* effects for protein content ranged from -0.70 (ASCC III-3-2-1 x NSCC-6-1-1) to 1.04 (ASCC I-1-2-1 x ASCC II 2-2-1). Six hybrids recorded significant and positive *sca* effects, while seven hybrids recorded significant and negative *sca* effects for the trait.

For carbohydrates, the *sca* effects ranged from -2.21 (ASCC III-2-1-1 x CM 120) to 4.59 (ASCC III-2-1-1 x NSCC-6-1-1). Seven hybrids had recorded significant and negative *sca* effects, while four hybrids had exhibited significant and positive *sca* effects for the trait.

4.5 CHARACTER ASSOCIATIONS

Phenotypic and genotypic correlations were studied for yield, yield component characters and quality parameters in sweet corn and the results are presented in Table 13.

Table 13 Character associations among grain yield, yield component characters and quality parameters in sweet corn

Character		Days to 50% maturity	Plant height (cm)	Ear length (cm)	Ear weight (g)	Ear height (cm)	100-seed weight (g)	Grain yield per plot (kg)	Total Sugars (%)	Proteins (%)	Carbohydrates (%)
Days to 50% silking	P	0.6851**	-0.5042**	-0.4742**	-0.4186**	-0.3948*	-0.0759	-0.6525**	0.1349	0.1718	-0.2137
	G	0.7903**	-0.5663**	-0.5802**	-0.5034**	-0.3983*	-0.2056	-0.7609**	0.2417	0.2514	-0.3214
Days to 50% maturity	P		-0.0735	-0.1049	-0.2045	-0.2176	-0.3789*	-0.6520**	0.1975	0.1431	-0.2018
	G		-0.0893	-0.1202	-0.2584	-0.2185	-0.3977*	-0.8692**	0.3142	0.2741	-0.2745
Plant height	P			0.7223**	-0.7664**	0.8907**	-0.0373	0.3610*	-0.2113	-0.4634**	0.7071**
	G			0.8447**	-0.8076**	0.8913**	-0.0534	0.4266**	-0.3017	-0.5139**	0.8132**
Ear length	P				-0.4925**	0.5320**	0.3116*	0.4200**	-0.0047	-0.3079	0.7738**
	G				-0.5078**	0.5366**	0.4659**	0.5287**	-0.0179	-0.3147	0.8419**
Ear weight	P					0.1719	0.0433	0.4522**	-0.0543	-0.0947	0.3217
	G					0.2345	0.0497	0.5353**	-0.1213	-0.1741	0.4178*
Ear height	P						0.6717**	0.5720**	0.1347	-0.3656*	-0.2149
	G						0.6726**	0.5799**	0.2139	-0.4231**	-0.3745
100-seed weight	P							0.5740**	-0.1954	-0.5083**	0.5474**
	G							0.6402**	-0.2831	-0.5719**	0.5936**
Grain yield per plot	P								-0.3595*	-0.5650**	0.1858
	G								-0.4117*	-0.5917**	0.2134
Total Sugars	P									0.6781**	-0.5349**
	G									0.7347**	-0.7124**
Protein	P										-0.8878**
	G										-0.9132**

**Significant at 1 per cent level

*Significant at 5 per cent level P - Phenotypic correlation coefficient

G - Genotypic correlation coefficient

The genotypic correlations were higher than phenotypic correlations and in general, were found to exhibit a similar trend. Hence, the phenotypic correlations alone are discussed here under. Grain yield per plot was found to be significantly and positively associated with the yield component characters, namely plant height, ear length, ear weight, ear height and 100-seed weight. However, negative and significant association of grain yield was noticed with days to 50 per cent silking, days to 50 per cent maturity, total sugars and protein content. The character association of total sugars with carbohydrate content was also found to be negative and significant. Protein content, however, recorded a strong positive association with total sugars.

