

**POPULATION IMPROVEMENT IN SUNFLOWER
(*Helianthus annuus* L.)**

By

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B.Sc. (Ag.)**

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE



**DEPARTMENT OF GENETICS AND PLANT BREEDING
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AUGUST, 2004

CERTIFICATE

Mr. D. GOPI KRISHNA has satisfactorily prosecuted the course of research and that the thesis entitled “**POPULATION IMPROVEMENT IN SUNFLOWER (*Helianthus annuus L.*)**” submitted is the result of original research work done and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any university.

Date :
Place : Hyderabad

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Major Advisor

CERTIFICATE

This is to certify that the thesis entitled “**POPULATION IMPROVEMENT IN SUNFLOWER (*Helianthus annuus* L.)**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide research work carried out by **Mr. D. GOPI KRISHNA** under our guidance and supervision. The subject of the thesis has been approved by the student’s advisory committee.

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

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DECLARATION

I, **D. GOPI KRISHNA**, hereby declare that the thesis entitled **“POPULATION IMPROVEMENT IN SUNFLOWER (*Helianthus annuus* L.)”** submitted to the Acharya N.G. Ranga Agricultural University for the degree of **‘MASTER OF SCIENCE IN AGRICULTURE’** is the result of original research work done by me. I further declare that the thesis or any part there of has not been published earlier in any manner.

Date :

Place : Hyderabad

(D. GOPI KRISHNA)

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	percent
Acc.	-	Accession
ANOVA	-	Analysis of variance
CD	-	Critical Difference
cm	-	centimeter
cv	-	coefficient of variation
d.f.	-	degrees of freedom
<i>et al.</i> ,	-	and others
fig.	-	figure
g	-	grams
gca	-	general combining ability
GA	-	Genetic advance
GAm	-	Genetic advance as per cent of mean
GCV	-	Genotypic coefficient of variability
kg / ha	-	Kilograms per hectare
m	-	meter
PCV	-	Phenotypic coefficient of variability
r	-	correlation coefficient
r_g	-	genotypic coefficient of variation
r_p	-	phenotypic coefficient of variation
<i>sca</i>	-	specific combining ability
S.E.	-	Standard error
<i>viz.</i>	-	namely

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*MATERIALS AND
METHODS*

ACKNOWLEDGEMENTS

*It is by the unfathomable grace and blessings of **Almighty** that I have been able to bring out this humble piece of work for which I am eternally indebted.*

*I wish to record my deep sense of gratitude and heartfelt regards to the esteemed chairman of my Advisory Committee **Dr. K. Hussain Sahib**, Professor and University Head, Department of Genetics and Plant Breeding, ANGRAU, Rajendranagar, Hyderabad, who had guided my research work with keen interest and meticulous efforts which has given me enough course to tackle this research work.*

*I also take this opportunity to express my sincere gratitude to **Dr. A.R.G. Ranganatha**, Senior Scientist (Plant Breeding), Directorate of Oilseeds Research, Rajendranagar, Hyderabad for his valuable suggestions and encouragement provided through out the investigation of this thesis.*

*I am deeply indebted to **Dr. B. S. Kulkarni**, Professor and University Head, Department of Statistics and Mathematics, ANGRAU, Rajendranagar, Hyderabad whose relentless efforts, selfless co-operation during my research work has helped me in bringing out this thesis into a presentable manner.*

*I am extremely grateful to **Dr. Ganga Kishan**, Professor, **Dr. Lawrance**, Professor, **Dr. S. Sudheer Kumar**, Associate Professor, **Dr. N.A. Ansari**, Associate Professor, **Dr. S. Sokka Reddy**, Associate Professor, **Dr. A. Lokanadha Reddy**, Associate Professor, **Dr. Kuldeep Singh Dangi**, Associate Professor, **Dr. N. Sridhar**, Assistant Professor, **Dr. M. Bharathi**, Assistant Professor, **Dr. J. Ravindra Reddy**, Assistant Professor, **Smt. Farzana Zabeen**, Assistant Professor, Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Hyderabad for their help at various stages of my thesis work.*

I take this opportunity to express my heartfelt thanks to all the staff members of the Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Hyderabad for their help and co-operation in the course of this post graduation.

*Diction is not enough to express my boundful gratitude and heartfelt regards to my beloved parents **Shri D. Parvaiah** and **Smt. D. Parvathi**, brothers **D. Venkatesh**, **D. Dhanumjay**, sister-in-law **Smt. D. Shymala** and children **D. Divyasri**, **D. Sharmila** whose everlasting love and inspiration were my strongest assets during the course of my life.*

*My affectionate thanks are due to my friends **Vijaybhaskar Goud**, **Laxminarayana**, **Chandrasekhar**, **Shiva**, **Pankaj**, **Baba**, **Raju**, **Rajender**, **Gowtham Ramesh**, **Kiran**, **Nageswar**, **Yadagiri**, **Srinivas**, **Kranthi** and junior friends for their selfless cooperation and a source of constant inspiration throughout my post graduation.*

*I take this opportunity to convey appreciation to **M/s. Aparna Computers**, Premavathipet, Rajendranagar for neat typing of thesis.*

I wish to extend my thanks to one and all who have contributed even in a small way in the completion of my research work.

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Degree to which it is submitted : **MASTER OF SCIENCE IN AGRICULTURE**

Faculty : **AGRICULTURE**

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Year of submission : **2004**

ABSTRACT

The present investigation was carried out with a primary objective of improving the sunflower population for seed yield and yield components. The original base population had developed by intermating six promising lines *viz.*, 234B, 207B, PCSP1, Morden, Acc.456 and Acc.1260 which were having superior agronomic features. The experiment was laid out at Directorate of Oilseeds Research Farm, Hyderabad for the improvement in its fourth base population (C₄ cycle) during *Rabi*, 2002 and selected genotypes during summer, 2003. The data were recorded on eight quantitative characters.

The analysis of variance revealed significant differences among the genotypes for all the characters studied. The variability parameter study exhibited the presence of enormous amount of variability in the base population for all the characters studied and the directional selection narrowed down the variability among selected genotypes for the same characters.

The directional selection adopted for the improvement of seed yield and its components made considerable improvement over the base population and was reflected by the positive selection differential for most of the characters.

Response to selection showed positive genetic gain for number of filled-seeds per plant, seed yield per plant, oil content and 100 seed weight, whereas genetic gain was in negative direction for unfilled-seed number per plant, days to maturity, plant height and head diameter.

The overall perusal of PCV and GCV revealed high values for seed yield and oil yield and moderate values for plant height, head diameter, 100 seed weight and oil content, whereas days to 50 per cent flowering and days to maturity recorded low values.

The heritability values were higher for days to 50 per cent flowering, days to maturity, plant height, head diameter, 100 seed weight, seed yield per plant and oil yield per plant. Further, high heritability coupled with high genetic advance as per cent of mean were observed for seed yield per plant and oil yield per plant indicating the role of additive gene action controlling these traits. High heritability with moderate genetic advance were recorded for plant height and 100 seed weight indicating the role of both additive and non-additive gene action. High heritability coupled with low genetic advance were recorded for days to 50 per cent flowering and days to maturity indicating the role of non-additive gene action.

