“COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY ATTRIBUTES IN SWEET POTATO [*Ipomoea batatas* (L.)Lam.]”

Ph. D. THESIS

by

PHOOL CHANDRA CHAURASIA

DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
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"COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY ATTRIBUTES IN SWEET POTATO [*Ipomoea batatas* (L.)Lam.]"

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PHOOL CHANDRA CHAURASIA

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CERTIFICATE - I

This is to certify that the thesis entitled **"COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY ATTRIBUTES IN SWEET POTATO [*Ipomoea batatas* (L.) Lam.]"** submitted in partial fulfilment of the requirements for the degree of **"Doctor of Philosophy"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur is a record of the bonafide research work carried out by **Shri Phool Chandra Chaurasia** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged by him.

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CERTIFICATE – II

This is to certify that the thesis entitled **"COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY ATTRIBUTES IN SWEET POTATO [*Ipomoea batatas* (L.) Lam.]"** submitted by **Shri Phool Chandra Chaurasia** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirements for the degree of Ph.D. in the **Department of Horticulture** has been approved by the external examiner and Student's Advisory Committee after oral examination.

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Department of Horticulture **(Phool Chandra Chaurasia)**
College of Agriculture, IGKV, Raipur
Date:

COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY ATTRIBUTES IN SWEET POTATO (*Ipomoea batatas* (L.) Lam.)

By

PHOOL CHANDRA CHAURASIA

ABSTRACT

The present investigation was conducted at Horticulture Research Farm, Department of Horticulture, under All India Coordinated Research Project on Tuber Crops, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) India during *Rabi*, 2010-11 and 2011-12 to ascertain the magnitude of heterosis, to determine the extent of variability, heritability and genetic advance for various quantitative characters, to estimate the general combining ability and specific combining ability of parents and hybrids. The biological materials used in the study includes eight parents having five local genotypes of Chhattisgarh as lines *viz.*, IGSP-12, IGSP-14, IGSP-C-15, IGSP-16, IGSP-18 and three testers (improved varieties) *viz*., Sree Rethna, Gauri, Indira Madhur and their resulting fifteen cross combinations and subsequent F_1 generation.

Combining ability analysis was carried out following the Line x Tester analysis for vine length (cm), vine weight (g), tuber length(cm), tuber diameter(cm), neck length of tuber (cm), number of tubers per plant, tuber yield per plant (g), tuber yield (t/ha), marketable tuber yield per plant (g), marketable tuber yield (t/ha), weevil-infested tuber yield per plant (g), weevil- infested tuber yield (t/ha), Harvest index (%), fresh and dry weight of foliage (g), dry matter of tuber (%),total soluble solids (%) and carotene (mg/100g).

. This suggests the possibility of exploiting heterosis in the present material. Line IGSP-12/Gauri was found good general combiner for harvest index (%),IGSP-14/Sree Rethna for tuber diameter; IGSP-14/Gauri for weevil- infested tuber yield tonnes per ha; IGSP-14/Indira Madhur for fresh and dry weight of tuber; IGSP-C-15/Gauri for carotene mg/100g; IGSP-16/Gauri for tuber length and dry matter of tuber; IGSP-18/Sree Rethna for vine length and vine weight; IGSP-18/Gauri for neck length for tuber.

Line IGSP-C-15 was found best general combiner for tuber yield per plant (g) and tuber yield (t/ ha), harvest index and carotene mg/100g, IGSP-16 was found good general combiner for vine length, vine weight, neck length, number of tubers per plant and fresh and dry weight of foliage. On the basis of sca effects, the hybrid, IGSP-16/Indira Madhur was found superior for number of tubers per plant, tuber weight per plant, tuber yield (t/ha), marketable tuber yield per plant, marketable tuber yield (t/ha), weevil- infested tuber yield per plant and Total soluble solids.

The estimates of relative heterosis, heterobeltiosis and standard heterosis were also obtained for tuber yield and its components. A high degree of heterosis was observed for all the characters studied. High level of heterosis for tuber yield per plant was shown by the hybrids, IGSP-16/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-16/Sree Rethna and IGSP-12/Indira Madhur.

High genotypic and phenotypic coefficients of variation were observed for weevil- infested tuber yield per plant ,vine weight per plant , tuber diameter ,neck length of tuber, marketable tuber yield per plant , vine length tuber yield per plant , number of tubers per plant and carotene (mg/100g).

High genetic advance were observed for average weevil- infested tuber yield per plant, vine weight per plant , tuber diameter, neck length of tuber and marketable tuber per plant. Whereas, high heritability were observed for average vine length, tuber diameter, tuber yield per plant, marketable tuber yield per plant and vine weight per plant,

Therefore, direct selection for these characters will help in development of high-yielding varieties of sweet potato of different tuber shapes, flesh and colour of tuber by using local genotypes for Chhattisgarh state.

Deptt. of Horticulture
College of Agriculture,
IGKV, Raipur (C.G.)

(S.N.Dikshit)
Chairman
Advisory Committee

CHAPTER- I

INTRODUCTION

Sweet potato [*Ipomoea batatas* (L.) Lam.] locally known as *Shakarkand* belongs to the family "convolvulaceae" and is one of the most popular tuber crops in India and abroad because of its yield potential and high calorific value. It is mainly cultivated almost in all the tropical and subtropical countries as well in the warmer region of temperate countries. Sweet potato is the world's seventh most important food crop other than wheat, rice, maize, barley, potato and cassava. It contains raw protein in fresh storage roots which ranges from minimum 2.4 to maximum 4.9 per cent on wet basis (Walter and Catignani, 1982). The starch content in raw sweet potato storage root varies from 33-73 per cent on dry basis (Truong *et al*., 1986).In addition to protein and starch, some of the sweet potato varieties provide 1-12 mg carotene per 100 g of tuber and make the tuber more nutritious (Lila Babu, 1988). Tubers of Sweet potato are used in the tropics mainly as food after boiling or steaming, baking or frying. They are sometimes candied with syrup or sugar and also used as pie filling, salted chips, puree, etc. and in escalloped form.

In the U.S.A., about 60 to 70 per cent of the sweet potatoes are used for human consumption in the form of fresh roots. They are also used as canned, frozen, dehydrated foods and as a variety of other products. In Japan, about half of the total crop is utilized for production of starch and the remaining parts as food items. In India, sweet potato is chiefly grown for human consumption and is used as food after boiling, baking or frying. In some parts of India, tubers are made into chips which after drying are ground into flour and used as a supplement to cereal flour in preparation of confectionary products, chapattis, puddings etc. Tubers of sweet potato as well as the vines are used as feed for cattle. They are a good substitute for maize or sorghum silage in feeding dairy cows. The sweet potato meal after drying and slicing is useful as a feed for dairy, beef cattle and sheep. The chipped tubers can be ensiled. The peel of tubers and spent pulp after the extraction of starch from tubers may also be used as a feed for livestock. Sweet potato is used as a source of starch in Japan, U.S.A. and India. A variety of products such as edible and fermentable syrups, industrial alcohol, acetone, lactic acid, vinegar and yeast can be prepared from the tubers. Sweet potato starch is also useful in laundry work where it imparts a cleaner colour, greater smoothness and stiffness to fabrics treated. It can also be used for coating in dry batteries, insulating fabrics, postage stamps and dextrin's and adhesive .Sweet potato starch is useful as an ingredient in the products of confectionary and baking industries. Bactericidal and fungicidal substances have been isolated from the vines and tubers of sweet potato. The plant has been used as an anti-diabetic in Philippines. The roots are considered as a laxative. In New Zealand, the whole plant or its infusion is reported to be used in the cases of low fever and skin disease. The chemical composition of sweet potatoes varies widely according to cultivar, climatic, degree of maturity and the duration of storage after harvesting.

Kay (1973) reported that sweet potatoes are having more nutritive value like, moisture 50-80 per cent, protein 0.95 to 2.4 per cent, ether extractable 1.8 to 6.4 per cent starch 8 to 29 per cent reducing sugars 0.5 to 2.5 per cent, pectin, non-starch carbohydrates 0.5 to 7.5 per cent, mineral matter 0.88 to 1.38 per cent etc. Potassium is known to be the predominant mineral available in sweet potato. Besides potassium, calcium 30 mg, magnesium 24 mg, sodium 13 mg, phosphorus 49 mg, sulphur 29 mg and iron 0.8 mg are available in the sweet potato tubers.

India is a leading vegetable producing country in the world. Presently, vegetable cultivation occupies 7.9 million hectares with an annual production of 129 million tonnes and productivity of 16.1 tonnes per hectare. Among the major tuber crops cultivated in India, sweet potato ranks third next to potato and cassava in area and production. In India, it is grown in an area of 126 million hectare producing 1246.3 million tonnes with a productivity of 9.3 tonnes per hectare (Anon, 2011), which is mainly concentrated in Orissa, Bihar,West Bengal and Uttar Pradesh. Presently, in Chhattisgarh sweet potato production is around 36723.45 tonnes in an area of about 3709.69 hectare with productivity of 9.12 tonnes per hectare (Anon, 2011).

Exploitation of heterosis has become a potential tool in the improvement of yield in sweet potato. The colour of sweet potato flesh is primarily due to carotenoid content, especially β-carotene. Normally, the cultivars vary in carotene content from 4 to 12 mg/100 g. The CTCRI, Trivandrum has identified varieties with carotene content of around 8 mg/100 g. In sweet potato, protein content varies from 0.5 to 3.5 per cent which is of high nutritional quality (Collins and Walter, 1982). Sweet potato also contains some quantity of vitamin C (20 to 30 mg per 100 g).

Heterosis breeding is here to stay as a potent genetic tool for exploiting the genetic divergence. Heterosis in F_1 generation is of much importance in cross-pollinated crops like okra as heterotic crosses may give transgressive segregates for economic traits in the advanced generations. The use of local varieties grown by farmers is in infant stage of utilization in sweet potato genetic improvement programmes for vegetable purpose. For the development/initiation of an effective breeding programme in sweet potato one needs to elucidate the genetic nature and magnitude of quantitative inherited traits and estimate prepotency of parents in hybrid combinations. Combining ability studies like line x tester analysis provides information in this direction. The study of general combining ability and specific combining ability helps in selection of superior parents and specific cross combinations respectively. The information generated in this process is used to understand the magnitude of heterosis and relative importance of additive and non-additive gene actions.

In Chhattisgarh, a large number of local sweet potato genotypes are grown by farmers and wide variability for economically important traits exists. The study of genetic variability, heritability, and heterotic parents in these sweet potato genotypes would provide realistic estimates for deciding an efficient and effective breeding programme for yield improvement in this crop for Chhattisgarh plains. Hence, there is an urgent need to have proper selection criteria for the development of desirable sweet potato genotypes possessing regional (local) adaptability along with premium market quality. Therefore, knowledge of genetic variability and nature of characters under improvement is an essential and prerequisite for launching breeding programme to achieve the goal in sweet potato for Chhattisgarh plains.

Genetic variability is very important factor for any crop improvement programme, but it is very little understood for sweet potato. The inheritance pattern of character in sweet potato is quite complex one. A study on the entire spectrum of variability is very essential to select the best lines suitable for this region. Hence, there is an urgent need to develop new improved genotypes of sweet potato suitable for agro-climatic condition of Chhattisgarh. Looking to the above facts, the present investigation entitled "**Combining ability analysis for yield and quality attributes in sweet potato [*Ipomoea batatas* (L.) Lam.]**" was carried out at Research &

Instructional Farm of Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) with the following objectives:

1. To determine the general and specific combining ability of parents and hybrids.
2. To determine gene action for tuber yield and its components.
3. To estimate the extent of heterosis (over mid parent, better parent and standard check) in F_1 generation of sweet potato.
4. To identify carotene rich hybrids of sweet potato.
5. To asses genetic variability and components for tuber yield and its attributes.

CHAPTER II

REVIEW OF LITERATURE

Sweet potato [*Ipomoea batatas* (L.) Lam.] locally known as *Shakarkand* belongs to the family "convolvulaceae" and is one of the most popular tuber crops in India and abroad because of its yield potential and high calorific value. It is mainly cultivated almost in all the tropical and subtropical countries as well in the warmer region of temperate countries. Sweet potato is the world's seventh most important food crop other than wheat, rice, maize, barley, potato and cassava. Considering the importance of sweet potato in Indian agriculture, attempts have been made to improve the productivity of this crop in recent past.

The literature pertaining to the different aspects of the present study has been reviewed under the following heads:

2.1 Mean performance

2.2 Combining ability

2.3 Gene action

2.4 Heterosis

2.5 Genetic variability

2.6 Heritability and genetic advance

2.1 Mean performance

Sen and Goswami (1990) tested eleven entries of sweet potato at BCKV, Mondouri, West Bengal during 1987-89 and found that the highest tuber yield of OP-21 was greatly influenced by tuber weight per plant, harvest index and number of tubers per plant.

Venkatachalam *et al.*(1990) conducted the uniform regional trials in sweet potato at Coimbatore with eleven entries and reported that X-38 recorded maximum tuber yield of 45.70 tonnes per hectare, over the years followed by CO-3 (37.10 t/ha).

Goswami (1990) conducted an evaluation trial at Jorhat with nine elite genotypes of sweet potato and concluded that genotype X-24 produced significantly maximum tuber yield (15.19 t/ha) followed by IB- (14.99 t/ha).

Kamalam (1990) studied fifteen sweet potato genotypes in Thiruvananthapuram and found that the entry S-313 recorded highest population mean for tuber yield, number of tubers, vine thickness and number of branches followed by S-1010,S-131,S-783 and S-24.

Upadhyay and Edison (1991) conducted a trial with thirteen varieties of sweet potato including five local varieties from Meghalaya,Tripura and Arunanchal Pradesh. At Arunanchal Pradesh they obtained a significant difference in the yield of tubers of different varieties. The varieties H-633 and Pusa Red were found superior with the tuber yield of 20 and 19 tonnes per hectare, respectively in both the years.

Nayar and Naskar (1994) reported that the productivity of the two open pollinated clones of sweet potato 76-OP-217 (Sree Nandini) and 76-OP-219 (Sree Vardhini) were significantly superior as compared to check varieties. The pooled mean yield of 20.2 t/ha and 18.30 t/ha recorded by the cultivars 76-OP-217 and 76-OP-219, respectively which showed significant differences with the check varieties.

Jaykrishna *et al.*(1999) conducted a trial at Kerala Agricultural University with four varieties of sweet potato and obtained maximum tuber yield 11.83 t/ha with the variety Kanhangad local followed by cross-4 (7.59 t/ha) and cross-5 (6.04 t/ha). Whereas, the minimum yield of 3.89 t/ha was recorded by the local variety.

Kannan *et al.*(2000) conducted an experiment with nine genotypes of sweet potato including two check varieties at Coimbtore and obtained the highest root yield of 13.10 t/ha in clone CIP-90-12-29 with least weevil incidence (7.65 %) followed by the clone RS III-2 with 29.05 t/ha. The clone CIP-90-12-29 registered an increased yield of 59.2 per cent over the check variety.

2.2 Combining ability

The knowledge of combining ability of parents is important for planning a sound breeding programme. The combining ability analysis helps the breeder in identifying the potential parents and also throws light on genetic system governing the various characters in the study. The concept of combining ability provides the scientific basis for formulating efficient breeding strategy for the improvement in yield as well as in any individual desired characters. Thus, combining ability analysis is essential for deciding the breeding methods for genetic amelioration in a crop. An understanding of genetic architecture of parents is necessary before initiating systematic breeding for crop improvement. Combining ability helps in identifying the parents which could be used for hybridization programme to provide superior hybrids in vegetable. The concept of combining ability provides the scientific basis for formulating efficient breeding strategy for the improvement in yield as well as in any individual desired characters.

Spraugue and Tatum (1942) first introduced concept of general combining ability (GCA) and specific combining ability (SCA) in single crosses of corn. The general combining ability suggests the overall performance of a line in various cross combinations. Whereas, the performance in particular hybrid combination could be treated as specific combining ability of that line.

General combining ability is the result of additive gene effect, while specific combining ability is considered to be composed of non-allelic interaction (Jinks, 1954).

Kempthorne (1957) developed a method of combining ability analysis based on different number of male and female parents. This leads to partitioning of the effects of hybrids into general combining ability effects of lines and specific combining ability effects. Another practical application in the early generation evaluation of parental material in the breeding programme was discussed by Jinks (1955), Allard (1956) and White House *et al.* (1958). Variance analysis of combining ability showed that the value of V (GCA) was greater than that of V(SCA) in 12 quantitative traits with the exception of number of roots in which V(SCA) was more superior than V(GCA). There were great differences among those traits on the V(GCA) of number of roots 14.76% internodal length 52.72%, fresh root weight 57.62%, top weight 57.65%, dry matter yield 60.56%, starch content 61.20% and number of branches 97.34%. The heritability, coefficient of correlation and regression on parent-offspring and GCV in population for 12 traits were also estimated.

Lu-SY *et al.* (1985) studied 6 varieties of sweet potato and observed that dry weight was less influenced by environmental conditions than the fresh weight. General combining ability effects for fresh weight and dry weight differed but specific combining ability effects were similar for both characters. It was concluded that selection of superior progenies from specific combinations was the best course of action.

Birhman and Kaul (1989) studied *tuberosum, andigena* potato germ plasm which exhibited a high degree of genetic variation in morphological, biochemical and reproductive traits. Sixty-five per cent of the 565 genotypes comprising 145 accessions of *Solanum tuberosum* sp. *andigena* obtained from Argentina, Bolivia, Chile, Colombia and Peru remain totally vegetative and never develop any floral bud when cultivated in northern India. In 18% of genotypes, the floral buds develop but they drop off from the plants prematurely. Thus, 83% of genotypes do not develop mature flowers. The frequency of such genotypes is maximum in the Bolivian genotypes. Whereas 17% of genotypes produce mature flowers, only 2% develop berries. The highest proportion of floral bud formation and their subsequent development and differentiation into mature flowers occur in Peruvian and Colombian genotypes. Partial to high male sterility occurs in 93% of the flowering genotypes; their pollen sterility ranges from 15% to 91%. Seven per cent of the flowering genotypes are completely pollen sterile. The male sterility is expressed variously, ranging from structural to sporogenous types. The floral bud formation, its development and retention to maturity, pollen and ovule functionability and fruit development are under the control of a large number of genes, most of which are unlinked and independent. Many of these genes are polygenic in nature.

Mohd Said (1993) reported that combining ability analysis showed significant GCA and SCA for yield, tuber number and mean tuber weight indicating the importance of both additive and non-additive gene actions for these characters in sweet potato. However, the GCA variances for yield and mean tuber weight were much larger than their respective SCA variances, whereas the SCA variance for tuber number was six times larger than its GCA variance. Plant type, growth rate, internodal length, vine thickness, leaf lobbing and petiole thickness showed significant difference only for SCA but not for GCA. Significant difference for GCA was found for leaf size only but n ot for both GCA and SCA for petiole length. The results revealed that GCA was more prevalent in yield, mean tuber weight and leaf size. SCA was more important for tuber n umber, plant type, growth rate, internodal length and leaf lobbing.

Padmanabhan and Jagdish (1996) studied combining ability for fruit characters and yield in 28 F_1 hybrids of brinjal and found that Cluster White was good general combiner for early flowering, dwarf plant type and fruit per plant in tomato.

Nedunzhiyan and Reddy (2000) studied correlation and regression in sweet potato (cv. Sankar) consisted of 13 various nitrogen management practices under rainfed conditions. A positive and strong correlation between growth parameters, yield- attributes and yield as well as between growth indices such as leaf area index, leaf area duration, crop growth rate, yield growth rate and dry matter production revealed that these were the primary yield determining traits in sweet potato.

Das and Barua (2001) studied combining ability in a four parent diallel cross of brinjal and reported both GCA and SCA mean squares were found significant for plant height, fruit length, fruits per plant, fruit weight and yield per plant indicating the importance of both additive and non additive gene actions. For days to first and 50% flowering only SCA mean squares were significant while for primary branches per plant and fruit girth only GCA mean squares were significant.

Shirke *et al.* (2002) studied yield and physico-chemical changes in the tubers of sweet potato mean vine length, number of tubers per vine and mean gross yield of tubers increased with the delay in the harvesting stage, i.e., 45 to 120 days after planting. The mean number of functional branches and functional leaves increased from 45 to 75 days after planting and decreased thereafter until 120 days after planting. The mean tuber length, mean tuber diameter and mean girth of tuber increased linearly as the age of the tuber increased. The starch content, total soluble solid content, and acidity of tuber increased with crop maturity (45 to 120 days after planting). The moisture content and reducing sugar content of tubers decreased with maturity. The total sugar content of sweet potato tuber increased from 45 to 75 days after planting, then decreased linearly.

Yu-Hua *et al.* (2003) analysed five purple sweet potato cultivars for their agricultural characters, yield of fresh tuber, nutrient content, disease resistance and growth of stems, leaves and root tubers and reported that starch and pigments were best extracted from cultivar Ayawyusky and the cultivar Xiaying was a high-quality edible variety. When breeding new purple sweet potato cultivars, it is recommended that parental cultivars with excellent characters should be selected for ideal combinations.

Aswani and Khandelwal (2005) reported that the estimates of GCA effects and *per se* performance indicated that parents P10 followed by P8 and P4 were good general combiner for most of the characters including fruit yield. The cross combination P1 X P4 have recorded significantly high SCA effects for days to first flowering and days to first fruiting indicated the importance of both additive and non - additive effects for these characters.

Jackson and Bohac (2006) studied thirty-five mostly dry-fleshed sweet potato, *Ipomoea batatas* (L.) Lam., genotypes and reported that there were highly significant entry effects for percentage of uninjured roots; wireworm, *Diabrotica*, and *Systena* (WDS) index; percentage of roots damaged by sweet potato weevil, *Cylas formicarius elegantulus* (Summers); percentage of roots damaged by sweet potato flea beetle, *Chaetocnema confinis* Crotch) and percentage of roots damaged by white grub larvae (primarily *Plectris aliena* Chapin). The susceptible control, 'SC1149-19', had a significantly lower percentage of uninjured roots, a significantly higher WDS rating and higher percentage infestations of flea beetle, grubs and sweet potato weevils than all other sweet potato entries in this study. Twenty-seven genotypes had significantly less insect damage than ‘Beauregard’, the leading commercial orange-fleshed cultivar in the United States. In addition, 11 genotypes had significantly less insect injury than ‘Picadito’, a commercial boniato-type sweet potato grown extensively in southern Florida. Overall, no genotypes were more resistant to soil insect-pests than the resistant checks ‘Sumor’ and ‘Regal’. Many of the advanced dry-flesh sweet potato genotypes had high levels of resistance to soil insect-pests, and they represent a useful source of advanced germplasm for use in sweet potato breeding programs.

Owolade (2006) studied thirteen cassava (*Manihot esculenta)* varieties which includes four IITA Improved used as lines and seven Landraces used as testers with various level of resistance to *Colletotrichum gloeosporioides* f. sp.*manihotis*, were crossed in a Line X tester design to determine the general (GCA) and specific (SCA) combining abilities relative to the inheritance. The Parents and the 36 F_1 hybrids were evaluated in year 2003 and 2004 on an infected field. The variances due to SCA and GCA showed that both additive and non-additive, possibly epistatic gene actions are important. Majority of the crosses between the resistance sources and the susceptible lines showed intermediate reactions and various degrees of partial dominance for canker development in cassava plants. The most resistance IITA improved variety I63397, had the highest negative GCA effect for resistance among the lines. The moderately resistance TME-8 had largest significant negative GCA among the landraces. Most the crosses involving I63397 and TME-8 had significantly high negative SCA effects. The contribution of these parents to heterosis of their hybrids will be towards reduction of disease symptoms. This suggests the importance of both the additive and non-additive in the development of resistance to cassava anthracnose disease. Therefore, recurrent selection with progeny evaluation is advocated for breeding for resistance to the disease.

Gopal and Minocha (2006) studied the effectiveness of genetic divergence for cross prediction in potato, progeny means, heterosis and specific combining ability effects correlated with parents' genetic distances (D values) estimated under six *in vitro* and four *in vivo* conditions, for tuber yield in 72 crosses (18x4) of 22 parents under autumn crop conditions for three successive generations. Genetic distances under in vitro conditions had no relationship with the progeny means for tuber yield. Whereas, those under in vivo conditions in the autumn seasons were positively associated with the progeny means. Similarly, heterosis for tuber yield had a stronger relationship with genetic distances based on an in vivo crop than those based on an in vitro crop. All correlation coefficients between genetic distances and specific combining ability effects were non-significant. The magnitudes of the significant correlation coefficients showed that genetic divergence can be used as an indirect parameter of moderate effectiveness in selecting parents to produce heterotic high yielding progenies. Such cross predictions, however, would be effective only if parents are evaluated under the conditions similar to those under which crosses are likely to be evaluated.

Sanford and Hanneman (2006) Studied complex hybrids containing genomes from three different *Solanum tuberosum* groups synthesized (3-way hybrids), utilizing 2n gametes in 4x–2x crosses. Ten such families were compared to nine analogous two-Group (2-way) hybrid families and nine (1-way) families representing conventional *Gp. tuberosum* breeding materials. The three types of crosses, representing three descending levels of heterozygosity, were placed in four field trials.The 3-way hybrids were never significantly superior to the 2-way hybrids for vigour, yield, or tuber type. When yields were adjusted for maturity differences, the 3-way hybrids tended to be inferior to the 2-way hybrids for yield. This suggests that there may be a heterotic threshold in the cultivated potato, beyond which point more heterozygosity does not result in greater vigour or more yield. While the 2-way and 3-way hybrids did not significantly differ from each other, they both dramatically surpassed the conventional 1-way crosses for vigour and yield (42%). The evidence of a possible heterotic threshold indicates that more sophisticated methods such as cell fusion and bilateral sexual polyploidization may not be necessary to exploit the full potential of the hybrid approach in the potato. A simple and direct “2-way” hybridization approach may be optimal, or at least would seem comparable with other hybrid approaches, and is a technology ready for immediate and widespread implementation.

Kamalakkannan *et al.* (2007) studied line x tester analysis in brinjal with eight lines and three testers to estimate the combining ability effect heterosis and nature of gene action for eight characters. The combining ability variances indicated the predominance of additive gene action for earliness, number of fruits and fruit yield per plant, while it showed non-additive gene action for plant height, number of branches per plant, fruit weight, fruit length and fruit girth indicating the scope for heterosis breeding in crop improvement of brinjal.

Sundharaiya and Venkatesan (2007) studied combining ability in eight bitter gourd lines, to identify suitable parents and crosses for further exploitation indicate the lines good general combiner for yield per vine. They also recorded negative general combining ability and lower per se for days to first female flowering and days to fruit maturity. They registered higher per cent and specific combining ability for fruit length, individual fruit weight and yield per vine. The study revealed that additive x additive and additive x dominance type of interactions played a major role for days to first female flowering, days to fruit maturity, number of fruits per vine, fruit length, fruit size index, cavity size index, single fruit weight and yield per vine.

Gasura *et al.* (2008) studied sweet potato cultivars with special reference to sweet potato virus disease (SPVD) resistance, growth habit, flowering seed set ability, tuber yield, shape, tuber skin, flesh colour, dry matter, starch, sugar and carotene content. Twenty cultivars were selected for use in the assessment of their breeding potential and for improvement of yield and quality attributes. Cultivar Munyeera displayed the highest level of SPVD resistance followed by New Kawogo and Polyster as exhibited by relative area under disease progress curves following natural field infection and graft inoculation with SPVD causing viruses, *Sweet potato chlorotic stunt virus* and *Sweet potato feathery mottle virus*. Flowering ability was low in some cultivars and a few did not flower at all. Some cultivars e.g. Munyeera, New Kawogo, Silk and Sowola which showed high flowering ability failed to fertilise and set seed when crossed to specific cultivars. Preliminary genetic analysis for yield and quality following crossing elite 7 female and 6 male cultivars in a North Carolina 2 mating design showed wide genetic variability in the F_1s for the important traits and heterosis was observed for some traits such as tuber size and number of tubers per plant. Up to five genes may be involved in carotene synthesis and probably in combination with other genes in different genetic backgrounds that can modify flesh colour from white to purple. The results demonstrate the possibility to improve sweet potato for yield and quality using the available germplasm.

Kays and Wang (2008) studied quality attributes such as flavour, insect resistance, starch chemistry, colour and nutritional attributes in the sweet potato. The selection method for a trait should be objective, accurate, and amendable to the assessment of large numbers of progeny. Using an analytical selection technique, it is possible to simultaneously select for multiple target populations having distinctly different flavour preferences, as well as for other complex traits.

Rajkumar and Pandey (2008) studied one hundred fourteen progenies from line tester (19 x 6) design for 10 characters in seedling and seedling-tuber crops. Specific combining ability (SCA) variance was predominant in expression of various traits than the general combining ability (GCA) variance except for tuber shape, which had almost equal variances. Genotypes JX90, CP 3125 and JN 1197 were found superior in both crops based on their GCA for all the traits. Kufri Bahar x JN 1197,JF 4841 x CP 3125, JX 90 x JN 1197,CP 2161 x JN1197, JX 90 x CP 3125 and JV 67 x JEX/A 592 were superior crosses for developing high yielding and uniform true seed population.

Yadav *et al.*(2008) studied combining ability in bitter gourd found good combiner for number of fruits per vine, number of fruit per plot, internodal length, days to first appearance of male flower and vine length. However, yield per plot, yield (q/ha) ,yield per plot , yield per vine, fruit width, days to first appearance of female flower, number of primary branches per vine exhibited significant specific combining ability (SCA).

Hutten *et al.* (2009) studied selection criteria for agronomic characters in a potato breeding programme at the diploid (2x) level which may differ from selection criteria used when selecting breeding lines at the tetraploid (4x) level. Differences between selection criteria are expected, (1) when expression of the characters is different at both ploidy levels and/or (2) when the effect of diploid breeding lines on agronomic characters of tetraploid progenies is different from the effect of tetraploid breeding lines. In these investigation sets of diploid and tetraploid progenies, each set derived from the same 2x.2x cross, were compared as to the expression of six agronomic characters. Diploid progenies had significantly lower yields (due to smaller tubers) and significantly higher under water weights than tetraploid progenies. Vine maturity and chip colour were similarly expressed at both ploidy levels. Correlations between yield and yield components, and between under water weight and chip colour were similar at both ploidy levels. The lower yields and higher under water weights found in diploids point to the need of different selection criteria for selecting diploid and tetraploid breeding lines.

Padma *et al.* (2009) studied the correlation and direct and indirect effects of different characters on tuber yield of Cassava. The study revealed that tuber yield was positively and significantly correlated with plant maximum positive direct effect on tuber yield. Therefore, emphasis should be given on tuber weight, plant height and also tuber width, while selecting a good genotype for enhancing the yield of cassava.