The study of inter-character associations between the yield component characters revealed significant and positive associations of days to 50 per cent silking with days to 50 per cent maturity. However, the trait was negatively and significantly associated with plant height, ear length, ear weight and ear height. Days to 50 per cent maturity also recorded negative and significant association with 100-seed weight. However, plant height recorded positive and significant associations with ear length, ear height and carbohydrate content. In contrast, ear weight and protein content had exhibited negative associations with plant height. Negative associations were also recorded between ear length and ear weight, 100-seed weight and protein content and protein content and total carbohydrates. However, positive associations were noticed for ear length with ear height, 100-seed weight and total carbohydrates; ear height with 100-seed weight, and 100-seed weight with total carbohydrates.

4.6 PATH-COEFFICIENT ANALYSIS

The direct and indirect effects of the path matrix for grain yield are presented in Table 14. Ear weight recorded the largest positive direct effect on grain yield, followed by 100-

Table 14 Direct and indirect effects of yield component characters and quality parameters on grain yield in sweet corn

Character	Days to 50% silking	Days to 50% maturity	Plant height	Ear length	Ear weight	Ear height	Test weight	Total sugars	Protein	Carbohydrates	Correlation with Grain yield per plot
Days to 50% silking	-0.0019	-0.2115	-0.1144	0.0137	0.0023	-0.0401	-0.0043	-0.2579	-0.0179	-0.0205	-0.6525**
Days to 50% maturity	0.0339	-0.0032	0.0053	-0.1978	-0.2234	-0.2336	0.0068	-0.0007	-0.0238	-0.0155	-0.6520**
Plant height	0.0349	-0.1536	0.3751	-0.0192	-0.0331	0.2062	0.0064	-0.0128	-0.0268	-0.0161	0.3610*
Ear length	0.1523	0.0007	0.0129	0.3819	0.2281	-0.0120	-0.0083	-0.3111	-0.0169	-0.0076	0.4200**
Ear weight	0.1376	-0.0129	-0.0184	0.1892	0.4157	-0.0167	-0.0029	-0.2535	0.0165	-0.0024	0.4522**
Ear height	0.2850	0.1492	0.1699	-0.0928	-0.0483	-0.1095	0.1064	-0.0410	-0.0237	0.1768	0.5720**
Test weight	0.0698	-0.0379	0.3019	-0.0698	-0.0292	0.0225	0.3913	-0.0762	-0.0073	0.0089	0.5740**
Total sugars	-0.3606	0.0003	-0.2138	0.2229	0.2190	-0.0447	-0.0055	-0.2054	0.0180	0.0113	-0.3595*
Protein	-0.5161	0.0692	-0.2595	0.0562	0.0662	-0.0329	-0.0029	0.0834	-0.0789	0.0503	-0.5650**
Carbohydrates	0.1626	0.0132	-0.0138	-0.0098	-0.0037	-0.0086	0.0014	0.0202	0.0194	0.0049	0.1858

**Significant at 1 and 5 per cent levels; Residual effect = 0.2316; Direct effects - Diagonal values (Bold faced); Indirect effects - Non-diagonal values

Table 15 Direct and indirect effects of grain yield, yield component characters and quality parameters on total sugars in sweet corn