The correlation analysis revealed that days to maturity, plant height, head diameter, number of filled-seeds per plant, oil content and oil yield per plant found to be significant and positively correlated with seed yield.

CHAPTER – I

INTRODUCTION

Oilseeds occupy a pride of place in Indian economy since the requirement of oils is increasing day by day due to increase in population and higher consumption of oils. To overcome the shortage and to meet the requirement of consumption, the output of oilseeds has to be increased by increasing productivity.

Cultivated sunflower (*Helianthus annuus* L.) is a member of family Asteraceae. It is a highly cross-pollinated species due to its protandrous and self-incompatibility nature of flowers. Generally, out-crossing takes place due to anemophily. Archaeological evidences indicate that the crop was first domesticated in the central part of the United States of America and presently the genus *Helianthus* possesses about 67 species. The cultivated sunflower is a diploid species having $2n=34$ chromosomes.

Introduction of sunflower as “a crop of all seasons” in India was taken up in view of its various advantages *viz.*, photoin sensitivity, short duration, high yield and better quality of oil.

Though sunflower was introduced into India in 1969 with four Russian varieties *viz.*, VNIIMK (EC-68413), Peredovik (EC-68414), Armavirskij (EC – 68415) and Armaverts (EC-69874), the large scale cultivation was started from 1972 onwards with the introduced varieties Peredovik (EC-68414) and Armavirskij (EC-68415). The performance of introduced varieties was not stable

for yield and oil content due to inherent self-incompatibility problem. This situation made researchers to focus their attention towards the development of high-yielding hybrids and varieties suitable to different local conditions.

Sunflower with its versatile nature is expected to play a significant role in the oilseed economy of the country. Its cultivation is expected to spread further to different cropping systems and areas including eastern and north-eastern regions and to the non-traditional areas. It is, therefore, imperative to intensify breeding efforts to evolve highly productive cultivars to suit diverse agro-ecological situations.

The conventional methods of breeding procedures, though significant and productive in their own right, impose restrictions on recombination rates, retain tight and undesirable linkages, restrict the number of desirable alleles at various loci that can be accumulated in the lines selected in the advanced generations and utilize only the fixable gene effects (additive and additive x additive gene effects). Thus, routine breeding methods such as mass selection, bulk method of breeding are ineffective and inadequate to explore the full range of genetic variability.

A new era opened in sunflower breeding with the discovery of cytoplasmic male sterility (Leclercq, 1969) and fertility restoration genes (Kinman, 1970; Vranceanu and Sloneascu, 1971; Enns, 1972) which revolutionized the sunflower industry. The hybrid sunflower development gained lot of momentum and subsequently number of hybrids were released with the inception of coordinated research network in the country. In India, major emphasis was given for heterosis breeding programme which resulted in the development of first commercial

hybrid BSH 1 (Seetharam *et al.*, 1980), giving an impetus to heterosis breeding programme. Subsequently, several high-yielding hybrids such as APSH-11, KBSH-1, MFSH-1, MFSH-8, MFSH-17, KBSH-44 etc., were released for commercial cultivation. Hybrids in sunflower were found superior due to high adaptability, high self-fertility and high yield coupled with tolerance to pests and diseases.

Seetharam and Virupakshappa (1994) emphasized that there is a need for evolving synthetic varieties for cultivation in dryland situations, as populations possess high buffering ability due to heterozygous and heterogeneous nature.

Several population improvement methods are in vogue for cross-pollinated crops. The selection methods widely employed for population improvement in cross-pollinated crops include mass selection, S_1 selection, half-sib and full-sib family selections besides other forms of recurrent selection schemes such as simple recurrent selection, recurrent selection for gca and sca and reciprocal recurrent selection.

Studies on population improvement methods in sunflower are scarce. Keeping in view the above problems, the present study was undertaken to improve the population in sunflower with the following objectives :

1. To find out the response to selection for various characters
2. To assess the extent of variability among the lines
3. To find out the genetic advance
4. To select the superior lines for the next cycle of improvement.

CHAPTER – II

REVIEW OF LITERATURE

The literature pertaining to the study is reviewed under the following heads :

2.1 Response to selection

2.2 Variability, heritability and genetic advance

2.3 Correlation

2.1 RESPONSE TO SELECTION

According to Marozov (1944 and 1947), the varieties derived from the closely related material have limited variability that lead to failure in increasing the seed yield of sunflower. He also observed that spatial isolation was effective to increase oil content following different selection methods. By applying mass selection, he could increase oil content of the seeds through reduction in husk percentage.

Stojkovic and Gibsman (1949) obtained promising material with high oil content through mass selection applied in a local variety. Individual plant and group selection methods involving remnant seed resulted in the production of two varieties with high (59%) oil content.

Semihnenko and Kamennobrodsckaja (1962) reported that selection for high percent seed-set resulted in the progenies with improved seed and oil yield.

But, the selection for head diameter had no significant effect on seed and oil yields.

Miller *et al.* (1977) obtained an increment of 12.2 per cent for oil content after three cycles of simple recurrent selection. They opined that selection for oil content in early generations would be effective in improving oil content as the heritability estimate for the trait was sufficiently high.

Three cycles of mass selection based on seed yield and oil content in three diverse populations, SF₁A, SF₂A and SF₃A revealed that seed yield decreased in SF₁A and SF₂A in cycle 2 but increased in cycle 3 (Harinarayana *et al.* 1980). Response to selection for seed yield in SF₃A was greater in cycle 3 than in cycle 2. Oil content increased in SF₁A and SF₃A in cycle 2, but thereafter the rate of increase slowed down in SF₃A. Population SF₂A which had highest oil content initially, exhibited slower response to selection for oil content.

After three cycles of reciprocal full-sib selection in sunflower, Miller and Hammond (1985) reported an increase in seed yield by 6.3 per cent per cycle.

Pandey *et al.* (1988) reported an increased seed yield of 28 per cent over the base population at the end of third cycle of modified mass selection.

After two cycles of recurrent selection for *gca*, Mamonov (1991) obtained an increment in yield by 13.9 per cent and oil content by 16.00 per cent in the improved sunflower population. Nearly 18.00 per cent of the selected families had higher *gca* in the second cycle of selection as compared to the first cycle.

Luduena *et al.* (1992) reported, populations P3 (bulked local adapted cultivars and wild species) and P4 (bulked Romanian cultivars Record, OS52 and Horizon) underwent mass selection for oil content and seed yield during 1989-91, while P1 (bulked Russian and wild species, resistant to *Puccinia helianthii*) underwent recurrent selection of SCA for these characters during 1990-91. Three cycles (C_3) of selection were applied to each population. P3 and P4 showed an increase in oil content, but the non-significant difference between C_2 and C_3 in P3, as well as C_3 and C_4 in P4, indicated that rate of improvement decreased with increasing number of selection cycles. P1 showed only a slight increase in oil content, possibly due to the low value of the base population.

