

**GENETIC VARIABILITY FOR SEED YIELD AND
GRAIN QUALITY PARAMETERS IN SUNFLOWER**

(Helianthus annuus L.)

By

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B.Sc. (Agri.)

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MASTER OF SCIENCE

(Agriculture)

IN

AGRICULTURAL BOTANY

(GENETICS AND PLANT BREEDING)



**DEPARTMENT OF AGRICULTURAL BOTANY
COLLEGE OF AGRICULTURE, LATUR
MARATHWADA AGRICULTURAL UNIVERSITY,
PARBHANI**

2007

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DISSERTATION

Submitted To
The Marathwada Agricultural University, Parbhani. In Partial
Fulfillment Of The Requirements For The Degree Of

MASTER OF SCIENCE
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DEPARTMENT OF AGRICULTURAL BOTANY
COLLEGE OF AGRICULTURE, LATUR
MARATHWADA AGRICULTURAL UNIVERSITY,
PARBHANI

2007



Dedicated To My Beloved

Aai, Pappa, Bhaiya And

Sir

For Building Up My

Educational Career

And Excellent Wishes

Throughout My Life

CANDIDATE'S DECLARATION

I hereby declare that the dissertation
or part thereof, has not been
previously submitted by
me for a degree of
any University.



Place : Latur

(DHANASHILA SUBHASH SUTAR)

Date : 19 / 5 / 2007

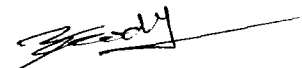
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CERTIFICATE – I

This is to certify that the dissertation entitled “**GENETIC VARIABILITY FOR SEED YIELD AND GRAIN QUALITY PARAMETERS IN SUNFLOWER (*Helianthus annuus* L.)**” submitted by **Miss. DHANASHILA SUBHASH SUTAR** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)** is record of original and bonafide research work carried out by her under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.

I also certify that the dissertation or part thereof has not been previously submitted by her for a degree of any university.

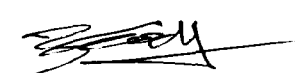
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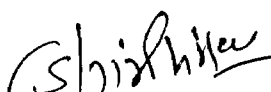
CERTIFICATE – II

This is to certify that the dissertation entitled “**GENETIC VARIABILITY FOR SEED YIELD AND GRAIN QUALITY PARAMETERS IN SUNFLOWER (*Helianthus annuus* L.)**” submitted by **Miss. DHANASHILA SUBHASH SUTAR** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)** has been approved by the student’s advisory committee after viva-voce examination in collaboration with the external examiner.


External Examiner

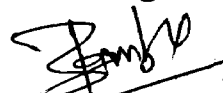

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Lastly with humble sense, I want to bow before that supreme cosmic consciousness from which everything originates and goes at end.

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(Dhanashila Subhash Sutar)

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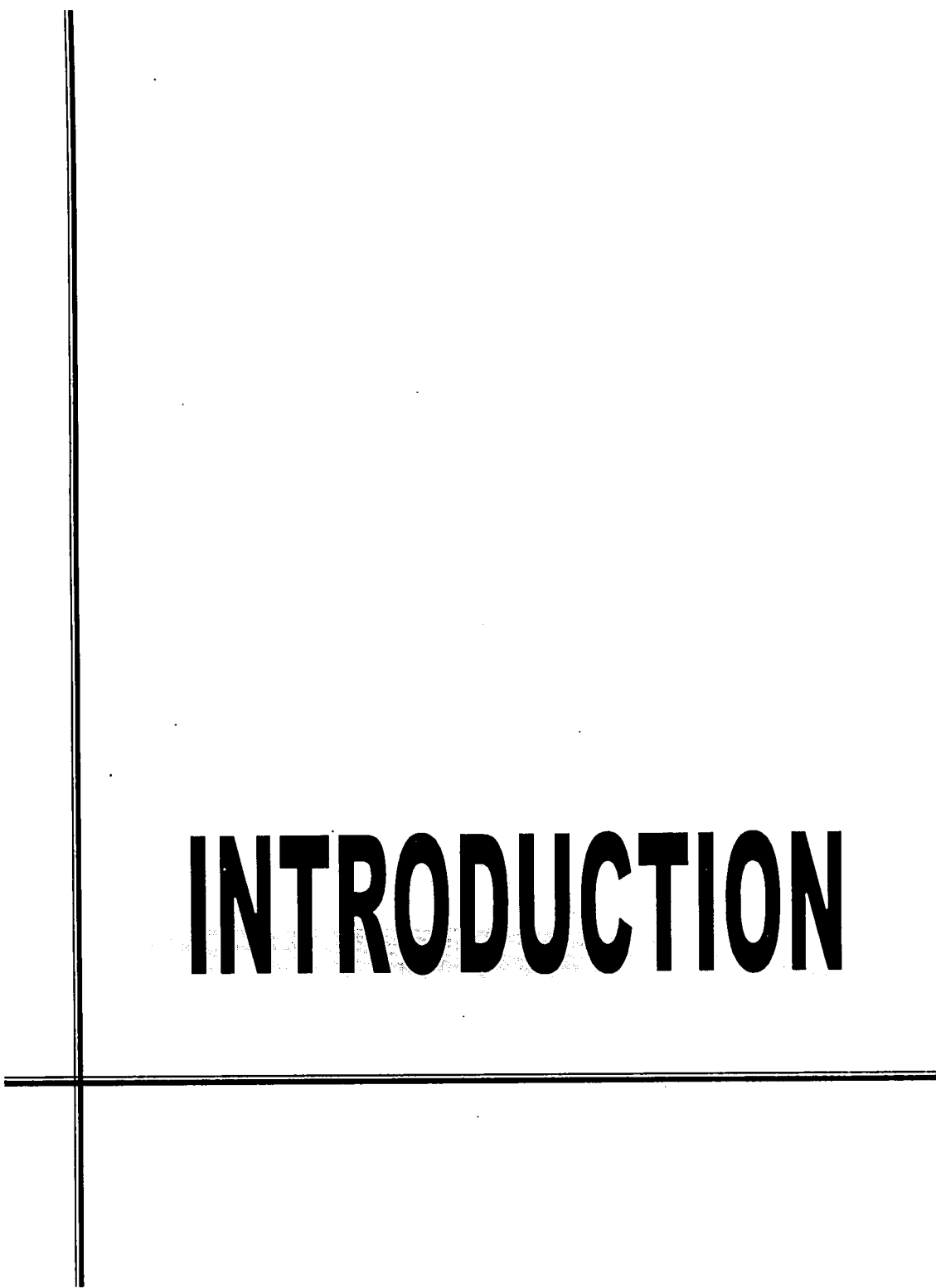
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ABBREVATIONS

%	-	per cent
*	-	Significant at 5 per cent
**	-	Significant at 1 per cent
C.D.	-	Critical difference
C.V.	-	Coefficient of variation
CMS	-	Cytoplasmic male sterility
cm	-	centimeter
d.f.	-	Degrees of freedom
ECV	-	Environmental coefficient of variation
<i>et al.</i> ,	-	and other
g	-	gram
GA	-	Genetic advance
GCV	-	Genotypic coefficient of variation
h^2 (BS)	-	Broad sense heritability
ha	-	Hectare
M S S	-	Mean sum of squares
ml	-	mili liter
PCV	-	Phenotypic coefficient of variation
r	-	Correlation coefficient
S.E.	-	Standard error
Sr.No.	-	Serial Number
viz.,	-	Namely
Vs.	-	Versus



INTRODUCTION

Chapter 1.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the fourth important oilseed crop in the world next to soybean, groundnut and rapeseed. The cultivated sunflower is an annual oilseed plant of *Compositae* family. The introduction of Russian varieties into Europe and Americas had a decisive impact on the development of sunflower as a commercial oilseed crop. Sunflower oil on commercial scale was first produced in Russia between 1830 and 1840. The genus *Helianthus* is derived from the greek word Helios meaning sun and anthos meaning flower. The genus name associates the characteristic heliotropism exhibited during the flowering period and *Helianthus annuus* was so named by Linnaeus, who encountered sunflowers living for only one season. There exists many perennials among the 67 recognized species and subspecies in the genus and few are annual species. The important two cultivated species are *Helianthus annuus* L. ($2n = 34$) the common diploid and *Helianthus tuberosus* L. ($2n = 102$) an hexaploid species cultivated for its tubers.

Sunflower relatively a new crop to Indian agriculture, has emerged as an important oilseed crop in the country. The ability of sunflower to adopt to diverse cultural and agro-climatic situations is well known. The special attributes such as photo insensitivity, ability to withstand drought, easy cultivation, earliness, potential for high yield, quality oil for edible use, wide choice of hybrids and varieties for cultivation and remunerative marketing avenues have made sunflower an attractive crop to farmers and an important component of both rainfed and irrigated agriculture.

Although nearly every part of the sunflower plant is useful in one way or the other, it is the oil that is most valuable. The sunflower oil has gained major economic importance worldwide. The oil is used as cooking and salad oil and as a lubricant and illuminant. As sunflower is considered to be a semi-drying oil, it finds place in the industry for manufacturing paints and varnish, soaps and detergents, margarines for shortening and other edible products including vanaspati. The by product after oil extraction forms an important protein meal in many food products and as feed in dairy industry. There is a growing interest for non-oilseed sunflowers as snack food in the developed countries, besides the increasing demand for sunflower as a bird feed due to its preference by many species of birds. The sub-standard oil or non-oil grade sunflower seeds are effectively used as a bird feed. The sunflower grown in large scale in Russia, Argentina, Ukraine, USA, China, Romania, France, Spain and India. These nine countries together produce 69 per cent of world production.

Sunflower is one of the fastest growing oilseeds in India. Presently (2004-05) India has the fourth largest area under sunflower (2.15 million ha) in the world. Its share in total world production is about 4 per cent (1.22 million tonnes) and accounts for 9 per cent of the world acreage. However, the yield at 566 kg/ha is the lowest among the major sunflower producing countries in the world. Sunflower accounts for about 8.4 per cent of total area under oilseeds India. It accounts for 5.5 per cent account value of output of all the major oilseeds major in the country. Currently the important sunflower growing states are Karnataka, Andhra Pradesh, Maharashtra, Haryana, Tamilnadu, Uttar Pradesh. Maharashtra ranks third in sunflower area and production.

In India sunflower is grown over an area of 23.5 lakh ha with a production of 14.88 lakh tonnes during 2005-06 due to favourable monsoon in major sunflower growing regions apart from remunerative prices (Anonymous, 2006a).

In Maharashtra the crop is grown in area of 3 lakh ha with a production of 1.7 lakh tonnes having average productivity of 519 kg per ha (Anonymous, 2006b). There are many studies reporting constraints limiting yield of sunflower. These include biotic, abiotic, technical and production related issues which individually and collectively are reducing the production efficiency of the crop. Small holding size, improper plant nutrition, grossly inadequate crop husbandry, problems in plant and soil health, lack of proper rotations and neglect of crop at crucial stages are largely contributing to poor productivity.

The emphasis of sunflower research has largely been on yield improvement through the development of superior hybrids, open pollinated varieties (OPVs) along with relevant agro production technologies. Large areas of sunflower planted in *kharif* continue to be rainfed where, uncertainties in crop growing environment are normally expected. For these areas, open pollinated varieties (OPVs) were bred in view of their lower seed cost and greater plasticity in terms of withstanding moisture stress and disease-pest on slaught. Breeding efforts during the initial phase of crop improvement programmes were directed towards the development of OPVs in the form of synthetics and composites. Mass and recurrent selection methods are still the effective breeding methods followed for population improvement in sunflower.

Inbreds were developed through cyclic selection from different genotypes inbreds lines that are developed from open pollinated variety are referred as first cycle inbred and those which are improved and developed from the pre-existing inbreds are known as second cycle inbreds. Earlier inbreds were developed from a heterozygous source. Now it is preferred to improve the existing inbreds rather than isolating new inbreds from a heterozygous population. The improvement of well established or existing inbreds is carried out in respect of productivity disease, insect and lodging resistance or any other character and for combining ability. Inbreds with such desirable characters are expected to produce high yielding disease resistant hybrids by following different breeding approaches.

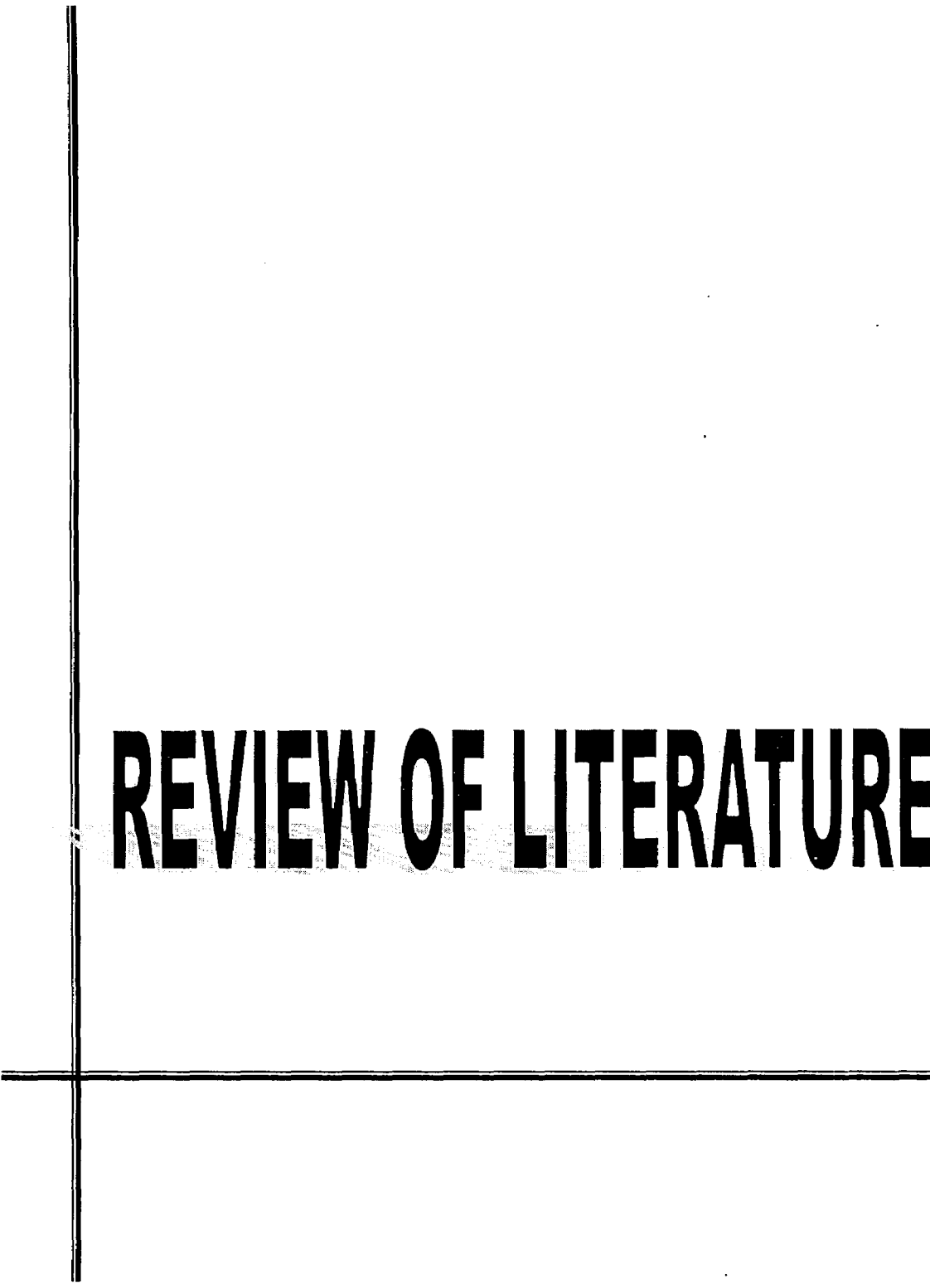
The 45 morphologically diverse, superior and stabilized inbreds developed at Oilseeds Research Station, Latur needs to be evaluated for *per se* performance and genetic variability. Variability could be determined with the help of genetic parameters, such as genetic coefficients of variation, heritability estimates and genetic advance. An understanding of heredity facilitates the development of useful genetic variability and selection of superior individuals. Correlation coefficient measures the association between two characters which is vital in planning an efficient breeding programme.