Character	Days to 50% silking	Days to 50% maturity	Plant height	Ear length	Ear weight	Ear weight	Test weight	Grain yield per plot	Protein	Carbohydrates	Correlation with Total sugars
Days to 50% silking	0.1649	0.2384	-0.0171	-0.0632	0.0585	-0.2060	-0.0467	0.1181	0.0097	-0.0149	0.2417
Days to 50% maturity	-0.0243	0.0737	0.0772	0.0414	0.0049	0.1644	0.0090	-0.0083	-0.0161	-0.0077	0.3142
Plant height	-0.0369	-0.0739	0.0071	0.0245	0.0097	-0.1959	0.0224	-0.0322	-0.0194	-0.0071	-0.3017
Ear length	0.1031	0.0049	-0.0530	-0.0045	-0.0601	-0.1040	-0.0699	0.1604	0.0089	-0.0036	-0.0179
Ear weight	0.1474	0.0044	-0.0493	-0.1275	0.0068	-0.1850	-0.0440	0.1210	0.0095	-0.0045	-0.1213
Ear height	-0.0530	-0.0743	0.2772	0.0871	0.0145	0.0096	0.0210	-0.0453	-0.0170	-0.0059	0.2139
Test weight	-0.0430	-0.0615	0.0899	0.0744	0.0409	-0.2795	0.0866	-0.1720	-0.0223	0.0034	-0.2831
Grain yield per plot	0.3819	0.0365	-0.0687	-0.0815	-0.0622	-0.1630	-0.0123	-0.4861	-0.0092	0.0029	-0.4117
Protein	0.4663	0.2186	-0.0984	-0.0455	-0.0196	-0.4510	-0.0498	0.0682	0.6388	0.0071	0.7347
Carbohydrates	-0.1426	-0.2299	-0.0306	0.0134	0.0053	-0.2936	0.0043	0.0541	0.0154	-0.1082	-0.7124

*, Significant at 1 and 5 per cent levels; Residual effect = 0.2159; Direct effects - Diagonal values (Bold faced); Indirect effects - Non-diagonal values

seed weight, ear length and plant height. The traits, days to 50 per cent silking, days to 50 per cent maturity, ear height, total sugars and protein content had recorded negative direct effects. The correlation of ear height with grain yield was, however, positive and significant. Further, positive indirect effects of ear height were noticed on grain yield per plot through days to 50 per cent silking, days to 50 per cent maturity, plant height, 100-seed weight and total carbohydrates.

The direct and indirect effects of the path matrix for total sugars are presented in Table 15. Protein content recorded large and positive direct effects on total sugars. However, grain yield per plot had recorded the largest negative direct effect on total sugars. Further, negative indirect effects of days to 50 per cent silking, plant height, ear length, ear weight, test weight, grain yield per plot, protein and carbohydrates were observed through ear height for total sugars. However, the indirect effect of days to 50 per cent maturity through ear height was positive.

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DISCUSSION

CHAPTER V

DISCUSSION

Maize is an important crop from the plant breeders point of view due to the fact that many of the bold and important concepts that have revolutionized the breeding methodologies are the outcome of research carried out on maize. Though extensive research has been carried out in the crop, potential aspects like breeding of sweet corn types with high yield potentials have remained relatively unemphasised. In this direction, the present investigation on "Combining ability studies for sweetness and yield improvement in maize" was undertaken and the results obtained are discussed here under.

5.1 ANALYSIS OF MEAN AND VARIANCE

The analysis of variance revealed significant differences among the genotypes for all traits studied, indicating the existence of sufficient variation for effective selection. The average performance of hybrids was different from that of parents for days to 50 per cent silking, plant height, ear length, ear weight, ear height, 100-seed weight, grain yield per plot and total carbohydrates, indicating high levels of heterosis for these traits. Further, the hybrids in general, were high yielding, bold-seeded and possessed superior ear characteristics, compared to parents. Significant differences were also noticed within the parents and hybrids for the various traits studied. The inbreds, ASCC III-2-1-1 and CM 120 were found to be high yielding with desirable ear characteristics. However, ASCC I-1-2-1 and NSCC-I-3-1-1 inbreds were found to be superior with regards to total sugars. These inbreds also exhibited superior performance over the checks, Madhuri and Trishulatha for total sugars. Among the hybrids, sweet corn x flint/dent crosses

were in general observed to be high yielding compared to sweet corn x sweet corn crosses (Table 16). The role of field corns (flint/dent) in the yield improvement of sweet corn has also been reported by several workers (Haber, 1945, Hunsperger and Davis, 1987; Davis *et al.*, 1988a and b; Tracy, 1990). However, these crosses had recorded unfavorable quality characteristics viz., low total sugars and protein content, in addition to high carbohydrate content (Table 16). Similar results were observed in the studies of Tracy (1990) and Cartea *et al.*, (1996). Further, Cartea *et al.* (1996) reported that flint corn has a less detrimental effect on grain quality compared to dent corn, in consonance with the results of the present investigation (Table 16).