Solankey and Singh (2010) studied line x tester analysis in okra with 20 parents (17 lines x 3 testers) and their 51 F1's, in two different seasons. The combining ability variances indicated the preponderance of non-additive gene action for all the characters. Studies indicated the scope of heterosis breeding in crop improvement in okra. The lines *viz.*, VRO-5, VRO-6, Arka Abhay, IC-218844 and testers like Arka Anamika proved to be the good general combiner and Arka Abhay x Arka Anamika was the good specific combiner for most of the yield and yield attributing traits.

Ummyiah *et al.*(2010) studied genetic variability analysis of twenty six genotypes of potato for seventeen yield and quality traits and reported that the characters namely tuber yield per plant, leaf area, average tuber weight, stolon length, total soluble solids (TSS), yield per plot and yield tonnes per ha, number of stolons and number of tubers per plant exhibited high heritability with high genetic gain indicating that these characters could be considered reliable tools for selection as they indicate dominance of additive gene effect.

Specific combining ability effects of crosses were related to general combining ability effects of the parents involved. Use of at least one parent with good general combining ability resulted in high-performing heterotic progenies for various characters. Superior parents and hybrids for yield and dry matter were also identified.

Manivel *et al.* (2010) studied heterosis, type and nature of gene action and the suitable parents for tuber dry matter, yield, tuber number and average tuber weight in potato. In general, progenies were better than mid parent value for number of tubers, lower for average tuber weight and as good as for yield and dry matter. Mean squares due to various sources including interactions with generations were significant for all the characters. Both additive and non-additive gene actions were equally important for various characters.

Fang *et al.* (2011) studied combining ability and heritability analysis using incomplete diallel cross to 5 high starch yield sweet potato parents. The results indicated that, out of the 5 parents, BB30-224 was a high yield and high dry matter containing parent, 8410-788 was a high yield and middle-dry matter content parent, Mianfen 1 was a high dry matter and middle-yield parent. Among the 10 combinations, BB30-224×Chuanshu34、Yushu 7×Chuanshu34, Mianfen 1×BB30-224, Mianfen 1×Yushu7 and 8410-788×Yushu7 were high starch yield combinations. The heritability of dry matter content, number of green leaves and length of vine was higher, weight of fresh tuber, weight of marketable tuber and weight of dry tuber have lower heritability.

2.3 Gene action

Knowledge of genetic architecture governing the inheritance of different quantitative characters provides a platform to formulate a systematic crop improvement programme and help in identifying the appropriate breeding technique for improvement in particular character/characters of economic importance. Being a favourable biological individual for genetic studies, several workers have tried to know the genetics of various morphological and quality characters along with tuber yield in sweet potato. The brief status of genetic studies related to the tuber yield and its component characters in sweet potato are presented below:

Mohd Said (1993) reported that gene interactions in the new genotypes probably have led to the presence of larger means and ranges of many characters. Analysis on diallel cross among six sweet potato accessions with different 02 -value showed the presence of more than 40% heterosis from many cross combinations for yield characters. With a few exceptions, most crosses showed less than 20% heterosis for morphological characters.

Phemba *et al.* (1998) studied eight sweet potato (*Ipomoea batatas*) genotypes of diverse geographic origin during the years 1995 and 1996 growing seasons to determine their performance and stability in seven representative environments in the highlands of Kivu in eastern Congo. Results of combined analysis of variance showed significant differences between genotypes and environments and significant genotype x environment interaction effects. The highest yielding genotypes were Yan Shu 1 (16.7 t ha^{-1}), Mulungu 1 (12.2 t ha^{-1}) and Mugande (11.9 t ha^{-1}), while the lowest yielding were Nong Da Hong (8.5 t ha^{-1}) and the local Caroline Lee (8.1 t ha^{-1}). Stability analysis of root yield, based on the regression coefficient, allowed the identification of high and stable yielding genotypes, with Yan Shu 1 and Mulungu 1 being the most stable and high yielding genotypes across all 7 environments. The response of genotypes of different origin to altitude showed that sweet potato is a low and mid-elevation crop of warm climates.

Velmurugan *et al.* (1999) evaluated terminal vine cuttings (15 cm) of seedlings from open-pollinated seeds of sweet potato collected from Taiwan and 9 clones from Tamil Nadu Agricultural University planted in the field in January 1993 and April 1993. Clones with higher number of tubers per vine showed higher mean values for tuber yield. Coefficient of variation (CV) for starch content was 48.04% at 90 DAP and 28.15% at 120 DAP. Highest variability was observed for weight of weevil-free tubers, followed by weight of tubers per vine and number of weevil-free tubers per vine.

Choudhary *et al.* (1999) studied genetic variability for fourteen quantitative traits in fifty genotypes of sweet potato. Wide range of variation was recorded for most of the traits. A wide difference between phenotypic coefficient of variation and genotypic coefficient of variation was observed for vine yield. Tuber cracking and total tuber yield showed high heritability coupled with high genetic advance, which indicated the presence of additive gene effect and thus the individual plant selection for these traits would be effective in sweet potato.

Hossain *et al.* (2000) studied 30 sweet potato genotypes evaluated for yield and its components at the Horticulture Farm of Bangladesh Agricultural University. Results revealed high phenotypic and genotypic coefficients of variation for number of tubers per plant, average tuber weight and tuber yield per plant. Estimates of heritability and genetic advance were highest for tuber yield per plant, average tuber weight and number of tubers per plant. Root yield was positively and significantly correlated with root diameter ($r = 0.756$), average tuber weight ($r = 0.729$) and number of tubers per plant (r = 0.635). The positive direct effect of last two characters on yield indicates that they should be given prime importance when selecting for high yield in sweet potatoes.

Biswas and Kumar (2000) evaluated performance of sweet potato cultivars Kalmegh, X-24 and Sree Vardhini in the hills of Uttar Pradesh in the kharif season of 1993. Sree Vardhini had the highest yield (38.93 t/ha) followed by Kalmegh, while the lowest was in X-24. Kalmegh had the highest percentage of minerals (4.19%, with the predominant minerals being K, Ca, Mg, Fe, P and S). The lowest crude fibre content (2.74%) and the highest dry matter accumulation (31.80%) were recorded in X-24. Dry matter accumulation in Sree Vardhini and Kalmegh were 23.86 and 22.27%, respectively.

2.4 Heterosis

Heterosis is increased or decreased in vigour of F_1 over its better parent or mid parent or check parent. As early as in 18^{th} and 19^{th} century, Knight (1979), Gartner (1849) and Darwin (1876) reported hybrid vigour in crops. However, East (1908) and Shull (1911) started systematic work on heterosis in maize. Shull (1914) introduced the term heterosis for the special stimulus of heterozygosis upon cell division, growth and other physiological activities of an organism. Shull (1948) defined heterosis to cover the real observable phenomena when unlike genetics are brought together to form a hybrid. In this sense, heterosis is synonymous of hybrid vigour.

Heterosis implies the excellence of F_1 over strictly homozygous parents involved in its formation and for the developmental stimulus resulting from the union of different gametes and the ‘Hybrid vigour’ to manifest the effect of heterosis. Shull (1914) was first to use the term ‘heterosis’. Heterosis is defined as superiority of F_1 hybrids over both of its parents in term of yield or some other characters.

In plant breeding programmes, the heterosis is referred to denote expression of increase vigour of hybrids over better parent but it was also expressed over mid parent and check present values. Therefore, there is need to use distinguished word for each heterosis. Recently the term heterobeltiosis has been proposed by Bister (1968) and Fonesoca and Patterson (1968) to describe the improvement of heterozygote in relation to better parent in the cross. Presently the term heterobeltiosis, relative heterosis and standard heterosis are being used to express heterosis over better parent, mid parent and check parent, respectively.

Heterosis is being utilized successfully now-a-days in cross-pollinated crops and vegetables. However, commercial exploitation of heterosis in self-pollinated crop is locked up due to difficulties in large scale emasculation as well as lack of suitable restorer genetic system. Efforts are in progress to remove the barriers and to search out the extent of heterosis for economic traits for successful utilization of hybrid vigour in self-pollinated crops.

Bacusmo and Carpama (1982) reported that leaf area index, crop growth rate, leaf angle of young leaves, internodal length, number of tubers per plant and mean root weight were positively correlated with root yield in sweet potato.

Vimala and Lakshmi (1990) revealed high heritability estimates in sweet potato for tuber length, tuber weight, number of branches, tuber girth and vine weight indicating additive genetic variance which was relatively more important than non-additive genetic variance for these characters. On the other hand, low heritability estimates were also observed for vine length, vine girth, number of leaves per branch, panicle length and number of tuber indicating non- additive genetic variance in sweet potato.

Nanda (1994) reported that direct effect on tuber yield of sweet potato was positive due to number of weevil- infested tubers whereas, rest of the characters viz., tuber girth, tuber length, number of tubers per plant exhibited negative direct effect.

Biswas *et al.* (1996) conducted field trial in West Bengal on sweet potato cv. Pusa Safed subjected to leaf removal treatments starting 20 d after planting to give 10, 20, 30 or 40 leaves/plant throughout the growing season. Leaf removal reduced root and shoot FW and DW compared with the control. Tuber yield at harvest was reduced from 24 t/ha in the control to 8.1 t/ha in the treatment where 10 leaves were left on the plant. Reducing sugar, total sugar and reserve polysaccharide contents in leaves, stems and tubers were reduced by leaf removal.

Sidhu (1996) evaluated seventy-five genotypes of sweet potato collected from different exotic and indigenous sources for yield and 5 other desirable characteristics. PSP21 gave the highest yield (10.26 t/acre), followed by PSP22 (9 t/acre), among the dark-red coloured genotypes, this colour having the highest acceptability in the market. PSP24 gave the highest yield (11.4 t/acre) among the light-red coloured genotypes, PSP26 (15 t/acre) among the pink coloured genotypes and PSP-27 (11.2 t/acre) among the brown coloured genotypes. These lines also had high carotene contents. In case of white coloured genotypes of sweet potato PSP28 (6.3 t/acre) had the highest yield potential.

Biswas *et al.* (1997) conducted a field trial on sweet potato cv. Pusa Safed irrigated at soil moisture tensions of 0.3, 0.6 or 0.9 atm., or were grown without irrigation. Tuber yields were 16.4, 23.6, 20.1 and 11.7 t/ha under four treatments of irrigation. Carbohydrate contents of plant organs were highest with irrigation at 0.6 atm. soil moisture tension at all growth stages.

Yamakawa (1998) reported that sweet potato (*Ipomoea batatas*) is one of the most important upland crops in southern Japan. Although its processing use has been mainly directed towards the starch industry, the starch from imported corn is replacing sweet potato starch because of its lower price. Sweet potato, known as an environmentally friendly crop, can grow under many unfavourable conditions such as drought and typhoon. It is important to identify new processing fields in order to upkeep sweet potato production. Cv. Joy White was released in 1994 for the alcohol industry on the basis of its high starch content and non- beta -amylase activity. Cv. Ayamurasaki was released in 1995 for the colourant industry because of its high anthocyanin content and high dry matter content. Another new cultivar, J-Red, was released in 1997 for the juice industry. This has a high β -carotene content and low dry matter content. Coloured powder or paste from sweet potato will become new materials with natural colour and rich nutrition for processing food. In the near future, the use of the sweet potato top will become more important from the view of nutrition and function. Research has just begun to select new lines for use in Japan.

Dayal and Yadav (1998) evaluated twelve advanced and 21 early generation clones of sweet potato for yield and quality traits during 1996-97 at the Potato Research Station, Babugary, Ghaziabad (UP). Some advanced hybrids exhibited significantly higher tuber yields than controls but showed high genotype environment interaction for tuber yield, although quality traits remained mostly stable. Early generation clones exhibited tuber yields as high as 31.3 t/ha.

Biswas *et al.* (2008) studied heterosis for six important yield-contributing quantitative traits in thirteen parents and their thirty hybrids of potato. Hybrids were derived from line-tester mating design. In the present investigation, degree of heterosis varied from trait to trait. Highest average mid, better and standard- parent heterosis was recorded in the tuber number, yield and average tuber weight traits, respectively.

2.5 Genetic variability

The extent of variability in a crop is of paramount importance in its improvement. There are two kinds of variability in crop plants, genetic and non-genetic. The genetic variability is the pre-requisite of any crop improvement programme. The non-genetic variability is the result of genetic and environmental interactions. The non-genetic or phenotypic component of variability is however, not of much use to breeders, since it cannot be perpetuated from generation to generation. Vavilov (1951) advocated that wide range of variability provides better scope of selecting desirable genotype. The study of genetic variability was made for the first time by the great biologist Fisher (1918) and subsequently the estimates of genotypic and phenotypic variations were used to predict the expected genetic response. Subsequently, a number of other workers have also discovered several techniques for the estimation of components of variance (Lush, 1940 and Robinson *et al.*, 1966). The genetic variability has been studied by many scientists in a number of crop plants.

Dayal *et al.* (1972) observed the highest genotypes and phenotypic co-efficient of variability for the traits viz., tuber yield, number of shoots, height of main shoot and number of nodes of main shoot in potato.

Chaudhary and Sharma (1984) reported high genotypic and phenotypic co-efficient of variation for tuber yield and tuber average, tuber weight followed by number of tubers per plant in potato.

Kamalam (1990) conducted a trial at Thiruvananthapuram with fifteen cultivars of sweet potato and observed very high variability for vine length, vine thickness, number of branches, number of tubers and tuber yield.

Garg and Bhutani (1991) reported highest genotypic and phenotypic variance for yield per plant followed by total yield and average tuber weight of potato.

Mohd Said (1993) studied genetic variability occurred in the local sweet potatoes. Exploitation of heterosis through bi-parental crossing between selected parents is a good approach for breeding this crop. Selection of parents, however, should not base solely on the divergence of the two parents but their combining ability should also be considered.

Dixit *et al.* (1994) observed the highest genotypic variability for stem per plant and tuber yield q/ha of potato.

Rajesh *et al.* (1996) studied variability among the genotypes in sweet potato for vine length, number of branches, number of leaves and tuber yield and reported high genotypic and phenotypic coefficients of variation. Genotypic co-efficient of variability was studied for tuber length, number of branches. Heritability estimates were recorded for vine length, number of leaves, number of branches and tuber yield. Path coefficient analysis revealed maximum direct effect on tuber yield through tuber weight, tuber width, number of branches and number of tubers also had direct effects on tuber yield. They suggested that selection based on tuber weight, tuber width and tubers per plant would be most suitable for tuber yield improvement in sweet potato.

Sandhu and Kang (1998) evaluated 286 collected *andigena* potato genotypes and reported high variability in shoot tuber, shoot number, shoot height, number of nodes, internodal length, leaflet index and tuber yield. The maximum values of co-efficient of variation were observed for shoot number, shoot height, leaflet index and tuber yield.

Alam *et al.* (1998) studied variability, correlation and path co-efficient analysis for eight characters utilizing fifteen genotypes of sweet potato. Analysis of variance revealed significant differences among the genotypes for all the traits studied. The higher genotypic and phenotypic coefficients of variation were recorded for number of branches, tubers per plant, yield per plant, number of leaves and vine length. High heritability along with high or moderate genetic advances were recorded for all the characters except tuber length. The characters tubers per plant, tuber width and weight of individual tuber were positively correlated with yield while vine length had a negative significant association with yield at both genotypic and phenotypic levels. Path analysis indicated that tubers per plant and tuber width had maximum positive direct effect and the vine length had maximum negative direct effect on yield.

Sharma (1999) reported the high genotypic co-efficient of variation for dry weight of root per plant, tuber bulking rate ,tuber yield, fresh weight of shoot per plant tuberization efficiency and dry weight of shoots per plant in potato.

Velmurugan *et al.* (2000) observed maximum variability for weight of weevil-free tubers per vine, weight of tubers per vine, number of weevil-free tubers per vine, harvest index and number of tubers per vine in sweet potato.

Anshebo *et al.* (2004) reported genetic variability and correlation coefficients for eight parameters in 86 genotypes of sweet potato (*Ipomoea batatas* L. Lam.) of diverse origin. For all the characters studied, phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) indicating the influence of environment on the expression of these traits. The characters viz., number of branches per plant, weight of single tuber, girth of tuber and length of tuber showed higher estimates of PCV and GCV. High heritability estimates were noticed for vine traits viz., length of vine, number of branches per plant and weight of foliage per plant. The least estimate of heritability was observed for number of tubers per plant. The characters such as number of branches per plant, weight of single tuber, girth of tuber and length of tuber showed high heritability estimates associated with high genetic advance indicating the presence of additive gene effect. Selection based on weight of single tuber, length of tuber and number of branches per plant can be effective for genetic improvement of sweet potato.

Joseph *et al.* (2005) reported sufficient variation both at the phenotypic and genotypic levels and tuber dry matter in potato.

Luthra *et al.* (2005) observed high phenotypic and genotypic co-efficient of variations for tuber yield, tuber number and average tuber weight of potato.

Roy and Singh (2006) reported that co-efficient of phenotypic and genotypic variation was narrow for the character emergence per cent, dry matter per cent, total sugar and total starch per cent in potato.

Verma *et al.* (2006) reported substantial variability and significant differential response due to genotypes for per cent emergence, tuber dry matter and total tuber yield in potato hybrid.

Barik (2007) observed high magnitude of phenotypic and genotypic co-efficient of variance for unmarketable tuber yield, total tuber yield and number of tuber per plant, whereas, the moderate magnitude of PCV and GCV was observed for per cent emergence, fresh weight of shoots per plant and plant height of potato.

Sharma *et al.* (2007) reported that tuber yield was highly significant and positively correlated with dry weight of roots, dry matter partitioning of root, fresh weight of root and number of tubers per plant at genotypic level, while it was negatively correlated with per cent dry weight of shoots and tuber at genotypic level in potato.

Engida (2007) studied variability among sweet potato (*Ipomoea batatas* (L) Lam.) genotypes for traits of economic importance which is vital to plan effective breeding programs. A replicated field experiment was carried out using thirty sweet potato genotypes selected at random from the germplasm collection of diverse sources. The specific purpose was to estimate the nature and magnitude of variability among yield and yield-related traits in the crop plant. The contributions of genetic variance to phenotypic variance were only 32.4 and 43.04%, for above ground dry matter content and storage root dry yield per plant, respectively suggesting the important role of environment in the expression of these traits. High genotypic coefficients of variation along with high heritability and expected genetic advances were recorded for vine length, vine internode length, leaf area, above ground fresh and dry weights, number of storage root per plant, individual storage root weight, storage root fresh yield per plant. Thus, future improvement of the crop plant should exploit the genetic variability available in the germ plasm collection.

Singh *et al.* (2008) studied variability and association of *Chlorophytum borivilianum* over two micro-environmental conditions on yield and yield-contributing morpho-metrical traits revealed the scope for genetic improvement in major yield-attributes of root length and diameter. An interrelationship among the yield and yield-attributes indicated that improvement in yield can be attained through improvement in root numbers, root length, and diameter; however, more emphasis must be paid on root diameter for organic conditions. The cause and effect study on the interrelationship exhibited the importance of productive root yield as a causation to improvement in yield.

Saikia *et al.* (2009) observed morphological characters such as plant type,vine colour, emerging leaf colour, nature of leaf colour, flowering nature, tuber shape, tuber skin colour and tuber flesh colour of sweet potato.

Cheema *et al.*(2009) studied genetic variability for all the 14 characters in 24 clones of arvi collected from different parts of North India was observed. Genotypes PA-7, PA-5, PA-4, PA-11 and PA-15 were comparatively higher yielding. The maximum corm weight, corm length, corm girth and starch were observed in PA-20 while PA-21, recorded the highest dry matter and lowest oxalate content. Estimates of phenotypic and genotypic coefficients of variation were high for number of leaves per plant, oxalate content, number of corms and cormels per plant, total yield per plant and corm weight. High heritability coupled with higher genetic advance for all the above characters indicated high proportion of inherited variation, additive gene effects and greater scope of improvement through selection. Total yield per plant was positively and significantly correlated with number of corms and cormels per plant, oxalate and protein content, and corm length. Path analysis revealed that number of cormels per plant, protein content, corm weight and length had direct and positive effects while number of corms per plant and oxalate content had indirect and positive effects on total yield per plant.

Akinwale *et al.* (2010) evaluated forty-three cassava genotypes to assess genetic variability for root yield and its components at three locations (Ibadan, Mokwa and Onne) in Nigeria, during 2004 - 2005 cropping season. Data were collected for cassava mosaic disease (CMD), cassava bacterial blight (CBB), sprouting, plant height, root number, root weight, shoot weight and root dry matter. Genotype x location interaction was significant for all the characters studied, indicating considerable influence of the environment on the expression of the traits. High heritability and genetic gain were observed in cassava mosaic disease (73.1%), root number (69.7%) and plant height (95.0%). They suggested that the traits are primarily under genetic control and that reliable selection with simple recurrent phenotypic selection would be rewarding.

Chaurasia *et al.* (2010) revealed significant differences among the okra genotypes for all the traits. It indicated that there was sufficient variability in the present materials. Maximum range of variability was recorded for fruit yield per plant followed by plant height, percentage plant affected by YVMV, percentage plant affected by mealy bug.

Lekha *et al.* (2011) studied twelve varieties of cassava released from CTCRI and twenty four cassava cultivars collected from central part of Kerala. The varieties were planted at the CTCRI farm and were evaluated for plant type, stem colour, leaf colour, leaf type, petiole colour, flowering, tuber shape, skin colour, rind colour and flesh colour.

2.6 Heritability and genetic advance

Genetic variation is important as it can be used for effective crop improvement programme when considered in relation to non-genetic variation. Fisher (1918) proposed the idea of partitioning of genetic variance.

Numerous experiments were conducted by breeders to determine relative importance of environmental and genetic variance. Lush (1940) defined the broad sense heritability as the ratio of genotypic variance to total variance. Different methods of estimating heritability have been given by Kaul (1967) and Reddy & Heyne (1968).

Burton (1952) has suggested that genotypic coefficient of variation together with heritability estimate would give the best picture expected for selection.

Johnson *et al.* (1955) stated that the broad sense heritability estimates may vary greatly depending upon the unit for which the variance is considered. They further emphasized that it indicated the effectiveness with which selection of genotypes can be based on the phenotypic performances. The value of heritability depends on all the components of variance; a change in any one of these components will effect the estimates. The amount of progress reported through selection for obtaining the best individuals can not be made on the basis of heritability alone. The genetic progress would enhance with an increase in heritability estimate. Hence, the heritability estimate could be best utilized in conjugation with genetic advance in predicting genetic gain.

Johnson *et al.* (1955) suggested that high heritability combined with high genetic advance is indicative of additive gene action and selection based on these characters would be more reliable.

Dayal *et al.* (1972) recorded broad-sense heritability estimates indicating that selection of tuber yield and shoot numbers in potato could be based on the phenotypic, while for node numbers and plant height, selection should be based on the progeny performance only.

Chaudhary and Sharma (1984) reported high heritability in broad sense for tuber yield, tuber plant and average tuber weight of potato.

Yoshinga *et al.* (2000) on the basis of data from 20 years of yield trials of seedling clones, inbreeding co-efficient (F) were calculated for 890 lines and cultivars using 2 methods of pedigree analysis. Correlations between F and yield, and the range of F, are tabulated for most of the years 1961-84. Yield was negatively correlated with F in years when maximum F was high, but showed no significant correlation in years when maximum F was <0.15. In general, yield decreased when F was >0.2 but did not decrease when F was <0.1. It is concluded that, before deciding on a crossing programme, F values should be computed for candidate crosses and crosses in which F > 0.1-0.2 should be avoided.

Vimala and Lakshmi (1990) conducted an experiment at Thiruvananthapuram with five parents of sweet potato and obtained high heritability estimates for tuber length, tuber weight, number of branches, tuber girth and vine weight indicating additive genetic variance which was relatively more important than non-additive genetic variance for these characters. On the other hand, low heritability estimates were also observed for vine length, vine girth, number of leaves per branch, panicle length and number of tubers indicating non-additive genetic variance.

Vimala and Lakshmi (1990) obtained low heritability estimates for vine length and also observed high heritability estimates for tuber length, tuber weight and tuber girth in sweet potato.

Dixit *et al.* (1994) revealed high heritability in broad sense for stems/shoots plant followed by tuber yield, protein and tuber shape in potato.

Rasul (1995) recorded the highest heritability, followed by crop stand and plant height in potato. High genetic gain was observed for tuber per ha tuber hill and plant height.

Alam *et al.*(1998) conducted a trial at Jorhat with fifteen genotypes of sweet potato and recorded high heritability along with moderate genetic advance for all the characters except tuber length.

Sharma (1999) revealed the highest value of heritability estimates for per cent dry weight of tuber followed by the fresh weight of tubers per plant, tuber yield kg per plot while, the lowest heritability value was noted for number of stolons per plant and for rest of the traits, moderate heritability values were recorded in potato.

Sankari *et al.*(2000) observed high heritability coupled with high genetic advance vine length, vine girth and yield of root per vine in sweet potato.

Hossain *et al.*(2000) conducted a trial at Bangladesh during 1994-95 and reported that the heritability and genetic advance were highest for tuber yield per plant, average tuber weight and number of tubers per plant.

Luthra (2001) reported high heritability estimates for plant type, dormancy period, average tuber weight, number of tubers and plant vigour in potato.

Bhagowati *et al.* (2002) recorded higher heritability of variation for the characters leaf number, tuber numbers and average tuber weight of potato.

Ikbal and Khan (2003) reported high heritability in broad sense coupled with high genetic advance for plant height and number of stems per shoot per plant in potato.

Luthra *et al.* (2005) revealed high genetic advance for tuber yield, tuber numbers and average tuber weight of potato.

Josheph *et al.*(2005) reported that heritability values were moderate to high for all characters except for number of leaves in potato.

Roy and Sharma (2006) observed high genetic advance for per cent emergence, total tuber yield, harvest index, dry matter per cent, total sugar and starch per cent of potato.

Chandrakar (2007) studied potato clonal population and reported high heritability for number of tubers and tuber weight per plant, whereas, moderate for plant height, harvest index unmarketable and marketable tuber yield per plot and low heritability for number of shoots, branches and number of compound leaves per plant, dry matter content of shoots and tubers. High heritability coupled with high genetic advances as per cent of mean was recorded for number and weight per plant.

Barik (2007) reported high heritability in broad sense for fresh weight of shoots per plant, harvest index (%) unmarketable tuber yield per plant, tuber dry matter per plant, per cent emergence, total number of leaves per plant, fresh weight of tuber per plant, total yield per plot, plant height and dry weight of shoot per plant. The high heritability estimates coupled with high genetic advance was recorded for unmarketable tuber yield per plant and total tuber yield.

Fang *et al.* (2011) reported that parents and crosses could be evaluated with general combining ability (GCA), variance of specific combining ability (SCA), means of crosses, and coefficient of variation. Reliable results could be obtained when combining ability was calculated with the means of crosses; one plant was planted per line when the number of lines of each cross exceeds 50, but 2 or more plants needed when it was about 30. Progenies with high-yielding potential and high starch content could be obtained when crosses were made with high GCA in dry matter weight and dry matter rate. The GCA of parents were comparatively stable, not changing with environment changes, but the SCA of some crosses were quite variable under different environmental conditions. When high fresh weight cultivars were used for parents, there was no great possibility to obtain a high fresh weight progeny.

CHAPTER III

MATERIALS AND METHODS

The present investigation entitled **"COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY ATTRIBUTES IN SWEET POTATO [*Ipomoea batatas* (L.) Lam.]"** was conducted at Horticultural Research Farm, Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *rabi* season 2009-10,2010-11 and 2011-12. The materials used and the methodologies adopted in the investigation are described below:

3.1 Location and Climate

Raipur is situated at $21^0$11' N latitude, $81^0$36' E longitude and at an altitude of 289.56 metres from mean sea level. The climate of Raipur is dry and sub-humid type. The average of 50 years of data showed that the annual rainfall ranges between 1200-1400 mm and mostly the rains are received from the middle of June to end of September, with occasional light showers during winter and summer season. The average maximum and minimum temperature are 42.8°C and 10.1°C in month of May and December, respectively.

Weekly average meteorological data during the span of experimentation (R*abi* 2009 to 2011), as recorded at Meteorological Observatory, IGKV, Raipur are presented in Appendix-I, II, III and depicted through Fig. 3.1 to 3.3.

3.2 Soil of the Experimental Field

The soil of the experimental field was sandy-loam in texture which is locally known as "*Matasi*" having the pH 7.5. The physico-chemical properties of experimental soil has been given in Table 3.1.

Table 3.1 : Physico-chemical properties of the experimental soil

PARTICULARS	Values	Rating	Method used
A. Physical Properties 1. Mechanical composition			
Sand (%)	54.18	-	
Silt (%)	21.34	-	International Pippet method
Clay (%)	24.48	-	(Black,1965)
Texture/class		Sandy-loam (*Inceptisols*)	
B. Chemical composition			
1. Organic carbon (%)	0.50	Medium	Walkley and Black's rapid titration method (Jackson,1967)
2. Available N (kg ha^{-1})	330.0	Medium	Alkaline permanganate method (Subbiah and Asija,1956)
3. Available P (kg ha^{-1})	20.0	High	Olsen's method (Olsen,1954)
4. Available K (kg ha^{-1})	400.0	High	Flame photometer method (Jackson,1967)
5. pH (1:2.5 soil:water)	7.5	Neutral	Digital pH meter

3.3 Experimental Materials

The experimental material used in the study includes eight genotypes. Out of which five genotypes were collected from various parts of the Chhattisgarh state, two genotype *i.e.*, Sree Rethna and Gauri from CTCRI, Trivandrum and Indira Madhur from IGKV, Raipur.

Seed were obtained from A.I.C.R.P on Tuber crops produced at Research cum Instructional Farm, Department of Horticulture,College of Agriculture,Indira Gandhi Krishi Vishwavidyalaya,Raipur (C.G.).

The experimental material consisted five local genotypes of Chhattisgarh as lines, *viz.*, IGSP-12, IGSP-14, IGSP-C-15, IGSP-16 and IGSP-18; three testers (improved varieties) *viz*., Sree Rethna, Gauri and Indira Madhur, resulting with fifteen cross combinations. The parents were crossed in L x T mating fashion during 2009-10 and the F_1's were evaluated in 2010-11.The cross was made by hand emasculation at 5:30 am to 7:30 am. All the experimental material including parents and hybrids were planted in Randomized Block Design with three replications during 2011-12 under All India Coordinated Research Project (A.I.C.R.P.) at Horticulture Research Farm, Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), India.