An interactive effect of various contributing traits influencing the seed yield is a complex entity. Moreover ancillary characters are being less influenced by environmental fluctuations than seed yield. Therefore selection based on these traits is more effective than seed yield *per se*. The path analysis was therefore, carried out to estimate the direct and indirect effects of various component traits for

recommending a reliable selection criteria. Thus the present investigation was undertaken to assess the nature and magnitude of genetic parameters and its utilization in development of superior genotypes with following objectives.

The objective of study are as given below.

1. To assess the genetic variability for seed yield and seed parameters.
2. To study the correlation and path analysis.



REVIEW OF LITERATURE

Chapter 2.

REVIEW OF LITERATURE

Variability is the important feature of any population and it is highly essential to exploit for crop improvement programme. It depends on the magnitude of heritability present in the traits. In addition to this the genetic advance under selection also gives the idea about the genetic gain attainable due to selection. The success of heterosis breeding mostly depends on the potential fertility restorer inbreds. In general the restoration in sunflower is very scanty. Quantitative characters are mostly polygenically controlled, with complete inheritance and environmental influence. Genetic variability determines the progress in breeding. Therefore, the knowledge of genetic make up and overall variability and the magnitude of heritable and non heritable components is essential for preparing breeding programme. The earlier studies regarding variability, heritability and genetic advance, correlation and path coefficient analysis is reviewed in following lines.

2.1 Genetic Variation For Yield and Yield Contributing Characters

Morphological and physiological characters are known to play major role in determining yield. The difference in expression of such characters is being a result of genetic variation (Bartual, *et al.*, 1985). Varshney and Singh (1976) observed considerable amount of genetic variability for seed yield, plant height and 1000 seed weight, however for other characters, estimated genetic variability was low.

Anand and Chandra (1979) studied 30 varieties from six different sources and reported marked variability in all the characters.

Lakshmanaiah (1980) studied 144 germplasm collections of sunflower for genetic variability for 13 quantitative characters. Analysis of variance revealed highly significant treatment differences for all the characters. The characters in general showed less genotypic co-efficient of variation except for seed yield and leaf number.

Ferieys (1981) studied genetic variability of the genus *Helianthus*. A brief description is given for a collections of 125 wild ecotypes representing 22 annual and 36 perennial species of the subspecies. Height ranged from 40 cm to 300 cm. Flowering dates stretched over 7 months and 1000 achene weight ranged from 1 to 10 g.

In a study of 3 hybrid F_1 s and their fertile inbred parents, Roath and Miller (1982) observed little difference in achene set between bagged and unbagged heads of two of the hybrids and their inbred parents.

Shinde *et al.* (1983) noticed high GCV for yield per plants, percentage of filled seeds, head diameter, plant height, 100 seed weight.

Caylak and Emiroglu (1984) reported significant differences in 100 achene weight and oil content, but not in height, head diameter, stem girth and seed yield.

Birch *et al.* (1985) reported difference in average filled achenes. Autogamy percentage was 54. The average self pollination per cent and 75 and 100 achene weight differences were due to variation in seed set. Self compatibility was low in the open pollinated cultivars.

Rangaswamy *et al.* (1986) reported significant difference among varieties for seed and oil yield per plot being highest in EC-68415.

Singh and Tapadia (1986) studied 36 genotypes of sunflower and reported that range was wide for plant height and limited for stem

diameter. Phenotypic and genotypic variances were high for plant height and low for stem diameter. Yield of filled seed per plant, 100 seed weight, head diameter variation with high heritability estimates.

Shivraju *et al.* (1987) studied 14 genotypes and reported that the seed set per cent under open-pollination ranged from 74.28 to 39.70. Highest autogamy per cent for hybrids (54.4%), inbred lines (45.70%), open pollinated varieties (7.09%) was recorded.

Alam *et al.* (1987) studied six characters in 32 selected genotypes. Analysis of variances revealed significant variation for all characters except days to maturity. Genotypic coefficient of variation was low in all the characters.

In the study of 30 exotic collections of sunflower over 3 seasons. Choudhary and Anand (1987) reported considerable amount of variability for all the characters except for seedling dry matter weight in *Kharif*. Variation at genotypic level were also quite high for the most of the traits indicating sufficient scope for selection.

Dilruba Begum *et al.* (1988) reported that genotypic coefficient of variations were high for yield per plant and 500 seed weight.

From the study of 36 genotypes obtained from 10 countries belonging to different continents Yadav *et al.* (1988) reported maximum variability.

From the evaluation of sunflower inbreds, hybrids populations, Swamy Gowda and Giriraj (1989) reported that all genotypes generally had higher seed production, autogamy and self compatibility during summer than any other season. Hybrids were more self compatible than inbreds and populations.

Choudhary and Anand (1989) studied that seed set under selfing was highest in spring followed by rabi and kharif. Under open pollination it was the highest in rabi followed by spring and kharif. High self pollination values were shown by EC-113790 in spring (77%) and the highest seed filling under open pollination was shown by edible sunflower.

From the data on 8 yield characters in 18 cultivars from 7 countries, El Ahmer *et al.* (1989) reported that Florida 2000 and IBH-16 were having the highest seed yields. Majak was late to 50 per cent flowering and had the most seeds per head, height, head diameter, 100 seed weight and yield per plant, SH-136/83 was earliest to flowering.

Chervet and Vear (1990) revealed considerable variation between genotypes for all the characters studied except number of days from sowing to emergence in the trials of 25 hybrids and 3 variations.

Gangappa (1991) reported high phenotypic co-efficient of variation for dry leaf weight, seed yield, dry stem weight and 100 seed weight. Low phenotypic and genotypic coefficient of variations were recorded for days to fifty per cent flowering and percent filled seeds.

Mohammad Tariq *et al.* (1992) evaluated 14 hybrids under rainfed condition during spring and reported that genotypic and phenotypic variances were high for plant height, oil content, achene yield.

Krizmanic *et al.* (1992) studied 21 new hybrids and reported considerable variation for oil content and achene yield.

Vasishtha *et al.* (1992) observed significant variation in seed oil and protein content and in various other oil quality components in 30 varieties of sunflower.

Dash *et al.* (1996) evaluated 18 early maturing hybrids of sunflower and reported that coefficient of variability was recorded highest (8.67) for seed yield. Seed yield per plant and seed yield per plot both recorded higher variances.

Patil *et al.* (1996) studied the magnitude of variation was maximum for weight of head followed by seed yield, oil yield per plant and seeds per head. Plant height and days to 50 per cent flowering were less affected by environment showing close correspondence between GCV and PCV. While characters such as head weight, seed yield, oil yield per plant and seeds per head were the most affected.

Gill *et al.* (1997) observed high estimates of heritability and genetic advance for stem girth, head diameter and 100 seed weight, while seed yield per plant and number of seeds per head exhibited moderate value for these parameters.

Chikkadevaiah *et al.* (1998) evaluated 52 germplasm accessions of sunflower, the analysis of variance revealed significant differences among the genotypes for all the characters. The estimates of GCV and PCV were high for seed yield per plant, head diameter and filled seed per plant.

Rukmini Devi *et al.* (1999) reported that yield per plant recorded highest GCV and PCV values followed by seed number per capitulum, while lowest value recorded for oil per cent.

Teklewold *et al.* (2000) studied PCV and GCV, broad sense heritability and genetic advance in 144 sunflower genotypes. They reported that analysis of variance revealed significant differences among the genotypes with respect to all the characters studied. Difference

between PCV and GCV was narrow for all the characters except number of filled seeds, harvest index and percentage of autogamy and leaf area.

Ravi (2001) observed a wide range of variability among the genotypes studied for harvest index, seed yield per plant and plant height. However for days to 50% flowering low variability was observed.

Komuraiah (2002) studied 101 genotypes of sunflower and reported that the number of filled seeds per head contributed highest to genetic variation followed by plant height, number of unfilled seeds, days to maturity, oil content, seed yield, days to 50 per cent flowering, number of leaves and diameter from the study of 101 genotypes.

Ramasubrahmanyam *et al.* (2002) studied genetic variability in sunflower and observed considerable amount of variability except kernel proportion in achene. All the characters were influenced leastly by environment, showing a close correspondence between GCV and PCV.

Rao (2002) evaluated 94 sunflower genotypes for genetic variation and showed that the number of filled seeds per heads contributed highest to the genetic variability followed by plant height, oil content and 100 seed weight.

Sujatha *et al.* (2002) studied the magnitude of variation which was maximum for oil yield, 100 seed weight, head diameter, autogamy, and oil content. Except oil content all the other character studied were leastly affected by environment showing a close correspondence between PCV and GCV.

Bharti *et al.* (2003) studied the variability, heritability and genetic advance of some important quantitative characters in sunflower. They observed that range of variation as well as phenotypic and

genotypic co-efficient of variation was high for seed weight, head diameter and seed yield per plant.

Rao *et al.* (2003) observed significant genotypic differences for all the traits studied. The highest phenotypic and genotypic co-efficient of variation were recorded for number of filled seeds per head, seed yield, plant height and test weight.

Seneviranthe *et al.* (2003) observed a high degree of variation in plant height, head diameter, number of days to 50% flowering, days to maturity, 100 seed weight, seed yield and oil content. Phenotypic and genotypic variations were high for seed and oil yield.

Shaikh *et al.* (2003) recorded highest genotypic and phenotypic coefficient of variation for seed yield per plant and number of seeds per head. Moderate heritability was recorded for seed weight, oil content and head diameter.

Habib (2004) studied the nature and extent of genetic variability and phenotypic and genotypic correlation among 10 seedling traits prevailing in a random mating population of sunflower. The result indicated that significant differences existed among all the traits evaluated. The estimates of broad sense heritability were high and significant for all the traits.

Reddy *et al.* (2004) studied sixty nine newly developed sunflower genotypes and one open pollinated cultivar (Morden) to determine the genetic divergence. The analysis of variance revealed a wide range of variability and significant differences among all the genotypes for all the characters studied.

Sultana *et al.* (2005) studied that genetic variability was highest for seed yield. Moderate amount of genetic and phenotypic variability was observed for plant height, head diameter and 100 seed

weight. Whereas GCV and PCV parameters were low for days to maturity and oil content.

2.2. Heritability and Genetic Advance

Shrivastava and Mishra (1976) studied the genotypic parameters for six characters and reported high heritability. Plant height had moderate genetic advance while test weight, stem diameter had low genetic advance. Plant height, yield per plant had high genetic advance with very high heritability indicating additive gene action in the control of this trait.

The study of Kloczowski (1976) revealed that with 30 per cent selection, genetic advance was highest with respect to plant height, 1000 achene weight and achene yield per plant while it was moderate for husk content percentage and low for oil content.

Varshney and Singh (1976) observed high predicated genetic advance with moderate heritability in seed yield, plant height, 1000 seed weight. Higher heritability was observed in case of oil content.

Rao (1980) reported the heritability in narrow sense was low for characters days to flowering, plant height, stem girth, head diameter, 100 seed weight and oil content.

Lakshmanaiah (1980) observed that heritability estimates in broad sense were high for oil content, days to flowering, leaf number and plant height, while it was low for seed yield. The characters which recorded high heritability values did not show high expected genetic advance.

Singh and Tapadia (1986) reported yield of filled seed per plant, 100 seed weight and head diameter had high genotypic coefficients of variation with high heritability estimates. High heritability along with high genetic advance was observed for yield of filled seeds per plant and

100 seed weight, indicating that selection for these characters would be effective.

Alam *et al.* (1987) observed highest heritability and genetic advance for seed yield per plant in 32 selected genotypes of sunflower.

Choudhary and Anand (1987) reported high heritability for days to heading, days to flowering, number of leaves, plant height at flowering and maturity, oil content and protein content in all season. The genetic advance was consistently high for seed yield in all 3 seasons. The characters with higher advance exhibited higher genetic variability.

Singh *et al.* (1987) observed that heritability estimates varied from 46 per cent for seed yield to 77 per cent for shelling percentage in evaluation of 3 sets of triple test crosses with 22 open pollinated varieties of sunflower.

Dilruba Begum *et al.* (1988) reported that broad sense heritability was high for yield per plant, 500 seed weight and head weight. The genetic advance was high for yield per plant, grain weight of head and plant height.

Khair *et al.* (1992) reported that broad sense heritability was high for head diameter (97.47%), plant height (78.10%), 100 achene weight (76.39%), oil content (74.84%) and seed yield (67.74%).

Shashikala (1992) reported that plant height, stem diameter, number of filled seeds per head, oil percent, yield per plant had low heritability, whereas days to 50 per cent flowering, number of leaves per plant and 100 seed weight had moderate heritability.

Mohammad Tariq *et al.* (1992) studied 14 hybrids under rainfed condition and reported that dominance and epistatics nature of

inheritance was reflected by high heritability and low genetic advance for different characters.

Rao *et al.* (1992) reported that the data of 12 characters in 8 sunflower varieties and their F_1 hybrids predominance of non-additive components.

Alvarez *et al.* (1992) observed wide genetic variability and significant genotype x environment interaction for various morphological, phenological and agronomic traits. Days to maturity, days to flowering, seed length and plant height showed the highest broad sense heritability. Direct estimates of genetic advance were high for seed number, seed and oil yield.

Suma and Virupakshappa (1993) while studying 196 accessions of sunflower observed high heritability and genetic advance as per cent of mean for seed yield (68.6% and 50.35%), oil yield (64.1% and 50.7%), 100 seed weight (72% and 31.6%) and seed filling percentage (64.9% and 33.9%).

Perumal and Rajeshkaran (1994) observed high GCV estimates for plant height, seed yield, 100 seed weight and stem girth. Further, they reported that most of the characters showed high to moderate heritability for seed yield, plant height and stem girth. Genetic advance as percentage of mean was higher for seed yield per plant, plant height, stem thickness and 100 seed weight.

Rukmini Devi (1994) reported that seed yield per plant, number of leaves, per plant, 100 seed weight, head diameter, days to maturity and plant height had high heritability.

Kshirsagar *et al.* (1995) evaluated 14 cultivars of sunflower for 8 quantitative characters and reported that variation was greatest for

seed yield per plant, followed by plant height and 100 seed weight. Heritability estimates of the later two traits were high, while that for yield it was moderate.

Patil *et al.* (1996) reported high heritability estimates with low genetic advance for days to 50 per cent flowering, plant height, stem diameter at the base, number of leaves and oil content estimates less genetic gains, lowest values of GCV, h^2 and GA were observed for yield, suggesting that this character can not be improved effectively by selection.