The sweet corn x sweet corn hybrids, ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1 had also recorded high yield and total sugars in the present study and were observed to be superior over both the checks, Madhuri and Trishulatha for both the traits. Among these, ASCC III-2-1-1 x NSCC-6-1-1 recorded high yield, total sugars and high protein content compared to both the checks, in addition to being early and bold seeded with superior ear characteristics. Hence, these potential hybrids should be advanced for further evaluation in multi-location and on-farm trials, prior to their commercial exploitation.

5.2 ANALYSIS OF HETEROSIS

Commercial exploitation of heterosis in crop plants is regarded a major breakthrough in the realm of plant breeding. Heterosis breeding had lead to considerable yield improvement of several cereal and other crops (Rai, 1979). In maize, Shull (1952) discussed the beginning of heterosis concept. In the present study, hybrid vigour was estimated over both mid and better parents for grain yield, yield component characters and the quality parameters

Table 16 Comparative performance of sweet corn x sweet corn, sweet corn x flint and sweet corn x dent hybrids for grain yield and quality parameters

Hybrid	Grain yield per plot (kg)	Total sugars (%)	Protein content (%)	Carbohydr- ates (%)
Sweet corn x sweet corn	2.29	10.49	14.85	33.90
Sweet corn x flint	2.66	6.26	13.26	41.98
Sweet corn x dent	2.75	5.92	13.24	44.44

viz., total sugars, protein content and carbohydrates. Further, standard heterosis, important from the practical view point, was also analyzed for the 24 hybrids over the sweet corn variety, Madhuri and the high yielding three-way hybrid, Trishulatha, with regards to grain yield and the quality parameters. The results indicated significant levels of heterosis in several hybrids for majority of the traits studied. The crosses exhibiting maximum desirable heterosis for grain yield and the quality parameters are presented in Table 17.

The expression of heterosis was most evident for grain yield per plot and ear weight followed by 100-seed weight and ear height. Similar high values of heterosis were recorded for grain yield per plot by Tomov and Min (1990). Widstrom and Mc Millan (1993) and Reddy (1996) in their studies on different maize hybrids. Kide *et al.* (1985) also reported highest manifestation of heterosis for grain yield in single crosses of sorghum. However, Tomov and Chan (1986) reported highest heterosis for plant height and height of ear insertion in their study of six single crosses and parents. Debnath (1987), on the other hand, reported high heterosis for number of grains per row, followed by ear length and 100-grain weight.

The high heterosis for grain yield per plot, observed in the present investigation, was found to be associated with high heterosis for the yield component character, viz., ear weight. Heterosis for grain yield was noticed to be more than 20 per cent over both Madhuri and Trishulatha in the hybrids, ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208. Further, sweet corn x dent/ flint hybrids had in general, exhibited high levels of heterosis for the trait, compared to sweet corn x sweet corn hybrids. Similar trend was also reflected in the *per se* performance of the hybrids for the trait. However, for total sugars, desirable heterosis (> 10 per cent) over Madhuri, the sweet corn check was noticed in the hybrids, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x ASCC

Table 17 Crosses exhibiting maximum desirable heterosis for grain yield and the quality parameters, over Madhuri and Trishulatha

Character	Hybrid with maximum desirable heterosis			
	Over Madhuri	Hybrid vigour (%)	Over Trishulatha	Hybrid Vigour (%)
Grain yield per plot	ASCC III-3-2-1 X CM 120	50.78	ASCC III-3-2-1 X CM 120	22.78
Total sugars	ASCC III-2-1-1 X NSCC-6-1-1	13.87	ASCC III-2-1-1 X NSCC-6-1-1	182.32
Protein content	ASCC II-3-2-1 X ASCC II-2-2-1	3.47	ASCC II-3-2-1 X ASCC II-2-2-1	48.49
Carbohydrates	ASCC III-3-2-1 X CM 208	86.20	ASCC III-3-2-1 X CM 208	-28.75