On the basis of combining ability analysis, variability study and looking to desirable phenotypic contrasting characters and local market preference five lines (*viz.*, IGSP-12, IGSP-14, IGSP.C-15, IGSP-16 and IGSP-18 were chosen for Line x Testers (*viz*., Sree Rethna, Indira Madhur and Gauri) crossing fashion to generate desirable genotypes for Chhattisgarh plains, suitable for *Rabi* season . The selected five lines and three testers cuttings were planted on 15^{th} October 2009 in crossing block.

Proper isolation of 2.0 m and bagging was done to check the chance of out crossing and mechanical mixture. The F_1 seeds were grown in nursery and after preparing cuttings, they were planted in main field under Randomized Block Design in three replications along with parents during Rabi, 2011-12. The observations for eighteen characters *viz.*, vine length, vine weight per plant, tuber length, tuber diameter, neck length of tuber, number of tubers per plant, tuber weight per plant, tuber yield tonnes per ha, marketable tuber yield per plant, marketable tuber yield tonnes per ha, weevil-infested tuber yield per plant, weevil-infested tuber yield tonnes per ha, harvest index (%),fresh and dry weight of foliage, dry matter of tuber (%),total soluble solids (%),carotene of tuber flesh (%) and organoleptic test were recorded on five plant basis in each replication. These observations were subjected to statistical analysis. Observations on morphological traits *viz.*, colour of flesh, tuber colour and leaf shape recorded visually. The details are as under:

Table 3.2: Details of the parents (lines and testers) used in the study

S. No.	Parents	Characters	Source
Lines			
1.	IGSP-12	Skin colour pink, flesh light yellow, narrow lobed, flowering time November.	IGAU, Raipur (C.G.)
2.	IGSP-14	Tuber red skin, flesh light yellow colour, narrow lobed, flowering time November.	IGAU, Raipur (C.G.)
3.	IGSP-C-15	Red skin tuber ,flesh orange colour, broad lobed, flowering time November.	IGAU, Raipur (C.G.)
4.	IGSP-16	White skin tuber, flesh orange colour, narrow lobed, flowering time November.	IGAU, Raipur (C.G.)
5.	IGSP-18	Red skin tuber, flesh yellow colour, narrow lobed, flowering time November.	IGAU, Raipur (C.G.)
Testers			
1.	Sree Rethna	Skin colour red, orange flesh, broad lobed, flowering time November.	CTCRI, Trivendrum
2.	Gauri	Red skin tuber, orange flesh colour, narrow lobed, flowering time November.	CTCRI, Trivendrum
3.	Indira Madhur	Red skin colour, flesh orange colour, narrow lobed, flowering time November.	IGAU, Raipur (C.G.)

Seed Treatment and Sowing of Seed:

As the sweet potato seed coat is very hard hence, before sowing of seeds in nursery beds, seeds were treated with concentrated Sulphuric acid (H_2SO_4) for one hours in beakers and then seeds were repeatedly washed with running tap water for removal of the acid residue completely.

Five well-pulverized nursery beds measuring 1.5 m wide and 3.0 m length were prepared and treated seeds were when at sown in miniature furrow (2.0 cm depth) carefully and covered with well-rotten farm yard manure. The watering, weeding and plant protection operations were done regularly as and when required.

Primary and Secondary Nursery Raising (vine)

After 90 days of sowing of true seeds in nursery beds, clones having thick roots were selected by visual observation. Top and middle portion of vine cuttings of selected clones with 3-4 nodes and about 20-30 cm long were clipped off and planted in primary nursery as single progeny rows with 60 x 20 cm spacing. Seed and seedlings are presented in (PlateI).

On the basis of shape, size, colour of tuber and flesh, weevil-infestation and growth habit, superior clones were selected from the seedling population in primary nursery after the 100 days of planting. The tubers of selected clones were treated with monocrotophos @ 1ml/lit. of water and planted as three progeny rows in secondary nursery with 60-20 cm spacing for multiplication.

Main Field Preparation

The experimental field was prepared finally by giving three criss-cross ploughing followed by harrowing. Before transplanting, pulverizing operation was done by rotavator. The experimental plot was divided into three replication with the help of measuring tape, rope and bamboo pegs and 69 plots of 2.4 m x 2.2 m size in each replication were prepared. The path distance to mark different replications as well as plots were shown in layout plan of the experiment.

Manure & Fertilizers Schedule

The crop was applied @75:50:75 NPK kg/ha in the form of urea, single super phosphate and muriate of potash, respectively. Urea was applied in two split doses, first as basal and second after the 45 days of vine transplanting in main field as top dressing. Full dose of phosphorus and potassium along with FYM 10 t/ha were applied as basal dose.

Transplanting

The upper and middle portions of vines of the finally selected clones multiplied in the secondary nursery were vertically planted in the well-prepared field at 60 cm x 20 cm spacing on the ridges.

Gap Filling:

The mortality of the seedling in the field was visualized from 3rd day after transplanting up to 7th day. Hence, gap filling was done by the seedling from the same nursery in order to maintain the desired plant density.

Irrigation Scheduling

Just after transplanting, the field was given a light irrigation. The later irrigations were given as per the need of the crop.

Intercultural Operations

Weeds under experimental plots were removed timely by hand weeding. Hoeing and earthing operations were done for two times at 30 to 60 days after planting.

Harvesting

Random competitive plants were selected and harvested from each plot at 120 days after planting.

3.4 Experimental Details

Breeding methods: **Hybridization and Selection:** Cross were made by adopting line x tester analysis as per **Kempthorne, 1957**.
No. of lines- 05
No. of tester- 03

Selection method : **Clonal selection:** (Seed progenies of the hybrids were further multiplied by vegetative means and evaluated with their parents and standard check)

Design of Experiment	–	Randomized Block Design
Number of Treatment	–	15 +8=23 (hybrids and parents)
Replications	–	03

Crossing Block

Plot size	:	2.4 m x 2.2 m
Plant spacing	:	60 cm x 20 cm
Distance between replications	:	75 cm
Distance between plots	:	50 cm
Date of planting of final evaluation trial	:	01 October, 2011

3.5 Observations Recorded:

(a) Vine length(cm)

Lengths of vine of five randomly selected plants from each plot of all three replications were measured at 120 days after transplanting. Length was measured in centimetre from the base of the plant to the top of the plant with the help of metre scale.

(b) Vine weight per plant (g)

After harvesting of the plant (at 120 DAP), the vegetative portion above the tuber neck was separated and weighed with the help of physical balance.

(c) Tuber length (cm)

Five randomly selected competitive plants were selected and harvested carefully at 120 days after transplanting. The marketable tubers of each selected plant measured with the help of small measuring tape and the average value recorded as length of tuber per plant.

(d) Diameter of tuber (cm)

Five randomly selected competitive plants were selected and harvested carefully at 120 days after planting. Three mature tubers from each selected plants from each plot were taken and their diameter (upper, middle and lower) was measured by using vernier-calipers and mean value was used to denote tuber diameter (cm) of each genotypes.

(e) Neck length of tuber (cm)

The neck length of five randomly selected plants (three tuber from each plant) in each plot at 120 days after planting were measured in between vine stem and tuber head.

(f) Number of tubers per plant

Number of tubers per plant were recorded on five randomly selected and harvested plants from each plot and each replication at the time of harvesting (at 120 DAP) and average number of tubers per plant was worked out.

(g) Tuber yield per plant (g)

Yield of tubers per plant was recorded for five randomly selected and harvested plants from each plot under three replications at different maturity dates with the help of physical balance and the average tuber yield per plant was calculated.

(h) Tuber yield (t/ha)

The tuber yield per plant of all genotypes in each replication was calculated as tuber yield tonnes per hectare.

(i) Marketable tuber yield per plant (g)

Only good quality tubers (excluding weevil-infested and very small tubers) from each plants were selected and weighed with the help of physical balance.

(j) Marketable tuber yield (t/ha)

The marketable tuber yield per plant (excluding weevil-infested and very small tubers) of all genotypes in each replication was calculated as marketable tuber yield tonnes per hectare.

(k) Weevil-infested tuber yield per plant (g)

Weevil-infested tubers from each plant were selected and weighed at 120 days after transplanting.

(l) Weevil-infested tuber yield (t/ha)

Weevil-infested tuber yield from each plant at 120 days after transplanting was calculated as tuber yield in tones per hectare.

(m) Harvest index (%)

Ratio between net tuber weight and gross weight of plant was calculated and recorded in term of percentage by the following formula.

$$HI (\%) = \frac{\text{Net Tuber weight}}{\text{Gross weight of plant}} \times 100$$

(n) Fresh and Dry weight of foliage (g)

Green foliage samples were taken from each genotype under each plots at 120 days maturity. Then, it was sun-dried for seven days and thereafter kept in the electric oven at 60 ^{0}C for 8 hours, finally dry weight of foliage was recorded and calculated in per cent by using the same formula as mentioned above.

(o) Dry matter of tuber (%)

Freshly harvested and matured tubers (120 DAP) were taken from each treatment and washed properly with water then chopped into small pieces and sun dried for seven days. Further, it was kept in the electric oven at 60 ^{0}C for 8 hours for drying and finally, dry weight of tuber was noted and calculated in percentage by following formula

$$DM (\%) = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

(p) Total soluble solids (%)

Mature and good quality tuber (120 DAP) was selected randomly from each replication and thoroughly washed with water. The tubers were crushed with crusher then it was squeezed through muslin cloth to obtain the juice. Finally juice was used to determine total soluble solids with the help of Erma Hand Refract meter.

(q) Carotene (mg/100g) of tuber flesh

Taken 5 g of fresh sample and crushed in 10-15 ml acetone, adding a few crystal of anhydrous sodium sulphate, with the help of pestle and mortal. The supernatant was decanted into beaker. The process was repeated twice and transferred the combined supernatant to a seperatory funnel, added 10-15 ml petroleum ether and mixed thoroughly. Two layers separated out on standing. The lower layer was discarded and collected upper layer in a 100 ml volumetric flask, made up the volume 100 ml with petroleum ether and optical density was recorded at 452 nm using petroleum ether as blank.

(r) Organoleptic evaluation

Organoleptic evaluation of the tuber of all sweet potato genotypes was done by a panel of five judges following the hedonic rating scale . The cooked tubers of sweet potato genotypes were evaluated considering four points *viz.*, flesh colour of tuber, mouthfeel, sweetness and taste. The mean score obtained was calculated as per the hedonic scale.

3.7 Statistical Analysis

3.7.1 Analysis of variance

Analysis of variance was done as per technique given by Panse and Sukhatme (1978).

The following linear model was used for analysis of variance

$$y_{ij} = \mu + t_i + b_j + e_{ij}$$

Where,

i = number of treatments

j = number of replications

y_{ij} = value of i^{th} treatment in j^{th} block

μ = general mean

t_i = effect of i^{th} treatment

b_j = effect of j^{th} block

e_{ij} = random error with restrictions that $e_{ij} \sim N(0, \sigma^2)$ has normal distribution.

The skeleton of ANOVA used is given below:

Source of variation	Degree of freedom	Sum of squares	MSS	F ratio
Replications	r-1	SSR	MSR	MSR/MSE
Treatments	t-1	SST	MST	MST/MSE
Error	(r-1)(t-1)	SSE	MSE	-
Total	rt-1			

Where, r = Number of replication

t = Number of treatment

σ^2_g = Expected genotype mean square

σ^2_e = Expected error mean square

The significance of difference among treatment means will be tested by F test at 5% level of significance. If significant F value is found, critical difference will be calculated to test the significance of difference between any two treatment mean as follows:

a. Critical Difference

CD = S Ed x t value at 5 % at error degree of freedom

$$S\ Ed = \sqrt{\frac{2\ MSE}{r}}$$

where,

S Ed = standard error of difference between two treatment means

MSE = Error mean of square

r = Number of replications

b. Standard error of mean

$$SEm = \sqrt{\frac{MSE}{r}}$$

c. Coefficient of variation (CV) (%)

Coefficient of variation is standard deviation expressed as percentage of mean

$$CV\ (\%) = \frac{SD}{\overline{X}} \times 100$$

Where,

SD = standard deviation

$\overline{X}$ = Mean

3.7.2 Studies on variability, heritability and genetic advance

3.7.2.1 Range

The range of the distribution was expressed by the limit of the smallest and the largest value of each observation.

3.7.2.2 Mean

The mean was recorded by summing up all the observation and then dividing by the total number of observations.

$$\overline{X} = \frac{\Sigma x}{N}$$

where,

Σx = Sum of all observations

n = Total number of observations

3.7.2.3 Heritability

Heritability in broad sense was estimated as the ratio of genotypic to the phenotypic variance and was expressed in percentage (Hanson *et al.*, 1956).

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

The broad sense heritability estimates were classified as low, moderate and high as follows:

0 - 30 % = Low

31 - 60 % = Moderate, and

> 60 % = High

3.6.2.4 Genetic advance

Genetic advance was estimated by using the method suggested by Johnson *et al.* (1955) and the formula is:

$$GA = k.\ h^2.\sigma p$$

where, GA = Genetic advance,

k = Selection differential (at 5%, k= 2.06),

h^2 = Heritability

σp = Phenotypic standard deviation.

GA was reported as percentage of mean and it was calculated as follows:

$$\text{Genetic advance as percentage of mean} = \frac{\text{Genetic advance}}{\bar{X}} \times 100$$

The GA was categorized as, >20% = High,

10 - 20% = Moderate, and

< 10% = Low.

3.6.2.5 Phenotypic and genotypic coefficient of variation

The phenotypic and genotypic components of variance were computed according to formulae given by Lush (1940). However, Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) in percentage were calculated according to Burton and De Vane (1959).

$$\sigma^2 g = \frac{MST - MSE}{r}$$

where, $\sigma^2 g$ = Genotype variance,

MST = Treatment mean square,

MSE = Error mean square

a. Phenotypic coefficient of variation (PCV)

$$\sigma^2p = \sigma^2g + \sigma^2e$$

$$PCV = \frac{\sigma p}{\bar{X}} \times 100 \qquad \{\sigma p = \sqrt{\sigma^2 p}\}$$

where, σ^2p & σp = Phenotypic variance and its standard deviation,

σ^2g & σg = Genotypic variance and its standard deviation,

σ^2e = Environmental variance,

$\bar{X}$ = General mean.

b. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sigma g}{\bar{X}} \times 100 \qquad \{\sigma g = \sqrt{\sigma^2 g}\}$$

3.6.3 Combining ability analysis

Combining ability analysis was carried out by the method suggested by Kempthorne (1957). Mean sum of squares that arises due to different sources of variation were estimated and their expected genetic values were calculated. A model analysis of variance (ANOVA) table for Line x tester analysis is given below:

ANOVA table for line x tester Analysis

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean squares**	**Expected mean squares**
Replication	(r-1)	RSS	-	-
Hybrids	(*l*t –1)	SS	-	-
Lines	(*l*-1)	SS (*l*)	M *l*	-
Tester	(t-1)	SS (t)	Mt	-
Lines x testers	(*l*-1) (t-1)	SS (*l* x t)	M (*l* x t)	-
Error	(r-1)(t-1)	ESS	Me	-

Total	(rt-1)	-	-	-

Where,

r = number of replications

l = number of lines

t = number of testers, and

g = number of genotypes

Estimation of full sib's and half sib's covariances were calculated from mean squares using following formula:

$$\text{Cov.(HS)} = \frac{Ml + Mt - 2M\,(l \times t)}{R\,(l \times t)}$$

$$\text{Cov.(FS)} = \frac{(Ml - Me) + (Mt - Me) + (Ml \times t - Me)}{3\,r}$$

Cov.(HS) and Cov.(FS) were utilized to estimate variance due to general combining ability (gca) and variance due to specific combining ability (sca) as under:

Variance of gca = Cov.(HS)

Variance of sca = Cov.(FS) – 2 Cov. (HS)

3.6.3.1 Estimation of GCA and SCA effects

The GCA and SCA effects of ijkth observation were estimated by adopting the following model.

$$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

Where,

μ	=	population mean
g_i	=	gca effect of ith line
g_j	=	gca effect of jth tester
s_{ij}	=	sca effect of hybrid of ith line with jth tester
e_{ijk}	=	Error effect associated with i^{jkth} observation

i = Number of lines

j = Number of testers

k = Number of replications.

The individual effects of gca and sca were estimated from the data obtained from two way tables of lines vs. Testers as given below. In this each data was totaled over replications.

Two way table for lines vs. tester:

Lines\ Tester	**1**	**2**	**3**	**4**	**Total**
1.	Xij	-	-	-	Xi..
2.	-	-	-	-	-
3.	-	-	-	-	-
4.	-	-	-	-	-
5.	-	-	-	-	-
6.	-	-	-	-	-
Total	X.j.	-	-	-	X…

$$\mu = \frac{X\ldots}{rlt}$$

$$g_i = \frac{Xi..}{rt} - \frac{X\ldots}{rlt} \qquad \{\text{Check } \sum g_i = 0\}$$

$$g_j = \frac{X.j.}{rt} - \frac{X\ldots}{rlt} \qquad \{\text{Check } \sum g_i = 0\}$$

$$s_{ij} = \frac{Xij.}{rt} - \frac{X\ldots}{rlt} \qquad \{\text{Check } \sum I \sum j S_{ij} = 0\}$$

Where,

X… = Total of all hybrid combination

Xi.. = Total of i^{th} line over 't' Testers and 'r' replications

X.j. = Total of j^{th} tester over 'l' lines and 'r' replication and

Xij. = Total of the hybrid between i^{th} line and j^{th} tester over 'r' replications

Significance of gca effects of lines is tested as:

g_i

$$t = \frac{}{SE\ (g_i)}$$

Significance of gca effects of testers is tested as:

$$t = \frac{g_j}{SE\ (g_j)}$$

Significance of sca effects of hybrids is tested as:

$$t = \frac{S_{ij}}{SE\ (S_{ij})}$$

The standard errors pertaining to gca and sca effects were worked out from the square root of error variance effects as given below:

(i) Standard error for testing the gca effects of tester :

$$SE\ (g_i) = \frac{\sqrt{MSE}}{rt}$$

(ii) Standard error for testing the significance of difference between gca effects of two lines:

$$SE\ (g_i\text{-}g_j) = \frac{\sqrt{MSE}}{rt}$$

(iii) Standard error for testing the gca effects of testers

$$SE\ (g_j) = \frac{\sqrt{MSE}}{rl}$$

(iv) Standard error for testing significance of difference between gca effects of three testers

$$SE\ (S_{ij}) = \frac{\sqrt{3MSE}}{rl}$$

(v) Standard error for testing the sca effects of hybrids:

$$SE\ (S_{ij}) = \frac{\sqrt{MSE}}{r}$$

(vi) Standard error for testing the significance of difference between sca effects of two hybrids

$$SE\ (S_{ij}\text{-}Sk_l) = \frac{\sqrt{2MSR}}{r}$$

3.6.5 Heterosis

Heterosis for each trait was worked out by utilizing the overall mean of each hybrid over replications for each trait.

a. Relative heterosis was estimated as per cent deviation of hybrid value from its mid parental value.

The formula used for estimating relative heterosis is under:

$$di = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

where,

di = Heterosis over mid parental value (relative heterosis),

$\overline{F_1}$ = Mean hybrid performance, and

$\overline{MP}$ = Mid parental value i.e., the arithmetic mean of two parents involved in the respective cross combination.

b. Heterobeltiosis was, calculated at the deviation of hybrid from the better parent as under

$$dii = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where,

dii = Heterobeltiosis i.e. heterosis over better parent,

$\overline{BP}$ = Average performance of better parent in the respected cross combination.

c. **Standard heterosis** was calculated as the deviation of the hybrid from the check variety in the present study as under:

$$\text{diii} = \frac{\overline{F_1} - \overline{CV}}{\overline{CV}} \times 100$$

where, diii = Standard heterosis, i.e. heterosis over standard parent.

$\overline{CV}$ = average performance of Check Variety,

CHAPTER-IV

EXPERIMENTAL FINDINGS

The present investigation was undertaken with the objectives of (i) To determine the general and specific combining ability of parents and hybrids (ii) to determine gene action for tuber yield and its components (iii) to estimate the extent of heterosis (over mid parent, better parent and standard check) in F_1 generation of sweet potato (iv) to identify carotene rich hybrids of sweet potato and (v) to asses genetic variability and components for tuber yield and its attributes.

The result obtained from the Line x Tester analysis of sweet potato experiment of present investigation with respect to mean performance, combining ability, gene action, gene effects, heterosis and association analysis are being presented under following heads:-

4.1 Evaluation of genotypes

The different genotypes i.e. five lines, three testers, fifteen F_1's were evaluated on their mean performance for eighteen yield and its components characters.

4.1.1 Mean performance

The observation on five plant basis for parents and hybrids on three replications for tuber yield and its component characters were used for calculating the mean performance. The observations were first averaged for five plants taken randomly for each genotypes in each replication and were later averaged over all three replications.

The mean performance of parents (five line and three testers) and fifteen hybrids are presented character wise in Table 4.1 and 4.2, respectively and described as below:

4.1.1.1. Mean performance of parents

4.1.1.1.1 Vine length (cm)

Mean performance of parents for vine length ranged from 56.33 cm (IGSP-C-15) to 141.67 cm, (Sree Rethna) with an overall mean of 89.38 cm. The average female parent vine length was 85.20 cm with line IGSP-C-15 recording a minimum vine length of 56.33 cm and line IGSP-16 showing maximum vine length of 136.67 cm.

Sree Rethna (141.67 cm) was observed to have maximum vine length among male parents followed by Gauri (72.33 cm) and Indira Madhur (66.67 cm). The average tester vine length was 93.56 cm with maximum vine length recorded for tester Sree Rethna .

4.1.1.1.2 Vine weight per plant (g)

The parents for average vine weight ranged from 120.00 g (IGSP-C-15) to 303.33 g (Sree Rethna) with an overall mean of 197.78 g. Among the lines, highest mean value for this trait was recorded for IGSP-16 (275.00g) and the lowest for IGSP-C-15 (120.00g) as compared to overall lines average 195.00g. Among the testers, Sree Rethna (303.33g) had the highest mean value for this trait followed by Gauri (176.67) and Indira Madhur (121.67 g) had lowest vine weight as compared to overall tested mean of 200.56 g.

4. 1.1.1.3 Tuber length (cm)

The mean of tuber length, among parents ranged from 14.00 cm (IGSP-18) to 20.00 cm (Sree Rethna) with an overall mean of 17.24 cm. Among the lines, IGSP-14 (18.00 cm) had longest tuber length while, IGSP-18 (14.00 cm) had smallest tuber as compared to average of female parents 15.93 cm. The testers overall mean was found to be 18.55 cm. Whereas, Sree Rethna (20.00 cm) showed longest tuber followed by tester Gauri (18.00 cm) and Indira Madhur (17.67 cm) which had the lowest mean value for this trait.

4.1.1.1.4 Tuber Diameter (cm)

The average tuber diameter for parents ranged from 2.5 cm (Gauri) to 4.32 cm (IGSP-14) with an overall mean of 3.34 cm. Among the lines IGSP-14 (4.32 cm) had the highest diameter and IGSP-18 (2.60 cm) had lowest tuber diameter as compared to line average of 3.54 cm. Sree Rethna (3.67 cm) recorded highest value for this trait among the testers while, Gauri (2.50 cm) had lowest tuber diameter as compared to overall testers mean of 3.14 cm.

4.1.1.1.5 Neck length of Tuber (cm)

The mean neck length of tuber among the parents ranged from 3.00 cm (IGSP-14) to 5.33 cm (Gauri) with an overall mean of 4.30 cm. The line, IGSP-16 (5.00 cm) had longest Neck length while, IGSP-14 (3.00 cm) had smallest neck length as compared to lines mean of 4.06 cm. The testers overall mean was found to be 4.55 cm whereas, Gauri (5.33 cm) showed longest neck length followed by testers Sree Rethna (4.67 cm) and Indira Madhur (3.67 cm).

4.1.1.1.6 Number of tubers per plant

The number of tubers per plant ranged from 3.33 (IGSP-14) to 4.67 (Sree Rethna) with an overall average of 4.18. Among the lines, IGSP-16 (4.33) showed highest number of tubers per plant while, IGSP-14 (3.33) had lowest number of tubers per plant as compared to the line mean 3.93. Among the testers, Sree Rethna (4.67) recorded maximum number of tubers per plant followed by Gauri and Indira Madhur (4.33) as compared to overall tested mean 4.44 .

Table 4.1: Mean performance of parents

Parents	Characters																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lines																	
IGSP-12	70.00	123.33	16.00	3.37	4.67	4.00	416.67	34.72	383.33	31.95	50.00	4.16	77.15	25.33	32.67	9.33	2.67
IGSP-14	89.00	266.67	18.00	4.32	3.00	3.33	408.33	34.03	326.67	27.22	33.34	2.78	60.50	26.33	24.00	12.33	4.67
IGSP-C-15	56.33	120.00	15.67	3.32	3.67	3.67	533.33	44.44	370.00	30.83	83.34	6.94	81.63	19.00	25.00	11.00	6.67
IGSP-16	136.67	275.00	16.00	4.10	5.00	4.33	516.67	43.06	403.33	33.61	66.67	5.56	65.25	30.00	21.33	8.67	7.00
IGSP-18	74.00	190.00	14.00	2.60	4.00	4.33	441.67	36.80	425.00	35.41	166.67	13.89	69.93	18.33	19.00	10.67	7.67
Av. of female parents	**85.20**	**195.00**	**15.93**	**3.54**	**4.06**	**3.93**	**463.33**	**38.61**	**381.67**	**31.80**	**80.00**	**6.67**	**70.89**	**23.79**	**24.40**	**10.40**	**5.73**
Testers																	
Sree Rethna (Check)	141.67	303.33	20.00	3.67	4.67	4.67	575.00	47.92	406.67	33.89	108.33	9.03	65.44	17.67	28.33	11.00	8.00
Gauri	72.33	176.67	18.00	2.5	5.33	4.33	425.00	35.42	383.34	31.95	33.33	2.78	73.31	22.67	31.33	10.33	9.00
Indira Madhur	66.67	121.67	17.67	3.27	3.67	4.33	458.33	38.19	266.67	21.55	83.33	6.94	79.01	24.33	30.33	11.00	8.67
Av. of male parents	**93.56**	**200.56**	**18.55**	**3.14**	**4.55**	**4.44**	**486.11**	**40.51**	**352.22**	**29.13**	**74.99**	**6.25**	**72.58**	**21.55**	**29.99**	**10.77**	**8.55**
Overall parental Avg.	**89.38**	**197.78**	**17.24**	**3.34**	**4.30**	**4.18**	**474.72**	**39.56**	**351.94**	**30.46**	**77.49**	**6.46**	**71.73**	**22.67**	**27.19**	**10.58**	**6.07**
SE	1.38	18.83	0.63	0.27	0.20	0.25	9.89	0.82	9.32	1.70	12.38	1.03	1.38	0.58	0.69	0.36	0.26
CD at 5%	2.83	38.57	1.28	0.56	0.41	0.50	20.25	1.68	19.09	3.48	25.36	2.11	2.82	1.18	1.42	0.72	0.54
CV	3.81	52.03	1.73	0.76	0.55	0.68	27.32	2.27	25.76	4.70	34.21	2.85	3.80	1.60	1.92	0.98	0.73

1. Vine length (cm)
2. Vine weight (g)
3. Tuber length (cm)
4. Tuber diameter (cm)
5. Neck length of Tuber (cm)
6. Number of Tubers per plant
7. Tuber yield per plant (g)
8. Tuber yield (t/ha)
9. Marketable tuber yield per plant (g)
10. Marketable tuber yield (t/ha)
11. Weevil-infested tuber yield per plant (g)
12. Weevil-infested tuber yield (t/ha)
13. Harvest index (%)
14. Fresh and Dry weight of foliage (g)
15. Dry matter of tuber (%)
16. Total soluble solids (%)
17. Carotene mg/100g

4.1.1.1.7 Tuber yield per plant (g)

The tuber yield per plant ranged from 408.33g (IGSP-14) to 575.00g (Sree Rethna) as compared to overall parental mean of 474.72 g. Among the lines, highest tuber yield per plant was recorded for IGSP-C-15 (533.33g) while, the lowest mean for IGSP-14 (408.33g) in comparison to lines mean of 463.33g. Among the testers, high mean value for tuber yield per plant was recorded for Sree Rethna (575.00g) while, the lowest mean value was recorded for Gauri (425.00g). The overall mean of testers was found to be 486.11g.

4.1.1.1.8 Tuber yield (t/ha)

The tuber yield tonnes per ha ranged from 34.03 tonnes (IGSP-14) to 47.92 tonnes (Sree Rethna) with an overall mean of 39.56 tonnes for parents. Among the lines, highest mean value for this trait was recorded for IGSP-C-15 (44.44 t/ha) and the lowest mean value was recorded for IGSP-14 (34.03 t/ha) as compared to the overall lines average of 38.61 tonnes. Among the testers, Sree Rethna (47.92 t/ha) had the highest mean value for tuber yield followed by Indira Madhur (38.19 t/ha) while, the lowest mean value was recorded for Gauri (35.42 t/ha) as compared to overall testers means of 40.51 tonnes per hectare.

4.1.1.1.9 Marketable tuber yield per plant (g)

The marketable tuber yield per plant ranged from 266.67g (Indira Madhur) to 425.00g (IGSP-18) as compared to overall parental mean of 351.94g. Among the lines, highest marketable tuber yield per plant was recorded for IGSP-18 (425.00g) while, the lowest mean for IGSP-14 (326.67g) in comparison to line mean of 381.67g. Among the testers, highest mean value for marketable tuber yield per plant was noted for Sree Rethna (406.67g). While, the lowest mean value was recorded for Indira Madhur (266.67 g). The overall mean of testers was found to be 352.22g.

4.1.1.1.10 Marketable tuber yield (t/ha)

It ranged from 21.55 tonnes (Indira Madhur) to 35.41 tonnes (IGSP-18) with an overall mean of 30.46 tonnes per ha for parents. Among the lines, highest mean value for this trait was recorded for IGSP-18 (35.41 t/ha) and the lowest mean value was recorded for IGSP-14 (27.22 t/ha) in comparison to the overall lines average of 31.80 tonnes.

Among the testers, Sree Rethna (33.89 t/ha) had the highest mean value for tuber yield tonnes per ha followed by Gauri (31.95 t/ha), while the lowest mean value was recorded for Indira Madhur (21.55 t/ha) as compared to overall testers mean at 29.13 tonnes per hectare.

4.1.1.1.11 Weevil-infested tuber yield per plant (g)

The parents for average weevil-infested tuber yield per plant ranged from 33.33g (Gauri) to 166.67g (IGSP-18) with an overall mean of 77.49g. Among the lines, highest mean value for this trait was recorded for IGSP-18 (166.67g) while, the lowest mean value was recorded for IGSP-14 (33.34 g) as compared to the overall lines average of 80.00g.