Intra-population recurrent selection based on half-sib families in gamma irradiated as well as common populations was studied by Silveira and Filho (1992). Additive variance for the traits studied was higher in irradiated population than in control.

Shivakumar (1995) noticed high response to selection for oil content and oil yield when followed half-sib and full-sib selection methods rather than mass and bulk-sib selection methods.

According to Telli *et al.* (1996) when sunflower cultivar subjected to open pollination followed by mass selection in two successive growing seasons to evaluate the genetic progress obtained by two selection cycles per year. He observed that spring selections were superior to summer ones.

Weginwar *et al.* (1998) developed a variety PKVSF-9 by recurrent selection. It is an early maturing variety (80-85 days). It had 21% higher seed yield and 22% higher oil content than Morden in multilocation trials.

Seneviratne (2002) reported an increase in seed yield of 35.42 per cent, plant height by 8.93 per cent, 100 seed weight by 11.89 per cent and oil content by 10.96 per cent over the base population at the end of three cycles of simple recurrent selection. He reported decrease in days to maturity by -10.53 per cent, head diameter by -9.93 per cent and number of unfilled seeds by -81.69 per cent.

2.2 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

There were attempts in the past to assess variability in sunflower populations for various traits and their heritable nature. The efficiency of selection in any crop depends upon the extent of variability and the genetic coefficient of variation expresses the real variability available in respect of seed yield and its component characters.

Efficiency and consistency of selection in a population in succeeding generations depend on the magnitude of heritable variation in relation to observed variation. High heritability of a character is useful for its better expression from generation to generation.

Lush (1949) proposed that heritability (narrow sense) as the ratio of additive variance to total variance. Burton and Devane (1953) proposed that the genetic gain of a particular character through selection can be expressed as the

product of heritability, phenotypic standard deviation and selection differential. Johnson *et al.* (1955) reported that though the heritability estimates give useful indication of relative values of selection, heritability values along with genetic advance should be considered to arrive at a more reliable conclusion. Hanson *et al.* (1956) suggested heritability in “broad sense” as the ratio of genetic variance to the total variance.

Low heritability was reported by Volif and Kasyaneko (1972) for characters like 100 seed weight and oil content. Klockzowski (1975) reported that genetic advance was higher for plant height and low for oil content. Srivastava and Mishra (1976) observed high heritability for seed yield per plant, 100 seed weight and stem girth. Low estimates of heritability were recorded for plant height and head diameter. However, Zali *et al.* (1977) recorded low heritability values for oil content.

Surendranath (1985) reported the highest GCV for plant height, whereas less variance for stem girth. He reported high heritability for plant height in F_2 and the highest genetic advance for plant height, while the lowest for stem girth. Singh and Yadava (1986) recorded high heritability for filled-seed per plant, 1000-seed weight and head diameter. Alam *et al.* (1987) noticed significant PCV and low GCV for seed yield, number of achenes and head diameter. He recorded high heritability and genetic advance for seed yield per plant.

Vanisree (1987) estimated heritability in narrow sense and found high values for days to 50 per cent flowering, plant height, oil per cent and 1000 seed weight.

Virupakshappa and Sindagi (1987) observed large range of variation for different characters *viz.*, plant height (50 to 187 cm), 100 seed weight (2.5 to 6.64 g), seed yield (4.15 to 40.63 g) and oil content (23.8 to 42.4%).

Gangappa (1991) noticed high PCV and GCV for dry leaf weight per plant, seed yield per plant, dry stem weight per plant and 100-seed weight. He reported high heritability and high expected genetic advance for total head weight and seed yield, whereas high genotypic and phenotypic variances for plant height, oil content and achene yield were observed by Muhammad *et al.* (1992). They reported high heritability and genetic advance for oil content and achene yield and high heritability and low genetic advance for plant height and capitulum diameter.

Shashikala (1992) noticed low heritability for characters like plant height, head diameter, number of filled-seeds per head, oil per cent and yield per plant, whereas moderate heritability for 100-seed weight. Jayaramaiah *et al.* (1993) and Jayarame Gowda (1994) recorded high GCV and PCV values for seed yield and oil yield per plant in sunflower.

Mogali and Virupakshappa (1994) found high PCV and GCV for 100-seed weight (41.7% and 40.1%, respectively), oil yield (38.4% and 30.7%), seed yield (35.8% and 26.4%), followed by number of filled-seeds per plant, plant height and head diameter. They observed high heritability and high genetic advance as per cent of mean for seed yield (68.6% and 50.5%, respectively), oil yield (64.1% and 50.7%), 100-seed weight (72% and 31.6%) and seed-filling (64.9% and 33.9%).

Narsaiah (1995) studied 70 genotypes and observed high variability for seed yield per plant followed by number of seed per capitulum and plant height. High heritability for plant height followed by seed yield per plant was noticed and also observed high genetic advance as per cent of mean for seed yield per plant and number of seeds per capitulum. Satisha (1995) noticed high PCV and GCV for seed yield per plant, oil yield per plant, stem girth and number of filled-seed.

Patil *et al.* (1996) observed high magnitude of genetic variation for head weight, seed yield and oil yield per plant. They reported high heritability coupled with low genetic advance as per cent of mean for plant height and oil content. They also noticed high genetic advance for head weight, seed yield, oil yield per plant and number of seeds per head.

Saravanan *et al.* (1996) observed high heritability estimates for capitulum diameter, plant height, number of leaves per plant, stem thickness and 100-seed weight. A combination of high heritability and high genetic advance was noticed for plant height, stem thickness, 100-seed weight and seed yield per plant.

In a genetic variability study comprising of 52 germplasm lines, Chakrapani (1997) noticed high GVC and PCV values for seed yield and head diameter. Gill *et al.* (1997) recorded 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. Chikkadevaiah *et al.* (1998) reported high estimates of genotypic and phenotypic coefficients of variability for seed yield per plant, head diameter

and filled-seeds per plant. They observed high heritability estimates for days to 50 per cent flowering, leaves per plant, husk per cent and seed oil content, whereas high genetic advance for filled-seeds per plant, seed-filling per cent and husk per cent.

Madrap *et al.* (1998) observed high broad sense heritability for plant height, head diameter, days to maturity, stem girth, filled-seeds, 1000-seed weight, oil content and seed yield per plant. Head diameter, 100-seed weight and yield per plant recorded high values for genetic advance. Similarly, high estimate of heritability coupled with high genetic advance were observed for plant height, 100-seed weight and yield per plant.

Rukmini Devi *et al.* (1999) reported that seed yield per plant recorded the highest GCV and PCV values followed by seed number per capitulum and head diameter, while the lower value was recorded for oil per cent. They reported the highest heritability for number of seeds per capitulum, seed yield per plant and the lowest heritability for oil per cent. Genetic advance was the highest for number of seed per capitulum followed by plant height. Genetic advance as per cent of mean was the highest for seed yield per plant followed by number of seed per capitulum, days to maturity and oil per cent.