II-2-2-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1. Among these, the hybrids, AASCC III-3-2-1 x NSCC-6-1-1 and ASCC III-2-1-1 x NSCC-6-1-1 had also exhibited desirable levels of heterosis (> 20 per cent) for grain yield over Madhuri and hence are potential high yielding sweet corn hybrids. Production of such promising sweet corn hybrids from crosses of sweet corn lines has also been reported earlier (Puskarie and Carrigan, 1988). Further, these hybrids had also recorded significant levels of heterosis in the desired direction for protein content, another quality trait, over mid-parent, better parent and the checks, Madhuri and Trishulatha. The *per se* performance of the hybrid, ASCC III-2-1-1 x NSCC-6-1-1, for these traits was also high and hence, it may be further evaluated under varied environmental conditions for possible potential commercial use.

5.3 ANALYSIS OF COMBINING ABILITY

The main objective of this part of study was to identify parents with better potential to transmit desirable characteristics to the progenies and identify the best specific crosses for yield and its attributes. The analysis of quantitative inheritance was also an equally important objective to gain knowledge regarding the nature and magnitude of gene action, which has an important bearing concerning the choice of most appropriate and efficient breeding procedures. Estimates of the relative contribution of general and specific combining ability effects within the genetic variability present in a population are also of interest to plant breeders as breeding methods differ appreciably depending upon the type of gene action.

The estimates of components of variance, σ^2_{gca} and σ^2_{sca} indicated the importance of non-additive gene action for all the traits studied, in the present investigation. Similar results were reported earlier for days to 50 per cent silking (Jones, 1954; Hallauer and Russel, 1962;

Tasanasuwan, 1976; Manmonhan, 1984; Reddy, 1989b); days to maturity (Venkatesh, 1994), plant height (Singh *et al.*, 1979; Bhalla and Khehra, 1980; Hanson and Johnson, 1981; Pajic, 1986; Anuradha, 1988; Reddy, 1989b; Vasal *et al.*, 1993), ear length (Bhalla and Khehra, 1980; Reddy, 1989a; Reddy, 1989b), ear height (Thompson *et al.*, 1971, Bhalla and Khehra, 1989, Reddy, 1989a and b), 100-seed weight (Sharma *et al.*, 1972; Bhalla and Khehra, 1980; Manmohan, 1984; Wu, 1987; Anuradha, 1988; Reddy, 1989a and b), grain yield per plot (Hallauer and Sears, 1968; Rao, 1970; Bhalla and Khehra, 1980; Singhania, 1980; Singh *et al.*, 1983; Pajic, 1986; Anuradha, 1988; Reddy, 1989a; Han *et al.*, 1991; Jha and Khehra, 1992) and protein content (Tasanasuwan, 1976; Kharistova and Kharistova, 1985; Vedenev *et al.*, 1986; Raghupathireddy, 1989).

A study of *gca* effects of the parental inbreds, for grain yield per plot, revealed the greatest effect for ASCC III-2-1-1 among lines and CM 120 and CM 208 among testers. The inbreds, CM 120 and CM 208 had also resulted in the production of high yielding single crosses (NSCC II-2-1-1 x CM 208, ASCC I-1-2-1 x CM 120, ASCC I-1-2-1 x CM 208, NSCC I-3-1-1 x CM 120, NSCC I-3-1-1 x CM 208, ASCC II-3-2-1 x CM 120, ASCC II-3-2-1 x CM 208, ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208) with regards to both *per se* performance and *sca* effects. These inbreds had also recorded significant and desirable *gca* effects for the yield component characters viz., ear length and ear weight and hence, are concluded to be high general combiners with good potential in hybrid breeding programs for yield. Similarly, the inbred, NSCC-6-1-1 was observed to be involved in the production of superior crosses (ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1) with regards to both *per se* performance and *sca* effects for total sugars. It had also recorded desirable *gca*

effects for the trait, and hence appears to be a potential combiner for production of hybrids with increased sugar levels.