Among the testers, Sree Rethna (108.33g) had the highest mean value for tuber trait, while Gauri (33.33g) recorded lowest mean weevil-infested tuber yield per plant as compared to overall testers mean of 74.99g.

4.1.1.1.12 Weevil-infested tuber yield (t/ha)

Weevil-infested tuber yield tonnes per ha ranged from 2.78 tonnes (Gauri) to 13.89 tonnes (IGSP-18) with an overall mean of 6.46 tonnes. Among the lines, IGSP-18 (13.89 t/ha) recorded the highest mean value whereas, IGSP-14 (2.78 t/ha) showed the lowest mean value. Among the testers, overall mean for this trait was recorded 6.46 tonnes with Sree Rethna (9.03 t/ha) which had the highest mean value as compared to lowest mean for Gauri (2.78 t/ha) per ha.

4.1.1.1.13 Harvest Index (per cent)

The harvest index ranged from 60.50 per cent (IGSP-14) to 81.63 per cent (IGSP-C-15) with an overall parental mean of 71.73 per cent. Among the female parents (lines), IGSP-15 (81.63 per cent) had highest mean value for this trait and IGSP-14 (60.50 per cent) showed lowest mean value as compared to lines average of 70.89 per cent. Among the testers, Indira Madhur (79.01 per cent) showed the highest per centage of total harvest index while, Sree Rethna (65.44 per cent) recorded the lowest mean value for this trait as compared to overall tester's mean of 72.58 per cent.

4.1.1.1.14 Fresh and dry weight of foliage (g)

The fresh and dry weight of foliage for parents ranged from 18.33g (IGSP-18) to 30.00g (IGSP-16) with an overall mean of 22.67g. Among the lines, IGSP-16 (30.00g) had highest fresh and dry weight of foliage while, IGSP-18 (18.33g) showed lowest fresh and dry weight of foliage as compared to lines mean of 23.79g. In testers, Indira Madhur (24.33g) recorded maximum value for this trait whereas, tester Sree Rethna (17.67g) had lowest value for this trait as compared to overall testers mean of 21.55g.

4.1.1.1.15 Dry matter of tuber (per cent)

The dry matter per centage ranged from 19.00 (IGSP-18) to 32.67 (IGSP-12) with an overall mean of 27.19 per cent. Among the lines, IGSP-12 (32.67%) had highest dry matter percentage of tubers. While, IGSP-18 (19%) recorded lowest dry matter per centage of tuber as compared to line mean (24.40%). Among the testers, highest mean value for this trait was recorded for Gauri (31.33%) followed by Indira Madhur (30.33%). While, lowest mean value was recorded for Sree Rethna (28.33%) as compared to overall testers mean of 29.99 per cent.

4.1.1.1.16 Total soluble solids (per cent)

The total soluble solids ranged from 8.67 per cent (IGSP-16) to 11.00 per cent,(Gauri, Sree Rethna,IGSP-15) with an overall parental mean of 10.58 per cent.

Among the female parents (lines), IGSP-C-15 (11.00%) had highest mean value for this trait and IGSP-16 (8.67%) showed lowest mean value as compared to lines average of 10.40 per cent. Among the testers, Sree Rethna and Indira Madhur (11.00%) showed the highest per centage of total soluble solids while, Gauri (10.33%) recorded the lowest mean value for this trait as compared to overall testers mean of 10.77 per cent.

4.1.1.1.17 Carotene (per cent) of tuber flesh

The carotene per centage of tuber flesh ranged from 2.67 mg/100g (IGSP-12) to 9.0 mg/100g (Gauri) with an overall parental mean of 6.07 mg/100g. Among the female parents IGSP-18 (7.67 mg/100g) had highest mean value for this trait and IGSP-12 (2.67 mg/100g) showed lowest mean value as compared to lines average of 5.73 mg/100g.

Among the testers, Gauri (9.00 mg/100g) showed the highest per centage of carotene of tuber flesh, while Sree Rethna (8.00mg/100g) recorded the lowest mean value for this trait as compared to over all tester mean of 8.55 mg/100 g.

4.1.1.2 Mean performance of hybrids

The mean performance of fifteen hybrids for tuber yield and its components are presented in Table 4.2

4.1.1.2.1 Vine length (cm)

Mean of vine length for the hybrids ranged from 35.00 cm (IGSP-16/Indira Madhur) to 126.67 cm (IGSP-18/Sree Rethna) with an overall hybrids mean of 79.38 cm. Maximum vine length among hybrids was recorded by IGSP-18/Sree Rethna (126.67 cm) followed by IGSP-C-15/Gauri (123.33cm), IGSP-18/Indira Madhur, IGSP-C-15/Indira Madhur (118.33 cm) and IGSP-12/Indira Madhur (90.00 cm).

4.1.1.2.2 Vine weight per plant (g)

The mean value of this trait varied from 158.33g (IGSP-12/Gauri) to 833.33g (IGSP-18/Sree Rethna) with an overall hybrids mean 460.56g. Maximum vine weight of hybrids was observed by IGSP-18/Sree Rethna (833.33g) followed by IGSP16/Sree Rethna (800.00g), IGSP-16/Indira Madhur (666.67g), IGSP-C-15/Indira Madhur (666.67g), IGSP-C-15/Gauri (633.33g) and IGSP-14/Gauri (625.00g)

Table 4.2: Mean performance of hybrids

Hybrids	Characters																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IGSP-12/Sree Rethna	40.00	183.33	11.33	6.68	2.08	6.00	381.67	31.80	133.33	11.10	-	-	67.24	17.67	28.00	9.67	8.00
IGSP-12/Gauri	70.00	158.33	16.00	7.17	2.50	4.00	408.33	34.03	316.67	26.38	108.33	9.03	72.09	19.33	18.00	10.00	7.67
IGSP-12/Indira Madhur	90.00	266.67	23.67	8.75	3.00	4.33	548.33	45.69	175.00	14.58	-	-	67.30	22.67	24.00	10.67	6.33
Average	**66.67**	**202.77**	**17.00**	**7.53**	**2.52**	**4.77**	**446.11**	**37.17**	**208.33**	**17.35**	**36.11**	**3.01**	**68.87**	**19.89**	**23.34**	**10.11**	**6.33**
IGSP-14/ Sree Rethna	70.00	525.00	16.33	17.83	2.00	1.33	425.00	35.42	608.33	50.69	-	-	44.84	23.00	23.00	11.00	5.33
IGSP-14/ Gauri	56.67	625.00	22.33	8.70	5.42	3.33	508.33	42.36	450.00	37.49	108.33	9.03	43.36	25.67	18.67	10.00	7.00
IGSP-14/ Indira Madhur	40.00	350.00	20.00	13.33	3.50	5.00	641.67	53.47	333.33	27.78	-	-	64.82	32.33	20.33	7.33	6.00
Average	**55.56**	**500.00**	**19.55**	**13.28**	**3.64**	**3.22**	**525.00**	**43.75**	**463.90**	**38.65**	**36.11**	**3.01**	**51.00**	**27.00**	**20.67**	**9.45**	**6.11**
IGSP-C-15/ Sree Rethna	85.00	300.00	19.67	13.33	4.33	3.33	333.33	27.77	116.67	9.72	133.33	11.11	53.28	19.00	19.67	11.00	5.33
IGSP-C-15/ Gauri	123.33	633.33	22.33	11.00	6.00	3.00	775.00	64.58	425.00	35.41	-	-	56.12	22.33	17.00	8.00	7.67
IGSP-C-15/ Indira Madhur	118.33	666.67	11.67	7.33	5.33	4.00	250.00	20.83	191.67	15.97	-	-	27.38	18.00	15.67	7.00	7.00
Average	**108.56**	**533.34**	**17.89**	**10.55**	**5.22**	**3.44**	**452.77**	**37.72**	**244.44**	**20.37**	**44.44**	**3.70**	**45.59**	**19.77**	**17.44**	**8.67**	**6.77**
IGSP-16/ Sree Rethna	65.00	800.00	16.00	12.53	2.33	3.67	625.00	52.08	391.67	32.63	150.00	12.50	43.88	20.33	29.00	9.00	4.67
IGSP-16/ Gauri	65.00	200.00	25.00	8.43	4.33	6.00	408.33	34.03	300.00	47.22	-	-	62.66	30.67	34.33	11.33	4.00
IGSP-16/ Indira Madhur	35.00	666.67	14.67	9.75	5.67	7.00	941.67	78.47	750.00	62.50	150.00	12.50	58.70	25.67	31.67	11.67	2.67
Average	**55.00**	**555.56**	**18.56**	**10.23**	**4.11**	**5.56**	**658.34**	**54.86**	**480.56**	**47.45**	**100.00**	**8.34**	**55.08**	**25.56**	**31.67**	**10.67**	**5.22**
IGSP-18/ Sree Rethna	126.67	833.33	23.67	16.00	8.00	4.00	258.33	21.52	491.67	40.97	-	-	23.71	25.67	31.67	9.00	6.00
IGSP-18/Gauri	88.33	433.33	10.67	10.51	10.9	3.67	525.00	43.75	200.00	16.67	108.33	9.03	55.02	30.00	21.33	10.67	6.00
IGSP-18/Indira Madhur	118.33	266.67	18.33	13.30	4.00	2.33	415.00	34.58	233.33	19.44	75.00	6.25	60.94	15.34	32.33	10.00	5.67
Average	**111.12**	**511.11**	**17.56**	**13.27**	**7.63**	**3.34**	**399.44**	**33.28**	**308.34**	**25.69**	**61.11**	**5.09**	**46.55**	**23.67**	**28.44**	**9.89**	**5.89**
Overall Average	**79.38**	**460.56**	**18.11**	**11.04**	**4.57**	**4.06**	**496.33**	**41.35**	**341.11**	**29.90**	**55.55**	**4.63**	**53.41**	**23.17**	**24.31**	**9.75**	**5.95**
SE	2.39	32.61	1.08	0.47	0.34	0.42	17.12	1.42	16.14	2.94	21.4	1.00	2.38	1.78	1.20	0.61	0.45
CD at 5%	4.90	66.80	2.22	0.97	0.71	0.87	35.07	2.92	33.00	6.04	43.92	2.05	4.88	3.66	2.46	1.25	0.93
CV	6.61	90.12	2.99	1.31	0.96	1.18	47.32	3.94	44.62	8.15	59.25	2.77	6.59	4.93	3.32	1.69	1.26

1. Vine length (cm)
2. Vine weight (g)
3. Tuber length (cm)
4. Tuber diameter (cm)
5. Neck length of Tuber (cm)
6. Number of Tubers per plant
7. Tuber yield per plant (g)
8. Tuber yield (t/ha)
9. Marketable tuber yield per plant (g)
10. Marketable tuber yield (t/ha)
11. Weevil-infested tuber yield per plant (g)
12. Weevil-infested tuber yield (t/ha)
13. Harvest index (%)
14. Fresh and Dry weight of foliage (g)
15. Dry matter of tuber (%)
16. Total soluble solids (%)
17. Carotene mg/100g

4.1.1.2.3 Tuber length (cm)

Mean for tuber length among hybrids ranged from 10.67 cm (IGSP-18/Gauri) to 25 cm (IGSP-16/Gauri) with an overall average of 18.11 cm. Maximum tuber length was recorded in IGSP-16/Gauri (25.00 cm), which was followed by IGSP-12/Indira Madhur,IGSP-18/Sree Rethna (23.67 cm), IGSP-14/Gauri,IGSP-C-15/Gauri (22.33 cm) and IGSP-C-15/Sree Rethna (19.67 cm) whereas, minimum tuber length was recorded in IGSP-18/Gauri (10.67 cm).

4.1.1.2.4 Tuber diameter (cm)

Mean for tuber diameter among the hybrids ranged from 7.17 cm (IGSP-12/Gauri) to 17.83 cm (IGSP-14/Sree Rethna) with an overall average of 11.04 cm. Maximum tuber diameter was recorded in IGSP-12/Gauri (17.83 cm) followed by IGSP-18/Sree Rethna (16.00 cm), IGSP-14/Indira Madhur, IGSP-15/Sree Rethna (13.33 cm) and IGSP-18/Indira Madhur (13.30 cm) whereas, minimum diameter was recorded in IGSP-12/Gauri (7.17 cm).

4.1.1.2.5 Neck length of tuber (cm)

Mean for neck length of tuber among the hybrids ranged from 2.00 cm (IGSP-14/Sree Rethna) to 10.90 cm (IGSP-18/Gauri) with an overall average of 4.57 cm. Maximum neck length of tuber was recorded in IGSP-18/Gauri (10.90 cm), which is followed by IGSP-18/Sree Rethna (8.00 cm), IGSP-15/Gauri (6.00 cm), IGSP-16/Indira Madhur (5.67 cm) and IGSP-14/Gauri (5.42 cm) whereas, minimum hybrid neck length of tuber was recorded in IGSP-14/Sree Rethna (2.00 cm)

4.1.1.2.6 Number of tubers per plant

The mean for this trait ranged from 1.33 (IGSP-14/Sree Rethna) to 7.00 (IGSP-16/Indira Madhur) with an overall average of 4.06. Highest number of tubers per plant was recorded for IGSP-16/Indira Madhur (7.00) followed by IGSP-12/Sree Rethna, IGSP-16/Gauri (5.00) and IGSP-12/Gauri, IGSP-C-15/Indira Madhur, IGSP-18/Sree Rethna (4.00).

Table 4.3.1 Mean performance of Sweet potato parents under organoleptic evaluation

S.No.	Genotypes	Notation	Flesh colour of tuber	Mouth feel	Sweetness	Taste	Overall rating
	Lines						
1.	IGSP-12	SP_1	3	4	3	2	3.00
2.	IGSP-14	SP_2	4	3	3	2	3.00
3.	IGSP-C-15	SP_3	3	3	4	3	3.25
4.	IGSP-17	SP_4	4	3	2	3	3.00
5.	IGSP-18	SP_5	3	4	3	2	3.00
	Testers						
1.	Sree Rethna	SP_6	3	3	4	3	3.25
2.	Gauri	SP_7	4	4	4	4	4.00
3.	Indira Madhur	SP_8	4	3	4	3	3.50

Table 4.3.2 Mean performance of Sweet potato hybrids under organoleptic evaluation

S. No.	Hybrids	Notation	Flesh colour of tuber	Mouth feel	Sweetness	Taste	Overall rating
1.	IGSP-12 x Sree Rethna	SP_9	2	2	3	2	2.25
2.	IGSP-12 x Gauri	SP_{10}	4	3	3	2	3.00
3.	IGSP-12 x Indira Madhur	SP_{11}	3	3	2	2	2.50
4.	IGSP-14 x Sree Rethna	SP_{12}	4	4	3	3	3.50
5.	IGSP-14 x Gauri	SP_{13}	4	3	2	3	3.00
6.	IGSP-14 x Indira Madhur	SP_{14}	4	3	2	3	3.00
7.	IGSP-C-15 x Sree Rethna	SP_{15}	4	3	2	2	2.75
8.	IGSP-C-15 x Gauri	SP_{16}	4	3	2	2	2.75
9.	IGSP-C-15 x Indira Madhur	SP_{17}	4	3	4	4	4.00
10.	IGSP-17 x Sree Rethna	SP_{18}	4	4	3	3	3.50
11.	IGSP-17 x Gauri	SP_{19}	2	2	2	2	2.00
12.	IGSP-17 x Indira Madhur	SP_{20}	1	3	2	3	2.25
13.	IGSP-18 x Sree Rethna	SP_{21}	4	4	4	3	3.75
14.	IGSP-18 x Gauri	SP_{22}	3	4	2	4	3.25
15.	IGSP-18 x Indira Madhur	SP_{23}	2	3	2	2	2.25

Hedonic Score

Colour		Mouth-feel		Sweetness		Taste	
White	**0**	Very dry	**0**	Not sweet	**0**	Disliked	**0**
Pigmented	**1**	Dry	**1**	Less sweet	**1**	Disliked moderate	**1**
Cream	**2**	Intermediate	**2**	Moderate sweet	**2**	Neither like nor dislike	**2**
Yellow	**3**	Moist	**3**	Sweet	**3**	Liked very much	**3**
Orange	**4**	Very moist	**4**	Very sweet	**4**	Like extremely	**4**

4.1.1.2.7 Tuber yield per plant (g)

Mean for tuber yield per plant among hybrids ranged from 250.00g (IGSP-C-15/Indira Madhur) to 941.67g (IGSP-16/Indira Madhur) which is followed by IGSP-C-15/Gauri (775.00g), IGSP-14/Indira Madhur (641.67g), IGSP-16/Sree Rethna (625.00g) and IGSP-12/Indira Madhur (548.33 g). The lowest hybrids mean of tuber yield per plant was recorded for IGSP-C-15/Indira Madhur (250.00g), IGSP-18/Sree Rethna (2.58g) and IGSP-C-15/Sree Rethna (333.33g).

4.1.1.2.8 Tuber yield (t/ha)

The mean for tuber yield tonnes per hectare among hybrids ranged from 20.83 t/ha per ha (IGSP-C-15/Indira Madhur) to 78.47 t/ha (IGSP-16/Indira Madhur) with an overall mean of 41.35 t/ha, which is followed by IGSP-C-15/Gauri (64.58 t/ha), IGSP-14/Indira Madhur (53.47 t/ha), IGSP-16/Sree Rethna (52.08 t/ha) and IGSP-12/Indira Madhur (45.69 t/ha). Lowest hybrid mean for tuber yield was recorded in IGSP-C-15/Indira Madhur (20.83 t/ha) followed by IGSP-18/Sree Rethna (21.52 t/ha) and IGSP-C-15/Sree Rethna (27.77 t/ha).

4.1.1.2.9 Marketable tuber yield per plant (g)

This trait among the hybrids ranged from 116.67g (IGSP-C-15/Sree Rethna) to 750.00 g (IGSP-16/Indira Madhur) with an overall mean of 341.11g, followed by IGSP-14/Indira Madhur (608.33g), IGSP-18/Sree Rethna (491.67g), IGSP-14/Gauri (450.00g) and IGSP-C-15/Gauri (425.00g).

4.1.1.2.10 Marketable tuber yield (t/ha)

This trait among the hybrids ranged from 9.72 t/ha (IGSP-C-15/Sree Rethna) to 62.50 t/ha (IGSP-16/Indira Madhur) with an overall mean of 29.90 t/ha which is followed by IGSP-14/Sree Rethna (50.69 t/ha), IGSP-18/Sree Rethna (40.97t/ha), IGSP-14/Gauri (37.49 t/ha) and IGSP-C-15/Gauri (35.41 t/ha).

4.1.1.2.11 Weevil-infested tuber yield per plant (g)

Mean for weevil-infested tuber yield per plant among hybrids ranged from 75.00g (IGSP-18/Indira Madhur) to 150.00g (IGSP-16/Sree Rethna) which is followed by IGSP-16/Indira Madhur (150.00g), IGSP-C-15/Sree Rethna (133.33g),IGSP-12/Gauri,IGSP-14/Gauri and IGSP-

18 Gauri (108.33g). Lowest weevil-infested tuber yield (33.34g) per plant was observed with line IGSP-14 when used as female parent.

4.1.1.2.12 Weevil-infested tuber yield per plant (t/ha)

The mean for weevil-infested tuber yield tonnes per ha among hybrids ranged from 6.25 t/ha (IGSP-18/Indira Madhur) to 12.50 t/ha (IGSP-16/Indira Madhur,IGSP-16/Sree Rethna) followed by IGSP-C-15/Sree Rethna (11.11 t/ha) and IGSP-C-12/Gauri, IGSP-14/Gauri (9.03 t/ha). Lowest hybrid mean of weevil-infested tuber yield t/ha was recorded by IGSP-18/Gauri (9.03 t/ha).

4.1.1.2.13 Harvest index (per cent)

The hybrids mean value of harvest index ranged from 23.71 per cent (IGSP-18/Sree Rethna) to 72.09 per cent (IGSP-12/Gauri) followed by IGSP-12/Indira Madhur (67.30%), IGSP-12/Sree Rethna (67.24%), IGSP-14/Indira Madhur (64.82%) and IGSP-16/Gauri (62.66%). Lowest hybrid mean of harvest index per centage was recorded for IGSP-18/Sree Rethna (23.71%) IGSP-C-15/Indira Madhur (27.38%) and IGSP-14/Gauri (43.36%).

4.1.1.2.14 Fresh and dry weight of foliage (g)

This trait among the hybrids ranged from 15.34 g (IGSP-18/Indira Madhur) to 32.33g (IGSP-14/Indira Madhur) with an overall mean of 23.17 g followed by IGSP-16/Gauri (30.67g), IGSP-18/Gauri (30.00g), IGSP-14/Gauri, IGSP-16/Indira Madhur, IGSP-18/Sree Rethna (25.67g) and IGSP-14/Sree Rethna (23.00g).

Highest harvest index (30.00g) was observed when line IGSP-16 was used as female parent.

4.1.1.2.15 Dry matter of tuber (per cent)

The highest per centage of dry matter of tuber among hybrids was recorded and the value ranged from 15.67 per cent (IGSP-C-15/Indira Madhur) to 34.33 per cent (IGSP-16/Gauri) followed by IGSP-18/Indira Madhur (32.33%), IGSP-18/Sree Rethna, IGSP-16/Indira Madhur

(31.67%) and IGSP-18/Sree Rethna (29.00%). Whereas, IGSP-C-15/Indira Madhur (15.67%), IGSP-C-15/Gauri (17.00%), IGSP-12/Gauri (18.00%) and IGSP-C-15/Sree Rethna (19.67%) recorded the minimum per centage of dry matter of tuber. Dry matter per centage was found more (32.67%) when IGSP-12 was used as female parent.

4.1.1.2.16 Total soluble solids (per cent)

The highest per centage of total soluble solids among hybrids was ranged from 7.00 per cent (IGSP-15/Indira Madhur) to 11.67 per cent (IGSP-16/Indira Madhur) which is followed by IGSP-16/Gauri (11.33%), IGSP-14/Sree Rethna, IGSP-C-15/Sree Rethna (11.00%), IGSP-12/Indira Madhur, IGSP-18/Gauri (10.67%), whereas IGSP-C-15/Indira Madhur (7.00%) recorded the minimum per centage of total soluble solids. Total soluble solids per centage was found more (11.00%) when IGSP-C-15 was used as female parent.

4.1.1.2.17 Carotene (mg/100g)

The mean carotene (mg/100g) among hybrids ranged from 4.00mg/100g (IGSP-16/Gauri) to 8.00 mg/100g (IGSP-12/Sree Rethna) with an overall mean of (5.95 mg/100g), which is followed by IGSP-12/Gauri (7.67mg/100g), IGSP-14/Gauri, IGSP-C-15/Indira Madhur,IGSP-16/Indira Madhur (7.00mg/100g) and IGSP-12/Indira Madhur (6.33mg/100g).

4.1.1.3. Organoleptic evaluation of parents and hybrids

Organoleptic evaluation of the tubers of all sweet potato genotype was done by a panel of five judges. The cooked tubers of sweet potato genotypes were evaluated considering four points *viz.*, flesh colour of tuber, mouth feel, sweetness and taste and their mean values were treated as over all rating Table 4.3.1 and 4.3.2 respectively.

Table 4.4 Analysis of variance for Line x Tester analysis for tuber yield and its component characters

Source	D.F.	Characters																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Replication	2	21.62	4611.95	5.60*	0.66	0.61	0.52	294.56	2.027	4963.40	89.09	688.40	4.743	15.13	1.92	41.05	0.71	1.49
Parents	7	3202.28	17030.35	10.35	1.23	1.88	0.56	11484.37	79.78	7880.80	59.90	5889.13	40.91	168.60	57.27	73.23	3.80	13.80
Hybrids	14	2915.07*	160757.93*	70.08*	33.36*	17.71*	6.43*	107476.42*	746.37*	98585.31*	750.76*	12281.74*	85.33*	614.68*	78.23*	119.26*	6.16*	6.32*
Parents vs. hybrids	1	1236.71	1086536.53	24.89	900.76	2.23	0.05	9363.28	64.93	13634.13	12.53	7972.90	55.45	5130.68	0.753	74.99	9.67	10.94
Lines	4	7202.77	190986.11	8.58	52.18	33.91	9.81	91963.33	638.65	140777.78	1463.76	6493.05	45.11	800.61	96.47	298.30	5.07	16.14
Testers	2	50.55	55847.22	18.95	66.08	17.48	2.86	98951.66	687.35	597.22	87.42	1513.88	10.52	540.42	76.42	75.28	2.02	3.35
Line x Testers	8	1487.36*	171871.52*	113.62*	15.78*	9.66*	5.64*	117364.16*	814.98*	101986.11*	560.09*	17868.05*	124.14*	540.28*	69.56*	40.73*	7.74*	2.16*
Error	44	17.18	3191.12	3.53	0.68	0.36	0.55	879.79	6.10	782.34	26.10	1379.69	3.16	17.06	3.03	4.34	1.13	0.62

***Significant at P = 0.05 level**

1. Vine length (cm)
2. Vine weight (g)
3. Tuber length (cm)
4. Tuber diameter (cm)
5. Neck length of Tuber (cm)
6. Number of Tubers per plant
7. Tuber weight per plant (g)
8. Tuber yield (t/ha)
9. Marketable tuber yield per plant (g)
10. Marketable tuber yield (t/ha)
11. Weevil-infested tuber yield per plant (g)
12. Weevil-infested tuber yield (t/ha)
13. Harvest index (%)
14. Fresh and dry weight of foliage (g)
15. Dry matter of tuber (%)
16. Total soluble solids (%)
17. Carotene mg/100g

The results obtained in the organoleptic evaluation are discussed with the help of following score card prepared under hedonic scale 0-4.

Score	**Rating**
3.5-4.0	Excellent
3.0-3.5	Very Good
2.5-3.0	Good
2.0-2.5	Acceptable
1.5-2.0	Poor
1.0-1.5	Unacceptable

The organoleptic evaluation ranged from 3.00 (IGSP-17) to 4.00 (Gauri) with an overall mean of 3.25. Among the lines, IGSP-C-15 (3.25) had highest overall rating of organoleptic score while other lines IGSP-12, IGSP-14, IGSP-17 and IGSP-18 showed lowest score of organoleptic evaluation.

Among the testers, highest score for this trait was recorded for Gauri (4.00) followed by Indira Madhur (3.50) and Sree Rethna (3.25) as compared to overall rating.

The mean organoleptic evaluation among hybrid ranged from 2.25 (IGSP-18/Indira Madhur) to 4.00 (IGSP-C-15/Indira Madhur, followed by IGSP-C-15/Sree Rethna, IGSP-C-15/Gauri (3.75), IGSP-14/Sree Rethna, IGSP-17/Sree Rethna (3.50) and IGSP-18/Gauri (3.25). Highest organoleptic score was found in IGSP-C-15 (3.25), when used as female parent.

The observation on other morphological traits *viz.,* plant type, vine internode, vine pigmentation, vine tip pubescence, general outline of leaf, type of leaf lobes, number of leaf lobes, abaxial leaf vein pigmentation, shape of central lobe, foliage colour, petiole length, petioles pigmentation, colour of root, root shape and tuber flesh colour of parents and hybrids (F_1) are presented in Appendix IV and V.

4.2 Combining ability analysis

Data on tuber yield and its components was recorded for fifteen hybrids, five lines and three testers which were used for combining ability analysis by following the line x Tester approach of Kampthorne (1957).