Saravanan *et al.* (1996) reported that moderate GCV and PCV were observed for head diameter, plant height and seed weight. A combination of high heritability and genetic advance was noticed for plant height, 100 seed weight and yield per plant which shows that these characters are suitable for improvement by selection. High heritability estimates were observed for all the characters studied.

Gill *et al.* (1997) observed high estimates of heritability and genetic advance for stem girth, head diameter and 100 seed weight, while seed yield per plant and number of seeds per head exhibited moderate values for these parameters.

Madrap *et al.* (1998) reported high heritability for test weight.

Wang *et al.* (1997) reported that plant height, seed number per plant, 100 seed weight, diameter of disc and seed weight per plant shows high heritability whereas days to maturity, days to flowering and husk percentage shows very low heritability. The characters showing wide genetic variation were husk %, seed number per plant, seed yield per plant and seed weight.

Kluze and Musnicki (1998) studied plant height at different development stages and some features characterizing stems of maturing plant, their leaves and heads; variability coefficient of plant height of hybrids and leaf morphology were less but the variability index did not differ so markedly; plant height, number of leaves per plant and vegetative part percentage changed very little under environmental conditions. So, they were more heritable than stem thickness under capitula, size of leaves and capitulum size.

Reddy (1999) observed high heritability coupled with high genetic advance as per cent of mean for seed yield per plant and number of filled and unfilled seeds per head.

Gomez *et al.* (1999) studied broad and narrow sense heritabilities of 11 traits in sunflower hybrids obtained from drought tolerant inbred lines. The traits with lowest heritabilities were those related to the reproductive ability, while the traits with higher heritabilities were those associate with biomass production and distribution.

Venkatesh Rao (1999) evaluated 84 genotypes and observed high heritability values for plant height, seed yield and head diameter. The genetic advance was high for number of filled seeds per head followed by number of unfilled seeds per head and plant height.

Ayubkhan (2001) studied yield performance, heritability and correlation in 20 sunflower genotypes. Broad sense heritability values ranged from 5.58 per cent (seed per capitulum) to 98.72 per cent (50 per cent flowering). 100 seed weight, first flower, complete flowering, maturity and oil content showed high heritability values of 98.65, 95.56, 98.38, 96.03 and 95.72 per cent respectively.

Ohja and Roy (2001) observed heritability and genetic components of variance for 10 characters in biparental families of sunflower. Result showed high genetic variance for yield per plant and plant height and low genetic variance for oil content. The high estimates of heritability observed for all the characters studied.

Ramasubrahmanyam *et al.* (2002) observed high heritability coupled with high genetic advance as per cent of mean, while kernel proportion in achene recorded high heritability with moderate genetic advance as percent of mean.

Mishra and Roy (2003) observed that heritability estimates from full sib families were higher than from half sib families for all the traits except number of leaves per plant and 100 seed weight. Plant height, 100 seed weight and number of leaves per plant showed high heritability.

2.3 Character Association

Correlation coefficient measures the intensity of association between two characters. This measurement of relationship is vital in planning an efficient breeding programme for the improvement of one or more economic characters which are known to depend on two or more metric traits. It is evident from the most of the reports that a positive and significant correlation exists between yield per plant with yield contributing characters.

Singh *et al.* (1977) recorded positive association of seed yield with seed weight and head diameter. The study made by Varshney and Singh (1977) revealed positive association of seed yield with various characters viz. plant height, maturity, head diameter and seed weight.

In another study, Nur (1978) noticed high correlation coefficient of filled achenes with days to maturity, plant height, head diameter and leaf area per plant.

Alba and Gerco (1979) also reported positive correlation of capitulum diameter and plant height with seed yield, while a positive correlation of plant height, head diameter and 100 seed weight with seed yield was indicated by Giriraj *et al.* (1979).

In the study of 30 varieties from 6 different sources Anand and Chandra (1979) observed positive correlation between seed yield and plant height, inflorescences diameter and seed weight. There was negative correlation between oil content and pericarp thickness.

Velkov (1980) reported the highest correlation between yield and head diameter. Inflorescences size was correlated with achene weight.

Sidhu and Bains (1980) observed significant positive correlation between seed yield and plant height, head diameter, 1000 seed weight.

Lakshmaniah (1980) studied 144 diverse germplasm collection of sunflower and correlation studies indicated that seed yield and oil content were positively and significantly correlated with capitulum, diameter, 100 seed weight, seed per capitulum, seed filling plant height, stem girth both at phenotypic and genotypic levels.

Rostov *et al.* (1984) observed close genotypic correlation between oil content in seed and husk percentage, duration of growth period and plant height.

Dhaduk *et al.* (1985) studied 36 genotypes of sunflower and observed that both at phenotypic and genotypic levels, head diameter, per

cent of filled seed and 100 seed weight were positively correlated with seed yield per plant.

Caylak and Emiroglu (1984) studied 7 cultivars and observed that head yield was strongly correlated with highest, stem girth, head diameter, 1000 achene weight in all cultivars.

Choudhry and Anand (1985) reported from the correlation analysis of data on 13 yield related character from 30 accessions seed yield was positively and significantly associated with number of leaves, plant height, stem and head diameter in 3 seasons.

Singh *et al.* (1985) studied 36 genotypes of sunflower and observed that both at phenotypic and genotypic levels, head diameter, percent of filled seeds and 100 seed weight were positively correlated with seed yield per plant.

Diaz Caprasco *et al.* (1986) observed positive correlation of head diameter and number of achenes per head with achene yield per plant.

Sheriff *et al.* (1986) noticed that seed yield was positively associated with plant height, number of leaves per plant, head diameter and number of seeds per head.

Shivram (1986) observed that genotypic correlation coefficients were highly significant in all cases except seed set and 1000 seed weight. The head diameter had positive and significant association with seed set, yield per plant and 1000 seed weight. Head diameter and 1000 seed weight had negative association on plot yield.

Vannozzi *et al.* (1986) studied 16 open pollinated varieties for 6 associated characters. Achene yield was closely related with oil yield, height, head diameter.

From the analysis of data from 7 x 7 diallel cross, Cecconi *et al.* (1987) reported that achene weight per capitulum was positively correlated with duration of reproductive stage, plant height and capitulum diameter.

From the studies on correlation, Giriraj *et al.* (1987) indicated close association of harvest index, leaf area, total dry matter with yield.

In the study of interline hybrids and their parents Marin (1987) reported a close genotypic correlation between number of achenes and number of florets per inflorescence.

Alam *et al.* (1987) observed that seed yield per plant was significantly and positively correlated with capitulum diameter and number of seeds per capitulum.

Sharma *et al.* (1987) observed that positive and significant association between plant height and stem girth, head diameter and stem girth, stem girth and seed yield per plant. The seed yield was positively and significantly related with 1000 seed weight and oil content.

Vanisree *et al.* (1988) reported that the significant and positive correlation of head diameter, stem diameter, 1000 seed weight, number of leaves per plant and plant height with yield.

Khandil and El-Mahandes (1989) reported head diameter as an indicator for seed yield as significantly associated with achene yield per capitulum.

Murthy and Shambulingappa (1989) reported that seed filling percentage, head diameter, 100 seed weight, stem girth and seed oil content had significant correlation with seed yield per plant at genotypic level.

Positive correlation was reported by Singh and Labana (1990) between seed yield and days to maturity, plant height, head diameter, grain filling and 1000 seed weight.

Chervet and Vear (1990) reported that leaf number showed significant correlation with emergence of flowering and maturity. Yield was significantly correlated with head and basal stem diameter, oil content showed a weak correlation with lateness.

Visk (1991) reported a close correlation was found between yield and duration of growth stage from flowering to maturity and between yield and 1000 seed weight.

Shashikala (1992) reported that seed yield per plant was significantly and positively associated with head diameter, number of filled seeds per plant, plant height and oil content.

Khan *et al.* (1992) reported that yield in sunflower was positively associated with days to maturity, plant height, head size and 100 achene weight.

Marinkovic (1992) reported that correlation coefficient between head diameter, seed per head, 100 seed weight and seed yield were positive and highly significant.

Krizmonic *et al.* (1992) reported that positive correlation between achene yield and oil yield, yield of oil and height and achene yield.

Mohammed Tariq *et al.* (1992) observed that the most characters, except 100 seed weight and days to maturity were positively correlated with yield.

Madrap *et al.* (1993) observed that yield per plant exhibited positive and significant association with filled seed percentage, flowering,

days to maturity whereas plant height showed positive significant association with seed yield, stem girth, head diameter. However, oil content, had showed weak positive correlation with seed yield. Harvest index was found chief determinant factor in seed yield of sunflower. There was positive correlation between stem height, stem girth, head diameter, oil content was positively correlated with filled seed.

Dahiphale and Pawar (1993) observed that plant height, head diameter, per cent filled seed, test weight showed significant positive correlation with seed yield per plant.

Choudhary and Anand (1993) observed that seed yield was significantly and positively correlated with number of leaves per plant, plant height, head diameter and 1000 seed weight in F_1 and F_2 oil content exhibited a positive significant association with seed yield only in F_2 .

Punia and Gill (1994) observed that seed yield had positive association with number of seed per head, head diameter, 100 seed weight, seed filling percentage and plant height.

Rukmini Devi (1994) reported seed yield was positively associated with days to maturity, plant height and number of leaves per plant.

Madrap *et al.* (1998) observed that yield per plant exhibited positive and significant association with filled seed percentage, flowering, days to maturity, whereas plant height showed positive significant association with seed yield, stem girth, head diameter. Oil content showed weak positive correlation with seed yield.

Narayana and Patel (1998) reported that plant height, stem width, head diameter, seed number per head, percentage filled seeds, seed index and seed weight per head were significantly related to seed yield.

Singh *et al.* (1998) reported that among capitulum characters such as head diameter, number of seeds per capitulum, 100 seed weight, filled seed percentage and seed yield, per plant all had significant and positive association with final seed yields, path analysis revealed that head diameter, number of seed per capitulum and 100 seed weight were important for seed yield of sunflower.

Sinha *et al.* (1998) reported that seed yield per plant exhibited highly significant and positive association with head diameter, leaf area index, number of seeds per head and 100 seed weight.

Nirmala *et al.* (1999) studied genotypic and phenotypic correlation among seed yield and 10 component characters in 65 sunflower genotypes. Pooled analysis of parents and crosses revealed that head diameter, leaves per plant, hundred seed weight and stem girth had significant correlation with yield. Head diameter, stem girth, hundred seed weight, number of leaves and oil content had significant and positive inter correlation among themselves.

Jayaramaiah *et al.* (2000) observed that there were significant positive correlation between seed yield per plant, plant height, number of filled seeds, head diameter, stem girth, 100 seed weight and harvest index on one side and oil yield per plant on the other. Percent autogamy was negatively correlated with seed yield per plant and other yield contributing traits days to maturity and oil content were significantly associated with seed yield per plant only in the inbred lines.

Satyanarayana (2000) studied correlation in 20 germplasm accessions along with 60 crosses of sunflower and reported that seed yield was highly correlated with days to 50 per cent flowering followed by number filled seeds and plant height.

Ayubkhan (2001) observed that the seed yield was positively associated with oil traits.

Ravi (2001) reported that seed yield had significant positive association with filled seeds per head, while head diameter, harvest index and seed set per cent recorded positive association with seed yield.

Komuraiah (2002) reported that number of filled seed per head recorded highest positive association with seed yield and other characters like head diameter, plant height, 1000 seed weight and oil content also exhibited positive correlation with seed yield.

Rao (2002) indicated that head diameter, number of filled seeds, plant height, test weight, number of leaves, oil content, days to maturity recorded positive association.

Dagustu (2002) observed that seed yield per plant was significantly and positively different in terms of number of seed per head, plant height, head diameter, 1000 seed weight and number of leaves per plant. Path coefficient analysis indicated that number of seeds per head followed by 1000 seeds per head followed by 1000 seed weight were the most important traits for seed yield per plant.

Gill *et al.* (2003) revealed that oil yield per plant that oil yield per plant had the highest correlation with seed yield per plant followed by number of seeds per head, head diameters, stem diameter, 100 seed weight, plant height and present oil content.

Kaya *et al.* (2003) studied significant correlation between seed and oil yield and other yield components, flowering time and hull rate were negative, others were positive.

Wani (2004) reported that yield was positively correlated with oil content, protein content, 1000 seed weight, head diameter, number of filled seeds per head and seed filling percentage.

2.4 Path coefficient analysis

Correlation does not show an exact picture of the relative importance of direct and indirect influence of each of component characters. The path coefficient analysis of cause and effect relationship provides the knowledge of relative importance of each of component characters.

Alba and Gerco (1979) reported that capitulum diameter and plant height had a direct effect on seed yield. Similar results were reported by Giriraj *et al.* (1979).

Beard and Geng (1982) observed that component representing plant shape and seed yield had direct effect on oil concentration.

Rao (1983) revealed that harvest index had the highest positive direct effect on yield. Plant height and total dry matter had the highest indirect effect on yield. Kernel oil content, leaf area and number of leaves per plant showed negative direct effect on yield.

Pathak *et al.* (1983) reported that achenes per plant and 1000 seed weight had the highest positive direct effect on yield.

From the path analysis 30 accessions of sunflower. Choudhary and Anand (1985) reported that days to flowering and plant height at flowering had direct effect on yield and other character have indirect effect. So these characters should be given the greatest weightage in selection for yield.

Mishra *et al.* (1985) observed that days to maturity and 100 seed weight had very high positive and significant influence on yield either directly or indirectly.

In the study of 36 genotypes and sunflower, Singh *et al.* (1985) reported that head diameter, per cent filled seeds and 100 seed weight had a positive direct effect on seed yield per plant.

Shivaram (1986) observed that yield per plant exerted direct effect on yield per plot followed by seed set percentage. The head diameter and 1000 seed weight exhibited negative and low direct effect on plot yield. Yield per plant contributed the highest positive effect on yield.

Vannozzi *et al.* (1986) reported that achene yield was closely related with oil yield, height and head diameter and had direct positive effects on oil yield. The length of the period from emergence to maturity had direct positive effects on oil content and yield.

From the path analysis Giriraj *et al.* (1987) studied leaf area influenced the seed yield and it had high direct and indirect effect on productivity.

While studying 21 hybrids and one variety, Rao *et al.* (1987) revealed that the harvest index had the highest direct effect on achene yield through plant height and total dry matter content. Oil content, mean leaf area and number of leaves per plant had a direct negative effect on achene yield.

Naskar *et al.* (1988) reported that the seed filling percentage had the greatest positive direct effect on yield followed by 100 seed weight.

Vanisree *et al.* (1988) studied 55 genotypes and reported that, stem diameter, head diameter, number of leaves per plant and seed setting per cent influenced yield directly whereas 1000 seed weight and plant height influenced via days to 50 per cent flowering and stem diameter respectively.

Murthy and Shambulingappa (1989) reported that seed filling per cent had maximum direct effect on seed yield and indirect effect through capitulum diameter, 100 seed weight, stem girth, seed oil showed negative direct effect even through it is significantly associated with seed yield. They suggested selection in seed filling per cent, capitulum diameter, 100 seed weight, stem girth for improvement in seed yield per plant.

Timini and Ado (1989) observed direct positive effect and indirect negative effect on yield by capitulum diameter and stem diameter respectively.

Singh and Labana (1990) reported that seed yield was positively correlated with days to maturity plant height, head diameter, grain filling and 1000 seed weight. Path co-efficient analysis indicated that head diameter had the greatest direct effect and 100 seed weight on seed yield followed by days to maturity and plant height.