The consideration of *per se* performance in combination with combining ability estimates was reported to provide a better criteria for efficient selection (Rao, 1972; Prasad and Singh, 1986) Hence, in the present investigation, *per se* performance, heterosis and *sca* effects were considered together for identification of superior hybrids. The crosses, ASCC III-2-1-1 x CM 120, ASCC III-2- 1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208 were found potential combinations for grain yield, while for total sugar, the hybrids, ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1 were found superior. Among these, the hybrid, ASCC III-2-1-1 x NSCC-6-1-1 had also recorded high *per se* performance and desirable *gca* effects for grain yield in addition to useful levels of heterosis (> 20 per cent) over mid-parent, better parent and Madhuri, the sweet corn check. Further, it had also recorded superior performance (*per se*, heterosis and *sca* effects)for protein content and the yield component characters, viz., plant height, ear length, ear weight and 100-seed weight and hence, is identified as a potential sweet corn hybrid for possible commercial exploitation.

5.4 ANALYSIS OF CHARACTER ASSOCIATIONS AND PATH EFFECTS

Yield and quality are complex characters governed by several contributing traits. Hence, character associations were studied in the present investigation to assess the relationships among yield, quality and their components for enhancing the usefulness of selection.

Phenotypic and genotypic correlations were found to be in perfect agreement with each other. However, genotypic correlations recorded a higher magnitude. This indicated the

masking effect of environment on genotypic correlations as reported by Rajput *et al.* (1996). Further, yield was found to be positively associated with plant height, ear length, ear weight, ear height and 100-seed weight. Similar results were reported earlier in maize, for the association of grain yield with plant height (Rao, 1986; Sharma and Kumar, 1987; Tyagi *et al.*, 1988); ear length (Ahmed *et al.*, 1978; Panchanadhan *et al.*, 1978; Bhole and Patil, 1984; Rao, 1986; Tyagi *et al.*, 1988); ear height (Godawat, 1982; Tyagi *et al.*, 1988; Prakash, 1996); and 100-kernel weight (Kumar, 1974; Panchanadhan *et al.*, 1978). Further, negative association was noticed for grain yield with days to 50 per cent silking (Lee *et al.*, 1986; Prakash 1996); days to maturity (Venkatesh, 1994), total sugars (Reddy, 1996) and protein content (Pollmer *et al.*, 1978. Satyanarayana, 1990). The character association of total sugars with carbohydrate content was also found to be negative and significant since carbohydrates/starch are the products of biochemical conversion of sugars (Smith, 1955, Gonzales *et al.*, 1976). However, total sugars and protein content recorded a strong positive association in the present study, similar to the findings of Reddy (1996).

A study of the inter-character associations among the yield components had also revealed positive associations for ear length with 100-Kernel weight. The results are in consonance with the findings of Ahmed *et al.* (1978) and Rao (1986). Similarly, the positive association of plant height and ear height, recorded in the present study, was also reported earlier (Zozulya, 1986). These results, thus indicated a possible scope for simultaneous improvement of these traits through selection. In contrast, significant and negative associations were noticed for plant height with ear weight and protein content; ear length with ear weight; and protein content with carbohydrates. Such negative correlations arise primarily from competition for a common possibility, such as nutrient supply and are observed when one component gets

advantage over the other (Srinivas, 1996).

Direct effect of a character on yield or any other dependent variable may be found through the study of genetic correlations. But path coefficient analysis allows to separate the direct effect and their indirect effects through other attributes by apportioning the correlations (Wright, 1921). Hence, the study of direct and indirect effects for grain yield and total sugars was taken up in the present investigation.