Table 4.5 General Combining Ability (GCA) effects of lines and testers for tuber yield and its components

PARENTS	Characters																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lines																	
IGSP-12	-12.77*	-257.78*	-1.17	-3.44*	-2.10*	0.71*	-50.22*	-4.18*	-132.78*	-12.54*	-19.44	-1.62	15.45*	-3.28*	-0.97	0.35	1.38*
IGSP-14	-23.88*	39.44*	1.37*	2.31*	-0.98*	-0.84*	28.67*	2.39*	122.78*	8.75*	-19.44	-1.62	-2.42	3.82*	-3.64*	-0.31	0.15
IGSP-C-15	29.44*	72.78*	0.04	-0.42	0.59*	-0.62*	-43.55*	-3.63*	-96.67*	-9.53*	-11.11	-0.93	-7.83*	-3.40*	-6.87*	-1.08*	0.71*
IGSP-16	-24.44*	95.00*	0.37	-0.73	-0.51*	1.48*	162.00*	13.50*	139.44*	17.55*	44.44*	3.70*	1.66	2.37*	7.35*	0.91*	-2.17*
IGSP-18	31.67*	50.56*	-0.62	2.29*	3.01*	-0.73*	-96.89*	-8.07*	-32.78*	-4.21*	5.56	0.46	-6.87*	0.48	4.13*	0.13	-0.06
Testers																	
Sree Rethna	-2.11	67.77 *	-0.77	2.29 *	-0.87*	-0.40 *	-91.66 *	-7.64*	7.22	-0.88	1.11	0.09	-6.83*	-2.04 *	1.95*	0.17	-0.08
Gauri	1.22	-50.56 *	1.28 *	-1.81 *	1.20 *	-0.06	28.66 *	2.39*	-2.78	2.73 *	9.44	0.78	4.42 *	2.42 *	-2.44 *	0.24	0.51 *
Indira Madhur	0.89	-17.22	-0.51	-0.48 *	-0.32 *	0.46 *	63.00 *	5.24*	-4.44	-1.85	-10.55	-0.88	2.40 *	-0.37	0.48	-0.42	-0.42 *
SE (lines)	1.38	18.83	0.62	0.27	0.20	0.24	9.88	0.82	9.32	1.70	12.38	1.03	1.37	0.58	0.69	0.35	0.26
SE (testers)	1.07	14.58	0.48	0.21	0.15	0.19	7.65	0.63	7.22	1.31	9.56	0.79	1.06	0.44	0.53	0.27	0.20

*Significant at P = 0.05 level

1. Vine length (cm)
2. Vine weight (g)
3. Tuber length (cm)
4. Tuber diameter (cm)
5. Neck length of Tuber (cm)
6. Number of Tubers per plant
7. Tuber yield per plant (g)
8. Tuber yield (t/ha)
9. Marketable tuber yield per plant (g)
10. Marketable tuber yield (t/ha)
11. Weevil-infested tuber yield per plant (g)
12. Weevil-infested tuber yield (t/ha)
13. Harvest index (%)
14. Fresh and dry weight of foliage (g)
15. Dry matter of tuber (%)
16. Total soluble solids (%)
17. Carotene mg/100g

Table 4.5 General Combining Ability (GCA) effects of lines and testers for tuber yield and its components

PARENTS	Characters																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lines																	
IGSP-12	-12.77*	-257.78*	-1.17	-3.44*	-2.10*	0.71*	-50.22*	-4.18*	-132.78*	-12.54*	-19.44	-1.62	15.45*	-3.28*	-0.97	0.35	1.38*
IGSP-14	-23.88*	39.44*	1.37*	2.31*	-0.98*	-0.84*	28.67*	2.39*	122.78*	8.75*	-19.44	-1.62	-2.42	3.82*	-3.64*	-0.31	0.15
IGSP-C-15	29.44*	72.78*	0.04	-0.42	0.59*	-0.62*	-43.55*	-3.63*	-96.67*	-9.53*	-11.11	-0.93	-7.83*	-3.40*	-6.87*	-1.08*	0.71*
IGSP-16	-24.44*	95.00*	0.37	-0.73	-0.51*	1.48*	162.00*	13.50*	139.44*	17.55*	44.44*	3.70*	1.66	2.37*	7.35*	0.91*	-2.17*
IGSP-18	31.67*	50.56*	-0.62	2.29*	3.01*	-0.73*	-96.89*	-8.07*	-32.78*	-4.21*	5.56	0.46	-6.87*	0.48	4.13*	0.13	-0.06
Testers																	
Sree Rethna	-2.11	67.77 *	-0.77	2.29 *	-0.87*	-0.40 *	-91.66 *	-7.64*	7.22	-0.88	1.11	0.09	-6.83*	-2.04 *	1.95*	0.17	-0.08
Gauri	1.22	-50.56 *	1.28 *	-1.81 *	1.20 *	-0.06	28.66 *	2.39*	-2.78	2.73 *	9.44	0.78	4.42 *	2.42 *	-2.44 *	0.24	0.51 *
Indira Madhur	0.89	-17.22	-0.51	-0.48 *	-0.32 *	0.46 *	63.00 *	5.24*	-4.44	-1.85	-10.55	-0.88	2.40 *	-0.37	0.48	-0.42	-0.42 *
SE (lines)	1.38	18.83	0.62	0.27	0.20	0.24	9.88	0.82	9.32	1.70	12.38	1.03	1.37	0.58	0.69	0.35	0.26
SE (testers)	1.07	14.58	0.48	0.21	0.15	0.19	7.65	0.63	7.22	1.31	9.56	0.79	1.06	0.44	0.53	0.27	0.20

*Significant at P = 0.05 level

1. Vine length (cm)
2. Vine weight (g)
3. Tuber length (cm)
4. Tuber diameter (cm)
5. Neck length of Tuber (cm)
6. Number of Tubers per plant
7. Tuber yield per plant (g)
8. Tuber yield (t/ha)
9. Marketable tuber yield per plant (g)
10. Marketable tuber yield (t/ha)
11. Weevil-infested tuber yield per plant (g)
12. Weevil-infested tuber yield (t/ha)
13. Harvest index (%)
14. Fresh and dry weight of foliage (g)
15. Dry matter of tuber (%)
16. Total soluble solids (%)
17. Carotene mg/100g

Table 4.6 Specific Combining Ability (SCA) effects of hybrids for tuber yield and its components

Hybrids	Characters																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IGSP-12 x Sree Rethna	-24.56*	-87.22*	-4.89*	-3.14*	0.43	1.62*	27.22	2.26	-82.22*	-5.37	-37.22	-3.10	5.10*	-0.17	2.71*	-0.62	0.75
IGSP-12 x Gauri	2.11	6.11	-2.29*	1.44*	-1.23*	-0.71	-66.44*	-5.54*	111.11*	6.29*	62.77*	5.23*	-1.21	-2.97*	-2.89*	-0.35	-0.17
IGSP-12 x Indira Madhur	22.44*	81.11*	7.17*	1.70*	0.80*	-0.91*	39.22*	3.27*	-28.89	-0.93	-25.56	-2.13	-3.98	3.15*	0.17	0.97	-0.57
IGSP-14 x Sree Rethna	16.55*	-42.78	-2.44*	2.24*	-0.76*	-1.48*	-8.33	-0.69	137.22*	12.91*	-37.22	-3.10	0.66	-1.95	0.37	1.37*	-0.68
IGSP-14 x Gauri	-0.11	175.56*	1.48	-2.77*	0.57	0.17	-45.33*	-3.78*	-11.11	-3.89	62.77*	5.23*	-12.07*	-3.75*	0.44	0.311	0.37
IGSP-14 x Indira Madhur	-16.44*	-132.77*	0.95	0.52	0.18	1.31	53.67*	4.46*	-126.11*	-9.02*	-25.55	-2.13	11.40*	5.71*	-0.82	-1.68	0.311
IGSP-C-15 x Sree Rethna	-21.77*	-301.11*	2.22	0.47	-0.01	0.29	-27.77	-2.32	-135.00*	-9.76*	87.78*	7.31*	14.51*	1.26	0.26	2.15*	-1.24*
IGSP-C-15 x Gauri	13.22*	150.56*	3.82*	2.25*	-0.42	-0.37	293.55*	24.46*	183.33*	12.31*	-53.89*	-4.49*	6.10*	0.13	2.00	-0.91	0.48
IGSP-C-15 x Indira Madhur	8.55*	150.56*	-6.04*	-2.73	0.43	0.09	-265.77*	-22.14*	-48.33*	-2.54	-33.89	-2.82	-20.62*	-1.40	-2.26	-1.24	0.75
IGSP-16 x Sree Rethna	12.11*	176.67*	-1.78	-0.004	-0.90*	-1.49*	58.33*	4.86*	-96.11*	-13.93*	48.89*	4.07*	-4.36	-3.17*	-4.62*	-1.84*	0.97*
IGSP-16 x Gauri	8.77*	-305*	5.16*	0.009	-0.98*	0.51	-278.67*	-23.22*	-177.78*	-2.96	-109.44*	-9.12*	3.15	2.68*	5.11*	0.42	-0.28
IGSP-16 x Indira Madhur	-20.89*	128.33*	-3.37*	-0.004	1.88*	0.97*	220.33*	18.36*	273.88*	16.89*	60.55*	5.04*	1.21	0.48	-0.48	-1.42*	-0.68
IGSP-18 x Sree Rethna	17.67*	254.44*	6.89*	0.42	1.23*	1.07*	-49.44*	-4.12*	176.11*	16.15*	-62.22*	-5.18*	-16.01*	4.04*	1.26	-1.06	0.20
IGSP-18 x Gauri	-24.00*	-27.22	-8.18*	1.33	2.07*	0.40	96.88*	8.07*	-105.56*	-11.75*	37.78	3.14	4.03	3.91*	-4.67*	0.53	-0.40
IGSP-18 x Indira Madhur	6.33*	-227.22*	1.28	-3.89	-3.31*	-1.47*	-47.44*	-3.95*	-70.56*	-4.40	24.44	2.03	11.98*	-7.9*	3.40*	0.53	0.20

*Significant at P = 0.05 level

1. Vine length (cm)
2. Vine weight (g)
3. Tuber length (cm)
4. Tuber diameter (cm)
5. Neck length of Tuber (cm)
6. Number of tubers per plant
7. Tuber yield per plant (g)
8. Tuber yield (t/ha)
9. Marketable tuber yield per plant (g)
10. Marketable tuber yield (t/ha)
11. Weevil-infested tuber yield per plant
12. Weevil-infested tuber yield (t/ha)
13. Harvest index (%)
14. Fresh and dry weight of foliage (g)
15. Dry matter of tuber (%)
16. Total soluble solids (%)
17. Carotene mg/100g

Table 4.7: Magnitude of gca variance and sca variance for tuber yield and its component characters

S. No.	Characters	Var. of gca	Var. of sca	Var. of gca/ Var. of sca
	1	2	3	4
1.	Vine length (cm)	50.47	490.06	0.102
2.	Vine weight (g)	-392.90	56226.80	-0.0069
3.	Tuber length (cm)	-1.54	36.70	-0.041
4.	Tuber diameter (cm)	-0.62	5.03	-0.123
5.	Neck length of Tuber (cm)	0.28	3.10	0.090
6.	Number of Tubers per plant	0.028	1.69	0.016
7.	Tuber yield per plant (g)	-349.57	38828.12	-0.009
8.	Tuber yield (t/ha)	-2.42	269.62	-0.0089
9.	Marketable tuber yield per plant (g)	-120.23	33734.59	-0.0035
10.	Marketable tuber yield (t/ha)	6.74	177.99	0.037
11.	Weevil-infested tuber yield per plant (g)	-197.50	5496.12	-0.035
12.	Weevil-infested tuber yield (t/ha)	-1.37	38.18	-0.035
13.	Harvest index (%)	2.63	174.40	0.015
14.	Total soluble solids (%)	-0.055	2.20	-0.025
15.	Fresh and dry weight of foliage (g)	0.30	22.17	0.013
16.	Dry matter of tuber (%)	2.77	12.12	0.22
17.	Carotene (mg/100g)	0.147	0.51	0.28

4.2.1 Analysis of Variance

The analysis of variance for Line x Tester analysis (Table 4.4) revealed significant variance for all the characters for parents, hybrids as well as parent vs hybrids. The variance due to hybrid was partitioned into variance due to line, testers and line x testers for all the characters.

The variance due to lines was significant for the characters *viz.,* vine length (cm), vine weight, tuber length, tuber diameter, neck length of tuber, tuber yield per plant, tuber yield t/ha, marketable tuber yield per plant, marketable tuber yield t/ha, weevil-infested tuber yield per plant, weevil-infested tuber yield t/ha and fresh and dry weight of foliage whereas, the variance due to lines was non-significant for the characters *viz.*, number of tubers per plant, harvest index, dry matter percentage and carotene. The variance due to testers was significant for all the characters except number of tubers per plant. While the variance due to line x testers were significant for all the characters except diameter of tuber.

4.2.2 Combining ability effects

The estimates of general combining ability (gca) effects of five lines and three testers and specific combining ability (sca) effects of fifteen hybrids for all the characters under study are presented in Table. 4.5 and Table 4.6, respectively and deseribed as under.

4.2.2.1 Vine length (cm)

The gca effects of the lines ranged from -12.77 (IGSP-12) to 31.67 (IGSP-18), the gca effects of two line IGSP-14 (-23.88) and IGSP-18 (31.67) were significant. The remaining two lines showed non-significant gca effects. Among the testers, gca effects ranged from -2.11 (Sree Rethna) to 1.22 (Gauri). The gca effects of three testers *viz.*, Gauri (1.22), Indira Madhur (0.89) were significant and Sree Rethna (-2.11) had negative gca effect. Positive sca effects was shown by hybrid, IGSP-12/Indira Madhur (22.44) followed by IGSP-18/Sree Rethna (17.67), IGSP-14/Sree Rethna (16.55) and IGSP-C-15/Gauri (13.22), while negative in IGSP-12/Sree Rethna (-24.56), IGSP-18/Gauri (-24) and IGSP-C-15/Sree Rethna (-21.77).

4.2.2.2 Vine weight (g)

Five lines were found significant for gca effect ranking from -257.78 (IGSP-12) to 95 (IGSP-16). The lines recorded significant positive gca effect were IGSP-16 and IGSP-C-15 whereas, other one lines showed significant negative gca effects. Among the testers, one tester had significant positive gca effects and two had negative gca effect which ranged from -50.56 (Gauri) to 67.77 (Sree Rethna). Tester showing positive gca effect were Sree Rethna (67.77) and Gauri (-50.56).

Among the fifteen hybrids, seven hybrids showed positive significant sca effect from which top ranking hybrid were, IGSP-18/Sree Rethna (254.44), IGSP-16/Sree Rethna (176.67), IGSP-14/Gauri (175.56). the range of sca effects of hybrids for this trait was -305 (IGSP-16/Gauri) to 254.44 (IGSP-18/Sree Rethna. Five hybrids had significant negative sca effects. Other three hybrids were found non-significant.

4.2.2.3 Tuber length (cm)

The gca effects of lines for tuber ranged from -1.17 (IGSP-12) to 1.37 (IGSP-14). Line IGSP-14 (1.37) had positive significant gca effects out of five lines and two lines had significant gca effects *viz.*, IGSP-16 (0.37) and IGSP-C-15 (0.04), remaining two lines IGSP-12(-1.17) and IGSP-18(-0.62) had negative gca effects.

Among the testers, one tester had significant positive gca effects and two had negative gca effect which ranged from -0.51 (Indira Madhur) to 1.28 (Gauri). Only one tester showing positive gca effect was Gauri (1.28).

The sca effects for tuber length ranged from -6.04 (IGSP-C-15/Indira Madhur) to 7.17 (IGSP-12/Indira Madhur). Four hybrids showed significant positive sca effects in which five top ranking hybrids for high significant positive sca effects were IGSP-12/Indira Madhur (7.17), IGSP-18/Sree Rethna (6.89) and IGSP-16/Gauri (5.16), Whereas, six hybrids had significant negative sca effects for the tuber length, five remaining hybrids showed non-significant sca effects.

4.2.2.4 Tuber diameter (cm)

Three lines out of five lines showed significant gca effects for tuber diameter which ranged from -3.44 (IGSP-12) to 2.31 (IGSP-14). Two lines showing significant positive gca were IGSP-14 and IGSP-18 whereas, line IGSP-12 had significant negative gca effect.

Among the testers the gca effect ranged from -1.81 (Gauri) to 2.29 (Sree Rethna) whereas, tester Sree Rethna (2.29) showed significant positive gca effects and Indira Madhur (-0.48) and Gauri (-1.81) showed significant negative gca effect.

The sca effects for tuber diameter ranged from -3.89 (IGSP-18/ Indira Madhur) to 2.25 (IGSP-C-15/Gauri). Four hybrids showed significant positive sca effects and the hybrid IGSP-C-15/Gauri showed high positive sca effects, whereas, two hybrids showed significant negative sca effects for tuber diameter.

4.2.2.5 Neck length of tuber (cm)

The gca effects of line for neck length of tuber ranged from -2.10 (IGSP-12) to 3.01 (IGSP-18). Five lines had significant gca effects and out of them two lines had significant positive gca effects *viz*., IGSP-18 (3.01) and IGSP-C-15 (0.59). Other three lines *viz*., (-0.51) IGSP-16, (-0.98) IGSP-14 and (-2.10) IGSP-12 had significant negative gca effects.

Among the testers, the gca effect ranged from -0.32 (Indira Madhur) to 1.20 (Gauri) whereas, tester Gauri (1.20) showed significant positive gca effects and Indira Madhur (-0.32) and Sree Rethna (-0.87) showed significant negative gca effect.

The sca effects for neck length of tuber ranged from (-3.31) IGSP-18/Indira Madhur to 2.07 (IGSP-18/Gauri). Nine hybrids showed significant sca effects out of four hybrids showing significant positive sca effects, the top ranking hybrids for high significant positive sca effects were IGSP-18/Gauri (2.07), IGSP-16/Indira Madhur(1.88) and IGSP-18/Sree Rethna (1.23), whereas, five hybrids had significant negative sca effects for the neck length of tuber and other remaining hybrid showed non-significant sca effects.

4.2.2.6 Number of tubers per plant

The two lines had significant gca effect out of five lines *viz.*, IGSP-16 (1.48) and IGSP-12 (0.71) had significant positive gca effects. Two testers showed significant gca effect whereas, Indira Madhur (0.46) had significant positive gca effects and Sree Rethna (-0.40) showed significant negative gca effect.

The range of sca effects was -1.49 (IGSP-16/Sree Rethna) to 1.62 (IGSP-12/Sree Rethna). Four hybrids showed significant negative sca effects and eight hybrids had non-significant sca effects for this trait. Seven hybrids out of fifteen showed significant sca effect for number of tubers per plant and three hybrids showed significant positive sca effects, among them the top ranking hybrids were, IGSP-12/Sree Rethna (1.62), IGSP-18/Sree Rethna (1.07) and IGSP-16/Indira Madhur (0.97).

4.2.2.7 Tuber yield per plant (g)

Among the five lines significant gca effect ranged between -96.83 (IGSP-18) to 162.00 (IGSP-16). Two lines *viz.*, IGSP-16 (162) and IGSP-14 (28.67) showed significant positive gca effects whereas, three testers reported significant gca effect *viz.*, Indira Madhur (63.00) and Gauri (28.66) had significant positives gca effects and Sree Rethna (-91.66) showed significant negative gca effects.

Among the fifteen hybrids, significant sca effects ranged from -278.67 (IGSP-16/Gauri) to 293.55 (IGSP-C-15/Gauri). The superior hybrids on the basis of high positive sca effects were, IGSP-C-15/Gauri(293.55),IGSP-16/Indira Madhur (220.33),IGSP-18/Gauri(96.88) and IGSP-16/Sree Rethna(58.33).whereas, six hybrids reported significant negative sca effects .

4.2.2.8 Tuber yield (t/ha)

Among the five lines, significants gca effect ranged between -8.07 (IGSP-18) to 13.50 (IGSP-16). Two lines *viz.,* IGSP-16(13.50) and IGSP-14 (2.39) showed significant positive gca effects. Three testers recorded significant gca effects *viz.,* Indira Madhur, Gauri and Sree Rethna while, Indira Madhur, Gauri showed significant positive gca effects.

Among all the fifteen hybrids, twelve showed significant sca effect which ranged from -23.22 (IGSP-16/Gauri) to 24.46 (IGSP-C-15/Gauri). The superior hybrids on the basis of high significant positive sca effects were *viz.,* IGSP-C-15/Gauri, IGSP-16/Indira Madhur and IGSP-18/Gauri whereas, six hybrids reported significant negative sca effects and three hybrids had non-significant sca effects for tuber yield tonnes/ha.

4.2.2.9 Marketable Tuber yield per plant (g)

The gca effects for this trait ranged from -132.78 (IGSP-12) to 139.44 (IGSP-16) and all lines showed significant gca effect from which two lines had significant positive effects *viz.,*IGSP-16 (139.44) and 122.78 (IGSP-14). All the testers showed non-significant gca effect for marketable tuber yield per plant.

Among all the fifteen hybrids, thirteen hybrids showed significant sca effects with the range varying between -177.78 (IGSP-16/Gauri) to 273.88 (IGSP-16/Indira Madhur). Five hybrids out of thirteen hybrids recorded positive significant sca effects. The top ranking hybrids on the basis of sca effects were IGSP-16/Indira Madhur, IGSP-C-15/Gauri,IGSP-18/Sree Rethna and IGSP-14/Sree Rethna. Whereas, eight hybrids showed significant negative sca effects and two hybrids showed non-significant sca effects for this trait.

4.2.2.10 Marketable tuber yield (t/ha)

The gca effects for this trait ranged from -12.54 (IGSP-12) to 17.55 (IGSP-16) and all lines showed significant gca effect from which two lines had significant positive effects *viz.,*IGSP-16 (17.55) and 8.75 (IGSP-14). Among the testers, one tester out of three showed significant positive gca effect for marketable tuber yield per plant.

The sca effects ranged from -13.93 (IGSP-16/ Sree Rethna) to 16.89 (IGSP-16/Indira Madhur). Nine hybrids out of fifteen showed significant sca effects. Five hybrids showed significant positive sca effects and some superior hybrids on the basis of sca effects were IGSP-16/Indira Madhur, IGSP-18/Sree Rethna and IGSP-14/Sree Rethna. Four hybrids showed significant negative sca effects and six hybrids had non-significant sca effects for this trait.

4.2.2.11 Weevil-infested tuber yield per plant (g)

The gca effects for this trait line ranged from -19.44(IGSP-12) to 44.44 (IGSP-16). Only one line (IGSP-16) showed significant gca effect (44.44) out of five lines. Among the three testers, Sree Rethna, Gauri and Indira Madhur had non significant gca effect.

Among all the fifteen hybrids, eight hybrids showed significant sca effects with the range varying between -109.44 (IGSP-16/Gauri) to 87.78 (IGSP-C-15/Sree Rethna). Out of eight hybrids, five hybrids recorded positive significant sca effects. The top ranking hybrids on the basis of sca effects were, IGSP-C-15/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Gauri, IGSP-16/Indira Madhur and IGSP-16/Sree Rethna and three hybrids showed significant negative effects and seven hybrids showed non-significant sca effects for this trait.

4.2.2.12 Weevil-infested tuber yield (t/ha)

The gca effects for this trait lines ranged from -1.62 t/ha (IGSP-12) to 3.70 t/ha (IGSP-16). Only line (IGSP-16) showed significant gca effect (3.70) out of five lines. Among three testers, Gauri ,Sree Rethna and Indira Madhur had non-significant gca effects.

Among all the fifteen hybrids, eight hybrids showed positive significant sca effects with the range between -9.12 t/ha (IGSP-16/Gauri) to 7.31 IGSP-C-15/Sree Rethna). Five hybrids recorded significant positive sca effects. The top ranking hybrids on the basis of sca effects were viz., IGSP-C-15/Sree Rethna, IGSP-14/Gauri, IGSP-12/Indira Madhur, and IGSP-16/ Indira Madhur. Three hybrids showed significant negative effects and seven hybrids showed non-significant sca effect for this trait.

4.2.2.13 Harvest Index (per cent)

The gca effect for this trait line ranged from -6.87 per cent (IGSP-18) to 15.45 (IGSP-12). Three lines had significant gca effects and out of them one line had significant positive effect IGSP-12 (15.45). Other two lines *viz*; IGSP-C-15 and IGSP-18 had significant negative gca effects. Among tester, two testers Gauri and Indira Madhur had significant positive gca effects and one tester Sree Rethna had significant negative gca effect.

Among all the fifteen hybrids, eight hybrids showed significant sca effects with the range varying between -20.62 (IGSP-C-15/Indira Madhur) to 14.51(IGSP-C-15/Sree Rethna) and five hybrids recorded significant positive sca effects. The top ranking hybrids on the basis of sca effects were IGSP-C-15/Sree Rethna, IGSP-18/Indira Madhur, IGSP-14/Indira Madhur,IGSP-C-15/Gauri and IGSP-12/Gauri. Whereas, three hybrids had significant negative sca effects and seven hybrids showed non-significant sca effects for this trait

4.2.2.14 Fresh and dry weight of foliage (g)

The gca effect for this trait line ranged from -3.40 (IGSP-C-15) to 3.82 (IGSP-14). Four lines had significant gca effect and two lines had significant positive effect IGSP-14 (3.82) and IGSP-16 (2.37) while, two lines had significant negative gca effects. Among the testers, two testers showed significant, one positively significant and one negatively significant .

The sca effects for fresh and dry weight of foliage ranged from-7.9 (IGSP-18/Indira Madhur) to 5.71(IGSP-14/Indira Madhur). Five hybrids out of fifteen showed significant positive sca effects, the top ranking hybrids for high significant positive sca effect were IGSP-14/Indira Madhur (5.71), IGSP-18/Sree Rethna (4.04) and IGSP-18/Gauri (3.91) whereas, four hybrids showed significant negative sca effects for fresh and dry weight of foliage, remaining six hybrids showed non-significant sca effects.

4.2.2.15 Dry matter of tuber (per cent)

The gca effect for this trait, line ranged from -6.87 (IGSP-C-15) to 7.35 (IGSP-16). Four lines had significant gca effect, two lines had significant positive effects IGSP-16 (7.35) and IGSP-18 (4.13) whereas, two lines showed significant negative sca effects. Among the testers two were significant for gca effects, Gauri (2.42) showed significant positive effects and Sree Rethna (-2.04) showed negative significant gca effects.

The sca effect for dry matter of tuber ranged from -4.67 (IGSP-18/Gauri) to 5.11 (IGSP-16/Indira Madhur) and three hybrids showed significant positive sca effects out of six sowing significant sca effect, the top ranking hybrids for high significant positive sca effect were, IGSP-16/Gauri (5.11), IGSP-18/Indira Madhur (3.40) and IGSP-12/Sree Rethna (2.71), whereas, three hybrids had significant negative sca effects for dry matter of tuber while, nine remaining hybrids showed non significant sca effects.

4.2.2.16 Total soluble solids (per cent)

Two lines out of five lines showed significant gca effects with range of -1.08 (IGSP-C-15) to 0.91(IGSP-16). One line showed significant positive gca effect (IGSP-16) and IGSP-C-15 other line showed significantly negative gca effects. All the three testers showed non-significant gca effects.

The sca effect for total soluble solids ranged from -1.84 (IGSP-16/Sree Rethna) to 2.15 (IGSP-C-15/Sree Rethna). Two hybrids showed significant positive sca effects, the top ranking hybrids for high significant positive sca effect were, IGSP-C-15/Sree Rethna and IGSP-14/Sree Rethna whereas, two hybrids had significant negative sca effects for total soluble solids, remaining eleven hybrids showed non-significant sca effects.

4.2.2.17 Carotene (mg/100g)

Three lines showed significant gca effect with range of -2.17 (IGSP-16) to1.38 (IGSP-12). Two lines showed significant positive gca effects viz; IGSP-12 and IGSP-C-15, line IGSP-16 had significant negative gca effects. Two testers showed significant gca effects and one tester Gauri showed significant positive gca effects.

Two hybrids showed significant sca effects out of fifteen hybrids and ranged from -1.24 (IGSP-C-15/Sree Rethna) to 0.97 (IGSP-16/Sree Rethna). IGSP-16/Sree Rethna showed positive sca effect whereas, IGSP-C-15/Sree Rethna had significant negative sca effects and thirteen hybrids showed non-significant gca effects.

4.3 Gene action

The magnitude of variance revealed that the gca (σ^2 gca) were relatively lower than the sca variance (σ^2 sca) for all the characters (Table 4.7).

The ratio of σ^2 gca/ σ^2 sca was less than unity for all the characters studied indicating predominance of non-additive gene action.

4.4 Variability, heritability and genetic advance

These parameters of variability were calculated for twenty three genotypes (eight parents and fifteen hybrids) under combining ability analysis for seventeen different characters.

4.3.1 Variability

The genotypic and phenotypic coefficients of variations are presented in Table 4.8. High genotypic as well as phenotypic coefficient of variations were recorded for traits *viz*., vine length (37.75 and 38.09%), vine weight (61.40 and 63.28%), tuber length (21.95 and 24.38%), tuber diameter (54.47 and 55.36%), neck length of tuber (43.75 and 45.75%), number of tubers per plant (27.27 and 32.78%), tuber yield per plant (31.67 and 32.25%), tuber yield (31.67 and 32.25%), marketable tuber yield per plant (41.48 and 42.67%), weevil-infested tuber yield per plant (84.80 and 103.06%) weevil-infested tuber yield (84.79 and 103.06%), harvest index (24.85 and 25.80%), fresh and dry weight of foliage (20.15 and 21.51%), dry matter of tuber (22.83 and 24.29%) carotene mg/100g (26.61 and 29.48%).

Moderate genotypic and phenotypic co-efficient of variations was observed for total soluble solids (12.33% and 16.12%).

High genotypic and phenotypic coefficients of variation were observed for vine length, vine weight, tuber length, tuber diameter, neck length of tuber, number of tubers per plant, tuber yield per plant, tuber yield t/ha, marketable tuber yield per plant, marketable tuber yield (t/ha), weevil-infested tuber yield per plant, weevil-infested tuber yield (t/ha), harvest index, fresh and dry weight of foliage, dry matter of tuber and carotene (mg/100g).

4.3.2 Heritability

The broad sense heritability estimates have been presented in Table 4.8. All the characters showed high broad sense heritability. Among the characters studied, highest heritability estimate was recorded for vine length (98.26%) followed by marketable tuber yield tonnes per ha (97.00%), tuber diameter (97.00%), tuber yield per plant (96.44%),tuber yield tonnes per ha (96.00%), marketable tuber yield per plant (96.00%), vine weight (94.14%), harvest index (93.00%),neck length of tuber (91.00%),fresh and dry weight of foliage (88.00%) and dry matter of tuber (88.00%).

The heritability estimates was found higher for all the characters studied from 94.30 per cent to 68.00 per cent indicating that the characters are less influenced by environmental factors, this closely follows and moderate heritability 57.00 per cent.

4.3.3 Genetic advance

Genetic advance expressed as per centage of mean is presented in Table 4.8. The weevil-infested tuber yield per plant and weevil-infested tuber yield (t/ha) recorded highest genetic advance as per centage of mean (143.72%) followed by average vine weight (122.72%), tuber diameter (110.38%), neck length of tuber (86.19%) and marketable tuber yield per plant (84.83%). Genetic advance in general was high for most of the characters studied except total soluble solids (18.80%), which showed moderate genetic advance as per centage of mean.

Table 4.8: Genotypic and phenotypic co-efficient of variations (GCV and PCV), Heritability (h^2), Genetic advance as % of mean and components of variance for tuber yield and its component characters

Characters	Heritability (%)	Genetic advance as % of mean	GCV %	PCV %	ECV %	Genotypic variance	Phenotypic variance	Environmental variance
	1	2	3	4	5	6	7	8
Vine length (cm)	98.26	77.09	37.75	38.09	5.02	971.00	988.18	17.18
Vine weight per plant (g)	94.14	122.72	61.40	63.28	15.31	51305.39	54496.51	319.12
Tuber length (cm)	81.11	40.73	21.95	24.38	10.60	15.17	18.70	3.52
Tuber diameter (cm)	97.00	110.38	54.47	55.36	9.92	20.63	21.31	0.68
Neck length of Tuber (cm)	91.00	86.19	43.75	45.75	13.38	3.87	4.23	0.36
Number of Tubers per plant	69.00	46.75	27.27	32.78	18.18	1.24	1.79	0.55
Tuber yield per plant (g)	96.44	64.06	31.67	32.25	6.08	23864.67	24744.47	879.79
Tuber yield (t/ha)	96.00	64.07	31.67	32.25	6.08	165.73	171.84	6.10
Marketable tuber yield per plant (g)	96.00	84.83	41.92	42.67	7.96	21693.68	22476.02	782.35
Marketable tuber yield (t/ha)	97.00	79.12	41.48	44.79	16.91	157.10	183.20	26.10
Weevil-infested tuber yield per plant (g)	68.00	143.72	84.80	103.06	58.58	2890.73	4270.42	1379.69
Weevil-infested tuber yield (t/ha)	68.00	143.72	84.79	103.06	58.57	20.09	29.67	9.58
Harvest index (%)	93.00	49.33	24.85	25.80	6.92	220.32	237.39	17.07
Fresh and dry weight of foliage (g)	88.00	38.88	20.15	21.51	7.54	21.67	24.70	3.03
Dry matter of tuber (%)	88.00	44.18	22.83	24.29	8.31	32.75	37.10	4.35
Total soluble solids (%)	57.00	18.80	12.33	16.12	10.62	1.48	2.61	1.13
Carotene mg/100g	81.00	49.47	26.61	29.48	12.70	2.76	3.39	0.63

4.5 Heterosis

Heterosis was estimated for all the seventeen characters. All the three types of heterosis *viz*., relative heterosis, heterobeltiosis and standard heterosis Sree Rethna (national check) were estimated and are presented in Table 4.9.