Visk (1991) reported that, head diameter, 1000 achene weight and amount of rainfall during flowering and maturity stage had greatest direct positive and indirect positive and negative effect on yield.

Morinkovic (1992) studied head diameter, flowers per head, seeds per head, 1000 seed weight, volume weight, kernel content in seed,

oil content and their correlations with seed yield per plant. The path analysis provided information about direct and indirect effects of the examined characteristics on seed yield per plant.

Badwal *et al.* (1993) observed high positive direct effect on oil yield by oil content, 100 seed weight, head diameter and oleic acid content, however plant height and palmitic acid content had direct negative effect on oil yield through stem thickness and linolic acid. This investigation revealed that oil content, 100 seed weight, head diameter, stem thickness may be given high priority for the improvement of oil yield in sunflower hybrid breeding.

Madrap *et al.* (1993) studied the path analysis of 80 hybrids and their parents for 10 yield contributing characters and reported that harvest index, filled seed percentage had the highest direct influence as grain yield in environments. Plant height also influenced grain yield. Days to maturity and days to 50 per cent flowering had the least direct effect on grain yield but they affected grain yield indirectly through plant height, oil content influenced grain yield through harvest index.

Suma *et al.* (1994) studied 196 germplasm accessions of sunflower and revealed that oil yield was highly and positively correlated with seed yield per plant and number of filled seed per plant. Number of filled seeds per plant had maximum direct effect on seed yield.

Lal *et al.* (1997) observed high positive genetic association for seed yield with plant height, number of leaves per plant, stem girth and head diameter. Plant height and 100 seed weight had positive direct effect on seed yield suggesting the possibility of direct selection through these traits. Test weight was adversely affected by plant height and head diameter.

Joksimovic *et al.* (1999) reported highly significant positive correlation between oil yield on one side and all the character under study on the other, Grain yield and kernal yield had positive direct effect on oil yield per plant where as the dry matter mass of the vegetative plant part, harvest index and leaf area had negative direct effect on oil yield.

Ashok *et al.* (2000) reported that yield per plant was positively and significantly correlated with days to maturity, plant height, diameter of stem and diameter of capitulum. These characters also showed the highest direct effect on yield percentage of oil content and 100 seed weight were positively correlated with yield, but showed negative direct effect on yield.

Ayubkhan (2001) observed that first flowering had the highest positive direct effect on seed yield followed by seed per capitulum, 100 achene weight complete flower, and head diameter, while 50% flowering had the greatest negative direct effect on seed yield.

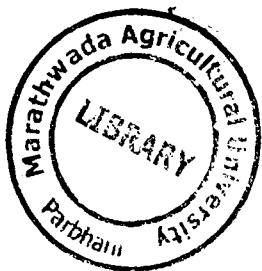
Chikkadevaiah (2002) studied 51 inbreds and 3 check of sunflower. Path analysis for seed yield at phenotypic level showed that direct effect was maximum for oil yield followed by 100 seed weight.

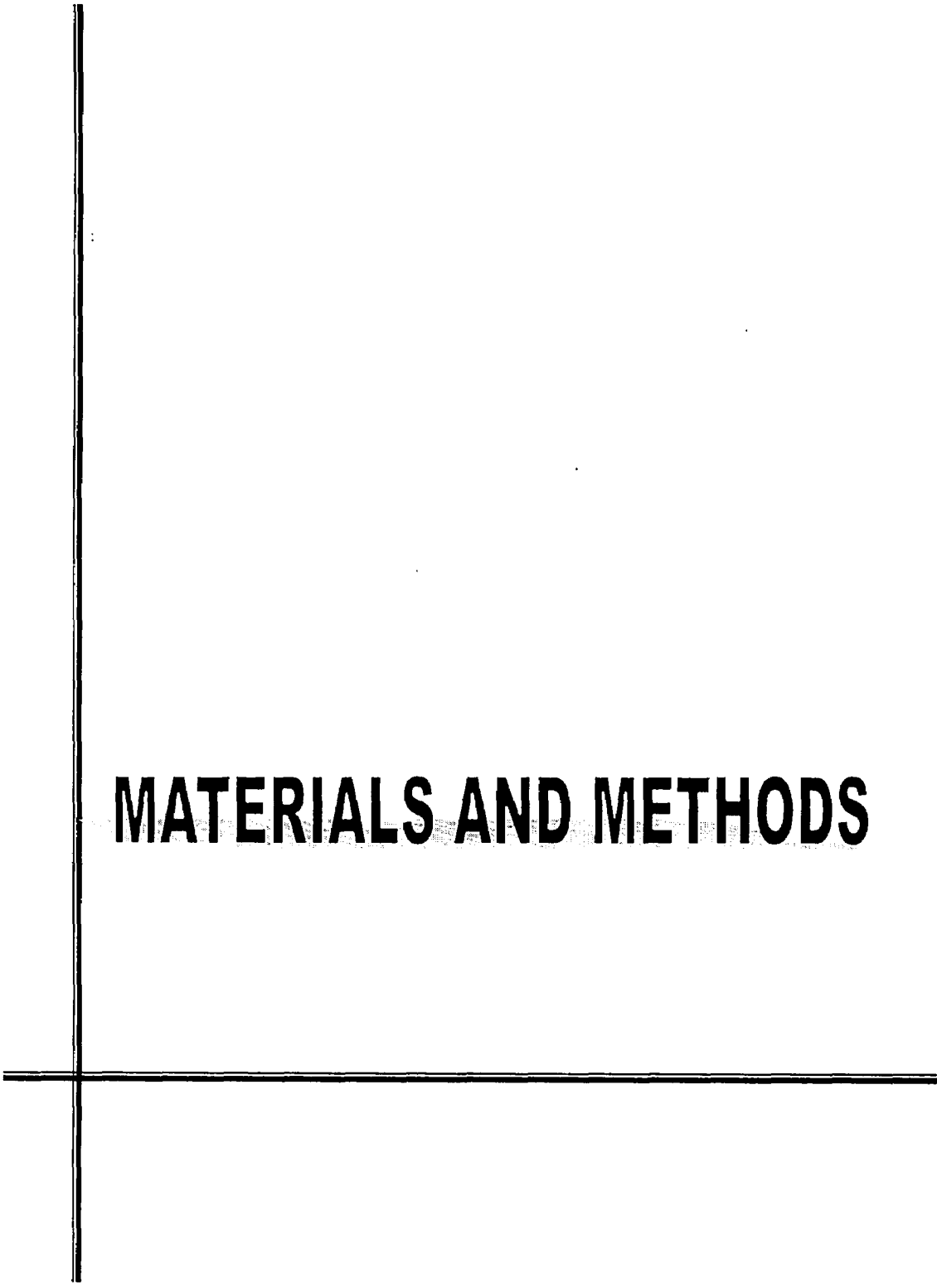
Rama Subrahmanyam (2002) studied sunflower genotypes consisting. 80 inbreds and five check for 11 characters. Path analysis revealed that seed yield was dependent mostly on the number of filled seed per head, test weight and kernel weight.

Tahir *et al.* (2002) reported that the highest correlation of seed yield was observed with number of filled seeds per plant. Maximum direct effect on seed yield was exhibited by number of filled seeds per plant. The head diameter also had a considerable effect on seed yield.

Nehru and Manjunath (2003) showed that the direct effect was maximum, for number of seeds per head followed by test weight on seed yield per plant, while seed yield had maximum direct effect on oil yield. The maximum indirect effect for any character was thought seeds per head was a major direct contributor.

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MATERIALS AND METHODS

Chapter 3.

MATERIAL AND METHODS

3.1 Experimental materials

The experimental material for the present investigation consisting newly developed 45 inbred lines of sunflower (*Helianthus annuus* L.) developed at Oilseeds Research Station, Latur including three checks were sown during *kharif* 2006 season. The details are given in Table 1.

Table 1 : List of sunflower inbred lines with checks

Sr. No.	Genotypes	Pedigree	Sr. No.	Genotypes	Pedigree
1	2		3	4	
1	GNPL-13	LS-3	24	IBDM-7	1 x 1 -2
2	GNPL-55	M x Rust	25	IBDM-14	VIII 1 x 3 -65
3	GNPL-93	3 x 3 -130	26	IBDM-16	V 12-1
4	GNPL-94	M x Rust-154	27	IBDM-27	VI-10-1
5	GNPL-113	ARM-15-33	28	LDMRM-02	1 x 1 -7
6	GP-09	DM-310	29	LDMRM-2-1	1 x 1 -6
7	GP-10	DM-310-4	30	LDMRM-14	3 x 3-14
8	GP-13	DM-387-3	31	LDMRM-14-1	3 x 3 -14-1
9	GP-18	Alt. 688	32	LDMRM-15	3 x 3-I
10	GP-46	32-B	33	LDMRM-25	3 x 3 F
11	IB-01	TBS-1-13	34	LDMRM-26	IV-3-1
12	IB-02	TBS-1-14	35	LDMRM-36	V-3-2
13	IB-09	TBS-2-5	36	LDMRM-67	III-2-4
14	IB-10	TBS-2-119	37	LDMRM-71	415 x 788
15	IB-14	TBS-2-132	38	K-9963	Sel. from GP-9963
16	IB-19	K-9953	39	HP-25-3	Sel. from HP-25
17	IB-20	Konark-2	40	3 x 3 I (d)	DM-28
18	IB-21	IHT-374	41	SP-20	Sel.from EC-68415
19	IB-25	Konark-2-94	42	C-120	Sel.from EC-68415
20	IB-29	Morden DMR	43	LSF-8 (C)	ORS, Latur.
21	IB-130	IHM-464	44	Morden A.K. (C)	Dr. PDKV, Akola
22	IBDM-2	415 x 488-72	45	SS-56 (C)	MPKV, Solapur
23	IBDM-4	3 x 3 -15			

3.2 Experimental methods

The experiment was laid out during *Kharif* 2006 at Oilseeds Research Station, Latur. The experimental details are as follows.

Design	:	Randomized Block Design
Treatments	:	45 (42 inbred lines + 3 checks)
Replications/Block	:	Three
Plot size	:	0.6 x 4.5 m
Fertilizer dose	:	60 kg N + 30 Kg P ₂ O ₅ + 30 kg K ₂ O/ha
Spacing	:	Row to row : 60 cm. Plant to plant : 30 cm.
Date of sowing	:	26.06.2006

Fourty two inbreds along with three standard check varieties were sown in three replications. Two to three seeds were dibbled per hill. One single line included 15 dibbles, following spacing of 60 cm between row to row and 30 cm between plant to plant. Fertilizer dose applied was 60 kg N + 30 kg P₂O₅ + 30 kg K₂O/ha at time of sowing. Thinning operation was completed 10-15 days after sowing keeping two healthy plants per hill and after 7 days of first thinning retaining one healthy plant per hill. All the recommended cultural, agronomical and plant protection measures was undertaken during the crop growth period.

3.3 Morphological observations

Five plants were randomly selected in each genotype for recording morphological observations.

1. Days to 50 per cent flowering

Number of days from the date of sowing till 50 per cent flowering of plants in each of the treatment were counted.

2. Days to maturity

Number of days from sowing to maturity of all plants showing capitulum yellow and drying of leaves in each entry were recorded.

3. Plant Height (cm)

The height of plant was measured in centimeters from base of the plant to the base of the capitulum.

4. Head Diameter (cm)

Head diameter was measured in centimeters at maturity.

5. Percentage of filled seeds per head

Total number of filled seeds and unfilled seeds of each selected plant in each treatment were counted and then filled seed percentage was calculated.

$$\text{Filling percentage} = \frac{\text{Filled seeds per head}}{\text{Total number of seeds per head (Filled seeds + unfilled seeds)}} \times 100$$

6. 100 seed Weight (g)

One hundred filled seeds randomly were picked from the seeds of five sampled plants and the weight was recorded in grams.

7. Husk Content (%)

Bulk quantity of filled seeds (25 g) from each entry was taken and shelled out. The weight of endosperms was weighted and per cent of husk content was calculated.

$$\text{Husk content (\%)} = \frac{\text{Weight of husk (g)}}{\text{Weight of seed (g)}} \times 100$$

8. Volume Weight (g/100 ml.)

The measuring cylinder was filled to 100 ml volume with seeds of each entry and was weighted in grams as volume weight.

9. Seed Yield Per Plant (g)

The cleaned produce of five selected plants was weighted and average weight was recorded as seed yield per plant.

10. Oil Content (%)

A random bulk sample of filled seeds weighing 15 grams was drawn from selected plants for estimation of oil content. The oil content was estimated at POC, Bangalore with the help of NMR.

3.4 Statistical Analysis

The statistical analysis for 45 inbreds was carried out as detailed below.

3.4.1 Analysis of variance

The mean values of all the treatments for the character under study were worked out. Standard error and critical difference at 1 and 5

per cent level of significance were calculated by using the formula (Panse and Sukhtme 1985).

$$1. \quad \text{Standard error (SE}_{\pm}) = \sqrt{\frac{MS_3}{r}}$$

Where,

MS_3 = Error means sum of squares

r = Number of replication

2. Critical Difference (CD) = SE x 1.414 x t value at 5 percent.

The analysis of variance will take the following form

Source of variation	df	MS	Expected square	F
Replications	(r-1)	MS_1	$\delta^2_e + g \delta^2_r$	
Genotypes	(g-1)	MS_2	$\delta^2_e + r \delta^2_g$	
Error	(r-1)(g-1)	MS_3	δ^2_e	

r = Number of replications

g = Number of genotypes

δ^2_e = Error variance.

δ^2_g = Genotypic variance

δ^2_r = Replication variance

3.4.2 Variability

The phenotypic, genotypic and environmental components of variances based on analysis of variance were estimated by using the following relation (Johnson *et al.* 1955).

$$\text{Mean square of error (MS}_e\text{)} = \delta_e^2$$

$$\text{Mean square of treatment (MS}_t\text{)} = \delta_t^2$$

i) Genotypic variance (δ_g^2) =

$$\delta_g^2 = \text{MS}_t - \text{MS}_e / r$$

ii) Phenotypic variance

$$\delta_p^2 = \delta_g^2 + \delta_e^2$$

iii) Environmental variance (δ_e^2) = Error MSS

The mean square of error is called as environmental variance.

iv) Genotypic coefficient of variation (GCV %).

The genotypic coefficient of variation was estimated by the equation as suggested by Burton (1952).

$$\text{GCV (\%)} = \sqrt{\delta_g^2 / \bar{X}} \times 100$$

Where

$$\text{GCV} = \text{Genotypic coefficient of variance}$$

$$\delta_g^2 = \text{Genotypic variance}$$

$$\bar{X} = \text{Grand mean of character}$$

v) Phenotypic coefficient of variation (PCV %)

The phenotypic coefficient of variation was estimated by following equation as suggested by Burton (1952).

$$\text{PCV (\%)} = \sqrt{\frac{\delta_p^2}{\bar{X}}} \times 100$$

Where,

δ^2_p = Phenotypic variance

$\bar{X}$ = Grand mean of the character

vi) Environmental coefficient of variation (ECV%)

$$ECV (\%) = \sqrt{\frac{\delta^2_e}{\bar{X}}} \times 100$$

Where,

δ^2_e = Environmental variance

$\bar{X}$ = Grand mean of the character

3.4.3 Heritability (Broad sense)

Heritability in broad sense (h^2) was calculated by using equation, as suggested by Allard (1960).

$$\text{Heritability } (h^2 \text{ bs}) = \frac{\delta^2_g}{\delta^2_p} \times 100$$

Where,

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

3.4.4 Genetic advance

The genetic advance (GA) under selection was estimated by adopting the formula suggested by Johnson *et al.* (1955a).

$$GA = K \times \delta^2_p \times h^2$$

Where,

- K = Selection differential (value of K at 5 per cent selection intensity = 2.06)
- δ^2_p = phenotypic standard deviation
- h^2 = heritability in broad sense

3.4.5 Expected genetic advance expressed as percentage of mean

The expected genetic advance in percentage of mean was calculated as

$$EGA = \frac{GA}{\bar{X}} \times 100$$

Where,

- EGA = Expected genetic advance
- G A = genetic advance
- $\bar{X}$ = grand mean of character

3.4.6 Correlation

Covariances were calculated for all the characters to find out correlation among the characters. The interrelationship of different yield contributing character was worked out according to Johnson *et al.* (1955b).

$$r = \frac{\text{Cov. (x. y)}}{(\delta^2_x \delta^2_y)^{1/2}}$$

Where

- r = correlation coefficient between the characters x and y.