Ear weight had exhibited the largest direct effect on grain yield followed by 100-seed weight, ear length and plant height. Singh *et al.* (1987) also reported ear weight and 1000-grain weight to be the most important components, exhibiting high and positive direct effects on grain yield. Similarly, Panchanadhan *et al.* (1978) reported 100-grain weight to exert maximum direct effect on grain yield. The results of studies by Sharma and Kumar (1987) also showed that grain yield of maize was directly influenced by number of grains per row and 1000-grain weight. The high direct effect of these traits appeared to be the main factor for their strong association with grain yield (Wakankar and Yadav, 1975). Hence, direct selection for these traits would be effective. However, the path coefficient studies of Rupak *et al.* (1979) revealed the maximum direct effect of plant height on yield. Further, ear height and total sugars recorded negative direct effects on grain yield in the present investigation. The correlation of ear height with grain yield was however, positive indicating the ineffectiveness of direct selection for the trait. Indirect selection for the trait via days to 50 per cent silking, days to maturity and plant height is hence, recommended. The results, thus emphasized the need for selection based on a plant type with bold-seed and superior ear characteristics viz., ear weight and ear length since these were found to be the important contributors for grain yield.

The study of path coefficients for total sugars indicated large and positive direct

effects of protein content, while negative direct effects were noticed for grain yield per plot. Further, indirect effects of other characters were mostly observed through ear height. The results, thus emphasized the need for a balanced selection between grain yield and protein content. A perusal of the results obtained from the character associations and path coefficient analyses for grain yield and total sugars, thus indicated contrasting selection criterion. Hence, a balance needs to be struck while breeding for yield and sweetness in maize.

5.5 CONCLUSIONS AND FUTURE STRATEGIES

Hybrids, in general, differed from parents and were high yielding, bold-seeded and possessed superior ear characteristics, in the present investigation. Further, non-additive gene action was noticed for yield, yield component characters and the quality parameters viz., total sugars, protein and carbohydrates favoring hybrid breeding program. Heterosis was also observed in several crosses for yield, yield component characters and the quality traits. The hybrids, ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208 were found potential combinations among the 24 hybrids evaluated for yield and majority of yield component characters studied, based on their *per se* performance, heterosis and *sca* effects, while the crosses, ASCC I-1-2-1 x NSCC-6-1-1, ASCC III-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1 were found superior for total sugars. Hence, these crosses need to be evaluated in on-farm trials and multiple environments to establish their stability in performance. Further, these crosses may also be advanced for isolation of desirable transgressive segregants and homozygous lines as they involved either both or atleast one good general combiner. The hybrid, ASCC III-2-1-1 x NSCC-6-1-1 alone was noticed to exhibit high *per se* performance, heterosis and desirable *sca*

effects for yield and majority of yield component characters in addition to the quality traits viz., total sugars and protein content. Hence, it was adjudged to be the most promising and potential high yielding sweet corn hybrid, requiring further evaluation towards possible commercial exploitation. This cross involved both parents with high *gca* effects indicating additive x additive type of gene action and hence, advance generations of the cross may also be utilized for the production of high yielding homozygous lines with increased sweetness.

Among the sweet corn inbreds studied, the inbred line, NSCC-6-1-1 was found to be potential parent for use in hybrid breeding programs, aimed at evolution of superior quality sweet corn hybrids. However, the dent (CM 208) and flint (CM 120) inbreds were observed to be potential parents in the breeding of high yielding hybrids. Further, the study of character associations and path analysis revealed a possible scope for improved sweetness and higher grain yields through a balanced selection for optimum protein content and superior ear characteristics viz., ear weight and ear length with emphasis on bold-seeded types.