The results obtained for different characters have been described below

4.5.1 Vine length (cm)

The relative heterosis of this trait ranged from -65.57 (IGSP-16/Indira Madhur) to 92.41 per cent (IGSP-C-15/Indira Madhur). Out of fifteen hybrids fourteen were showed significant relative heterosis of which nine hybrids showed negative heterosis and six hybrids showed positive heterosis. The top hybrids showed significant negative relative heterosis for this trait were, IGSP-16/Indira Madhur, IGSP-C-15/Gauri, IGSP-18/Indira Madhur and IGSP-12/Indira Madhur etc.

The heterobeltiosis ranged from -74.39 per cent (IGSP-16/Indira Madhur) to 77.50per cent (IGSP-C-15/Indira Madhur). Among five hybrids showing significant positive heterobeltiosis and IGSP-12/Sree Rethna, IGSP-12/Gauri, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur and IGSP-16/Sree Rethna etc. showed negative heterosis for this trait.

The standard heterosis for vine length ranged from -75.29 per cent (IGSP-16/Indira Madhur) to -10.59 per cent (IGSP-18/Sree Rethna). All fifteen hybrids showed negative significant standard heterosis for this trait.

4.5.2 Vine weight (g)

The range of relative heterosis for vine weight varied from -11.44 per cent (IGSP-16/Gauri) to 451.72 per cent (IGSP-C-15/Indira Madhur). Among the fifteen hybrids, twelve hybrids showed significant heterosis, two exhibited non-significant negative relative heterosis. The top ranking hybrids for this trait were IGSP-C-15/Gauri, IGSP-18/Sree Rethna, IGSP-16/Indira Madhur IGSP-14/Gauri and IGSP-16/Sree Rethna etc.

Table 4.9 Heterosis (Over mid parent, better parent and check variety) for tuber yield and component characters

Hybrids	Vine length (cm)			Vine weight per plant (g)			Tuber length (cm)			Tuber diameter (cm)			Neck length of Tuber (cm)			Number of Tubers per plant		
	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH(%)
IGSP-12 x Sree Rethna	-62.20*	-71.76*	-71.76*	-14.06	-39.56 *	-39.56 *	-37.04 *	-43.33 *	-43.33 *	-8.33	82.27 *	82.27 *	-55.36 *	-55.36 *	-55.36 *	38.46 *	28.57 *	28.57 *
IGSP-12 x Gauri	-1.64	-3.23	-50.59 *	5.56	-10.38	-47.80 *	-5.88	-11.11	-20.00 *	144.32 *	112.87 *	95.45 *	-50.00 *	-53.13 *	-46.43 *	-4.00	-7.69	-14.29
IGSP-12 x Indira Madhur	31.71 *	28.57 *	-36.47 *	117.69 *	116.22 *	-47.80 *	40.59 *	33.96 *	18.33 *	163.82 *	159.90 *	138.64 *	-28.00 *	-35.71 *	-35.71 *	4.00	0.00	-7.14
IGSP-14 x Sree Rethna	-39.31*	-50.59 *	-50.59 *	84.21 *	73.08 *	73.08 *	-14.04	-18.33 *	-18.33 *	346.76 *	313.13 *	386.36 *	-47.83 *	-57.14 *	-57.14 *	-66.67 *	-71.43 *	-71.43 *
IGSP-14 x Gauri	-29.75 *	-36.33 *	-60.00 *	181.95 *	134.38 *	106.04*	24.07 *	24.07 *	11.67	155.26 *	101.54 *	137.27 *	30.00 *	1.56	16.07	-13.04	-23.08	-28.57 *
IGSP-14 x Indira Madhur	-48.61 *	-55.06 *	-71.76 *	80.26 *	31.25	15.38	12.15	11.11	0.00	251.65 *	208.88 *	263.64 *	5.00	-4.55	-25.00 *	30.43 *	15.38	7.14
IGSP-C-15 x Sree Rethna	-14.14 *	-40.00 *	-40.00 *	41.73 *	-1.10	-1.10	10.28	-1.67	-1.67	281.86 *	263.64 *	263.64 *	4.00	-7.14	-7.14	-20.00	-28.57 *	-28.57 *
IGSP-C-15 x Gauri	91.71 *	70.51 *	-12.94 *	326.97 *	258.49 *	108.79*	38.61 *	29.63 *	16.67 *	278.22 *	231.66 *	200.00 *	33.33 *	12.50	28.57 *	-25.00	-30.77 *	-35.71 *
IGSP-C-15 x Indira Madhur	92.41 *	77.50 *	-16.47 *	451.72 *	447.95 *	119.78*	-30.00*	-33.96*	-41.67 *	122.78 *	121.11 *	100.00 *	45.45 *	45.45 *	14.29	0.00	-7.69	-14.29
IGSP-16 x Sree Rethna	-53.29 *	-54.12 *	-54.12 *	176.66 *	163.74 *	163.74*	-11.11	-20.00 *	-20.00 *	222.75 *	205.69 *	241.82 *	-51.72 *	-53.33 *	-50.00 *	-18.52	-21.43	-21.43
IGSP-16 x Gauri	-37.80 *	-52.44 *	-54.12 *	-11.44	-27.27	-34.07 *	47.06 *	38.89 *	25.00 *	155.56 *	105.69 *	130.00 *	-16.13	-18.75	-7.14	38.46 *	38.46 *	28.57 *
IGSP-16 x Indira Madhur	-65.57 *	-74.39 *	-75.29 *	236.13 *	142.42 *	119.78*	-12.87	-16.98	-26.67**	164.71 *	137.80 *	165.91 *	30.77 *	13.33	21.43	61.54 *	61.54 *	50.00 *
IGSP-18 x Sree Rethna	17.47 *	-10.59 *	-10.59 *	237.84 *	174.73 *	174.73 *	39.22 *	18.33 *	18.33 *	410.64 *	336.36 *	336.36 *	84.62 *	71.43 *	71.43 *	-11.11	-14.29	-14.29
IGSP-18 x Gauri	20.73 *	19.37 *	-37.65 *	136.36 *	128.07 *	42.86*	-33.33*	-40.74*	-46.67*	312.42 *	304.49 *	186.82 *	133.93 *	104.69 *	133.93 *	-15.38	-15.38	-21.43
IGSP-18 x Indira Madhur	68.25 *	59.91 *	-16.47 *	71.12 *	40.35	-12.09	15.79	3.77	-8.33	353.41 *	307.14 *	262.73 *	4.35	0.00	-14.29	-46.15*	-46.15 *	-50.00 *

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Hybrids	Tuber weight per plant (g)			Tuber yield (t/ha)			Marketable tuber yield per plant (g)			Marketable tuber yield (t/ha)			Weevil- infested tuber yield per plant (g)			Weevil-infested tuber yield ((tonnes)		
	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
IGSP-12 x Sree Rethna	-23.03 *	-7.78	-33.62 *	-23.03 *	-33.63 *	-33.63 *	-66.24 *	-67.21 *	-67.21 *	-66.26 *	-67.23 *	-67.23 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-12 x Gauri	-2.97	-3.92	-28.99 *	-2.96	-3.92	-28.99 *	-17.39 *	-17.39 *	-22.13 *	-17.40	-17.40	-22.15	160.00 *	116.67	0.00	159.98 *	116.72	0.00
IGSP-12 x Indira Madhur	25.33 *	19.64 *	-4.64	25.34 *	19.64 *	-4.65	-46.15 *	-54.35 *	-56.97 *	-45.48 *	-54.35 *	-56.97 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-14 x Sree Rethna	-13.56 *	-26.09 *	-26.09 *	-13.57 *	-26.09 *	-26.09 *	65.91 *	49.59 *	49.59 *	65.89 *	49.56 *	49.56 **	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-14 x Gauri	22.00 *	19.61 *	-11.59 *	22.00 *	19.61 *	-11.60 *	26.76 *	17.39 *	10.66	26.75 *	17.37	10.63	225.00 *	225.00 *	0.00	224.82 *	224.82 *	0.00
IGSP-14 x Indira Madhur	48.08 *	40.00 *	11.59 *	48.06 *	39.99 *	11.57 *	12.36	2.04	-18.03 *	13.92	2.06	-18.04	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-C-15 x Sree Rethna	-39.85 *	-42.03 *	-42.03 *	-39.86 *	-42.04 *	-42.04 *	-69.96 *	-71.31 *	-71.31 *	-69.95 *	-71.30 *	-71.30 *	39.13	23.08	23.08	39.12	23.07	23.07
IGSP-C-15 x Gauri	61.74 *	45.31 *	34.78 *	61.74 *	45.32 *	34.77 *	12.83 *	10.87	4.51	12.83	10.86	4.49	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-C-15 x Indira Madhur	-49.58 *	-53.13 *	-56.52 *	-49.59 *	-53.13 *	-56.53 *	-39.79 *	-48.20 *	-52.87 *	-39.01 *	-48.19 *	-52.87 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-16 x Sree Rethna	14.50 *	8.70 *	8.70 *	14.49 *	8.68 *	8.68 *	-3.29	-3.69	-3.69	-3.31	-3.71	-3.71	71.43 *	38.46	38.46	71.40 *	38.46	38.46
IGSP-16 x Gauri	-13.27 *	-20.97 *	-28.99 *	-13.27 *	-20.96 *	-28.99 *	-23.73 *	-25.62 *	-26.23 *	44.06 *	40.49 *	39.33 *	-100.00	-100.00 *	-100.00 *	-100.00	-100.00 *	-100.00 *
IGSP-16 x Indira Madhur	93.16 *	82.26 *	63.77 *	93.16 *	82.25 *	63.75 *	123.88 *	85.95 *	84.43 *	126.61 *	85.95 *	84.41 *	100.00 *	80.00 *	38.46	99.95 *	79.99 *	38.46
IGSP-18 x Sree Rethna	-49.18 *	-55.07 *	-55.07 *	-49.19 *	-55.08 *	-55.08 *	18.24 *	15.69 *	20.90 *	18.24	15.70	20.89	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *	-100.00 *
IGSP-18 x Gauri	21.15 *	18.87 *	-8.70 *	21.16 *	18.88 *	-8.70 *	-50.52 *	-52.94 *	-50.82 *	-50.51 *	-52.94 *	-50.83 *	8.33	-35.00	0.00	8.32	-35.00	0.00
IGSP-18 x Indira Madhur	-7.78	-9.45	-27.83 *	-7.77	-9.45	-27.83 *	-32.53 *	-45.10 *	-42.62 *	-31.73 *	-45.10 *	-42.63 *	-40.00	-55.00 *	-30.77	-40.02	-55.01 *	-30.79

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Hybrids	Harvest index (%)			Fresh and dry weight of foliage (g)			Dry matter of tuber (%)			Total soluble solids (%)			Carotene mg/100 g		
	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
IGSP-12 x Sree Rethna	-5.69	-12.85 *	2.75	-17.83 *	-30.26 *	0.00	-8.20	-14.29 *	-1.18	-4.92	-12.12	-12.12	50.00 *	0.00	0.00
IGSP-12 x Gauri	-4.17	-6.56	10.16	-19.44 *	-23.68 *	9.43	-43.75 *	-44.90 *	-36.47 *	1.69	-3.23	-9.09	31.43 *	-14.81 *	-4.17
IGSP-12 x Indira Madhur	-13.81 *	-14.83 *	2.83	-8.72	-10.53	28.30 *	-23.81 *	-26.53 *	-15.29 *	4.92	-3.03	-3.03	11.76	-26.92 *	-20.83 *
IGSP-14 x Sree Rethna	-28.79 *	-31.48 *	-31.48 *	4.55	-12.66 *	30.19 *	-12.10 *	-18.82 *	-18.82 *	-5.71	-10.81	0.00	-15.79	-33.33 *	-33.33 *
IGSP-14 x Gauri	-35.19 *	-40.86 *	-33.75 *	4.76	-2.53	45.28 *	-32.53 *	-40.43 *	-34.12 *	-11.76	-18.92 *	-9.09	2.44	-22.22 *	-12.50
IGSP-14 x Indira Madhur	-7.07	-17.96 *	-0.95	27.63 *	22.78 *	83.02 *	-25.15 *	-32.97 *	-28.24 *	-37.14 *	-40.54 *	-33.33 *	-10.00	-30.77 *	-25.00 *
IGSP-C-15 x Sree Rethna	-27.55 *	-34.73 *	-18.59 *	3.64	0.00	7.55	-26.25 *	-30.59 *	-30.59 *	0.00	0.00	0.00	-27.27 *	-33.33 *	-33.33 *
IGSP-C-15 x Gauri	-27.55 *	-31.24 *	-14.24 *	7.20	-1.47	26.42 *	-39.64 *	-45.74 *	-40.00 *	-25.00 *	-27.27 *	-27.27 *	-2.13	-14.81 *	-4.17
IGSP-C-15 x Indira Madhur	-65.91 *	-66.46 *	-58.17 *	-16.92 *	-26.03 *	1.89	-43.37 *	-48.35 *	-44.71 *	-36.36 *	-36.36 *	-36.36 *	-8.70	-19.23 *	-12.50
IGSP-16 x Sree Rethna	-32.85 *	-32.95 *	-32.95 *	-14.69 *	-32.22 *	15.09	16.78 *	2.35	2.35	-8.47	-18.18 *	-18.18 *	-37.78 *	-41.67 *	-41.67 *
IGSP-16 x Gauri	-9.56 *	-14.53 *	-4.26	16.46 *	2.22	73.58 *	30.38 *	9.57	21.18 *	19.30 *	9.68	3.03	-50.00 *	-55.56 *	-50.00 *
IGSP-16 x Indira Madhur	-18.62 *	-25.71 *	-10.30	-5.52	-14.44 *	45.28 *	22.58 *	4.40	11.76	18.64 *	6.06	6.06	-65.96 *	-69.23 *	-66.67 *
IGSP-18 x Sree Rethna	-64.97 *	-66.09 *	-63.77 *	42.59 *	40.00 *	45.28 *	33.80 *	11.76	11.76	-16.92 *	-18.18 *	-18.18 *	-23.40 *	-25.00 *	-25.00 *
IGSP-18 x Gauri	-23.18 *	-24.95 *	-15.93 *	46.34 *	32.35 *	69.81 *	-15.23 *	-31.91 *	-24.71 *	1.59	0.00	-3.03	-28.00 *	-33.33 *	-25.00 *
IGSP-18 x Indira Madhur	-18.16 *	-22.87 *	-6.88	-28.13 *	-36.99 *	-13.21	31.08 *	6.59	14.12 *	-7.69	-9.09	-9.09	-30.61 *	-34.62 *	-29.17 *

*Significant at P=0.05 level, RH=Relative heterosis, HB=Heterobeltiosis, SH= Standard Heterosis

Table 4.10 : Top five hybrids on the basis of heterosis for tuber yield per plant (g)

S.No.	Hybrids		
	Relative heterosis (%)	**Heterobeltiosis (%)**	**Standard heterosis (%)**
1.	IGSP-16/Indira Madhur **(93.16 %)**	IGSP-16/Indira Madhur **(82.26 %)**	IGSP-16/Indira Madhur **(63.77 %)**
2.	IGSP-C-15/Gauri **(61.74 %)**	IGSP-C-15/Gauri **(45.31 %)**	IGSP-C-15/Gauri **(34.78 %)**
3.	IGSP-14/Indira Madhur **(48.08 %)**	IGSP-14/Indira Madhur **(40.00 %)**	IGSP-14/Indira Madhur **(11.59 %)**
4.	IGSP-12/Indira Madhur **(25.33 %)**	IGSP-12/Indira Madhur **(19.64 %)**	IGSP-16/ Sree Rethna **(8.70 %)**
5.	IGSP-14/Gauri **(22.00 %)**	IGSP-14/Gauri **(19.61%)**	IGSP-12/ Indira Madhur **(4.64%)**

Figures in parentheses shows heterosis percentage

The heterobeltiosis ranged from -1.10 per cent (IGSP-C-15/Sree Rethna) to 447.95 per cent (IGSP-C-15/Indira Madhur). Out of fifteen hybrids, ten showed significant heterosis over better parent, from which one hybrid showed significant negative heterobeltiosis for this trait. Highest negative heterobeltiosis was exhibited by hybrid IGSP-12/Sree Rethna, while, nine hybrids exhibited significant positive heterobeltiosis for vine weight.

The standard heterosis for this trait ranged from -47.80 per cent (IGSP-12/Gauri and IGSP-12/Indira Madhur) to 174.73 per cent (IGSP-18/Sree Rethna). Nine hybrids out of fifteen exhibited positive significant standard heterosis for vine weight per plant.

4.5.3 Tuber length (cm)

The relative heterosis for this trait ranged from -37.04 per cent (IGSP-12/Sree Rethna) to 47.04per cent (IGSP-16/Gauri). Among fifteen hybrids, eight hybrids showed significant relative

Table 4.11: Carotene rich hybrids of sweet potato

S.No.	Hybrids	Carotene (mg/100g)
1.	IGSP-12/ Sree Rethna	8.00
2.	IGSP-12/Gauri	7.67
3.	IGSP-C-15/Gauri	7.67
4.	IGSP-14/Gauri	7.00
5.	IGSP-C-15/Indira Madhur	7.00
6.	IGSP-12/ Indira Madhur	6.33
7.	IGSP-14/ Indira Madhur	6.00
8.	IGSP-18/ Sree Rethna	6.00
9.	IGSP-18/Gauri	6.00

heterosis, eight hybrids exhibited positive significant whereas, other six hybrids showed negative significant relative heterosis for vine weight per plant.

The extent of heterobeltiosis ranged from -43.33 per cent (IGSP-12/Sree Rethna) to 38.89 per cent (IGSP-16/Gauri) for this trait. Fifteen hybrids, ten hybrids showed significant heterobeltiosis and only five hybrids out of them showed significant positive heterobeltiosis for tuber length.

The heterosis over check variety was observed from -46.67 per cent (IGSP-18/Gauri) to 25.00 per cent (IGSP-16/Gauri).Eleven out of fifteen hybrids significant and five hybrids are showing significant positive heterosis, nine hybrids negative standard heterosis for tuber length.

4.5.4 Tuber diameter (cm)

The relative heterosis for this trait ranged from -8.33 per cent (IGSP-12/Sree Rethna) to 410.64 per cent (IGSP-18/Sree Rethna). All fourteen hybrids had significant positive relative heterosis except one hybrid (IGSP-12/Sree Rethna) which had negative relative heterosis.

The extent of heterobeltiosis ranged from 82.37 per cent (IGSP-12/Sree Rethna) to 336.36 per cent (IGSP-18/Sree Rethna) for this trait. All hybrids showed positive significant heterobeltiosis for tuber diameter.

The heterosis over check variety was observed from 82.27 per cent (IGSP-12/Sree Rethna) to 386.36 per cent (IGSP-14/Sree Rethna). All fifteen hybrids showed significant standard heterosis was observed significant positive standard heterosis for this trait.

4.5.5 Neck length of Tuber (cm)

The relative heterosis for this trait ranged from -55.36 per cent (IGSP-12/Sree Rethna) to 135.93 per cent (IGSP-18/Gauri). Eleven hybrids out of fifteen exhibited significant relative heterosis whereas, five hybrids showed negative significant relative heterosis, remaining six hybrids had significant positive standard heterosis for neck length of tuber.

The extent of heterobeltiosis ranged from -57.14 per cent (IGSP-14/Sree Rethna) to 104.69 per cent (IGSP-18/Gauri) for this trait. Eight hybrids out of fifteen hybrids showed significant heterobeltiosis while, three hybrids exhibited positive significant heterobeltiosis for neck length of tuber.

The heterosis over check variety was observed from -57.14 per cent (IGSP-14/Sree Rethna) to 133.93 per cent (IGSP-18/Gauri). Out of fifteen hybrids nine hybrids showed significant standard heterosis whereas, remaining six hybrids showed positive standard heterosis for neck length of tuber.

4.5.6 Number of tubers per plant

The range of relative heterosis for fruit length was observed between -66.67 per cent (IGSP-14/Sree Rethna) to 61.54 per cent (IGSP-16/Indira Madhur). Six hybrids showed significant relative heterosis out of fifteen, two hybrids showed negative significant for relative heterosis, remaining four hybrids showed positive significant relative heterosis for number of tubers per plant.

Heterobeltiosis for this trait ranged from -71.43 per cent (IGSP-14/Sree Rethna) to 61.54 per cent (IGSP-16/Indira Madhur). Seven hybrids out of fifteen showed significant and three hybrids showed significant positive heterobeltiosis, remaining four hybrids exhibited negative significant heterosis over better parent for number of tubers per plant.

The heterosis over check variety (standard heterosis) ranged from -71.43 per cent (IGSP-14/Sree Rethna) to 50.00 per cent (IGSP-16/Indira Madhur) for number of tubers. Among fifteen hybrids, eight hybrids were significant. three hybrids showed positive significant standard heterosis over check variety and remaining five hybrids exhibited significant negative standard heterosis for number of tubers per plant.

4.5.7 Tuber yield per plant (g)

The relative heterosis for fruit girth ranged from -49.58 per cent (IGSP-C-15/Indira Madhur) to 93.16 per cent (IGSP-16/Indira Madhur).Thirteen hybrids showed significant relative heterosis out of fifteen hybrids for this trait, seven hybrids had significant positive heterosis, On the other hand, six hybrids showed significant negative heterosis for this trait.

The heterosis over better parent (heterobeltiosis) ranged from -55.07 per cent (IGSP-18/Sree Rethna) to 82.26 per cent (IGSP-16/Indira Madhur). Out of fifteen hybrids, twelve showed significant heterobeltiosis for this trait. Only seven hybrids exhibited significant positive heterosis over better parent and remaining five hybrids had negative significant better parent (heterobeltiosis) for tuber yield per plant.

The range of standard heterosis for tuber yield was observed from -56.52 per cent (IGSP-C-5/Indira Madhur) to 63.77 per cent (IGSP-16/Indira Madhur). All fourteen hybrids showed significant standard heterosis, except one hybrid. Four hybrids out of fourteen hybrids exhibited significant positive heterosis over check variety while, other hybrids showed significant negative heterosis over check variety.

4.5.8 Tuber yield (t/ha)

For tuber yield, the relative heterosis among the hybrids ranged from -49.59 per cent (IGSP-C-15/Indira Madhur) to 93.16 per cent (IGSP-16/Indira Madhur). Among fifteen hybrids, thirteen hybrids showed significant in which seven hybrids showed positive relative heterosis. While, other eight hybrids exhibited significant negative heterosis for this trait.

The heterobeltiosis (heterosis over better parent) for tuber yield ranged from -55.08 per cent (IGSP-18/Sree Rethna) to 82.25 per cent (IGSP-16/Indira Madhur). Out of fifteen hybrids, thirteen hybrids exhibited significant heterobeltiosis. Seven hybrids showed positive significant heterobeltiosis and eight hybrids had negative heterobeltiosis for tuber yield .

The standard heterosis for tuber yield ranged from -56.53 per cent (IGSP-C-15/Indira Madhur) to 63.75 per cent (IGSP-16/Indira Madhur). Among fourteen hybrids out of fifteen showed significant standard heterosis whereas, four hybrids showed positive significant and ten hybrids exhibited negative significant heterosis over check variety.

4.5.9 Marketable tuber yield per plant (g)

The value of relative heterosis for this trait ranged from -69.96 per cent (IGSP-C-15/Sree Rethna) to 123.88 per cent (IGSP-16/Indira Madhur). Thirteen hybrids showed significant relative heterosis and five hybrids exhibited positive significant relative heterosis while, remaining eight hybrids showed negative significant relative heterosis for marketable tuber yield per plant.

The heterobeltiosis for this trait ranged from -71.31 per cent (IGSP-C-15/Sree Rethna) to 85.95 per cent (IGSP-16/Indira Madhur). Twelve hybrids out of fifteen hybrids showed significant heterobeltiosis, only four hybrids showed significant positive heterobeltiosis for this trait while, eight hybrids exhibited significant negative heterobeltiosis for this trait.

The heterosis over check variety ranged from -71.31 per cent (IGSP-C-15/Sree Rethna) to 84.43 per cent (IGSP-16/Indira Madhur). Among fifteen hybrids, twelve hybrids showed significant standard heterosis for this trait. Three hybrids showed significant positive standard heterosis and other nine hybrids exhibited significant negative heterosis over check variety for marketable tuber yield per plant.

4.5.10 Marketable tuber yield (t/ha)

The mid-parent heterosis (relative heterosis) for this trait ranged from -69.95 per cent (IGSP-C-15/Sree Rethna) to 126.61 per cent (IGSP-16/Indira Madhur). Ten hybrids showed significant relative heterosis and four hybrids showed positive significant relative heterosis whereas, remaining six hybrids exhibited significant negative heterosis for this trait.

The heterobeltiosis for this trait ranged from -71.30 per cent (IGSP-C-15/Sree Rethna) to 85.95 per cent (IGSP-16/Indira Madhur). Nine hybrids showed significant heterobeltiosis out of fifteen hybrids and three hybrids exhibited significant positive heterobeltiosis for this trait while, six hybrids had significant negative heterobeltiosis for this trait.

The extent of standard heterosis for marketable tuber yield ranged from -71.30 per cent (IGSP-C-15/Sree Rethna) to 84.41 per cent (IGSP-16/Indira Madhur). Nine hybrids exhibited significant standard heterosis and three hybrids showed significant positive standard heterosis for marketable tuber yield.

4. 5.11 Weevil-infested tuber yield per plant (g)

The relative heterosis for this trait ranged from -100 per cent (IGSP-12/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-16/Gauri and IGSP-18/Sree Rethna) to 225 per cent (IGSP-14/Gauri). Eleven hybrids showed significant relative heterosis for this trait out of fifteen hybrids. Among fifteen hybrids, four hybrids showed significant relative heterosis positive value whereas, remaining seven hybrids showed significant negative relative heterosis for this trait.

The range of heterobeltiosis for this trait ranged from -100 per cent (IGSP-12/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-16/Gauri and IGSP-18/Sree Rethna) to 225 per cent (IGSP-14/Gauri). Eleven out of fifteen hybrids showed significant heterobeltiosis and only two hybrids showed significant positive heterobeltiosis while, other nine hybrids exhibited significant negative heterobeltiosis for this trait.

The standard heterosis for this trait was observed from -100 per cent (IGSP-12/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-16/Gauri and IGSP-18/Sree Rethna) to 225 per cent (IGSP-14/Gauri) to 38.46 per cent (IGSP-16/Sree Rethna and IGSP-16/Indira Madhur). Eight hybrids out of fifteen hybrids showed significant negative standard heterosis and only three hybrids exhibited significant positive value for this character, other nine hybrids showed significant negative heterosis over check variety.

4.5.12 Weevil-infested tuber yield (t/ha)

The heterosis over mid parent (relative heterosis) ranged from -100 per cent (IGSP-12/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-16/Gauri and IGSP-18/Sree Rethna) to 224.82 per cent (IGSP-14/Gauri)) for this trait. Among fifteen hybrids, eleven hybrids exhibited significant relative heterosis for this trait. Four hybrids showed positive significant relative heterosis while, remaining seven hybrids showed significant negative relative heterosis for this trait.

The extent of heterosis over better parent (heterobeltiosis) ranged from -100 per cent (IGSP-12/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-16/Gauri and IGSP-18/Sree Rethna) to 225 per cent (IGSP-14/Gauri) to 38.46 per cent (IGSP-16/Sree Rethna). Out of fifteen hybrids, eleven hybrids showed significant heterobeltiosis and two among them exhibited significant positive

Table 5.1: SCA effects of hybrid combinations and GCA effects of the parents for tuber yield per plant (g)

Cross combination	SCA effects	GCA effects of females parent	GCA effect of male parents
IGSP-C-15/Gauri	293.55*	-43.55*(L)	28.66*(H)
IGSP-16/Indira Madhur	220.33*	162.00*(H)	63.00*(H)
IGSP-18/Gauri	96.88*	-96.89*(L)	28.66*(H)
IGSP-16/Sree Rethna	58.33*	162.00*(H)	-91.66*(L)
IGSP-14/Indira Madhur	53.67*	28.67*(H)	63.00*(H)
IGSP-12/Indira Madhur	39.22*	-50.22*(L)	63.00*(H)

*Significant at P = 0.01 level
H= High combining ability
L= Low combining ability

heterobeltiosis while, the remaining nine hybrids showed significant negative heterobeltiosis for this trait.

The standard heterosis for this trait was observed from -100 per cent (IGSP-12/Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-16/Gauri and IGSP-18/Sree Rethna) to 225 per cent (IGSP-14/Gauri) to 38.46 per cent (IGSP-16/Sree Rethna,and IGSP-16/Indira Madhur). Eight hybrids out of fifteen had significant standard heterosis and remaining nine hybrids showing non significant standard heterosis for this trait.

4.5.13 Harvest index (per cent)

Relative heterosis for average fruit weight ranged from -65.91 per cent (IGSP-C-15/Indira Madhur) to -4.17 per cent (IGSP-12/Gauri). Twelve hybrids out of fifteen hybrids showed significant relative heterosis for this trait. All hybrids exhibited significant negative relative heterosis for this trait.

Heterobeltiosis for average fruit weight ranged from -66.46 per cent (IGSP-C-15/Indira Madhur) to -6.56 per cent (IGSP-12/Gauri). Fourteen hybrids exhibited significant heterosis over better parent. All hybrids showed significant negative heterobeltiosis for this trait.

The standard heterosis for this character ranged from -63.77 per cent (IGSP-18/Sree Rethna) to 10.16 per cent (IGSP-12/Gauri). Eight hybrids showed significant standard heterosis and three of them exhibited significant positive heterosis over check variety, whereas, the other twelve hybrids showed significant negative standard heterosis for this traits.

4.5.14 Fresh and dry weight of foliage (g)

The relative heterosis for fresh and dry weight of foliage ranged from -19.44 per cent (IGSP-12/Gauri) to 46.34 per cent (IGSP-18/Gauri). Nine hybrids showed significant relative heterosis for this trait out of fifteen and four hybrids exhibited significant positive relative heterosis whereas, seven hybrids showed significant negative relative heterosis.

The heterobeltiosis for this trait ranged from -30.26 per cent (IGSP-12/Sree Rethna) to 40.00 per cent (IGSP-18/Sree Rethna). Ten hybrids out of fifteen hybrids showed significant heterobeltiosis. Out of them, three hybrids showed significant positive heterobeltiosis. While, remaining, ten hybrids showed significant negative heterobeltiosis.