Cov. (x. y) = covariance between x and y.

δ^2_x and δ^2_y are the respective variances of x and y.

The significance of correlation coefficient was tested against 'r' values given by Fisher and Yates (1963) at (n-2) degrees of freedom at 5 and 1 per cent level of significance.

3.4.7 Path coefficient analysis

Path coefficient analysis was carried out according to Dewey and Lu (1959). The direct and indirect path coefficients were calculated by solving the following set of 'p' simultaneous equations by the abbreviated Doolittle technique.

$$P_{01} + P_{02} r_{12} + \dots + P_{0p} r_{1p} = r_{01}$$

$$P_{01} r_{12} + P_{02} + \dots + P_{0p} r_{2p} = r_{02}$$

$$P_{01} r_{1p} + P_{02} r_{2p} + \dots + P_{0p} = r_{0p}$$

Where, $P_{01}, P_{02}, \dots, P_{0p}$ are the path effects of 1, 2, ..., p variable on 'o' variable.

$r_{12}, r_{13}, \dots, r_{1p}, \dots, r_{p(p-1)}$ are the possible correlation coefficients between various independent variables and $r_{01}, r_{02}, \dots, r_{0p}$ are the correlations of independent variables with dependent variables. The different effects of 'i' th variable via 'j' th variable were worked out as $(P_{0j} \times P_{ij})$.

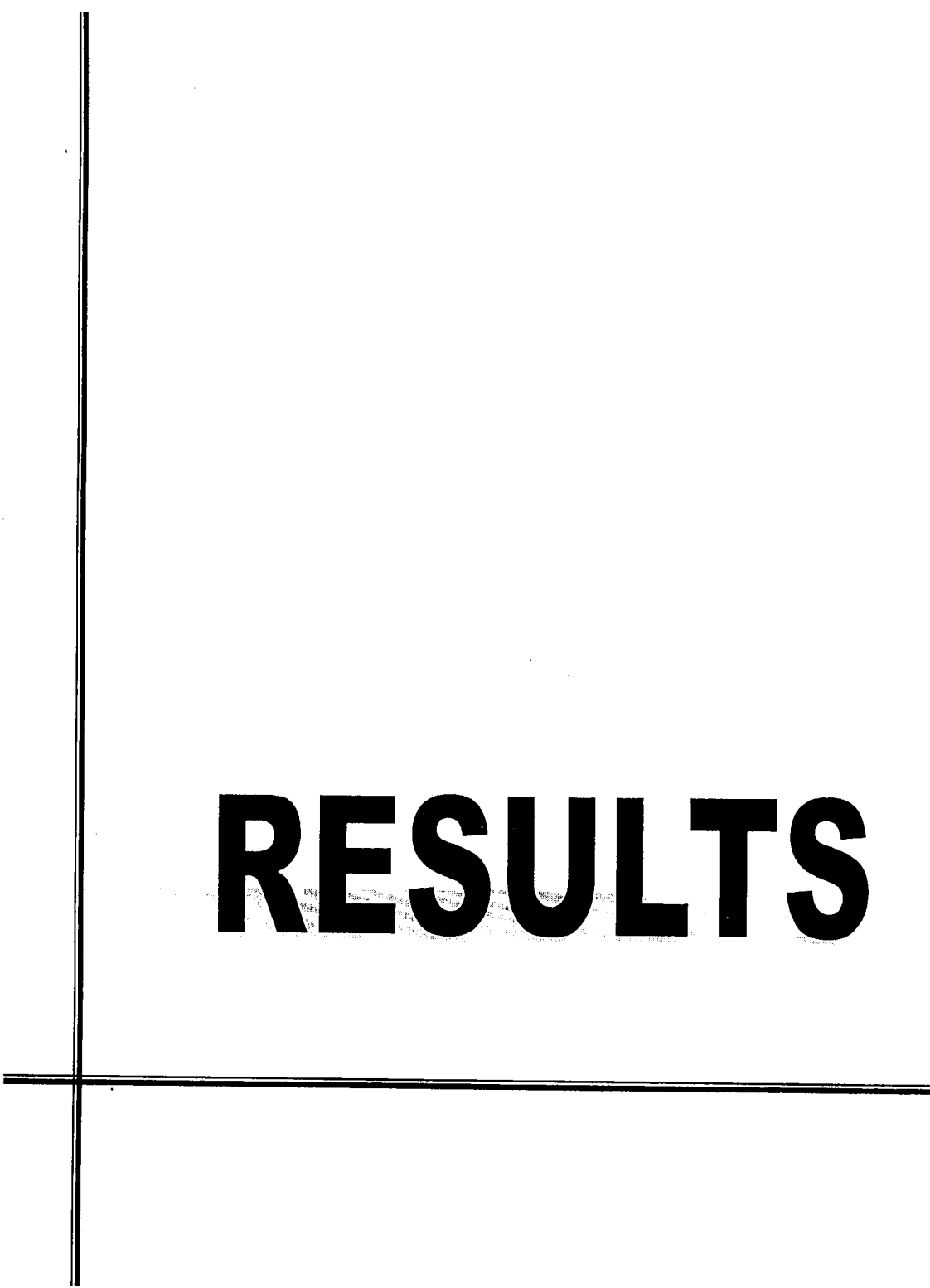
From the simultaneous equations it is clear that the correlation coefficient is the sum of direct and indirect path coefficients.

Residual effect was calculated as under

$$P^2_{OX} = 1 - (P^2_{01} + 2P_{01} P_{02} r_{12} + 2P_{01} P_{03} r_{13} + \dots)$$

$$P^2_{O2} = 2P_{01} P_{03} r_{23} + \dots + P^2_{0p})$$

$$\text{Residual factor} = P^2_{op}$$



RESULTS

CHAPTER 4.

RESULTS

Fourty two inbreds along with three standards checks were evaluated for seed yield and grain quality parameters. The results obtained are described under the following heads.

4.1 Analysis of variance

4.2 Mean performance

4.3 Genetic parameters

4.4 Correlation

4.5 Path analysis

4.1 Analysis of variance

Analysis of variance was worked out to assess the variation in the inbreds for ten characters. The significance was marked by applying 'F' test.

Analysis of variance for ten characters consisting of replication mean squares, treatment mean squares, error mean squares and critical differences at 5 per cent and 1 per cent is given in Table 2. The mean sum of squares due to treatments were highly significant for the characters under study. The analysis of variance showed that differences among the treatments in respect of all characters were significant at both 5 per cent and 1 per cent level. This indicates that differences exist among inbred lines for yield and its contributing characters.

Table 2 : Analysis of variance for different characters studied in 45 inbreds of sunflower

Sr. No.	Characters	Mean sum of squares		
		Replications (2 df)	Treatments (44 df)	Error (88 df)
1.	Days to 50% flowering	3.474	43.467**	1.807
2.	Days to maturity	8.029	42.388**	3.135
3.	Plant height (cm)	0.274	974.305**	2.758
4.	Head diameter (cm)	0.207	8.272**	1.336
5.	Filling %	1.162	82.311**	2.359
6.	100 seed weight (g)	0.373	3.030**	0.084
7.	Husk content (%)	1.607	131.787**	1.584
8.	Volume weight g/100 ml	1.029	25.714**	2.287
9.	Seed yield per plant (g)	0.474	136.623**	1.057
10.	Oil content (%)	8.706	40.339**	1.562

** Indicates significant at 1 per cent level of probability

4.2. Mean performance of the inbreds

The results of per se performance of inbreds for all the characters is presented in Table 3.

4.2.1 Days to 50 per cent flowering

The character ranged from 44.66 (Morden (C)) to 65.66 (GP-46) days with an average of 55.16 days. The inbreds viz. GP-46 (65.66), IB-01 (62.00), GNPL-55 (61.33), LDMM-2-1 (61.00) and GP-18 (60.66) found to be late for days to 50 per cent flowering over the best check Morden (44.66).

Table 3 : Mean performance of different characters studied in 45 inbred lines of sunflower.

Sr. No.	Inbred lines	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed illing (%)	100 seed weight (g)	Husk content (%)	Volume weight g/100 ml	Seed yield per plant (g)	Oil content (%)
1	2	3	4	5	6	7	8	9	10	11	12
1	GNPL-13	57.00	86.66	102.33	13.00	71.33	5.44	35.33	40.00	34.00	37.42
2	GNPL-55	61.33	93.00	124.00	14.00	72.33	4.34	33.33	39.00	21.66	33.93
3	GNPL-93	52.66	92.00	99.00	15.00	64.00	6.68	24.33	40.00	17.66	32.63
4	GNPL-94	55.66	95.00	109.66	13.00	62.00	4.43	24.00	39.66	21.00	29.79
5	GNPL-113	58.00	98.33	126.00	11.33	66.33	5.17	32.66	40.33	34.33	33.19
6	GP-09	58.33	97.66	141.66	11.66	65.00	4.13	25.33	36.33	17.66	19.80
7	GP-10	55.66	94.66	103.00	17.00	67.33	3.59	25.33	38.66	20.00	28.90
8	GP-13	52.33	94.00	123.33	12.00	38.33	3.26	21.00	41.00	15.66	25.71
9	GP-18	60.66	96.33	134.33	12.66	64.33	3.59	35.00	38.66	30.00	23.84
10	GP-46	65.66	95.33	155.00	12.00	62.66	3.06	35.00	43.00	21.00	28.66
11	IB-01	62.00	95.00	118.00	14.00	78.66	4.51	19.00	40.33	21.00	33.45
12	IB-02	58.00	96.00	113.00	12.00	67.00	3.69	37.33	36.00	21.66	29.48
13	IB-09	54.33	92.00	96.00	10.00	68.33	4.32	24.00	39.33	20.00	35.16
14	IB-10	57.66	98.66	115.33	11.00	62.66	3.66	25.00	34.66	16.00	24.01
15	IB-14	59.00	97.00	101.33	14.33	66.33	3.60	26.00	39.33	18.66	29.64
16	IB-19	55.33	95.00	132.33	13.33	65.33	4.38	20.00	37.00	19.33	30.49
17	IB-20	60.00	98.33	121.00	11.00	66.66	3.50	25.00	43.00	16.33	37.75
18	IB-21	58.66	98.33	107.66	12.00	71.66	5.07	26.66	46.33	35.00	34.80
19	IB-25	56.66	97.00	119.66	12.66	76.66	4.36	23.33	43.00	30.33	33.03
20	IB-29	59.00	98.33	145.33	14.66	74.00	3.66	21.00	38.00	33.00	32.44
21	IB-130	57.66	97.66	110.00	11.33	71.00	5.27	33.66	43.33	20.00	35.68
22	IBDM-2	55.00	97.00	115.00	14.00	66.66	5.24	24.00	43.66	33.33	36.47
23	IBDM-4	56.66	96.66	21.33	15.66	63.66	6.21	21.33	44.00	18.00	32.99
24	IBDM-7	59.00	97.66	102.00	12.00	67.66	5.44	33.66	38.66	24.00	30.04

1	2	3	4	5	6	7	8	9	10	11	12
25	IBDM-14	54.66	95.00	118.00	10.00	72.00	2.95	17.00	42.66	21.66	31.49
26	IBDM-16	55.66	89.00	88.00	15.00	70.66	4.95	15.00	46.00	38.66	36.61
27	IBDM-27	54.33	86.66	36.33	12.00	63.00	4.47	31.00	39.66	28.00	35.34
28	LDMRM-02	56.00	96.66	132.00	11.66	58.66	4.66	22.33	43.33	16.00	30.27
29	LDMRM-2-1	61.00	97.66	147.00	10.00	66.33	4.61	33.00	40.33	19.33	35.01
30	LDMRM-14	51.66	95.00	102.00	10.33	62.00	4.39	26.00	40.66	19.00	35.45
31	LDMRM-14-1	52.33	95.00	96.00	11.66	64.66	3.80	42.33	43.33	17.00	37.26
32	LDMRM-15	56.00	88.33	101.00	11.66	54.33	5.65	22.33	41.66	15.33	32.99
33	LDMRM-25	52.33	95.33	71.00	11.33	57.00	3.33	13.66	39.33	18.66	37.40
34	LDMRM-26	60.33	100.00	136.00	11.33	65.33	4.76	31.33	41.00	17.66	36.82
35	LDMRM-36	52.66	92.00	94.00	12.00	64.00	3.49	18.00	38.66	17.00	35.38
36	LDMRM-67	52.66	92.33	134.00	13.00	61.66	4.56	28.33	46.66	29.33	34.28
37	LDMRM-71	55.66	95.66	118.00	11.33	58.33	5.44	28.00	39.33	24.33	27.96
38	K-9963	56.33	96.00	108.00	11.33	69.00	4.34	25.00	37.00	29.00	30.36
39	HP-25-3	56.00	97.00	137.66	12.00	58.00	7.00	35.33	37.00	30.66	32.78
40	3 x 3 I (d)	55.00	95.00	116.33	13.00	74.33	5.32	24.33	43.00	37.00	37.28
41	SP-20	55.66	95.66	124.00	15.00	66.00	6.79	15.00	38.00	32.00	32.64
42	C-120	57.66	96.66	144.00	13.33	73.00	2.95	24.66	45.66	16.00	37.83
43	LSF-8 (C)	50.66	88.00	126.00	12.00	73.00	5.21	35.00	37.66	25.00	32.97
44	Morden (C)	44.66	84.66	125.00	16.00	64.00	5.05	31.00	44.00	21.66	35.66
45	SS-56 (C)	47.00	86.33	133.66	14.00	68.00	5.37	20.66	38.00	22.66	31.28
Grand Mean		56.10	94.57	117.21	12.61	66.51	4.57	26.68	40.58	23.45	32.74
S.E. $\pm$		0.77	1.02	0.95	0.66	0.88	0.16	0.72	0.87	0.59	0.72
C.D. at 5%		2.18	2.87	2.69	1.87	2.49	0.47	2.04	2.45	1.66	2.02
C.V. (%)		2.39	1.87	1.41	9.16	2.30	6.36	4.71	3.72	4.38	3.81

4.2.2 Days to maturity

Days to maturity ranged between 84.66 (Morden (C)) to 100.00 days (LDMRM-26) with an average of 92.33 days. Inbreds viz. IB-10 (98.66), IB-29 (98.33), IB-130 (97.66) and IB-25 (97.00) were found to be late for days to maturity over the best check Morden (84.66).