Teklewold *et al.* (1999) reported high range for number of filled seed (64 – 1451), per cent autogamy (0 – 80.5), seed yield per plant (2.65 – 70.2 g) and seed-set per cent (29.27 – 89.64). They also noticed high PCV and GCV values for oil yield (61.09 and 57.82), seed yield per plant (58.24 and 56.83), number of filled-seed (41.73 and 34.37) and 100-seed weight (33.01 and 29.34)

and lower values for days to flowering, days to maturity, seed-set per cent and oil content. They observed high broad-sense heritability estimates for days to 50 per cent flowering, days to maturity, seed yield, oil yield, oil content and plant height. They also found high genetic advance as per cent of mean for oil yield and seed yield per plant. High heritability estimates coupled with high genetic advance were observed for seed yield and oil yield.

Ashok *et al.* (2000) reported high range for phenotypic and genotypic coefficient of variation for yield per plant and 100-seed weight. Days to 50 per cent flowering, plant height, stem diameter and capitulum diameter showed moderate PCV and GCV and low variability was recorded for days to maturity and oil content. They reported high heritability for plant height, days to 50 per cent flowering, days to maturity, capitulum diameter, 100-seed weight, seed yield per plant and oil content. A combination of high heritability and genetic advance was noticed for days to 50 per cent flowering, plant height, capitulum diameter, 100-seed weight and seed yield per plant.

Studies on full-sib and half-sib selection by Roy and Mishra (2000) showed high genetic advance in both the families for plant height, 100-seed weight and seed yield per plant. Genetic advance was high for head diameter, leaf length, leaf width in half-sib families, whereas in full-sib families genetic advance was low for these traits. For the characters like days to first flowering, days to 50 per cent flowering and days to maturity, the genetic advance was low in both the families.

Ojha and Roy (2001) studied 10 characters in sunflower for estimation of genetic components of variance and heritability. Results showed high genetic variance for yield per plant and plant height, low genetic variance for oil content. Khan (2001) observed high heritability values for days to 50 per cent flowering, 100-seed weight, days to maturity and oil content.

Sujatha *et al.* (2002) studied 51 inbreds and three control genotypes of sunflower which showed significant differences for 15 quantitative characters. The range of variation was the highest for per cent autogamy followed by plant height and oil yield, whereas it was the lowest for number of days to 50 per cent flowering and stem girth. Rao *et al.* (2003) studied 11 characters in 82 genotypes of sunflower for genetic variability, character association and path coefficients. Analysis of variance revealed significant genotypic differences for all the traits. The highest phenotypic and genotypic coefficients of variation were recorded for number of filled-seed per head (48.127 and 47.776, respectively), seed yield (45.723 and 45.522), plant height (21.069 and 20.581) and test weight (20.227 and 20.099).

2.3 CORRELATION

The estimation of genetic correlation coefficients between seed yield and its component characters had been of immense help for the selection of desired plant ideotype. Yield being dependent on morpho-physiological characters of the plant, it is desirable to know the contribution of these individual characters for developing effective selection strategies.

Dhaduk *et al.* (1985) from the analysis of data of oil yield and yield related traits in 20 diverse varieties suggested that breeding programme aimed at improving seed yield should be emphasized on capitulum diameter and 100-seed weight followed by number of filled-seeds per capitulum and harvest index. Singh *et al.* (1985) reported a positive correlation of head diameter, per cent filled seeds and 100-seed weight with seed yield per plant. According to Diaz *et al.* (1986), head diameter and number of achenes per head showed a high positive correlation with achene yield per plant.

Sharma *et al.* (1987) reported significant and positive correlation of 1000-seed weight and oil content with seed yield. Sheriff *et al.* (1987) observed that capitulum diameter and seed number per capitulum were the characters most closely related to seed yield. Naskar *et al.* (1988) studied correlation among seed yield and yield characters in 19 hybrids of sunflower. They observed significant and positive inter-correlation of seed yield, seed-filling per cent and 1000-seed weight. Khan *et al.* (1989) reported a positive correlation between yield and yield components as well as among yield components. They also observed a high correlation between head size and seed yield.

Chervet and Vear (1990) revealed that head diameter and plant height significantly correlated with seed yield. The characters like plant height, head diameter and 100-seed weight had highly significant and positive correlation with seed yield as observed by Chidambaram and Sundaresan (1990). Gangappa (1991) observed total head weight followed by harvest index and head diameter showed high positive correlation with seed yield. Alvarez *et al.* (1992) reported

that seed yield and oil yield were strongly correlated with seed number and seed weight, however, correlation between seed yield and oil content was not significant.

Lawrence and Mohammed (1993) observed that plant height, head diameter, number of leaves, leaf area per plant, number of seeds per head and 100 seed weight were positively correlated with one another and with seed yield per plant. Positive phenotypic correlation of seed yield with number of seeds per head, head diameter, 100-seed weight, seed-filling per cent and plant height was reported by Punia and Gill (1994), whereas, Rukmini Devi *et al.* (1998) reported positive correlation of seed yield with days to maturity and plant height. Narsaiah (1995) observed significant positive correlation of plant height, head diameter, days to maturity, number of seeds per head and test weight with seed yield.

The positive correlation of seed yield with head diameter, 100-seed weight, kernel oil content, plant height and leaf area was showed by Amenla *et al.* (1996). Doddamani *et al.* (1997) studied the inter-relations of eight characters in 47 genotypes of sunflower and reported that the head diameter followed by 100-seed weight and plant height showed a significant positive correlation with seed yield. A study on 30 genotypes of sunflower by Madrap *et al.* (1998) revealed that directional selection for 1000-seed weight, head diameter and yield per plant would be most effective for improving yield in sunflower.

Venkateswara Rao (1999) evaluated 84 sunflower genotypes and reported that the character seed yield had significant positive correlation with plant height, days to 50 per cent flowering, days to maturity, stem girth, number of filled-seeds per head and unfilled-seeds per head. Satyanarayana (2000) studied correlations in sunflower and reported the highest correlation of yield with days to 50 per cent flowering followed by number of filled-seeds and plant height. Teklewold *et al.* (2000) studied inter-relationships of 12 morpho-physiological traits on 144 sunflower genotypes. The study revealed that there was significant positive correlation between seed yield and plant height, number of filled-seeds, head diameter, 100-seed weight and harvest index, while days to maturity and oil content had significant negative association with seed yield.

Khan (2001) observed that days to 50 per cent flowering, number of seeds per capitulum, head diameter, days to maturity and 100-achene weight showed positive correlation with seed yield. Komuraiah (2002) studied character association in 101 sunflower genotypes and reported that number of filled-seeds per head recorded the highest positive correlation with seed yield. Nehru and Manjunath (2003) reported that genotypic correlation coefficients were higher than phenotypic correlation coefficients. Seed yield was positively associated with growth and yield components. Among the yield components, correlation of number of seeds per head was maximum with yield followed by head diameter, 100-seed weight and plant height.