CHAPTER VI

SUMMARY

The present investigations on "Combining ability studies for sweetness and yield improvement in maize (*Zea Mays* L.)" were undertaken with ten lines, involving eight sweet corn lines, in addition to a dent and a flint line. Among these, six (NSCC II-2-1-1, ASCC I-1-2-1, NSCC I-3-1-1, ASCC II-3-2-1, ASCC II-2-1-1 and ASCC III-3-2-1) were used as lines and four (ASCC II-2-2-1, NSCC-6-1-1, CM 120 and cm 208) as testers, in a 6 x 4 line x tester mating, for the production of 24 hybrids. The parents (lines and testers) and their F_1 hybrids (24) were evaluated for heterosis and combining ability at the College Farm, College of Agriculture, Rajendranagar, during *rabi* 1996-97, in a randomized block design with three replications. Character associations and path coefficients were also studied for yield, yield component characters and the quality parameters viz., total sugars, protein and carbohydrates.

The analysis of variance revealed significant differences among the genotypes for all traits studied. Further, the study of analysis of variance for combining ability revealed the pre-ponderance of non additive gene action for all traits studied, favoring a hybrid breeding program. The hybrids, in general, were high yielding and bold seeded with superior ear characteristics, compared to the parents. High levels of heterosis were also observed in several crosses for the various traits studied. The expression of heterosis was most evident for grain yield per plot and ear weight, followed by 100-seed weight and ear height.

Standard heterosis for yield ranged between 2.07 to 50.78 per cent, over Madhuri and -10.97 to 22.78 over Trishulatha and for total sugars, it ranged between -43.75 to 13.87, over Madhuri and 39.47 to 182.32 over Trishulatha. The highest standard heterosis for grain yield was recorded in the cross, ASCC III-3-2-1 x CM 120. However, the cross, ASCC III-2-1-1

x NSCC-6-1-1 recorded the highest standard heterosis over both Madhuri (13.87%) and Trishulatha (182.32%) for total sugars.

The study of *per se* performance, heterosis and specific combining ability effects revealed the superiority of ASCC III-2-1-1 x CM 120, ASCC III-2-1-1 x CM 208, ASCC III-3-2-1 x CM 120 and ASCC III-3-2-1 x CM 208 crosses, for yield and majority of yield component characters studied, while the crosses, ASCC I-1-2-1 x NSCC-6-1-1, ASCC II-3-2-1 x NSCC-6-1-1, ASCC III-2-1-1 x NSCC-6-1-1 and ASCC III-3-2-1 x NSCC-6-1-1 were found superior for total sugars. However, the cross, ASCC III-2-1-1 x NSCC-6-1-1, alone exhibited superior performance for both yield (2.57 kg/plot) and total sugars (11.66%), in addition to protein content and majority of the yield component characters viz., plant height, ear length, ear weight and 100-seed weight with regards to mean values, heterosis and *sca* effects and hence, is a potential high yielding, superior quality sweet corn hybrid. Further, the above crosses involved either both, or at least one good general combiner parent and hence, may be advanced for isolation of homozygous lines or transgressive segregants, respectively.

High general combining ability for yield and its component traits was noticed in the inbred lines, CM 120 and CM 208, while high *gca* for total sugars was noticed for the inbred line, NSCC-6-1-1. These inbreds had also resulted in the production of high yielding and high sugar hybrids, and hence, have potential application in sweet corn improvement programs.

Studies on character associations and path analysis emphasized the need for selection based on plant type with bold seed and superior ear characteristics viz., ear weight and ear length for grain yield. However, for total sugars, plant types with optimum yields and high protein content were found desirable. Hence, while breeding for both grain yield and increased sweetness, it might be desirable to target for optimum yielding hybrids with moderately high protein and sugars, compared to either low yielding hybrids with high protein and sugars or high

yielders with low protein and sugars. The hybrid, ASCC III-2-1-1 x NSCC-6-1-1 fitted the above criterion and hence, is identified as a potential high yielding, superior quality, sweet corn hybrid, for possible commercial exploitation.

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*Originals not seen