4.2.3 Plant height (cm.)

The plant height among the inbreds ranged from 71.00 (LDMRM-25) to 155.00 cm. (GP-46) with an average of 113 cm. Inbreds viz. IB-09 (96.00), LDMRM-36 (94.00), IBDM-16 (88.00), IBDM-27 (86.33) and LDMRM-25 (71.00) were found significantly dwarf as compared to the check Morden (125).

4.2.4 Head diameter (cm)

Head diameter ranged between 10.00 (IB-09) to 17.00 cm (GP-10) with an average of 13.5 cm. The inbreds GP-10 (17.00), IBDM-04 (15.66) and IBDM-16 (15.00) were at par with check Morden (17.00) for head diameter.

4.2.5 Seed filling percentage

The variation ranged from 54.33 (LDMRM-15) to 78.66 per cent (IB-01) with an average of 66.49 per cent. The inbreds viz., IB-01 (78.66), IB-25 (76.66), 3 x 3 I (d) (74.33), IB-29 (74.00) and C-120 (73.00) were found superior over highest yielding check LSF-8 (73.00).

4.2.6 100 seed weight (g)

The variation for 100 seed weight ranged from 2.95 (IBDM-16) to 7.00 g (HP-25-3) with an average of 4.97 g. The inbred HP-25-3(7.00) recorded higher 100 seed weight followed by SP-20 (6.79), GNPL -93 (6.68) , IBDM-04 (6.21) and LDMRM-15 (5.65) as compared to best check SS-56 (5.37).

4.2.7 Husk content (%)

The variation for husk content ranged from 13.66 (LDMRM-25) to 42.33 (LDMRM-14-1) per cent with an average of 27.99 percent. The inbreds viz., LDMRM-25 (13.66), SP-20 (15.00), IBDM-14 (17.00), LDMRM-36 (18.00) and IB-01 (19.00) were found superior over best check SS-56 (20.00).

4.2.8. Volume weight g/100 ml

The differences for volume weight ranged from 34.66 (IB-10) to 46.66 g (LDMRM-67) with an average of 40.66 g. The inbreds viz. LDMRM-67 (46.66), IB-21 (46.33), IBDM-16 (46.00) and C-120 (45.66) recorded significant superior volume weight over the standard check SS-56 (38.00).

4.2.9 Seed yield per plant (g)

The variation ranged from 15.33 (LDMRS-15) to 38.66 g (IBDM-16) with an average of 26.99 g. The inbreds viz., IBDM-16 (38.66), 3 x 3 1 (d), (37.00), IB21 (35.00), GNPL-113 (34.33) and GNPL-13 (34.00) were found significantly superior over the best check LSF-8 (25.00 g).

4.2.10 Oil content (%)

The variability for oil content ranged from 23.84 (GP-18) to 37.83 per cent (C-120) with an average of 30.83 per cent. The inbreds viz. C-120 (37.83), IB-20 (37.75), GNPL-13 (37.42), LDMM-25 (37.40) and 3x3 I (d) exhibited significantly higher oil content over best check Morden (35.66).

4.3 Genetic parameters

Genetic parameters viz., phenotypic variance (δ^2p), genotypic variance (δ^2g), genotypic coefficient of variation (GCV), phenotypic coefficient variation (PCV), heritability (broad sense), genetic advance (GA) and expected genetic advance as per cent of mean (EGA) were worked out and are presented in Table 4. In general the genotypic and phenotypic variances were more or less equal for all characters.

4.3.1 The variance component

The amount of variation in quantitative characters are measured and expressed as variance. The whole amount of observed variation of phenotypic variation present in the characters does not give a true account of the variation which is fixable in the succeeding years of generation, while genotypic variation is the amount of fixable index from one generation to the next generation.

The environmental variation varies from one place to other and as such cannot be fixed up.

The GCV and PCV values were more or less equal in magnitude for all characters.

Table 4 : Parameters of genetic variability for yield and yield contributing characters.

Sr. No.	Name of the Characters	Range	Mean	Genotypic variance	Phenotypic variance	Environmental variance	GCV (%)	PCV (%)	ECV (%)	Heritability (h ² bs) (%)	Genetic advance (GA)	Expected genetic advance (EGA)
1	Days to 50% flowering	44.66-65.66	55.16	13.88	15.69	1.80	6.75	7.18	2.43	88.46	7.21	13.07
2	Days to maturity	84.66-100.00	92.33	13.08	16.21	3.13	3.91	4.36	1.91	80.69	6.69	7.24
3	Plant height (cm)	71-155	113	323.848	326.60	2.75	15.92	15.99	1.46	99.15	36.91	32.66
4	Head diameter (cm)	10-17	13.5	2.31	3.64	1.33	11.25	14.13	12.59	63.46	2.49	18.44
5	Seed filling %	54.33-78.66	66.49	26.65	29.01	2.35	7.76	8.10	2.30	91.86	10.19	15.32
6	100 seed weight (g)	2.95-7.00	4.97	0.98	1.06	0.08	19.91	20.71	4.44	92.45	1.96	39.43
7	Husk content (%)	13.66-42.33	27.99	43.40	44.98	1.58	23.53	26.68	4.49	96.48	13.33	47.62
8	Volume weight g/100 ml	34.66-46.66	40.66	7.80	10.09	2.28	6.86	7.81	3.71	77.30	5.05	12.42
9	Seed yield per plant (g)	15.33-38.66	26.99	45.18	46.23	1.05	24.95	25.24	3.39	97.73	13.71	50.82
10	Oil content (%)	23.84-37.83	30.83	12.92	14.48	1.56	11.65	12.34	4.05	89.22	6.99	22.67

4.3.2 Estimates of variability parameters (GCV and PCV)

4.3.2.1 Genotypic and phenotypic coefficient of variation (GCV and PCV)

On the basis of mean, the genotypic and phenotypic coefficient of variation was observed to be high for seed yield per plant (24.95, 25.24) followed by husk content percentage (23.53, 26.68), 100 seed weight (19.91, 20.71) and plant height (15.92, 15.99). The estimated values was least for days to maturity (3.91, 4.36). For the rest of the characters genotypic and phenotypic coefficient of variation was ranged from 6.75 to 11.65 and 7.18 to 12.34, respectively.

4.3.3 Heritability

The range of heritability in broad sense varied between 63.46 to 99.15. The heritability estimates (broad sense) were high for plant height (99.15) followed by seed yield per plant (97.73), husk content percentage (96.48), 100 seed weight (92.45), seed filling percentage (91.86), oil content (89.22), days to 50 per cent flowering (88.46), days to maturity (80.69), volume weight (77.30) and head diameter (63.46).

4.3.4 Genetic advance (GA)

The genetic advance ranged between 1.96 to 36.91. Higher estimates of genetic advance were observed for plant height (36.91) followed by seed yield per plant (13.71), husk content percentage (13.33), seed filling percentage (10.19), days to 50 per cent flowering (7.21), oil content (6.99), maturity days (6.69), volume weight (5.05), head diameter (2.49) and 100 seed weight (1.96).

High heritability accompanied with high genetic advance were found in characters viz., plant height (99.15, 36.91) followed by

seed yield per plant (97.73, 13.71), husk content percentage (96.48, 13.33), seed filling percentage (91.86, 10.19), whereas high heritability accompanied with low genetic advance were found in rest of the characters like head diameter (63.46, 2.49), volume weight (77.30, 9.05), days to maturity (80.69, 6.69), days to 50 per cent flowering (88.46, 7.21), oil content (89.22, 6.99) and 100 seed weight (92.45, 1.96).

4.3.5 Expected genetic advance as per cent of mean (EGA)

Expected genetic advance as per cent of mean (EGA) ranged between 7.24 to 50.50. It was highest for seed yield per plant (50.82) followed by husk content percentage (47.62), 100 seed weight (39.43), plant height (32.66), oil content percentage (22.67), head diameter (18.44), seed filling percentage (15.32), days to 50 per cent flowering (13.07), volume weight (12.42) and days to maturity (7.24).

4.4 Correlation

The correlation coefficient is a most important statistical constant used as a measure of the degree of association between two characters. The correlation studies help the breeder to compute the required genetic make up of the ideal variety. In order to find out the association or correlations between the characters considered in the present study. Phenotypic and genotypic correlation coefficients were worked out for ten quantitative characters (Table 5).

4.4.1 Yield per plant with other characters

Positive and significant phenotypic and genotypic correlations were observed between yield and yield contributing components viz., 100 seed weight, oil content percentage head diameter and seed filling percentage and negative and non-significant correlation

Table 5 : Estimates of genotypic (G) and phenotypic (P) correlation for 10 characters in 45 inbreds of sunflower.

Sr. No.	Character	Plant height (cm)	Test weight (g)	Oil content (%)	Days to 50% flowering	Days to maturity	Head diameter (cm)	Seed filling (%)	Husk content (%)	Volume weight g/100 ml	Seed yield per plant (g)
1	Plant height (cm)	G 1.000	-0.029	-0.239**	0.326**	0.310**	0.016	0.122	0.214*	-0.005	-0.0059
		P 1.000	-0.031	-0.225**	0.307**	0.271**	0.022	0.120	0.209*	0.004	-0.0064
2	Test weight (g)	G 1.000	1.000	0.204*	-0.209*	-0.193*	0.274**	-0.158	0.118	0.001	0.3601**
		P 1.000	1.000	0.181*	-0.195*	-0.189*	0.219*	-0.144	0.117	-0.003	0.3397**
3.	Oil content (%)	G 1.000		1.000	-0.2	-0.227**	-0.022	0.197*	-0.012	0.530**	0.1807*
		P 1.000		1.000	-0.177*	-0.176*	-0.036	0.185*	0.023	0.464**	0.1711*
4	Days to 50% flowering	G 1.000			1.000	0.655**	-0.171*	0.198*	0.220*	-0.050	0.0421
		P 1.000			1.000	0.547**	-0.153	0.183*	0.196*	0.040	0.0383
5	Days to maturity	G 1.000				1.000	-0.316**	0.052	0.047	-0.063	-0.0837
		P 1.000				1.000	-0.209*	0.038	0.032	-0.038	-0.0813
6	Head diameter (cm)	G 1.000					1.000	0.210*	-0.181*	0.134	0.2271**
		P 1.000					1.000	0.170*	-0.126	0.078	0.1785*
7	Seed filling (%)	G 1.000						1.000	-0.067	0.129	0.3502**
		P 1.000						1.000	-0.056	0.13	0.3261**
8	Husk content (%)	G 1.000							1.000	-0.025	0.0127
		P 1.000							1.000	-0.021	0.0092
9	Volume weight g/100 ml	G 1.000								1.000	0.1502
		P 1.000								1.000	0.1368
10.	Seed yield per plant (g)	G 1.000									1.000
		P 1.000									1.000

* Indicates significant at 5% level.

** Indicates significant at 1% level.

with plant height, days to maturity both at genotypic and phenotypic level. However, positive but non-significant correlation with days to 50 per cent flowering, husk content percentage and volume weight both at genotypic and phenotypic level.

4.4.2 Plant height and other characters

Plant height had shown positive and significant correlation with days to 50 per cent flowering, days to maturity and husk content percentage both at genotypic and phenotypic level. However negative and significant correlation with oil content percentage at both level. Whereas, negative and non-significant correlation with 100 seed weight and seed yield per plant at both genotypic and phenotypic level and negative and non-significant correlation with volume weight at genotypic level and non-significant and positive correlation at phenotypic level. Head diameter had shown positive non-significant correlation with plant height both at genotypic and phenotypic level.

4.4.3 100 seed weight and other characters

100 seed weight had shown positive and significant correlation with oil content percentage and head diameter, both at genotypic and phenotypic level. However, negative and significant correlation with days to 50 per cent flowering and days to maturity both at genotypic and phenotypic level. While negative and non-significant correlation with seed filling percentage at both level and positive and non-significant correlation with husk content percentage at both level.

4.4.4 Oil content percentage and other characters

Oil content percentage had shown positive and significant correlation with seed filling percentage and volume weight both at genotypic and phenotypic level and negative and significant correlation

with days to maturity at both level. While negative but significant correlation with days to 50 per cent flowering at phenotypic level and positive and non-significant correlation at genotypic level. However, negative and non-significant correlation with head diameter at both level.

4.4.5 Days to 50 per cent flowering and other characters

It had shown positive and significant correlation with days to maturity, seed filling percentage and husk content percentage both at genotypic and phenotypic level and negative and significant correlation with head diameter at genotypic level and negative and non-significant correlation at phenotypic level. However negative and non-significant correlation with volume weight at genotypic level and positive and non-significant correlation at phenotypic level.

4.4.6 Days to maturity and other characters

Days to maturity had shown negative and significant correlation with head diameter at both level. However, positive but non-significant correlation with seed filling percentage and husk content percentage and negative and non-significant correlation with volume weight at both level.

4.4.7 Head diameter and other characters

It had shown positive and significant correlation with seed filling percentage at phenotypic level and negative but significant correlation with husk percentage at genotypic level. Whereas, positive and non-significant correlation with volume weight at both level.

4.4.8 Seed filling percentage and other characters

It had shown positive but non significant correlation with volume weight both at genotypic and phenotypic level. Whereas, negative and non-significant correlation with husk content percentage both at genotypic and phenotypic level.

4.4.9 Husk content percentage and other characters

It had shown negative and non-significant correlation with volume weight at genotypic and phenotypic level.

4.4.10 Volume weight and other characters

Volume weight had shown positive but non-significant correlation with seed yield per plant at genotypic and phenotypic level.

4.5 Path analysis

The correlation studies do not show the exact picture of direct and indirect effect of yield contributing characters. Path analysis was carried out to find out the direct and indirect contributions of each of the characters towards seed yield per plant. Path coefficient analysis with genotypic and phenotypic correlation coefficients are presented in Table 6.

4.5.1 Seed yield Vs. plant height

In genotypic path analysis the character plant height had negative direct effect (-0.0694) on seed yield per plant. However, positive indirect effect on seed yield per plant through oil content, days to 50 percent flowering and seed filling percentage were of low magnitude. While, rest of characters had negative indirect effect on yield.

Table 6 : Genotypic and phenotypic path analysis for direct (Diagonal) and Indirect (off diagonal) effects of yield components on yield.