CHAPTER III

MATERIALS AND METHODS

3.1 DEVELOPMENT OF BREEDING MATERIAL

Population improvement is a cyclic process, which adopts a repeated cyclic selections in the population to improve the performance of the population. The initial base population (C_0) has been developed at Project Coordinating Unit (Sunflower), Bangalore. The promising six lines *viz.*, 234B, 207B, PCSP 1, Morden, Acc.456 and Acc.1260 were selected to generate the base population. The specific features of these lines are furnished below :

Component lines	Attributes
234 B	High <i>gca</i> , compact seed packing in the head, bold seed size
207 B	Resistant to rust and downy mildew, high <i>gca</i>
PCSP 1	High yield and high oil content
Morden	Early, dwarf and good plant type
Acc. 456	High biomass
Acc. 1260	Tolerant to moisture stress

The base gene pool was generated by crossing *inter se* during *kharif*, 1995 and crossed seed obtained was bulked. The bulked seed was grown during summer, 1996 and sib-pollinated to generate more variability.

Using this base population, cyclic selection has been practiced at Directorate of Oilseeds Research, Hyderabad by adopting simple recurrent selection method which required three cropping seasons per cycle (Fig. 1).

The present study was under taken in its fourth cycle of selection process (C_4) during *Rabi*, 2002 and summer, 2003 to improve the third base population.

3.2 METHOD

Rabi, 2002

Using seeds of intermated lines of third selection cycle (C_3), a population of around 20,000 plants was raised in bulk. Recommended package of practices were followed to raise a healthy crop. From this population, about 2,000 plants were selected based on phenotypic superiority and were selfed. Out of these 2,000 plants, based on the various traits *viz.*, high autogamy, high oil content, number of filled-seeds and high seed yield, the better performing 200 plants were selected for the progeny test during *Rabi*, 2002.

Summer, 2003

From the remnant seed, the promising 200 plants selected along with three checks *viz.*, Morden, GAUSUF-15 and KBSH-1 were sown in Randomised Block Design and replicated twice at Directorate of Oilseeds Research, Hyderabad. The experimental material of 200 genotypes along with three checks are presented in Table 1.

Each genotype was sown in a row of 4.5 m length with a spacing of 60 x 30 cm. Two to three seeds were sown per hill to facilitate good emergence and to provide uniform stand. Thinning was done at second week after sowing to retain one healthy seedling per hill. Recommended package of practices were followed to raise a healthy crop.

3.3 OBSERVATIONS RECORD

In each entry, five competitive plants were selected at random and observations were recorded for seed yield and yield contributing characters. The method of recording data for each trait is described below.

3.3.1 Days to 50% flowering (days)

In each line, number of days taken for flowering in at least 50 per cent of the plants was counted and recorded.

3.3.2 Days to maturity (days)

It was recorded as the number of days from the date of sowing to the day on which the back of the capitulum in 50 percent of plants in a line turned to lemon yellow colour.

3.3.3 Plant height (cm)

The height of the fully-matured plants were measured in centimetres from the base of the plant to the attachment of the capitulum.

3.3.4 Head diameter (cm)

The diameter of the mature head at its maximum width was measured in centimeters.

3.3.5 Number of filled-seeds per plant

Total number of filled-seeds per head were counted and recorded.

3.3.6 Number of unfilled-seeds per plant

Total number of unfilled-seeds per head were counted and recorded.

3.3.7 100 seed weight (g)

One hundred filled-seeds were randomly taken, weighed and recorded in grams.

3.3.8 Seed yield per plant (g)

The total weight of filled-seeds from individual plants was recorded in grams after threshing and drying.

3.3.9 Oil content (%)

The seed oil content was determined directly with the help of Nuclear Magnetic Resonance (NMR) spectrometer in per cent at Directorate of Oilseeds Research, Hyderabad.

3.3.10 Oil yield per plant (g)

This was obtained by multiplying seed yield per plant with respective oil content.

3.4 STATISTICAL ANALYSIS

The details of various statistical methods followed are furnished below:

3.4.1 Analysis of variance

The data for different characters were statistically analysed for randomized block design (Panse and Sukhatme, 1957).

$$Y_{ij} = m + g_i + v_j + e_{ij}$$

Where,

Y_{ij} = phenotypic observation of i^{th} treatment in j^{th} replication

m = general mean

g_i = effect of i^{th} genotype

v_j = effect of j^{th} genotype

e_{ij} = random error

The analysis of variance for each character was carried out as indicated below:

Source of variation	d.f	SS	MSS	F-value
Replications	$r-1$	RSS	$M'r$	$M'r/M'e$
Treatments	$t-1$	TSS	$M't$	$M't/M'e$
Error	$(r-1)(t-1)$	ESS	$M'e$	
Total	$rt-1$			

where,

r = number of replications

t = number of genotypes

d.f = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

$M'r$ = mean sum of squares due to replication

$M't$ = mean sum of squares due to treatments

$M'e$ = mean sum of squares due to error

The test of significance was carried out by referring to 'F' table values. (Fisher and Yates, 1967).

3.4.2 Estimation of genetic parameters

3.4.2.1 Variance

The genotypic and phenotypic variances were calculated as per the formulae of Burton and Devane (1953).

Genotypic variance (σ^2g) =

$$\frac{\text{Mean sum of squares due to treatment (M't)} - \text{Mean sum of squares due to error (M'e)}}{\text{Number of replications}}$$

Phenotypic variance (σ^2p) = $\sigma^2g + \sigma^2e$

σ^2e = Error variance

Phenotypic (PCV) and genotypic (GCV) coefficients of variation were calculated by the formulae of Burton (1952).

$$\text{PCV (\%)} = \frac{\text{Phenotypic standard deviation } (\sigma p)}{\text{General mean } (\bar{x})} \times 100$$

$$\text{GCV(\%)} = \frac{\text{Genotypic standard deviation } (\sigma g)}{\text{General mean } (\bar{x})} \times 100$$

Categorization of the range of variation was followed as proposed by Sivasubramanian and Menon (1973)

Less than 10%	:	Low
10 to 20 %	:	Moderate
More than 20 %	:	High

3.4.2.2 Heritability in broad-sense [h^2 (b)]

Heritability in broad sense was estimated as per Allard (1960).

$$[h^2 (b)] = \frac{\text{Genotypic variance } (\sigma^2g)}{\text{Phenotypic variance } (\sigma^2p)} \times 100$$

As suggested by Johnson *et al.* (1955), $h^2(b)$ estimates were categorized as :

Low	:	0 – 30%
Medium	:	31 – 60%
High	:	61% and above

3.4.2.3 Genetic advance (GA)

This was estimated as per the formula proposed by Lush (1949) and Johnson *et al.* (1955).

$$\text{Genetic advance under selection (GS)} = k \cdot \sigma_p h^2(b)$$

Where,

K = selection differential at 5 or 10 per cent selection intensity which accounts to a constant value 2.06 and 1.76, respectively (Lush, 1949).

σ_p = phenotypic standard deviation

$h^2(b)$ = heritability in broad sense

3.4.2.4 Genetic advance as percent of mean

Genetic advance as per cent of mean was computed using the following formulae:

$$GAm = \frac{GS}{\bar{x}} \times 100$$

Where, \bar{x} = Mean for the character

This was classified as suggested by Johnson *et al.* (1955)

Low = Less than 10%

Moderate = 10 – 20 %

High = More than 20 %

3.4.2.5 Selection intensity (i)

It is the amount of selection applied, expressed as the proportion of the population favoured (selected).