The heterosis over check variety for fresh and dry weight of foliage ranged from -13.21 per cent (IGSP-18/Indira Madhur) to 83.02 per cent (IGSP-14/Indira Madhur). Nine hybrids showed significant positive standard heterosis out of them nine hybrids showed significant positive standard heterosis While, remaining one hybrid showed significant negative value for this character.

4.5.15 Dry matter of tuber (per cent)

The range of relative heterosis for dry matter of tuber was observed between-47.75 per cent (IGSP-12/Gauri) to 33.80 per cent (IGSP-12/Gauri). Fourteen hybrids out of fifteen showed

Table 5.2 Best general combiners and specific combiners for different characters

S. No.	Characters	Best general combiners		Best specific combiners
		Lines	Testers	
1	Vine length (cm)	IGSP-16,IGSP-14	Sree Rethna	IGSP-18/Sree Rethna, IGSP-C-15/Indira Madhur, IGSP-18/Indira Madhur
2	Vine weight (g)	IGSP-16,IGSP-14	Sree Rethna	IGSP-18/Sree Rethna, IGSP-16/Sree Rethna, IGSP-16/Indira Madhur
3	Tuber length (cm)	IGSP-14,IGSP-12, IGSP-16	Sree Rethna	IGSP-16/Gauri, IGSP-12/Indira Madhur, IGSP-18/Sree Rethna, IGSP-C-15/Gauri
4	Tuber diameter (cm)	IGSP-14,IGSP-16	Sree Rethna, Indira Madhur	IGSP-14/Sree Rethna, IGSP-18/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Sree Rethna
5	Neck length of tuber (cm)	IGSP-16	Gauri	IGSP-18/Gauri, IGSP-18/Sree Rethna, IGSP-C-15/Sree Rethna
6	Number of Tubers per plant	IGSP-16,IGSP-18	Sree Rethna	IGSP-16/Indira Madhur, IGSP-12/Sree Rethna, IGSP-16/Gauri, IGSP-14/ Indira Madhur
7	Tuber yield per plant (g)	IGSP-C-15,IGSP-16	Sree Rethna	IGSP-16/Indira Madhur, IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-16/Sree Rethna
8	Tuber yield (t/ha)	IGSP-C-15,IGSP-16	Sree Rethna	IGSP-16/Indira Madhur, IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-16/Sree Rethna
9	Marketable tuber yield per plant (g)	IGSP-18,IGSP-16	Sree Rethna	IGSP-16/Indira Madhur, IGSP-14/Sree Rethna, IGSP-18/Sree Rethna
10	Marketable tuber yield (t/ha)	IGSP-18,IGSP-16	Sree Rethna	IGSP-16/Indira Madhur, IGSP-14/Sree Rethna, IGSP-18/Sree Rethna
11	Weevil-infested tuber yield per plant (g)	IGSP-14	Gauri	IGSP-12/ Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri
12	Weevil-infested tuber yield (t/ha)	IGSP-14	Gauri	IGSP-12/ Sree Rethna, IGSP-12/Indira Madhur, IGSP-14/Sree Rethna, IGSP-14/Indira Madhur, IGSP-C-15/Gauri
13	Harvest index (%)	IGSP-C-15, IGSP-12	Indira Madhur, Gauri	IGSP-12/ Gauri , IGSP-12/Indira Madhur, IGSP-12/Sree Rethna, IGSP-14/Indira Madhur,
14	Total soluble solids (%)	IGSP-14	Sree Rethna, Indira Madhur	IGSP-16/Indira Madhur , IGSP-16/Gauri, IGSP-14/Sree Rethna, IGSP-C-15/ Sree Rethna
15	Fresh and dry weight of foliage (g)	IGSP-16	Sree Rethna	IGSP-14/Indira Madhur, IGSP-16/Gauri, IGSP-18/Gauri,
16	Dry matter of tuber (%)	IGSP-12	Gauri	IGSP-16/Gauri, IGSP-14/Indira Madhur, IGSP-16/Indira Madhur, IGSP-18/Sree Rethna
17	Carotene (mg/100g)	IGSP-18	Gauri	IGSP-12/Sree Rethna,IGSP-12/ Gauri, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur, IGSP-12/Indira Madhur
18	Organoleptic taste	IGSP-C-15	Gauri	IGSP-C-15/Indira Madhur,IGSP-18/Sree Rethna, IGSP-18/Sree Rethna ,IGSP-14/ Sree Rethna, IGSP-18/ Gauri

significant relative heterosis, from which five hybrids exhibited positive significant relative heterosis. Other nine hybrids showed significant negative heterosis for dry matter of tuber.

Heterobeltiosis for this trait ranged from -48.35 per cent (IGSP-C-15/Indira Madhur) to 11.76 per cent (IGSP-18/Indira Madhur). Ten hybrids exhibited significant heterosis over better parent and one hybrid showed significant positive heterobeltiosis and remaining hybrids had significant negative heterobeltiosis for this trait.

The heterosis over check variety (standard heterosis) ranged from -44.71 per cent (IGSP-C-15/Indira Madhur) to 21.18 per cent (IGSP-16/Gauri) for dry matter per cent. Eleven hybrids from fifteen hybrids reported significant standard heterosis and two hybrids showed significant positive heterosis over check variety whereas, ten hybrids showed significant negative standard heterosis.

4.5.16 Total soluble solids (per cent)

The relative heterosis for this trait ranged from -37.14 per cent (IGSP-14/Indira Madhur) to 19.30 per cent (IGSP-16/Gauri). Six hybrids out of fifteen hybrids showed significant relative heterosis and two hybrids among them showed significant positive relative heterosis for this trait and other nine hybrids had significant negative relative heterosis for this trait.

The heterobeltiosis for this trait ranged from -40.54 per cent (IGSP-14/Indira Madhur) to 9.68 per cent (IGSP-16/Gauri). Among fifteen hybrids, five hybrids, showed significant heterobeltiosis for this trait remaining hybrids among them exhibited significant negative heterobeltiosis for total soluble solids.

The heterosis over check variety for total soluble solids was observed from -36.36 per cent (IGSP-C-15/Indira Madhur) to 6.06 per cent (IGSP-16/Indira Madhur). Five hybrids showed significant standard heterosis and all seven hybrids exhibited significant negative standard heterosis for this character.

Table 5.3: Desirable parents/hybrids for tuber yield and its components

S.No.	Parents/hybrids	Desirable characters
Lines		
1.	IGSP-12	Tuber yield per plant (g), dry matter (%)
2.	IGSP-14	Tuber length (cm), tuber diameter (cm), total soluble solids (%)
3.	IGSP-C-15	Harvest index (%),organoleptic taste
4.	IGSP-16	Vine length (cm),vine weight (g), neck length (cm), fresh and dry weight of foliage (g)
5.	IGSP-18	Number of tubers per plant, marketable tuber yield per plant (g), weevil infested tuber yield per plant (g)
Testers		
1.	Sree Rethna	Vine length (g) ,tuber yield per plant(g), vine weight (g), tuber length (cm), number of tubers, marketable tuber yield per plant (g), weevil-infested tuber yield per plant
2.	Gauri	Neck length, dry matter percentage, carotene (mg/100g),organoleptic taste
3.	Indira Madhur	Harvest index (%), fresh and dry weight of foliage (g), total soluble solids (%)
Hybrids		
1.	IGSP-12/Sree Rethna	Carotene (mg/100g)
2.	IGSP-12/Gauri	Harvest index (%)
3.	IGSP-14/Sree Rethna	Tuber diameter (cm)
4.	IGSP-14/Indira Madhur	Fresh and dry weight of foliage (g)
5.	IGSP-C-15/Indira	organoleptic taste
6.	Madhur	weevil-infested tuber yield per plant (g)
7.	IGSP-16/Sree Rethna	Tuber length (cm), dry matter (%)
8.	IGSP-16/Gauri IGSP-16/Indira Madhur	Number of tubers per plant, tuber yield per plant (g), marketable tuber yield per plant (g), weevil-infested tuber yield per plant (g), total soluble solids (%)
9.	IGSP-18/Sree Rethna	Vine length (cm), vine weight (g)
10.	IGSP-14/Gauri	Neck length (cm)

4.5.17 Carotene (mg/100g)

The relative heterosis for this trait ranged from -65.96 per cent (IGSP-16/Indira Madhur) to 50.00 per cent (IGSP-12/Sree Rethna). Among fifteen hybrids, nine hybrids showed significant relative heterosis and two hybrids among them showed significant positive relative heterosis for this trait and other seven hybrids showed significant negative relative heterosis for this trait.

The heterobeltiosis for this trait ranged from -55.56 per cent (IGSP-16/Gauri) to -14.81 per cent (IGSP-12/Gauri). Among fifteen hybrids, five hybrids showed significant heterobeltiosis for this trait. All hybrids among them exhibited significant negative heterobeltiosis for carotene mg/100g.

The heterosis over check variety for total soluble solids was observed from -66.67 per cent (IGSP-16/Indira Madhur) to -4.17 per cent (IGSP-12/Gauri). Among fifteen hybrids ten hybrids exhibited significant standard heterosis for this character.

The top five hybrids selected on the basis of highest relative heterosis, heterobeltiosis and standard heterosis for total tuber yield per plant are presented in Table 4.10.

The estimates of relative heterosis, heterobeltiosis and standard heterosis were also obtained for tuber yield and its components. A high degree of heterosis was observed for all the characters studied. The highest relative heterosis was exhibited by the hybrid, IGSP-C-15/Indira Madhur followed by IGSP-18/Sree Rethna, IGSP-14/Gauri and IGSP-18/Gauri; high heterobeltiosis was reported in IGSP-C-15/Indira Madhur followed by IGSP-18/Sree Rethna, IGSP-14/Gauri and IGSP-18/Gauri ; Highest standard heterosis was shown by IGSP-14/Sree Rethna followed by IGSP-18/Sree Rethna, IGSP-18/Gauri and IGSP-16/Indira Madhur for total tuber yield per plant. However, a high degree of heterosis for other traits in desired direction was also observed.

4.6 Carotene rich hybrids

4.6.1 Parents

The mean performance of carotene rich hybrids are presented in Table 4.11 and (PlateV), (PlateVI).

The carotene of tuber flesh ranged from 2.67 mg/100g (IGSP-12) to 9 mg/100 g (Gauri) with an over all parental mean of 6.25 mg/100 g.

Among the female parent (lines), IGSP-18 (7.67 mg/100 g) had highest mean value for this trait and IGSP-12 (2.67 mg/100 g) showed lowest mean value as compared to line average of 5.73 mg/100 g. Among the testers, Gauri (9 mg/100 g) showed highest per centage of carotene of

Table 5.4 Shape, *per se* performance, sca effects, heterosis of F_1 hybrids, shape and gca effects of the parents for total tuber yield per plant (g)

S. No.	Hybrids	Tuber shape	*per se performance* tuber yield per plant	sca effects	gca effects of female	gca effects of male	Heterosis		
							RH (%)	HB (%)	SH (%)
	1	2	3	4	5	6	7	8	9
1.	IGSP-16/Indira Madhur	Long elliptic	941.67	220.33*	162*(H)	63.00*(H)	93.16*	82.26*	63.77*
2.	IGSP-C-15/Gauri	Long oblong	775.00	293.55*	-43.55* (L)	28.66*(H)	61.76*	45.31*	34.78*
3.	IGSP-14/Indira Madhur	Elliptic	641.67	53.67*	28.67*(H)	63.00*(H)	48.08*	40.00*	11.59*
4.	IGSP-16/Sree Rethna	Long oblong	625.00	58.33*	162*(H)	-91.67*(L)	14.50*	8.7*	8.7*
5.	IGSP-12/Indira Madhur	Elliptic	548.33	39.22*	-50.22*(L)	63.00*(H)	25.33*	19.64*	-4.64*

***Significant at P= 0.05 level; H= High combining ability, L= Low combining ability**
RH= Relative heterosis, HB= Heterobeltiosis, SH= Standard heterosis

tuber flesh while, Sree Rethna (8.0 mg/100 g) recorded the lowest mean value for this trait compared to over all tester mean of 8.55 mg/100 g.

4.6.2 Hybrids

The hybrids mean for this trait ranged from 4.00 mg/100 g (IGSP-16/Gauri) to 8.00 mg/100 g (IGSP-12/Sree Rethna) with an overall mean of (5.60 mg/100 g),which is followed by IGSP-12/Gauri (7.67 mg/100 g), IGSP-14/Gauri, IGSP-C-15/Indira Madhur (7.00 mg/100 g) and IGSP-12/Indira Madhur (6.33 mg/100 g). Highest values of carotene were observed in IGSP-12/Sree Rethna (8.00 mg/100 g) in which line IGSP-12 was used as female parent.

CHAPTER – V

DISCUSSION

Commercial exploitation of heterosis in last quarter of 20th century has led to remarkable yield advance in several crops irrespective of their breeding systems. In vegetable crops, several hybrids and varieties have been developed having consumer's preference and quality. The productivity of F_1 hybrids of sweet potato had led to the preference of farmers for cultivation. The consumer's preference is also varying from region to region for yield, flesh colour and other traits.

Systematic and organized research is still lacking in tuber crops including sweet potato, particularly in the state of Chhattisgarh. Considering round the year cultivation of sweet potato, there is tremendous scope for developing high-yielding hybrids and varieties coupled with tolerance/resistance to major insect specially for weevil.

The state is endowed with vast majority of local genotypes of sweet potato which lacks the high productivity coupled with disease pest problems and quality parameters like carotene, total soluble solids and organoleptic test etc. This need felt objective was taken care in the present investigation by including the local genotypes of Chhattisgarh.

The present investigation was undertaken to work out the selection of desirable genotypes for tuber yield and measuring the gca and sca varieties and their effects as well as the genotypic components of varieties of parents lines and hybrids along with heterosis association analysis for tuber yield and its components. The Line x Tester design used in the present investigation comprised of eight genetically diverse parents lines.

The usefulness of this technique is based on magnitude of heterosis, nature of gene action and combining ability of parents. Under these circumstances, the present investigation L x T analysis in sweet potato was undertaken during 2009 to 2011. The results of the present findings are discussed under the following heads:

5.1 Combining Ability and Gene Action

5.1.1 Vine length (cm)

The variance due to gca was higher than gca variance for vine length, indicating the key dominance of non additive gene action for vine length.

The results are similar to finding of Birhman and Kaul (1989), Mohd Said,(1993) and Das and Barua (2001), whereas additive gene action for vine length was reported by Gopal (1998) and Das and Barua (2001), who reported importance of both additive and non-additive gene action for this trait. Positive gca effect are desirable as a crop habits is spending and eruct are related to tuber yield.

All five lines registered significant gca effect and two lines (IGSP-18, IGSP-C-15) showed significant positive effect among the testers. Among the hybrids, high positive gca effect were recorded for IGSP-12/Indira Madhur followed by IGSP-18/Sree Rethna, IGSP-14/Sree Rethna, IGSP-C-15/Gauri and IGSP-16/Sree Rethna.

These findings indicate that the high mean performance of the crosses is associated with positive gca effect with hybrids having non or out of the parents showing high gca effect, thereby suggesting the presence of non-additive gene action. Similar observations were also reported by Gopal (1998), Das and Barua (2001) and Singh *et al.* (2003).

5.1.2 Vine weight (g)

The ratio of gca variance to sca variance being less than unity form vine weight relatives pre dominance of non-additive gene action

The results are in accordance with the reports of Singh *et al.* (2003). Whereas, contradictory results were also reported by Mohd Said (1993), Padmanabhan and Jagdish (1996), but Das and Barua (2001) reported that it is governed by both additive and non-additive gene action.

Line IGSP-16, IGSP-C-15, IGSP-18 and IGSP-14 showed significant positive gca effect and among the tester Sree Rethna showed significant positive gca effect for vine weight per plant which determines the tuber yield per plant.

Among the hybrids, high positive significant gca effect was shown by IGSP-18/Sree Rethna followed IGSP-16/Sree Rethna, IGSP-14/Gauri, IGSP-C-15/Gauri, IGSP-C-15/Indira Madhur and IGSP-16/Indira Madhur. The lines and testers of these hybrids also showed high and low gca effect indicative of the predominance of additive gene action for these crosses resulted in their heterosis performance. These findings are in accordance to the observations of Birhan and Kaul (1989), Das and Barua (2001) and Singh *et al. (*2003).

5.1.3 Tuber length (cm)

The variance due to gca was greater than sca variance indicating the performance of non-additive gene action for this trait.

Positive and significant general combining ability effects were observed in the parents IGSP-14 and tester Gauri. Among the hybrids, high significant gca effect was shown by IGSP-12/Indira Madhur followed by IGSP-18/Sree Rethna, IGSP-16/Gauri and IGSP-C-15/Sree Rethna. IGSP-12, one of the parents of some of the crosses mentioned above had positive gca effect but most of them had negative gca effect thereby, confirming the presence of non-additive gene action in the form of over dominance and epistasis for hybrids with high gca effects. The results are in confirmation with Pandey and Sharma (1997), Gopal (1998), Kumar and Kang *(*2002) and Padma *et al.(*2009).

The preference of different tuber shape from region to region therefore, involvement of the specific genotypes as per requirement may be useful as a parent in hybridization programme for getting the desirable tuber crops in resulting genotypes.

5.1.4 Tuber diameter (cm)

The ratio of gca variance and sca variance being less than unify tuber diameter revealed predominance of non-additive gene action.

The importance of non-additive gene action for tuber diameter was also reported by earlier workers like, Padmanabhan and Jagdish (1996) and Solanky and Singh (2010).

The gca effects was found highest in line IGSP-18 and IGSP-14 whereas, IGSP-12, IGSP-C-15 and IGSP-16 had significant negative gca effects. Whereas, high gca effect was shown by tester Sree Rethna. In case of hybrids, high positive gca effects was shown by IGSP-C-15/Gauri followed by IGSP-14/Sree Rethna, IGSP-12/Indira Madhur and IGSP-12/Gauri.

The high gca effects of hybrids are associated with the present performance of the hybrids having non one of them parents having high gca effects indication the predominance of non-additive gene action. These findings are similar to the reports of Das and Barua (2001), Yu-Hua *et al.*(2003),Yadav *et al.*(2008) and Ummyiah *et al.*(2010).

5.1.5 Neck length of tuber (cm)

The variance due to sca is greater than gca variance, indication the predominance of non-additive gene action for this trait. Similar results were suggested by Gaur *et al.* (1993), Gopal (1998) and Kumar *et al.*(2008) whereas ,both additive and non-additive gene action for this trait reported by Padmanabhan and Jagdish (1996), and Jackson and Bohac (2006).

Positive and significant general combining ability effects were observed in the parents IGSP-18 and IGSP-C-15 and tester. Among the hybrids, high significant gca effect was shown by IGSP-18/Gauri followed by IGSP-16/Indira Madhur, IGSP-18/Sree Rethna and IGSP-12/Indira Madhur.

The high sca effects of hybrids are associated with the per gca performance of the hybrids having none or one of the parents having high gca effects indicated the predominance of non-additive gene action. These finding are similar to the reports of Mohd Said (1993) and Ashwani and Khandelwal (2005).

5.1.6 Number of tubers per plant

The variance due to sca is greater than gca variance, indicated the predominance of non-additive gene action for this trait which ultimately favours the possibility of exploiting heterosis in the present material for number of tubers per plant.

The gca result are in accordance with the findings of Owolad (2006), Fang *et al.* (2011) whereas, additive gene action was reported by Kamalakkannan *et al.*(2007).

Lines, *viz.,* IGSP-16 and IGSP-12 had significant positive gca effects whereas, only one tester Indira Madhur showed significant positive gca effects. Among the hybrids, IGSP-12/Sree Rethna showed highest positive gca effect followed by IGSP-18/Sree Rethna and IGSP-16/Indria Madhur. One of the parents of all the crosses mentioned above for positive gca effects showed negative gca effects, thereby confirming the presence of non-additive gene action in the form of over dominance and epistle for hybrids with high sca effects. Barman and Kaul (1989), Mohd Said (1993), Jackson and Bohak (2006) suggested the high gca and sca effect for number of tubers per plant.

5.1.7 Tuber yield per plant (g)

The gca variance for tuber yield per plant was greater than variance due to sca, indicating predominance of non-additive gene action which revealed the exploitation of heterosis in the present material. Similar results were also reported by Gaur *et al.*(1993) Padmanabhan and Jagdish (1996), Gopal (1998) and Kumar *et al.*(2008), and importance of both additive and non-additive gene action was reported by Manivel *et al.*(2010). Yield per plant is the effect of the component characters related to it. Among the lines two lines showed significant positive gca effects *viz.,* IGSP-16/ and IGSP-12 (PlateII). Two tester *viz.,* Indira Madhur and Sree Rethna (PlateIII) showed significant positive gca effects.

In case of hybrids, six hybrids showed significant positive gca effects for this trait. Among those superior hybrids on the basis of high positive gca effects were IGSP-C-15/Gauri, IGSP-

16/Indira Madhur, IGSP-18/Gauri, IGSP-16/Sree Rethna and IGSP-14/Indira Madhur (PlateIV). The top hybrids on the basis of sca effects along with gca effects of their parents for tuber yield per plant are presented in Table 5.1. These findings are in accordance with the reports of Yu Hua *et al.*(2003), Rajkumar *et al.*(2008) and Yadav *et al.*(2008). The best general and specific combiners for tuber yield related trait have been depicted in Table 5.2 and 5.3.

5.1.8 Tuber yield (t/ha)

The sca variance for tuber yield (t/ha) was greater than variance due gca indication predominance of non-additive gene action. Among the lines two lines showed significant positive gca effects *viz.,* IGSP-16 and IGSP-14. Only two testers' *viz.,* Indira Madhur and Gauri showed significant positive gca effects.

In case of six hybrids showed significant positive gca effects for this trait. Among those superior hybrids on the basis of high positive gca effects were, IGSP-C-15/Gauri followed by IGSP-16/Gauri, IGSP-18/Gauri, IGSP-16/Sree Rethna and IGSP-14/Indira Madhur. The top hybrids on the basis of gca effects along with gca effects of their parents for tuber yield per plant are presented in Table 5.1.These findings are in accordance with the reports of Tai (1976), Sharma *et al*.(1998) and Yu Hua *et al.*(2003).

5.1.9 Marketable tuber yield per plant (g)

The sca variance for this trait was greater than the variance due to gca, which indicates the predominance of non-additive gene action for this character. Similar results have been reported by Pandey and Gupta (1997).

Among the female parents, IGSP-16 and IGSP-14 showed significant positive gca effects. Whereas, in case of tester were non significant. Parents with high gca effects are good general combiner for this trait. Among the hybrids, six hybrids recorded significant positive effects, IGSP-16/Indira Madhur effects top ranks followed by IGSP-C-15/Gauri, IGSP-18/Sree Rethna, IGSP-14/Sree Rethna and IGSP-12/Gauri showed highest sca effects.

These hybrids had one or both showing high gca effects indication the presence of non-additive gene action for this trait. These finding are in accordance with the reports of Plaisted *et al.*(1962) and Pandey and Gupta (1997).

5.1.10 Marketable tuber yield (t/ha)

The sca variance for this trait was greater than the variance due to gca, which indicates the predominance of non-additive gene action for this character. Similar results have been reported by Pandey and Gupta (1997).

Among the female parents, IGSP-16 and IGSP-14 showed significant positive gca effects. Whereas in case of tester, Gauri showed significant positive gca effects.

Top five by hybrids are IGSP-16/Indira Madhur followed by IGSP-18/Sree Rethna, IGSP-14/Sree Rethna, IGSP-C-15/Gauri and IGSP-12/Indira Madhur. These finding are in accordance with the reports of Plaisted *et al.*(1962) and Pandey and Gupta (1997).

5.1.11 Weevil-infested tuber yield per plant (g)

The sca variance for this trait was greater than the variance due to gca, which indicates the predominance of non-additive gene action for this character. These findings are in accordance with the reports of Tai (1976),Yu Hua *et al.*(2003) and Sharma *et al.* (1998).

Among the female IGSP-16 showed positive significant positive sca effects whereas, in case of tester all testers had non-significant gca effects. Among the hybrids, five hybrids recorded significant positive gca effects top parents IGSP-C-15/Sree Rethna followed IGSP-14/Gauri, IGSP-12/Gauri, IGSP-16/Indira Madhur and IGSP-16/Sree Rethna.

5.1.12 Weevil-infested tuber yield (t/ha)

The sca variance for this trait was greater than the variance due to gca, which indicates the predominance of non-additive gene action for this character. These findings are in accordance with the reports of Tai (1976), Sharma *et al.* (1998) and Yu Hua *et al.* (2003).

Among the female IGSP-16 showed positive significant effects whereas, in case of tester, all testers had non-significant gca effects. Among the hybrids five hybrids recorded significant positive gca effects top parents were, IGSP-C-15/Sree Rethna followed by IGSP-14/Gauri, IGSP-12/Gauri, IGSP-16/Indira Madhur and IGSP-16/Sree Rethna.

5.1.13 Harvest Index (%)

The sca variance noticed for this trait was greatest than that of gca variance indicating the predominance of non-additive gene action.

These findings are in accordance with the reports of Tai (1976) Sharma *et al.* (1998) and Yu Hua *et al.* (2003),

The character gca effects for lines was found highest in only IGSP-12 and among tester *viz*., Gauri and Indira Madhur had significant positive gca effects. In case of hybrids, highest significant positive gca effects was observed for IGSP-C-15/Sree Rethna followed IGSP-18/Indira Madhur, IGSP-14/Indira Madhur and IGSP-12/Sree Rethna.

5.1.14 Fresh and dry weight of foliage (g)

The ratio of sca variance and the gca variance was less than unity for fresh and dry weight of foliage revealed predominance of non-additive gene action. The gca effects was highest in line IGSP-14 and IGSP-16 whereas, IGSP-12 and IGSP-C-15 had significant negative gca effect shown by tester Gauri. These results are in accordance with the findings of Vimala *et al.* (2011) and Zhiang *et al.* (2002).

In case of hybrids, high positive gca effects was shown by IGSP-14/Indira Madhur, IGSP-18/Sree Rethna, IGSP-18/Gauri, IGSP-12/Indira Madhur and IGSP-16/Gauri.

One of the parents of all the crosses mentioned above for positive gca effects showed negative gca effects thereby confirming the presence of non-additive gen action in form of over dominance and epistasis for hybrids with high gca effects.

5.1.15 Dry matter of tuber (%)

The variance due to sca is greater than gca variance, indicating, there predominance of non-additive gene action for this trait which ultimately favour the possibility of exploiting heterosis in the present material for dry mater of tuber (%). These result are in accordance with findings of Takahata *et al.* (1993), Rahman *et al.* (1998), Bhattacharya (2001),Chattopadhyay *et al.* (2002) and Zhiang *et al.* (2002).

Lines *viz.,* IGSP-16 and IGSP-18 had significant positive gca effects whereas, only one tester Sree Rethna showed significant positive gca effects. Among the hybrids, IGSP-16/Gauri showed highest positive gca effect, followed by IGSP-18/Indira Madhur and IGSP-12/Indira Madhur. One of the parents of all the crosses mentioned above for positive gca effects showed negative gca effects, there by confirming the presence of non-additive gene action in the form of over dominance and epistasis for hybrids with high gca effects.

5.1.16 Total soluble solids (%)

The gene action for this trait was predominantly non-additive as the estimated variance of sca was higher than all gca variance. Similar results were obtained by Lila Babu *et al.*(1990), Chattopadhyay *et al.* (2002) and Zhang *et al.* (2002).

Among the lines, IGSP-16 showed significant positive gca effects and all testers exhibited negative gca effects. Whereas, two hybrids showed positive significant gca effects top rankers were IGSP-15/Sree Rethna and IGSP-14/Sree Rethna.

The presence of one or both the parents with positive gca effects in the percentage of hybrids with high negative gca effects indicated the existence of non-additive gene action.

5.1.17 Carotene mg/100 g

The ratio of sca variance and gca variance being less than unit indication predominance of non-additive gene action for this character. Thus, it revealed the possibility of exploiting heterosis for this character. Among the lines, high gca effect was shown by IGSP-12 and IGSP-C-15, in testers, high gca effect was observed in Gauri. In case of hybrids, high gca effects was shown by IGSP-16/Sree Rethna.

The presence of one or both the parents with positive gca effects in the percentage of hybrids with high negative gca effects indicating the existence of non-additive gene action.

Similar results were obtained by Lila babu (1988), Goswami (1990), Vasudevan *et al.* (1990) and Takahata *et al.* (1993)

5.2 Genetic Variability, Heritability and Genetic Advance

For improvement of crop character, the breeder has to select superior individual from their phenotypic expression. Selection based on the phenotypic expression is sometime misleading, as the development of a character is the result of the heritable and non-heritable factors. This highlights the imperative need for partitioning the overall variability into its heritable and non-heritable components. Thus, the components of variation such as genotypic co-efficient of variance (GCV) and phenotypic co-efficient of variation (PCV) were computed. The PCV was higher than the GCV for the characters under study.

The genotypic co-efficient of variation helps to measure the range of genetic variability in character and provides measure to compare the genetic variability present in various quantitative characters. Burten (1952) suggest that genotypic co-efficient of variation along with heritability gives clear picture of gain to be expected from selection. The character, which exhibited high heritability indicator the presence of additive gene action and such characters could be fixed by resorting to selection (Panse, 1957). According to Johnson *et al.* (1955), heritability estimates could not be alone guideline for improvement work, since high heritability does not mean high expected genetic gain.

Therefore, the heritability estimates appear to be more meaningful when accompanied by estimates of genetic advances. Thus, the data of present investigation subjected to heritability in broad sense and genetic advance for all the characters under study and estimates of heritability grouped into high (above 60%), moderate (31 to 60%) and low (below 30%). In the same way the estimates of genotypes advance as percentage of mean grouped into high (above 20%), moderate (10 to 20%) and low (below 10%) as suggested by Johnson *et al.* (1955). The results obtained on above genetical parameters are discussed below:

High genotypic as well as phonotypic co-efficient of variations were observed for *viz.,* weevil infested tuber yield tonnes per hectare, weevil-infested tuber yield per ha, vine weight per plant, tuber diameter neck length of tuber, marketable tube yield per plant, vine length, tuber yield per plant and tuber yield tonne/ha moderate magnitude of GCV and PCV were observed for number of tubers per plant, carotene mg/100 g. Harvest index (%), dry matter of tuber, tuber length (cm.), fresh and dry weight of foliage, low GCV and PCV were observed for total soluble solids (%). The estimates of GCV and PCV of the present study were closely in agreement with the finding of Singh *et al.* (1998).

The heritability estimates was found higher for all the characters studied from 57.00 per cent to 98. 26 per cent indication that the characters are less influenced by environmental factors, this closely follows the findings of Singh *et al.* (1988).