Sr. No.	Character	Plant height (cm)	100 seed weight (g)	Oil content (%)	Days to 50 % flowering	Days to maturity	Head diameter (cm)	Seed filling (%)	Husk content (%)	Volume weight (g/100 ml)	Correlated yield (r)
1	Plant height (cm)	G -0.0694 P -0.0554	-0.0133 -0.0122	0.0189 0.0037	0.0450 0.0331	-0.0306 -0.0153	-0.0002 0.0005	0.0497 0.0430	-0.0054 -0.0043	-0.0007 0.0004	-0.0059 -0.0064
2	100 seed weight (g)	G 0.0020 P 0.0017	0.4554 0.4001	-0.0161 -0.0030	-0.0289 -0.0211	0.0191 0.0107	-0.0041 0.0055	-0.0644 -0.0514	-0.0030 -0.0024	0.0002 -0.0003	0.3601 0.3397
3	Oil content (%)	G 0.0166 P 0.0125	0.0929 0.0724	-0.0791 -0.0166	-0.0276 -0.0191	0.0224 0.0100	0.0003 -0.0009	0.0803 0.0663	0.0003 0.0005	0.0746 0.0461	0.1807 0.1711
4	Days to 50 % flowering	G -0.0226 P -0.0170	-0.0954 -0.0782	0.0158 0.0029	0.1382 0.1081	-0.0646 -0.0309	0.0026 -0.0038	0.0806 0.0652	-0.0055 -0.0040	-0.0070 -0.0040	0.0421 0.0383
5	Days to maturity	G -0.0215 P -0.0150	-0.0880 -0.0756	0.0180 0.0029	0.0905 0.0591	-0.0986 -0.0565	0.0047 -0.0052	0.0213 0.0134	-0.0012 -0.0006	-0.0088 -0.0037	-0.0837 -0.0813
6	Head diameter (cm)	G -0.0011 P -0.0012	0.1247 0.0877	0.0017 0.0006	-0.0236 -0.0165	0.0312 0.0118	-0.0149 0.0251	0.0857 0.0607	0.0045 0.0026	0.0189 0.0078	0.2271 0.1785
7	Seed filling (%)	G -0.0085 P -0.0067	-0.0720 -0.0575	-0.0156 -0.0031	0.0273 0.0197	-0.0052 -0.0021	-0.0031 0.0043	0.4073 0.3574	0.0017 0.0011	0.0181 0.0130	0.3502 0.3261
8	Husk content (%)	G -0.0148 P -0.0116	0.0539 0.0468	0.0009 0.0004	0.0304 0.0212	-0.0046 -0.0018	0.0027 -0.0032	-0.0272 -0.0201	-0.0251 -0.0204	-0.0036 -0.0021	0.0127 0.0092
9.	Volume weight (g/100 ml)	G 0.0003 P -0.0002	0.0007 -0.0014	-0.0420 -0.0077	-0.0069 -0.0043	0.0062 0.0021	-0.0020 0.0020	0.0525 0.0466	0.0006 0.0004	0.1408 0.0994	0.1502 0.1368

Residual (G) : 0.8220, Residual (P) : 0.8505

Dark figures denotes direct effects

Path analysis at phenotypic level reveals that plant height had negative direct effect (-0.0554) on yield. However, the positive indirect effects through oil content percentage, days to 50 per cent flowering, head diameter, seed filling percentage and volume weight and negative indirect effect through, rest of characters on yield.

4.5.2 Seed yield Vs. 100 seed weight

100 seed weight in genotypic path analysis had high positive direct effect (0.4554) on seed yield per plant. However, the positive indirect effect on seed yield per plant through plant height, days to maturity and volume weight. While rest of characters had negative indirect effect on yield.

Path analysis at phenotypic level reveals that the 100 seed weight had positive direct effect (0.4001) on seed yield. However, positive indirect effects through plant height, days to maturity and head diameter were of low magnitude and rest of characters had negative indirect effect on seed yield.

4.5.3 Seed yield Vs. oil content percentage

Oil content percentage in genotypic path analysis had negative direct effect (-0.0791) on seed yield per plant. However, positive indirect effect on seed yield via, plant height, 100 seed weight, days to maturity, head diameter, seed filling percentage, husk content percentage and volume weight were considerably of low magnitude. The negative indirect effect observed through only days to 50 per cent flowering.

At phenotypic level, oil content percentage had small negative direct effect (-0.0166) on yield. However, positive indirect

effect via. plant height, 100 seed weight, days to maturity, seed filling percentage, husk content percentage and volume weight.

4.5.4 Seed yield Vs. days to 50 per cent flowering

Days to 50 per cent flowering at genotypic level had positive direct effect (0.1382) on seed yield per plant. However, positive indirect effect on seed yield per plant via. oil content percentage, head diameter and seed filling percentage were of low magnitude. While, rest of characters had negative indirect effect on seed yield.

Path analysis at phenotypic level had positive direct effect (0.1081) on seed yield per plant. However, positive indirect effects via. oil content percentage and seed filling percent were of low magnitude.

4.5.5 Seed yield Vs. days to maturity

Days to maturity at genotypic, path analysis had negative direct effect (-0.0986) on seed yield per plant. However, positive indirect effect on seed yield via. oil content percentage, days to 50 per cent flowering, head diameter and seed filling percentage were of low magnitude. While, negative indirect effect on seed yield via. plant height, 100 seed weight, husk content percentage and volume weight.

Path analysis at phenotypic level, had low negative direct effect on seed yield. Similarly, plant height, 100 seed weight, head diameter, husk content percentage and volume weight also had low negative indirect effect on seed yield. The characters oil content percentage, days to 50 per cent flowering and seed filling percentage had positive indirect effect on seed yield.

4.5.6 Seed yield Vs. head diameter

Head diameter at genotypic level had negative direct effect (-0.0149) on seed yield per plant. However, negative indirect effect via. plant height and days 50 per cent flowering. While, positive indirect effect on seed yield via. 100 seed weight, oil content percentage, days to maturity, seed filling percentage, husk content percentage and volume weight.

Path analysis at phenotypic level, head diameter had positive direct effect (0.0251) on seed yield. Similarly, 100 seed weight, oil content percentage, days to maturity, seed filling percentage, husk content percentage and volume weight had positive indirect effect on seed yield. While, rest of characters have negative indirect effect of low magnitude for seed yield.

4.5.7 Seed yield Vs. seed filling percentage

Seed filling percentage at genotypic level had high positive direct effect (0.4073) on seed yield per plant. However, positive indirect effect via. days to 50 per cent flowering, husk content percentage and volume weight. While, the characters plant height, 100 seed weight, oil content percentage, days to maturity and head diameter had negative indirect effect on seed yield. Seed filling percentage at phenotypic level had high positive direct effect (0.3574) on seed yield. However, the days to 50 per cent flowering, days to maturity, head diameter, husk percentage and volume weight also had low positive indirect effect on seed yield. The characters plant height, oil content percentage, 100 seed weight and days to maturity had low negative indirect effect on seed yield.

4.5.8 Seed yield Vs. husk content percentage

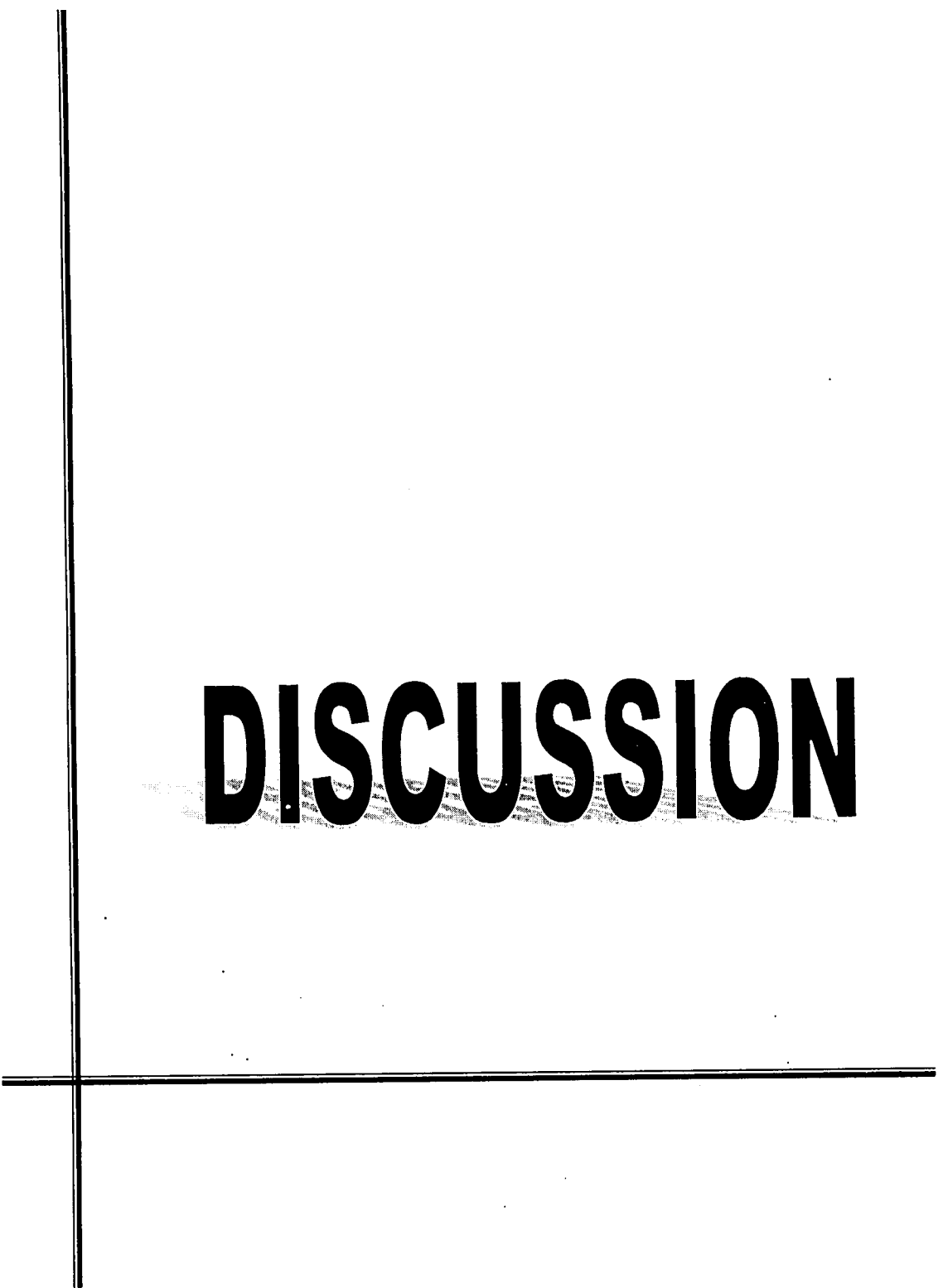
Husk content percentage at genotypic level had negative direct effect (-0.0251) on seed yield per plant. However, the indirect negative effect via. plant height, days to maturity, seed filling percentage and volume weight. While, 100 seed weight, days to 50 per cent flowering, oil content and head diameter had positive indirect effect for seed yield per plant.

Husk content percentage at phenotypic level, had negative direct effect (-0.0204) on seed yield per plant. However, negative indirect effect via. plant height, days to maturity, head diameter, seed filling percentage and volume weight on seed yield per plant. While, positive indirect effect via. 100 seed weight, oil content percentage and days to 50 per cent flowering on seed yield per plant.

4.5.9 Seed yield Vs. volume weight

Volume weight at genotypic level had positive direct effect (0.1408) on seed yield plant. However, positive indirect effects via. plant height, 100 seed weight, days to maturity and seed filling percentage were of low magnitude. The negative indirect effects were observed through oil content percentage, days to 50 per cent flowering and head diameter.

Volume weight at phenotypic level had positive direct effect (0.0994) on seed yield per plant. However, positive indirect effects through days to maturity, head diameter, seed filling percentage and husk content percentage on seed yield. While, rest of characters had negative indirect effect for seed yield.



DISCUSSION

Chapter 5.

DISCUSSION

Inbreds are the basic component in hybrid development programme in sunflower. Potential inbreds can be developed using various breeding approaches which are in turn used for development of CMS, restorer and open-pollinated populations. Forty five inbreds were developed. Before exposure of these inbreds to component breeding it is essential to study the genetic variation and pattern of character association. The results obtained on evaluation of these lines are discussed briefly under the following heads.

5.1 Analysis of variance and mean performance

5.2 Genetic parameters

5.3 Correlation

5.4 Path analysis

5.1 Analysis of variance and mean performance

The analysis of variance (Table 2) showed highly significant differences in genotypes for all the characters indicating the existence of sufficient variability among inbreds. The magnitude of mean sum of squares particularly for plant height, husk content percentage and seed yield per plant was high and it was less for 100 seed weight and head diameter. Wide range of variability was observed for days to 50 per cent flowering, plant height, head diameter, seed filling percentage, husk content percentage, seed yield per plant and oil content percentage. Existence of significant variability of various characters in sunflower inbred have been reported earlier by Gowda and Giriraj (1989), Lakshmanaiah (1980)

Mean performance

The inbreds have shown better mean performance for character under study and is given in (Table 7). The IBDM-27 (86.66) and LDMRM-15 (88.33) exhibited earlier maturity and LDMRM-26 (100.00), IB-10 (98.66), IB-29 (98.33) were of late maturity.

Table 7 : Best five inbreds with desirable high mean performance for different characters

Sr. No.	Characters	Inbreds	Desirable high mean performance
1.	Days to 50 per cent flowering	Morden (C)	44.66
		SS-56 (C)	47.00
		GP-13	52.33
		LDMRM-67	52.66
		IB-09	54.33
2.	Days to maturity	Morden (C)	84.66
		SS-56 (C)	86.33
		IBDM-27	86.66
		LSF-8 (C)	88.00
		LDMRM-15	88.33
3.	Plant height (cm)	LDMRM-25	71.00
		IBDM-27	86.33
		IBDM-16	88.00
		LDMRM-36	94.00
		IB-09	96.00
		Morden (C)	125.00
4.	Head diameter (cm)	GP-10	17.00
		Morden (C)	16.00
		IBDM-04	15.66
		IBDM-16	15.00
		IB-29	14.66
5.	Seed filling percentage	IB-01	78.66
		IB-25	76.66
		3 x 3 I(d)	74.33
		IB-29	74.00
		C-120	73.00
		LSF-8 (C)	73.00

6.	100 seed weight (g)	HP-25-3	7.00
		HP-20	6.79
		GNPL-93	6.68
		IBDM-04	6.21
		LDMRM-15	5.65
		SS-56 (C)	5.37
7.	Husk content (%)	LDMRM-25	13.66
		SP-20	15.00
		IBDM-14	17.00
		LDMRM-36	18.00
		IB-01	19.00
		SS-56 (C)	20.66
8.	Volume weight (g/100 ml)	LDMRM-67	46.66
		IB-21	46.33
		IBDM-16	46.00
		C-120	45.66
		Morden (C)	44.00
9.	Seed yield per plant (g)	IBDM-16	38.63
		3x3 I(d)	37.00
		IB-21	35.00
		GNPL-113	34.33
		GNPL-13	34.00
		LSF-8 (C)	25.00
10.	Oil content (%)	C-120	37.83
		IB-20	37.75
		GNPL-13	37.42
		LDMRM-25	37.40
		3 x 3 I(d)	37.28
		Morden (C)	35.66

The inbreds LDMRM-25 (71.00), IBDM-27 (86.33) and IBDM-16 (88.00) showed reduced plant height. The maximum head diameter was recorded by GP-10 (17.00) followed by Morden (C) (16.00), IBDM-04 (15.66) and IBDM-16 (15.00). The inbred lines exhibiting significantly high seed filling percentage were IB-01 (78.66), IB-25 (76.66) and 3 x 3 I (d) (74.33). Similar results were reported by Choudhary and Anand (1989) that seed set under selfing was highest in

spring followed by rabi and kharif. High self pollination values were shown by EC-113790 in spring (77%). The high 100 seed weight to the extent of 7.00 g was found in inbred HP-25-3 (7.00) followed by SP-20 (6.79), GNPL-93 (6.68), IBDM-04 (6.21) and LDMRM-15 (5.65). The inbred like LDMRM-15 (13.66), SP-20 (15.00), IBDM-14 (17.00), LDMRM-36 (18.00) and IB-01 (19.00) were superior in low husk content percentage. The volume weight in inbred lines viz., LDMRM-67 (46.66), IB-21 (46.33), IBDM-16 (46.00) and C-120 (45.66) were at par with check variety Morden (44.00). The inbred superiority in respect of seed yield per plant and oil content percentage was observed in IBDM-16, 3 x 3 I(d), IB-21, GNPL-113, IB-29, GNPL-13, SP-20 and C-120, IB-25, LDMRM-25 IBDM-02, respectively. Similar results were reported by Rangaswamy *et al.* (1986).