3.4.2.6 Selection differential (S)

It is the average superiority of selected individuals over the mean of population of their origin.

$$S = \bar{x} - \mu$$

$$\bar{x} = \text{The average of all selected individuals}$$

$$\mu = \text{Mean of the population in which selection was applied}$$

3.4.2.7 Selection response

It is the deviation of the progeny mean (\bar{x}) of selected individuals from the original (unselected) population mean (μ). It is often referred as genetic advance or genetic gain under selection.

3.4.2.8 Selection response per cycle

Selection response per cycle was computed using the following formulae:

$$\text{Selection response per cycle} = \frac{\text{Genetic gain}}{\text{Number of cycles}}$$

3.4.3 Character association

Genotypic and phenotypic correlation coefficients were calculated using the method given by Johnson *et al.* (1955).

3.4.3.1 Phenotypic correlation coefficient

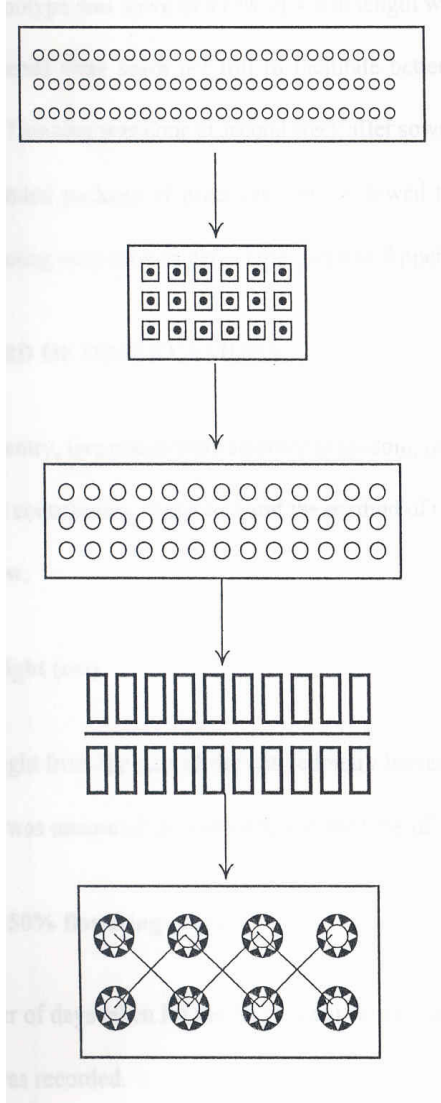
$$r_{p\ 1.2} = \frac{\text{Phenotypic covariance between 1 and 2}}{(\text{Phenotypic variance of 1} \times \text{Phenotypic variance of 2})^{1/2}}$$

3.4.3.2 Genotypic correlation coefficient

$$r_{g\ 1.2} = \frac{\text{Genotypic covariance between 1 and 2}}{(\text{Genotypic variance of 1} \times \text{Genotypic variance of 2})^{1/2}}$$

The test of significance of correlation coefficient was carried out by referring to 't' table values at n-2 degrees of freedom at 5% and 1% level of probability, where 'n' is the number of pairs of observations (Fisher and Yates, 1967).

Rabi, 2002



Fourth base population (C₄) >20,000 plants

Selfing of morphologically superior 2,000 plants

Laboratory analysis and selection of superior 200 plants

Summer, 2003

Progeny test in two replicates, selection of superior 50 plants

Intermating superior 50 plants (remnant seeds) to create fifth base population for the fifth selection cycle (C₅)

Fig 1 Selection cycle for population improvement (Simple recurrent selection)

Table-1 Experimental material of 203 sunflower genotypes.

S.No.	Genotype	S.No.	Genotype	S.No.	Genotype	S.No.	Genotype
1.	GP ₂ -197	51.	GP ₂ -924	101.	GP ₂ -1348	151.	GP ₂ -1886
2.	GP ₂ -218	52.	GP ₂ -936	102.	GP ₂ -1353	152.	GP ₂ -1894
3.	GP ₂ -219	53.	GP ₂ -944	103.	GP ₂ -1354	153.	GP ₂ -1895
4.	GP ₂ -234	54.	GP ₂ -946	104.	GP ₂ -1355	154.	GP ₂ -1902
5.	GP ₂ -243	55.	GP ₂ -957	105.	GP ₂ -1365	155.	GP ₂ -1905
6.	GP ₂ -320	56.	GP ₂ -971	106.	GP ₂ -1382	156.	GP ₂ -1914
7.	GP ₂ -334	57.	GP ₂ -975	107.	GP ₂ -1386	157.	GP ₂ -1943
8.	GP ₂ -337	58.	GP ₂ -985	108.	GP ₂ -1387	158.	GP ₂ -1944
9.	GP ₂ -357	59.	GP ₂ -1001	109.	GP ₂ -1396	159.	GP ₂ -1979
10.	GP ₂ -374	60.	GP ₂ -1025	110.	GP ₂ -1397	160.	GP ₂ -1991
11.	GP ₂ -382	61.	GP ₂ -1032	111.	GP ₂ -1400	161.	GP ₂ -1992
12.	GP ₂ -414	62.	GP ₂ -1048	112.	GP ₂ -1402	162.	GP ₂ -2000
13.	GP ₂ -457	63.	GP ₂ -1049	113.	GP ₂ -1406	163.	GP ₂ -2006
14.	GP ₂ -511	64.	GP ₂ -1065	114.	GP ₂ -1435	164.	GP ₂ -2008
15.	GP ₂ -516	65.	GP ₂ -1074	115.	GP ₂ -1431	165.	GP ₂ -2030
16.	GP ₂ -527	66.	GP ₂ -1082	116.	GP ₂ -1449	166.	GP ₂ -2035
17.	GP ₂ -607	67.	GP ₂ -1087	117.	GP ₂ -1451	167.	GP ₂ -2038
18.	GP ₂ -618	68.	GP ₂ -1111	118.	GP ₂ -1455	168.	GP ₂ -2072
19.	GP ₂ -629	69.	GP ₂ -1138	119.	GP ₂ -1460	169.	GP ₂ -2109
20.	GP ₂ -631	70.	GP ₂ -1144	120.	GP ₂ -1466	170.	GP ₂ -2114
21.	GP ₂ -637	71.	GP ₂ -1146	121.	GP ₂ -1470	171.	GP ₂ -2140
22.	GP ₂ -653	72.	GP ₂ -1158	122.	GP ₂ -1481	172.	GP ₂ -2165
23.	GP ₂ -662	73.	GP ₂ -1163	123.	GP ₂ -1491	173.	GP ₂ -2170
24.	GP ₂ -669	74.	GP ₂ -1168	124.	GP ₂ -1497	174.	GP ₂ -2226
25.	GP ₂ -671	75.	GP ₂ -1177	125.	GP ₂ -1502	175.	GP ₂ -2227
26.	GP ₂ -681	76.	GP ₂ -1180	126.	GP ₂ -1503	176.	GP ₂ -2240
27.	GP ₂ -687	77.	GP ₂ -1205	127.	GP ₂ -1515	177.	GP ₂ -2249
28.	GP ₂ -688	78.	GP ₂ -1217	128.	GP ₂ -1516	178.	GP ₂ -2250
29.	GP ₂ -701	79.	GP ₂ -1230	129.	GP ₂ -1526	179.	GP ₂ -2273
30.	GP ₂ -713	80.	GP ₂ -1231	130.	GP ₂ -1528	180.	GP ₂ -2275
31.	GP ₂ -722	81.	GP ₂ -1235	131.	GP ₂ -1583	181.	GP ₂ -2279
32.	GP ₂ -724	82.	GP ₂ -1237	132.	GP ₂ -1619	182.	GP ₂ -2280
33.	GP ₂ -737	83.	GP ₂ -1257	133.	GP ₂ -1625	183.	GP ₂ -2328
34.	GP ₂ -747	84.	GP ₂ -1258	134.	GP ₂ -1645	184.	GP ₂ -2339
35.	GP ₂ -750	85.	GP ₂ -1259	135.	GP ₂ -1676	185.	GP ₂ -2355
36.	GP ₂ -761	86.	GP ₂ -1284	136.	GP ₂ -1690	186.	GP ₂ -2385
37.	GP ₂ -777	87.	GP ₂ -1291	137.	GP ₂ -1696	187.	GP ₂ -2401
38.	GP ₂ -778	88.	GP ₂ -1301	138.	GP ₂ -1736	188.	GP ₂ -2419
39.	GP ₂ -779	89.	GP ₂ -1304	139.	GP ₂ -1746	189.	GP ₂ -2445
40.	GP ₂ -782	90.	GP ₂ -1305	140.	GP ₂ -1779	190.	GP ₂ -2446
41.	GP ₂ -793	91.	GP ₂ -1307	141.	GP ₂ -1782	191.	GP ₂ -2451
42.	GP ₂ -796	92.	GP ₂ -1308	142.	GP ₂ -1783	192.	GP ₂ -2460
43.	GP ₂ -831	93.	GP ₂ -1312	143.	GP ₂ -1819	193.	GP ₂ -2484
44.	GP ₂ -854	94.	GP ₂ -1314	144.	GP ₂ -1821	194.	GP ₂ -2489
45.	GP ₂ -762	95.	GP ₂ -1316	145.	GP ₂ -1824	195.	GP ₂ -2527
46.	GP ₂ -866	96.	GP ₂ -1317	146.	GP ₂ -1827	196.	GP ₂ -2545
47.	GP ₂ -874	97.	GP ₂ -1327	147.	GP ₂ -1836	197.	GP ₂ -2567
48.	GP ₂ -890	98.	GP ₂ -1335	148.	GP ₂ -1856	198.	GP ₂ -2640
49.	GP ₂ -899	99.	GP ₂ -1346	149.	GP ₂ -1862	199.	GP ₂ -2657
50.	GP ₂ -920	100.	GP ₂ -1347	150.	GP ₂ -1867	200.	GP ₂ -2663
						201.	Morden
						202.	GAUSUF-15
						203.	KBSH-1