High heritability estimates were obtained for vine length, tuber diameter, tuber yield per plant, tuber yield tonnes per ha, marketable tuber yield per plant and vine weight per plant. The additive genetic variance was relatively more important than non-additive genetic variance for the total soluble solids.

Non additive genetic variance played a major role since the heritability estimates was very low. Similar finding was reported by Jong (1974).

Sankari *et al.* (2000) reported that high heritability coupled with high genetic advance was observed for vine length, vine girth and yield tuber per vine.

Vimala and Lakshmi (1990) reported that high heritability estimates were obtained for tuber length, tuber weight, number of branches, tuber girth and vine weight whereas, low heritability estimates were observed for vine length, vine girth number of leaves per branch, petiole length and number of tubers.

High genotypic as well as phenotypic co-efficient of variations were observed for traits *viz.* Weevil-infested tuber yield per plant, vine weight per plant, tuber diameter, neck length of tuber and marketable tuber yield per plant. Moderate magnitude of GCV and PCV were observed for vine length, tuber yield per plant, number of tubers per plant and carotene mg/100g whereas, low GCV and PCV were observed for total soluble solids. The estimates of GCV and PCV of the present study was closely in agreement with the finding of Kamalam *et al.* (1977), Balashanmugam *et al.* (1980) Rao *et al.* (1992), Kumar *et al.* (1996), Alam *et al.* (1998), Hossain *et al.* (2000), Sankari *et al.* (2000) and Engida *et al.* (2007).

The heritability estimates was found higher for all the characters studied from 57.00% to 98.26 % indicating that the characters are less influenced by environmental factors.The result closely follows the finding of Mahungu *et al.* (1970), Patel *et al.* (1973), Kamalam *et al.* (1977), Jones *et al.* (1986), Rao *et al.* (1992), Mohd Said (1993), Mok *et al.* (1997), Alam *et al.* (1998), Bhutani *et al.* (2003), Ashebo *et al.* (2004), Luthra *et al.* (2005), Sahu *et al.* (2005) Chandrakar (2007), Kumar *et al.* (2008), Cheema *et al.* (2009), Akinwale *et al.* (2010), Chaurasia *et al.* (2010), Yadav *et al.* (2010) and Lekha *et al.* (2011).

Genetic advance

The amount of progress expected through selection for obtaining the individuals can not be made only on the basis of heritability alone. Hence, the heritability estimates could be best utilized in conjugation with genetic advance for prediction genetic gain.

High genetic advance as per cent of mean estimate was recorded for weevil-infested tuber yield tonnes per ha, vine weight per plant, tuber diameter, neck length of tuber and marketable tuber yield per plant. Similar result were reported by Thamburaj and Muthukrishna (1976), Vimala and Lakshmi (1990), Ashebo *et al.* (2004), Sahu *et al.* (2005), Cheema *et al.* (2009), Akinwale *et al.* (2010), Chaurasia *et al.* (2010), Yadav *et al.* (2010) and Lekha *et al.* (2011),who also observed high genetic advance for number of tubers per plant and tuber length whereas, high heritability and genetic advance were measured for biological yield per plant, total tuber yield per plant and vine weight per plant. Sankari *et al.* (2000) reported that high genetic advance was observed for vine length, vine diameter and yield of roots per vine.

These characters showed the predominance of additive gene action and can be improved through selection.

5.3 Heterosis

The 20th century was recorded in the history of crop improvement programme for the development of superior varieties and hybrids in different crops which has revolutionized the productivity and making the country self reliant. The vegetable crops are not exceptions to it. The varieties and hybrids in the crops like Brinjal, Tomato, Okra, Cabbage and tuber crops and many other vegetables have created impact among the farmers for their cultivation.

In the present study heterosis is reported overmid parents (relative heterosis) over better parents (heterobeltiosis), over check varieties (standard heterosis) *viz.*, Sree Rethna (National check), Gauri (orange-fleshed), Indira Madhur (high-yielding varieties). The results of the present study are discussed for the following characters with respect to heterosis.

5.3.1 Vine length (cm)

Highest positive relative heterosis was shown by IGSP-15/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-18/Indira Madhur, IGSP-18/Gauri and IGSP-18/Sree Rethna. Highest positive standard heterobeltiosis was exhibited by IGSP-C-15/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-18/Indira Madhur, IGSP-12/Indira Madhur and IGSP-18/Gauri. Highest negative standard heterosis was shown by IGSP-16/Indira Madhur. Nine, eight and fifteen hybrids showed significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively. These finding of heterosis are similar to observations of Bacusmo and Carpama (1982),Vimala and Lakshmi (1990) and Gopal and Minocha (1998).

5.3.2 Vine weight (g)

Highest positive relative heterosis was shown by IGSP-C-15/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-18/Sree Rethna, IGSP-14/Gauri and IGSP-18/Gauri. Highest positive heterobeltiosis was observed for IGSP-C-15/Indira Madhur followed by IGSP-18/Sree Rethna, IGSP-16/Indira Madhur, IGSP-14/Gauri and IGSP-18/Gauri whereas, highest positive standard heterosis was exhibited by IGSP-18/Sree Rethna followed by IGSP-16/Sree Rethna followed by IGSP-C-15/Gauri, IGSP-18/Sree Rethna, IGSP-14/Gauri and IGSP-18/Gauri for vine weight per vine.

5.3.3 Tuber length (cm)

High positive relative heterosis was recorded for fifteen hybrids *viz*., IGSP-16/Gauri, IGSP-13/Indira Madhur, IGSP-18/Sree Rethna, IGSP-C-15/Gauri and IGSP-14/Gauri.

Highly significant positive hetrobeltiosis was exhibited for IGSP-16 followed by IGSP-12/Indira Madhur, IGSP-C-15/Gauri, IGSP-14/Gauri and IGSP-18/Sree Rethna, whereas, IGSP-16/Gauri, IGSP-18/Sree Rethna, IGSP-12/Indira Madhur, IGSP-C-15/Gauri and IGSP-14/Gauri showed highly significant positive standard heterosis for tuber length.

These hybrids with high *per se* performance need not to be the one with high gca effects and vice-versa. Similar result for heterosis were reported by Bacusmo and Carpama (1982), Vimala and Lakshmi (1990) and Nanda (1994).

5.3.4 Tuber diameter (cm)

The relative heterosis for tuber diameter was found significant in fourteen hybrids, the top ranking hybrids were IGSP-18/Sree Rethna, IGSP-18/Indira Madhur, IGSP-14/Sree Rethna, IGSP-18/Gauri and IGSP-C-15/Sree Rethna. The heterosis over better parent was found positively significant in all fifteen hybrids. The top ranking hybrids were, IGSP-18/Sree Rethna, IGSP-14/Sree Rethna, IGSP-18/Indira Madhur, IGSP-18/Gauri and IGSP-C-15/Sree Rethna. All hybrids showed positive significant standard heterosis, the top ranking hybrids were, IGSP-14/Sree Rethna, IGSP-18/Sree Rethna, IGSP-C-15/Sree Rethna, IGSP-C-15/Indira Madhur, IGSP-18/Sree Rethna and IGSP-16/Sree Rethna. Similar result have been reported by Sidhu (1996), Biswas *et al.* (1997) and Dayal and Yadav (1998).

5.3.5 Neck length of tuber (cm)

High positive relative heterosis was recorded for eleven hybrids *viz.*, IGSP-18/Gauri, IGSP-18/Sree Rethna, IGSP-C-15/Indira Madhur, IGSP-C-15/Gauri and IGSP-16/Indira Madhur. Highly significant positive heterobeltiosis was exhibited for IGSP-C-18/Gauri followed by IGSP-18/Sree Rethna, IGSP-C-15/Indira Madhur, IGSP-C-15/Gauri and IGSP-16/Indira Madhur. Whereas, IGSP-18/Gauri, IGSP-18/Sree Rethna, IGSP-C-15/Gauri, IGSP-16/Indira Madhur and IGSP-14/Gauri showed highly significant positive standard heterosis for neck length of tuber. Similar results for heterosis were reported by Biswas *et al.* (1997),Yamakawa (1998) and Dayal and yadav (1998).

5.3.6 Number of tubers per plant

Highest positive relative heterosis was shown by the hybrid, IGSP-16/Indira Madhur followed by IGSP-16/Gauri and IGSP-14/Indira Madhur. Highest positive heterobeltiosis was shown by the hybrid IGSP-16/Indira Madhur, followed by IGSP-16/Gauri, IGSP-12/Sree Rethna and IGSP-14/Indira Madhur. Highest positive standard heterosis was exhibited by IGSP-16/Indira Madhur, IGSP-16/Gauri and IGSP-12/Sree Rethna. Most of the hybrids showed negative relative heterosis heterobeltiosis and standard heterosis. Similar results were observed by Bacusmo and Carpama (1982),Vimala and Lakshmi (1990) and Nanda (1994).

5.3.7 Tuber yield per plant (g)

High positive relative heterosis was shown by IGSP-16/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-12/Indira Madhur and IGSP-14/Gauri. Six hybrids showed significant positive heterobeltiosis, the hybrids showing highest heterobeltiosis were IGSP-16/Indira Madhur followed IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-12/Indira Madhur and IGSP-14/Gauri. Highest positive standard heterosis was exhibited by IGSP-16/Indira Madhur (PlateVII) followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur (PlateVIII), IGSP-16/Sree Rethna (PlateIX) and IGSP-12/Sree Rethna. The top five hybrids selected on the basis of highest relative heterosis,heterobeltiosis and standard heterosis for tuber yield per plant are presented in Table 4.10 and the detailed genetic analysis of the top hybrids are depicted in Table 5.4. Similar results were also observed by Patel *et al.*(1973), Bacusmo and Carpama (1982), Vimala and Lakshmi (1990), Neele *et al.* (1991) and Gopal and Minocha (1998).

5.3.8 Tuber yield (t/ha)

High positive relative heterosis was shown by IGSP16/Indira Madhur, IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-12/Indira Madhur and IGSP-14/Gauri. Seven hybrids exhibited significant positive heterobeltiosis and the hybrids showing highest heterobeltiosis were IGSP-16/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-12/Indira Madhur and IGSP-14/Gauri. Highest positive standard heterosis was shown by IGSP-16/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur and IGSP-16/Sree Rethna. Similar results were also reported by Patel *et al.* (1973), Bacusmo and Carpama (1982), Vimala and Lakshmi (1990), Neele *et al.* (1991) and Gopal and Minocha (1998).

5.3.9 Marketable tuber yield per plant (g)

Highest relative heterosis was shown by IGSP-16/Indira Madhur followed by IGSP-14/Sree Rethna, IGSP-14/Gauri, IGSP-18/Sree Rethna and IGSP-C-15/Gauri. High heterobeltiosis was observed in the hybrid IGSP-16/Indira Madhur followed by IGSP-14/Sree Rethna, IGSP-14/Gauri and IGSP-18/Sree Rethna. Highest standard heterosis was found in the hybrid IGSP-

16/Indira Madhur followed by IGSP-14/Sree Rethna and IGSP-18/Sree Rethna. These finding are similar to the reports of Neele *et al.* (1991) and Gopal and Minocha (1998) .

5.3.10 Marketable tuber yield (t/ha)

Highest relative heterosis was shown by IGSP-16/Indira Madhur followed by IGSP-14/Sree Rethna, IGSP-16/Gauri and IGSP-14/Gauri. High heterobeltiosis was observed in the hybrid IGSP-16/Indira Madhur followed by IGSP-14/Sree Rethna and IGSP-16/Gauri. Highest standard heterosis was found in the hybrid IGSP-16/Indira Madhur followed by IGSP-14/Sree Rethna and IGSP-16/Gauri. The results are in agreement with the report of Bacusmo and Carpama (1982),Vimala and Lakshmi (1990) and Gopal and Minocha (1998).

5.3.11 Weevil-infested tuber yield per plant (g)

The highest relative heterosis was observed for IGSP-14/Gauri followed by IGSP-12/Gauri, IGSP-16/Indira Madhur and IGSP-16/Sree Rethna were prominent whereas, eight hybrids exhibited significant negative relative heterosis. The heterobeltiosis of this trait was found highest in two hybrids *viz*., IGSP-14/Gauri and IGSP-16/Indira Madhur. Eight hybrids exhibited significantly negative standard heterosis for this character. Similar result were reported by Bacusmo and Carpama (1982), Vimala and Lakshmi (1990) and Gopal and Minocha (1998).

5.3.12 Weevil-infested tuber yield (t/ha)

The highest relative heterosis was observed for eleven hybrids and IGSP-14/Gauri followed IGSP-12/Gauri, IGSP-16/Indira Madhur and IGSP-16/Sree Rethna were prominent whereas, seven hybrids exhibited significant negative relative heterosis. The heterobeltiosis of this trait was found highest in two hybrids *viz*.,IGSP-14/Gauri and IGSP-16/Indira Madhur. Eight hybrids exhibited significant negative standard heterosis for this character.

Similar findings were reported by Bacusmo and Carpama (1982),Vimala and Lakshmi (1990) and Gopal and Minocha (1998).

5.3.13 Harvest Index (%)

All relative heterosis was shown significant negative relative heterosis and also heterobeltiosis and standard heterosis result found all significant negative heterosis. These finding of heterosis are similar to observation of Gopal *et al.* (1998),Patel *et al.* (2007) and Vaghela *et al.* (2007).

5.3.14 Fresh dry weight of foliage (g)

Higher positive relative heterosis was shown by IGSP-18/Gauri followed by IGSP-18/Sree Rethna, IGSP-14/Indira Madhur and IGSP-16/Gauri. Highest positive heterobeltiosis was shown by the hybrid IGSP-18/Sree Rethna followed by IGSP-18/Gauri and IGSP-14/Indira Madhur. Highest positive standard heterosis was shown by IGSP-14/Indira Madhur, followed by IGSP-16/Indira Madhur, IGSP-18/Gauri, IGSP-14/Gauri, IGSP-16/Indira Madhur, IGSP-16/Sree Rethna and IGSP-14/Sree Rethna. These finding of heterosis are similar to observations of Vasudevan *et al.* (1996), Rahman *et al.* (1998), Bhattacharya (2001), Chhattopadhyay *et al.* (2002) and Zhang *et al*. (2002).

5.3.15 Dry matter of tuber (%)

Highest positive heterosis was shown by IGSP-18/Sree Rethna followed by IGSP-18/Indira Madhur, IGSP-16/Gauri, IGSP-16/Indira Madhur and IGSP-16/Sree Rethna heterobeltiosis in these hybrids all hybrids were prominent whereas ten hybrids exhibited significant negative heterobeltiosis heterosis. Highest positive standard heterosis was shown by IGSP-16/Gauri and IGSP-18/Indira Madhur in overall nine hybrids were exhibited significant negative standard heterosis. Similarly result were reported by Vasudevan *et al.* (1996), Rahman *et al*. (1998), Bhattacharya (2001),Chhattopadhyay *et al.* (2002) and Zhang *et al.* (2002).

5.3.16 Total soluble solids (%)

Highest relative heterosis in total soluble solids was shown by IGSP-16/Gauri and IGSP-16/Indira Madhur and three hybrids exhibited significant negative relative heterosis. The highest heterosis over better parent was exhibite by IGSP-18/Sree Rethna followed by IGSP-16/Sree

Rethna, IGSP-14/Gauri and IGSP-C-15/Indira Madhur. Standard heterosis in total soluble solids, eight hybrid shown significant negative heterosis entry fifteen hybrids. Similar result were reported by Vasudevan *et al.* (1996), Rahman *et al.* (1998), Bhattacharya (2001), Chhattopadhyay *et al.* (2002) and Zhiang *et al.* (2002).

5.3.17 Carotene (mg/100g)

Nine hybrids shown negative significant relative heterosis out of fifteen hybrids. Heterobeltiosis heterosis, eleven hybrids out of fifteen were significant negative and also standard heterosis ten hybrids found negative significant in carotene mg/100 g. These finding of heterosis are similar to observation of Goswami (1990), Kays (1992), Takahata (1993) and Vasudevan *et al.* (1996).

CHAPTER-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

The present investigation entitled "Combining ability analysis for yield and quality attributes in sweet potato (*Ipomoea batatas* L. Lam.)" was undertaken to study the heterosis, to determine the extent of variability, heritability and genetic advance for various quantitative characters, to estimate the general combining ability and specific combining ability of parents and hybrids, respectively and finally to study the association of tuber yield and its contributing traits of sweet potato.

The experimental material consisted five local genotypes of Chhattisgarh as lines, *viz*., IGSP-12, IGSP-14, IGSP-C-15, IGSP-16 and IGSP-18; three testers (improved varieties) *viz*., Sree Rethna, Gauri and Indira Madhur, resulting with fifteen cross combinations. The parents were crossed in L x T mating fashion during 2009-10 and the F_1's were evaluated in 2010-11. All the experimental material including parents, hybrids were planted in Randomized Block Design with three replications during 2011-12 in All India Coordinated Research Project (A.I.C.R.P.), Horticulture Research Farm, Department of Horticulture,Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), India.

Observations were recorded for vine length (cm), vine weight (g), tuber length (cm) tuber diameter (cm), neck length of tuber (cm),number of tubers per plant, tuber yield per plant (g), tuber yield (t/ha), marketable tuber yield per plant (g), marketable tuber yield (t/ha), weevil-infested tuber yield per plant (g), weevil-infested tuber yield (t/ha), harvest index (%), fresh and dry weight of foliage (g), dry matter of tuber (%), total soluble solids (%) and carotene (mg/100g) on five random competitive plant basis in each replication. Line x Tester analysis was carried out adopting the method suggested by Kempthorne (1957). Analysis of variance revealed that the variance due to lines was significant for the character *viz*., Vine length (cm) and total tuber yield per plant Whereas, the variance due to lines was non-significant for other all characters. The variance due to Testers was non-significant for all the characters except total tuber yield per plant, while, the variance due to Line x Testers were significant for all the characters.

On the basis of combining ability analysis, the following lines were found good general combiner for different characters. Line IGSP-12 was found good general combiner for dry matter of tuber; line IGSP-14 was best combiner for tuber length and total soluble solids; line IGSP-C-15 for tuber yield per plant, tuber yield tonnes per ha, harvest index (%) and carotene (mg/100g). Line IGSP-16 was found good general combiner for vine length, vine weight, neck length of tuber, number of tubers per plant and fresh and dry weight of foliage tuber, line IGSP-18 for marketable tuber yield per plant, marketable tuber yield tonnes per ha, weevil-infested tuber yield per plant and weevil-infested tuber yield (t/ha).

On the basis of specific combining ability effects, the following hybrids have been found superior for different characters. Hybrid, IGSP-12/Gauri for harvest index (%);IGSP-14/Sree Rethna for tuber diameter; IGSP-14/Gauri for weevil-infested tuber yield tonnes per ha; IGSP-14/Indira Madhur for fresh; IGSP-C-15/Gauri for carotene (mg/100g); IGSP-16/Gauri for tuber length and dry matter of tuber IGSP-16/Indira Madhur for number of tubers per plant, tuber yield per plant, tuber yield tonnes per ha, marketable tuber yield per plant, marketable tuber yield tonnes per ha, weevil-infested tuber yield per plant and total soluble solids; IGSP-18/Sree Rethna for vine length and vine weight; IGSP-18/Gauri for neck length of tuber.

High genotypic and phenotypic coefficients of variation were observed for weevil-infested tuber yield tonnes per ha, weevil-infested tuber yield per plant, vine weight per plant, tuber diameter, neck length of tuber, marketable tuber yield per plant, marketable tuber yield tonnes per ha. Moderate genotypic and phenotypic coefficient of variations were observed for vine length, tuber yield per plant, tuber yield tonnes per ha, number of tubers per plant, carotene (mg100g), harvest index, dry matter of tuber and tuber length whereas, low genotypic and phenotypic coefficient of variations were observed for fresh and dry weight of foliage and total soluble solids.

All the characters showed high broad sense heritability estimates. High genetic advance was observed for vine length (cm), vine weight (g), tuber length (cm) tuber diameter (cm), neck length of tuber (cm), number of tubers per plant, tuber weight per plant (g), tuber yield (t/ha), marketable tuber yield per plant (g), marketable tuber yield (t/ha), weevil infested tuber yield per plant (g), weevil-infested tuber yield (t/ha), harvest index (%), fresh and dry weight of foliage (g), dry matter of tuber (%), total soluble solids (%), and carotene (mg/100g).

The estimates of relative heterosis, heterobeltiosis and standard heterosis were also obtained for tuber yield and its components. A high degree of heterosis was observed for all the characters studied. The highest relative heterosis was exhibited by the hybrid, IGSP-16/Indira madhur, followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-12/Indira Madhur and IGSP-14/Gauri; high heterobeltiosis was reported in IGSP-16/Indira Madhur, followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-12/Indira Madhur and IGSP-14/Gauri. Highest standard heterosis was shown by IGSP-16/Indira Madhur followed by IGSP-C-15/Gauri, IGSP-14/Indira Madhur ,IGSP-16/Sree Rethna and IGSP-12/Indira Madhur for total tuber yield per plant. However, a high degree of heterosis for other traits in desired direction was also observed. Therefore, direct selection for these characters will help in development of high yielding varieties of sweet potato of different tuber shapes and flesh colour by using local genotypes for Chhattisgarh.

Suggestions for future work

Based on the results obtained from the present investigation, the following future line of work is suggested.

1. The local genotype of Chhattisgarh used as line *viz.*, IGSP-C-15, IGSP-16 and IGSP-18 identified as best general combiner for tuber yield per plant should further be utilized in hybrid breeding programme.

2. Testers, Sree Rethna, Gauri, and Indira Madhur identified as good general combiners for most of the characters should be utilized in recombination breeding programme.
3. The hybrids, IGSP-16/Indira Madhur, IGSP-C-15/Gauri, IGSP-14/Indira Madhur, IGSP-16/Sree Rethna and IGSP-12/Indira Madhur showed superior *per se* performance and high standard heterosis for tuber yield per plant.
4. The lines and testers identified with high carotene can be utilized in development and improvement in deficiency of Vitamin A and hybrids with organoleptic taste can be used for demand of highly carbohydrates food requirement.
5. Characters like vine length, number of tubers plants, weevil-infested tuber yield per plant and marketable tuber yield per plant should be considered as selection criterion for developing high-yielding varieties in sweet potato for Chhattisgarh plains.
6. Large number of local genotypes available in Chhattisgarh which may have valuable genes for different characters, should be collected, evaluated and utilized for the development of different flesh colour and root shape variants of sweet potato particularly for Chhattisgarh State.

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APPENDIX-IV

Other Morphological characters of parents

Genotypes	Plant type	Vine internode		Vine pigmentation		Vine tip pubescence	General outline of leaf	Type of leaf lobes
		Length	Diameter	Predominant colour	Secondary colour			
IGSP-12	Erect	Short	Very short	green	Purple nodes	Moderate	hastate	Moderate
IGSP-14	Semi compact	Very short	Very short	Green few purple colour	Purple nodes	Very heavy	Cordate	No lateral lobes
IGSP-C-15	Erect	Long	Short	Green	Green base	None	Lobed	Slight
IGSP-16	Semi compact	Long	Intermediate	Green few purple spot	Purple nodes	Moderate	Cordate	No lateral lobed
IGSP-18	Erect	Very long	Long	Green	Purple nodes	Sparse	Cordate	No lateral lobed
Sree Rethna	Semi compact	Short	Long	Green few purple colour	Green tip	Sparse	Reniform	Moderate
Gauri	Erect	Intermediate	Intermediate	Green few purple colour	Green nodes	Sparse	Reniform	No lateral lobed
Indira Madhur	Erect	Very long	Long	Green	Purple nodes	Sparse	Cordate	No lateral lobed

Cont…

Note: Erect (less than 75 cm), Semi compact (75-150 cm), Spreading (151-250 cm), Extremely spreading (more than 250 cm)

Genotypes	Number of leaf lobes	Shape of central lobe	Abaxial leaf vein pigmentation	Foliage colour		Petiole length	Vein pigmentation	Petiole colour	Skin colour of Tuber	Root shape	Flesh colour
				Mature leaf colour	Immature leaf colour						
IGSP-12	3	Semi-Elliptic	Green	Green	Green	Short	Pigmented spots in several veins	Purple with green near stem	Dull white	Elliptic	Pale orange
IGSP-14	4	Semi-Elliptic	Green	Green	Green	Short	Pigmented spot in main rib	Green	Red	Long oblong	Cream
IGSP-C-15	1	Semi-circular	Green	Green	Green	Short	Main rib partially pigmented	Green	Red	Elliptic	orange
IGSP-16	5	Semi-circular	Purple spot in several veins	Green	Green	Short	Pigmented spot in main rib	Some petiole purple or green	White	Elliptic	Light orange
IGSP-18	5	Elliptic	Green	Green	Green	Short	Main rib partially pigmented	Green	Red	Long elliptic	Yellow
Sree Rethna	7	Semi-Elliptic	Purple spot in several veins	Green	Green	Very Short	No pigmentation	Green	Red	Round elliptic	Orange
Gauri	5	Semi-circular	All veins mostly or totally purple	Green	Green	Very short	Pigmented spots in several veins	Green	Dark red	Round elliptic	Dark orange
Indira Madhur	5	Semi-circular	Purple spot in several veins	Green with purple edge	Green with purple edge	Short	No pigmentation	Green	Red	Elliptic	Dark orange

APPENDIX-V

Other Morphological characters of hybrids

Genotypes/Lines	Plant type	Vine internode		Vine pigmentation		Vine tip pubescence	General outline of leaf	Type of leaf lobes
		Length	Diameter	Predominant colour	Secondary colour			
IGSP-12 x Sree Rethna	Erect	Short	Very short	green	Purple nodes	Moderate	hastate	Moderate
IGSP-12 x Gauri	Erect	Very short	Short	Green	Purple base	Sparse	Cordate	No lateral lobes
IGSP-12 x Indira Madhur	Semi compact	Short	Very short	Green many purple spot	Purple nodes	Sparse	Cordate	No lateral lobes
IGSP-14 x Sree Rethna	Erect	Very short	Very short	Green few purple colour	Purple nodes	Very heavy	Cordate	No lateral lobes
IGSP-14 x Gauri	Erect	Intermediate	Intermediate	Green	Green base	Heavy	Lobed	Slight
IGSP-14 x Indira Madhur	Erect	Short	Intermediate	Green	Purple nodes	Sparse	Lobed	Slight
IGSP-C-15 x Sree Rethna	Semi compact	Long	Short	Green	Green base	None	Lobed	Slight
IGSP-C-15 x Gauri	Semi compact	Very short	Very short	Green many purple spot	Purple nodes	Sparse	Triangular	Moderate
IGSP-C-15 x Indira Madhur	Semi compact	Very short	Short	Green few purple spot	Purple nodes	Moderate	Triangular	Moderate
IGSP-16 x Sree Rethna	Erect	Long	Intermediate	Green few purple spot	Purple nodes	Moderate	Cordate	No lateral lobed
IGSP-16 x Gauri	Erect	Very long	Intermediate	Green few purple spot	Purple nodes	Sparse	Cordate	No lateral lobed
IGSP-16 x Indira Madhur	Erect	Long	Short	Green few purple colour	Green purple nodes	Sparse	Cordate	No lateral lobed
IGSP-18 x Sree Rethna	Semi compact	Very long	Long	Green	Purple nodes	Sparse	Cordate	No lateral lobed
IGSP-18 x Gauri	Semi compact	Short	Long	Green few purple colour	Green tip	Sparse	Reniform	No lateral lobed
IGSP-18 x Indira Madhur	Semi compact	Intermediate	Intermediate	Green few purple colour	Green nodes	Sparse	Reniform	No lateral lobed

Note: Erect (less than 75 cm), Semi compact (75-150 cm), Spreading (151-250 cm), Extremely spreading (more than 250 cm)

Genotypes/Lines	Number of leaf lobes	Shape of central lobe	Abaxial leaf vein pigmentation	Foliage colour		Petiole length	Vein pigmentation	Petiole colour	Skin colour of Tuber	Root shape	Flesh colour
				Mature leaf colour	Immature leaf colour						
IGSP-12 x Sree Rethna	3	Semi-Elliptic	Green	Green	Green	Short	Pigmented spots in several veins	Purple with green near stem	Red	Elliptic	Pale orange
IGSP-12 x Gauri	4	Semi-Elliptic	Green	Green	Green	Short	Pigmented spot in main rib	Green	Red	Long oblong	Dark orange
IGSP-12 x Indira Madhur	1	Semi-circular	Green	Green	Green	Short	Main rib partially pigmented	Green	Pink	Elliptic	Cream
IGSP-14 x Sree Rethna	5	Semi-circular	Purple spot in several veins	Green	Green	Short	Pigmented spot in main rib	Some petiole purple or green	Purple red	Round	Creamy
IGSP-14 x Gauri	5	Elliptic	Green	Green	Green	Short	Main rib partially pigmented	Green	Red	Long irregular	Dark orange
IGSP-14 x Indira Madhur	7	Semi-Elliptic	Purple spot in several veins	Green	Green	Very Short	No pigmentation	Green	Dark purple	Elliptic	Dark orange
IGSP-C-15 x Sree Rethna	5	Semi-circular	All veins mostly or totally purple	Green	Green	Very short	Pigmented spots in several veins	Green	White	Long oblong	Dark orange
IGSP-C-15 x Gauri	5	Semi-circular	Purple spot in several veins	Green with purple edge	Green with purple edge	Short	No pigmentation	Green	White	Long irregular	Dark orange
IGSP-C-15 x Indira Madhur	5	Semi-circular	Green	Mostly purple	Mostly purple	Very Short	Main rib partially pigmented	Green	White	Elliptic	White
IGSP-16 x Sree Rethna	3	Semi-Elliptic	Purple spot in several veins	Green	Green with purple edge	Short	No pigmentation	Green	Pink	Long oblong	Dark orange
IGSP-16 x Gauri	5	Semi-circular	Green	Green	Green with purple edge	Very Short	Main rib partially pigmented	Green with purple near stem	Red	Long elliptic	White
IGSP-16 x Indira Madhur	3	Semi-circular	Green	Green	Green	Short	No pigmentation	Green	Purple red	Long elliptic	Dark orange
IGSP-18 x Sree Rethna	5	Semi-Elliptic	Green	Mostly purple	Green	Short	Pigmented spot in main rib	Green	Dark purple	Long irregular	Dark orange
IGSP-18 x Gauri	5	Semi-circular	Green	Green	Green	Very Short	All veins mostly pigmented	Purple with green near stem	Purple red	Long elliptic	Yellow
IGSP-18 x Indira Madhur	5	Semi-circular	Purple spot in several veins	Green	Green	Very Short	No pigmentation	Green	Dark purple	Long elliptic	White