5.2 Genetic parameters

The genetic diversity is basis for plant breeding. For studying variability, various parameters were calculated viz., genotypic and phenotypic variance, coefficient of variation, heritability and genetic advance has been given in Table 4.

5.2.1 Variance component

Low differences were observed for genotypic and phenotypic variances for all the characters under study indicates least influence of environment on the expression of trait. Highest genotypic and phenotypic variance was observed for plant height followed by husk content percentage, seed filling percentage, days to 50 per cent flowering and days to maturity. In sunflower, high genotypic and phenotypic coefficient of variances for plant height and yield contributing characters

has been reported by Singh and Tapadia (1986), Mohammed Tariq *et al.* (1992). GCV and PCV values were more or less equal and small in magnitude for days to 50 per cent flowering, days to maturity, seed filling percentage, volume weight, plant height, seed yield per plant and oil content percentage. Similar results were reported by Patil *et al.* (1996). However, more difference is observed between head diameter and husk content percentage.

5.2.2 Heritability and genetic advance

Heritability is the measure of transmission of an attribute from one generation to other, while the genetic advance is a genetic gain of particular character. The high heritability coupled with high genetic advance for any particular character indicates its suitability for further improvements. However, the characters with moderate heritability coupled with high genetic advance are of paramount importance in breeding programme, while low heritability with low genetic advance are not necessarily be included in further studies as they are much influenced by non genetic factors.

The characters viz., plant height, seed yield and husk content percentage expressed high estimates of heritability in broad sense accompanied by high genetic advance indicating that those characters are predominantly governed by additive gene action and selection for these traits would be more effective for desired genetic improvement. Similar findings were made by Wang *et al.* (1997), Choudhary and Anand (1987) and Rukmini Devi (1999) were reported the high heritability for plant height. Alam *et al.* (1987), Suma and Virupakshappa (1993) and Reddy (1999) reported high heritability for seed yield per plant. Shrivastava

and Mishra (1976), Kloczowski (1976) were reported highest genetic advance for plant height and seed yield per plant.

The characters 100 seed weight, oil content percentage, days to 50 per cent flowering, days to maturity, volume weight seed filling percentage and head diameter exhibited high heritability accompanied lower genetic gain with suggest that variability for this character is probably due to non-additive gene action indicating the limited scope for improving these characters through phenotypic selection. Patil *et al.* (1996) also reported high heritability with low genetic advance.

The GA expressed as per cent of mean for seed yield per plant, husk content percentage, 100 seed weight and plant height was high magnitude and for days to maturity, days to 50 per cent flowering and volume weight were of low magnitude These results are inconfirmative with previous results of Suma and Virupakshappa (1993) and Ramasubrahmanyam *et al.* (2002) studied genetic advance in sunflower and reported high values.

5.2.3 Genotypic and phenotypic coefficient of variation

The phenotypic coefficient of variation was marginally higher than genotypic coefficient of variation for all the character, indicating the apparent variation is not only due to genotypic but also little influence of environment. The higher estimates of genotypic and phenotypic coefficients of variation were observed for seed yield per plant, husk content percentage, 100 seed weight and plant height indicating scope for improving these characters by selection. Similar findings are given by Dilruba Begum (1988), Gangappa (1991), Chikkadevaiah *et al.* (1998), Rao *et al.* (2003), Shaikh *et al.* (2003), Perumal and Rajeshkaran (1994). The genotypic and phenotypic

coefficients of variation were low for days to 50 per cent flowering, days to maturity, head diameter, seed filling percentage and volume indicating limited scope for selection in these traits. These results are in confirmative with previous results of Gangappa (1991). Considering the estimates of genetic parameters it is evident that the plant height, husk content percentage and seed yield per plant are the most important characters showing additive gene effects and selection for these traits would be more effective for improving seed yield.

5.3 Correlation studies

When a particular character is influenced by number of factors, it becomes necessary to evaluate to how and to what extent they are associated. The correlation studies of ten quantitative characters were worked out at genotypic and phenotypic levels in order to know the absolute association among the characters. These studies would enable the breeders to exercise the selection programme for those characters which are highly correlated with each other and specifically with yield.

In the present study the genotypic correlation coefficients were slightly higher than their respective phenotypic correlation coefficient (Table 5) for most of the character. Seed yield per plant was highly significant and positively correlated with 100 seed weight, oil content percentage, head diameter and seed filling percentage and low in magnitude with volume weight, husk content percentage and days to 50 per cent flowering. Whereas seed yield per plant showed negative correlation with plant height and days to maturity. In support of these findings seed yield per plant highly significant and positively correlated with 100 seed weight, head diameter and number of filled seeds were reported by Jayaramaiah *et al.* (2000), Punia and Gill (1994), Dahiphale

and Pawar (1993), Marinkovic (1992), Sinha *et al.* (1998), Shashikala (1992), Dhaduk *et al.* (1985), Narayana and Patel (1998), Singh and Labana (1990), Khan *et al.* (1992). Singh *et al.* (1977), Varshney and Singh (1977), Anand and Chandra (1979), Sidhu and Bains (1980), Singh *et al.* (1985), Sheriff *et al.* (1986), Alam *et al.* (1987), Vanisree *et al.* (1980), Murthy and Shambulingappa (1989) and Ravi (2001).

Among the yield component days to 50 per cent flowering, days to maturity and husk content were positively and significantly correlated between each other indicating that simultaneous selection for these characters might bring an improvement in seed yield.

5.4 Path analysis

The path analysis reveals that whether the association of yield contributing characters with yield is due to their direct effect or is a consequence of their indirect effect via sources of other traits. If the correlation between yield and character is due to direct effect of character, it reflects a true relationship between them and selection can be practiced for such character. If the correlation is mainly due to indirect effect of the character through the another component trait, breeder has to select the later trait through which the indirect effect is exerted.

Path coefficient analysis revealed that direct effects of oil content percentage, both at genotypic and phenotypic and head diameter at genotypic level were observed to be negative but its correlation with seed yield was significantly higher which might be due to high indirect effects via. 100 seed weight, seed filling percentage and volume weight. These results are inconfirmative with the results of Rao *et al.* (1987), Rao (1983) showed oil content had negative direct effect on yield. Shivram (1986) reported that head diameter had negative effect on yield. The

plant height had negative direct effect as well as negative association with seed yield. Their indirect effects via. 100 seed weight, days to maturity and husk content percentage. The characters 100 seed weight seed filling percentage followed by days to 50 per cent flowering and volume weight had highest positive direct effect on seed yield at both genotypic and phenotypic level. These traits also had strong positive association with seed yield indicating importance of direct selection for the traits. Similar results were reported by Giriraj *et al.* (1979), Lakshmanaiah (1980), Velkov (1980).

Choudhary and Anand (1985) reported that days to 50 per cent flowering and plant height had direct effect on yield. Singh *et al.* (1985) and Mishra *et al.* (1985) observed that 100 seed weight had very high positive and significant influence on yield directly.

Madrap *et al.* (1993), Suma *et al.* (1994), Ramasubrahmanayam (2002), Tahir *et al.* (2002), Murthy and Shambulingappa (1989) and Naskar *et al.* (1988) reported that seed filling percentage had maximum direct effect on seed yield.

The value of residual effect (G) 0.822 and (P) 0.850 though it is high indicating that beside the character studies there are important yield contributing characters both at genotypic and phenotypic level.

5.5 Utilization of information for improvement of sunflower crop

To start any breeding programme assessment of variability must be studied. In this investigation desirable variability has been observed. There was less environmental effects, which clear from various parameters of variability. Similarly heritability (h^2) was also more for plant height followed by seed yield per plant, husk content, 100 seed weight, seed filling percentage, oil content, days to 50 per cent flowering, days to maturity, volume weight and head diameter. The high

heritability indicates that these traits are generally governed by the additive gene action and the genotype of the traits strongly reflects the phenotype. High genetic advance coupled with high heritability estimates were noted for plant height followed by seed yield per plant, husk content and seed filling percentage. It suggests that in these characters heritabilities is most likely due to additive genetic effect and hence direct selection in these characters will be more effective. Correlation coefficients is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. Thus correlation measures the mutual relationship between two or more variables.

The estimates of correlation coefficient showed significant positive association of seed yield, 100 seed weight, oil content percentage, head diameter and seed filling percentage. Significant association among the yield component indicated that selection for one trait would be simultaneously helpful in the selection of other related traits, thereby ultimately resulting in improvement of seed yield.

An interactive effect of various contributing traits influencing the seed yield is a complex entity. Moreover, ancillary characters are being less influenced by environmental fluctuation than seed yield. Therefore, selection based on these traits is more effective than the seed yield per se. The path analysis was therefore, carried out to estimate the direct and indirect effects of various component traits recommending a reliable selection criteria. The results revealed that test weight and seed filling percentage had high direct effect on seed yield. The residual variation indicate that effect of unexplainable factors was 0.8220. It is concluded that for the effective selection of high yielding strains due weightage should be paid to 100 seed weight, seed filling percentage and volume weight in present inbreds of sunflower.

SUMMARY

Chapter 6.

SUMMARY

The present investigation was undertaken to estimate the extent of genetic variability heritability, genetic advance, character association and path analysis for yield and yield contributing characters in sunflower (*Helianthus annuus* L.). The material used for present study comprised 45 inbred lines including checks viz., LSF-8, Morden and SS-56. The material was raised in randomized block design with three replications during kharif season of 2006-07.

Observations were recorded on the characters viz., days to 50 per cent flowering, days to maturity, plant height, head diameter, filling percentage, 100 seed weight, husk content, volume weight, seed yield per plant and oil content.

The data was analysed and results obtained are summarized below.

6.1 Analysis of variance showed significant differences for all the characters among inbreds indicating the presence of wide genetic variability in material.

6.2 On the basis of mean performance the highest seed yield per plant was observed in IBDM-16 (38.66) followed by 3 x 3 I (d) (37.00), IB-21 (35.00), GNPL-113 (34.33) and GNPL-13 (34.00). Similarly the inbred lines viz., Morden (C), LDMRM-25, GP-10, IB-01, HP-25-3, LDMRM-67 and C-120 showed better mean performance for early maturity, plant height and husk content percentage, head diameter, seed filling percentage, 100 seed weight, volume weight, and oil content percentage, respectively.

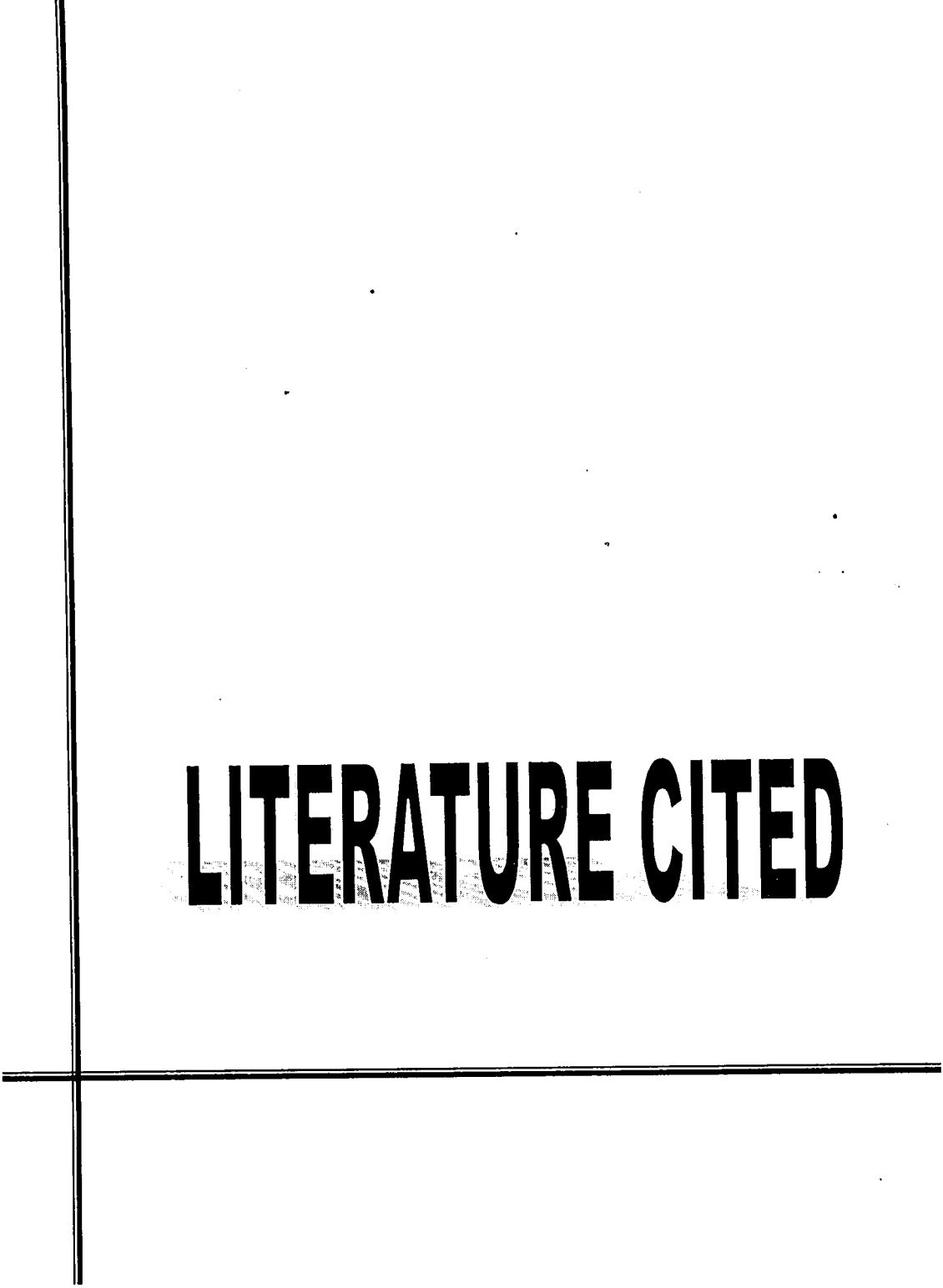
6.3 The genotypic and phenotypic coefficient of variation was observed to be high for seed yield per plant (24.90, 25.19) followed by husk content percentage (23.53, 26.68), 100 seed weight (19.91, 20.71) and plant height (15.92, 15.99) indicating scope for improving these characters by selection.

6.4 The characters viz., plant height, seed yield per plant, husk content percentage expressed high estimates of heritability in broad sense accompanied by high genetic advance indicating that these characters are predominantly governed by additive gene action and selection for these traits would be more effective for desired genetic improvement.

6.5 Seed yield per plant was highly significant and positively correlated with 100 seed weight, oil content percentage, head diameter and seed filling percentage. The genetic improvement in yield can be achieved by applying strong selection to above character which is genetically correlated.

Among the yield components days to 50 per cent flowering, days to maturity and husk content percentage were positively and significantly correlated between each other indicating their simultaneous selection for these characters might bring an improvement in seed yield.

6.6 Path analysis at genotypic and phenotypic level revealed that the characters 100 seed weight followed by seed filling percentage, days to 50 per cent flowering and volume weight had highest positive direct effect. These traits also had strong positive association with seed yield indicating importance of direct selection for these traits.



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* Originals not seen