CHAPTER – IV

RESULTS

The base population of the fourth cycle of selection (C_4) was raised in *Rabi* 2002 and about 2000 phenotypically superior plants were selected, selfed and the data were collected on days to maturity, plant height, head diameter, filled and unfilled-seed number, seed yield and oil content. These data were analyzed for the estimation of mean and range for above characters and are presented in Table 2.

The 200 plants selected from above population, along with three checks were raised in RBD replicated twice and the data were collected on eight characters *viz.*, days to 50 per cent flowering, days to maturity, plant height, head diameter, seed yield per plant, 100 seed weight, oil content and oil yield per plant. Data were analyzed for the estimation of mean, range, response to selection, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad-sense), genetic advance, genetic advance as per cent of mean and correlation of yield with its component characters.

The results are presented below under the following heads :

4.1 MEAN PERFORMANCE OF THE FOURTH POPULATION

The mean and range values of different characters of 2000 selected plants in the fourth cycle of population and spectrum of variability are presented in Table 3 to Table 9.

Days to maturity

This character exhibited a range from 80 to 109 days. The mean number of days to maturity was 95.45 days.

Plant height (cm)

Plant height ranged from 50 cm to 185 cm with a mean of 116.14 cm indicating high variability among the individuals of the population.

Head diameter (cm)

Head diameter recorded the high value of 20 cm and the low value of 4 cm with a mean of 10.88 cm.

Filled-seed number per plant

Number of filled-seeds per plant ranged from 0 to 1326 showing a high variability with a general mean of 550.99.

Unfilled-seed number per plant

Number of unfilled-seeds per plant ranged from 0 to 793 seeds with a general mean of 284.87 unfilled-seeds.

Seed yield per plant (g)

The mean value for seed yield ranged from 0 to 60.0 g with a general mean of 11.84 g indicating a high variability.

Oil content

Oil content was analysed for 500 samples only, out of 2000 samples. Oil per cent in the base population ranged from 38.8 to 46.4 per cent with a general mean of 42.86.

4.2 VARIABILITY PARAMETERS OF 203 LINES

The variability parameters of 203 lines for seed yield and yield contributing characters are furnished in Table 10, 11 and 12

The analysis of variance revealed that there were significant differences among the 203 lines for all the characters studied. It indicated that high amount of variability was present in the material selected (Table 13). The data pertaining to seed yield and its component characters are presented below :

Days to 50 per cent flowering

The mean of days to 50 per cent flowering of progenies was 54.95 days with the range 46 to 67 days. This character exhibited comparatively low variance (12.50).

Days to maturity

This trait recorded a mean of 84.95 days among progenies and the maturity duration ranged from 76 to 97 days. The estimate of selection differential was – 10.50 days.

Plant height

The mean plant height for the progenies ranged from 73.15 to 150.15 cm with a mean of 118.9 cm. The population exhibited a high variance (219.37), while the selection differential for the trait was 2.76.

Head diameter

The head diameter showed a range from 7.5 to 15.0 cm against the overall mean of 11.01 cm. For this character the variance was 2.3, whereas the selection differential value was 0.13 cm.

100 Seed weight

The overall mean observed for this trait was 6.03 g with a range of 4.05 to 8.4 g and variance of low value (0.97) was recorded.

Seed yield per plant

The range of seed yield per plant of the selected progenies was comparatively lower (15.25 to 49.25 g) than that of the base population (0-60 g). The variance showed for this character in the progenies was 53.49. A selection differential of 15.24 g was recorded.

Oil content

Among the progenies, the mean oil per cent ranged from 27.05 to 41.95 with the overall mean of 34.82 per cent. This trait showed a selection differential of -8.04 per cent.

Oil yield per plant

This trait showed a variance of 8.44 and a mean of 9.46 g among the progenies. The range recorded was 4.93 to 17.85 g in the progenies compared to the range of 0 to 13.25 g in the base population. This trait showed a selection differential of 3.83 g.

4.3 RESPONSE TO SELECTION

The mean and range for the seed yield and yield contributing characters of the original base population and the fourth cycle base population and the gain achieved after four cycles of selection are presented in Table-14 and Fig.2.

Days to maturity

A wide range (74 to 111 days) of days to maturity was present in the original base population and in the fourth population it was narrowed down to 76 to 97 days only. The mean of the original base population was 95 days and in fourth base population it was 85 days. The genetic gain was 10 days (decrease of -10.53%) with a response of -2.5 days per cycle.

Plant height

The original base population ranged from 49 to 215 cm, whereas fourth base population showed a range from 73.15 to 150.15 cm. The mean was 137.8 cm in the original base population, while it was 118.90 cm in fourth base population. The genetic gain for the character after four cycles of selection was –

18.9 cm (decrease of -13.71 per cent) with an average response of -4.72 cm per cycle.

Head diameter

This character displayed a range from 3 to 27 cm in original base population and a narrow range of 7.5 to 15.00 cm in fourth base population. The means were 15.2 and 11.01 cm in original and fourth populations, respectively. This character showed a genetic gain of -4.19 cm after four cycles of selection (-27.56%) showing a response of -1.04 cm per cycle.

Number of filled-seeds per head

This trait exhibited a range from 0 to 693 seeds per head in the original base population and cyclic selection resulted in increase in the range from 0 to 1326 seeds per head in the fourth base population. The means were 39.3 and 550.99 seeds per head in original and fourth populations, respectively. Cyclic selection resulted an increase of 1302.01 per cent for the character. The response to selection was 127.92 filled-seeds per head per cycle.

Number of unfilled-seeds per head

This character displayed a range from 0 to 1715 seeds per head in original base population and 0 to 793 seeds in the fourth base population. The means in the original and fourth populations were 655 and 284 seeds, respectively. The genetic gain for the character was -370.43 (-56.53%) seeds with a response of -92.61 unfilled-seeds per head per cycle.

100 seed weight

This character displayed mean of 3.87 and 6.03 g in original and fourth population, respectively, whereas the range in original population was from 1.8 to 5.9 g. In fourth base population, the range was 4.05 to 8.4 g. Percentage increase due to cyclic selection for the character was 55.81 per cent. The genetic gain was 2.16 g with response of 0.54 g per cycle.

Seed yield per plant

Seed yield per plant recorded a range from 0 to 84.47 g in original base population, whereas from 15.25 to 49.25 g in fourth base population. The mean of 4.32 g and 27.08 g were recorded for original and fourth populations, respectively. This character recorded a genetic gain of 22.76 g (526.85%) with a selection response of 5.69 g per cycle.

Oil content

Oil content exhibited a range from 15.0 to 40.7 per cent in original base population and from 27.05 to 41.95 per cent in the fourth population. The mean of 28.84 per cent was observed in original base population, whereas it was 34.82 per cent in the fourth base population. The genetic gain for four cycles of selection was 5.98 per cent increase (20.73%) with a response of 1.49 oil per cent per cycle.

4.4 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The phenotypic and genotypic coefficients of variability, heritability in broad-sense, genetic advance and genetic advance as per cent of mean were

calculated for eight characters for the 203 lines progenies and are presented in Table-15 and Fig.3 and 4. The phenotypic coefficient of variability (PCV) and genotypic coefficient of variability (GCV) values were on par for all the characters.

Days to 50 per cent flowering

High heritability (78.25 per cent), with low PCV (6.26%) and GCV (5.53) were observed for days to 50 per cent flowering and the genetic advance as per cent of mean was 8.61 per cent.

Days to maturity

The expected genetic advance as per cent of mean for days to maturity exhibited a low value of 5.66 per cent, while it recorded high heritability value of 79.94 per cent with low PCV (4.03%) and GCV (3.60%).

Plant height

Plant height showed moderate PCV (12.46%), GCV (9.40%) and high heritability (57.01%), whereas genetic advance as per cent of mean was 14.63 per cent.

Head diameter

The PCV and GCV values observed for the head diameter were 13.77 and 5.85 per cent, respectively. Heritability in broad-sense for this character was 18.06 per cent, while genetic advance as per cent of mean was 5.12 per cent.

100-seed weight

The character 100 seed weight recorded moderate PCV value of 16.37 per cent and GCV value of 15.97 per cent, whereas heritability and genetic advance as per cent of mean were 95.21 per cent and 32.10 per cent, respectively.

Seed yield per plant

The progenies recorded moderate PCV and GCV values (27.00 and 25.66 per cent, respectively) for seed yield and 90.31 per cent heritability and genetic advance as per cent of mean was 50.23 per cent.

Oil content

The PCV and GCV values observed for this character were 10.07 and 5.00 per cent, respectively. Heritability in broad sense for the character was 24.65 per cent. The genetic advance as per cent of mean was 5.11 per cent.

Oil yield per plant

A high genetic advance as per cent of mean (52.46 per cent) was observed for oil yield with a heritability value of 82.90 per cent. The PCV and GCV values were moderate (30.72 and 27.97 per cent, respectively).

In general among the characters studied the highest heritability (95.21%) was recorded for 100 seed weight, while the highest genetic advance as per cent of mean was noticed for oil yield (52.46%). Oil yield per plant also recorded the highest PCV (30.72%) and GCV (27.97%) values.

4.5 CHARACTER ASSOCIATION

4.5.1 Base population

The correlation coefficients for seed yield and yield attributes in the base population of the fourth cycle are presented in Table-16.

Plant height ($r = 0.1764^{**}$), head diameter ($r=0.1703^{**}$), number of filled seeds ($r=0.1165^{**}$) showed significant positive correlation with days to maturity.

Plant height showed significant positive correlation with all the characters. High association was observed for head diameter ($r=0.4602^{**}$), seed yield per plant ($r=0.3221^{**}$) and number of filled-seeds ($r=0.3026^{**}$).

Head diameter showed significant positive correlation with all the characters. It showed high association with plant height ($r=0.4602^{**}$).

Number of filled-seeds showed high significant positive correlation with seed yield per plant ($r=0.8701^{**}$), whereas moderate correlation with oil content ($r=0.3276^{**}$), plant height ($r=0.3026^{**}$) and head diameter ($r=0.2684^{**}$).

Number of unfilled-seeds exhibited significant positive correlation with days to maturity ($r=0.1165^{**}$), head diameter ($r=0.1891^{**}$) and plant height ($r=0.2142^{**}$). Number of filled-seeds ($r=-0.1369^{**}$), oil content ($r=-0.1561^{**}$) and seed yield per plant ($r=-0.1674^{**}$) showed significantly negative correlation with number of unfilled seeds.

Seed yield per plant ($r=0.8754^{**}$), number of filled-seeds ($r=0.3276^{**}$), plant height ($r=0.1355^{**}$) and head diameter ($r=0.1027^{**}$) showed significant

positive correlation with oil content. The character, number of unfilled-seeds ($r=-0.1561^{**}$) exhibited significant negative correlation with oil content.

Number of filled-seeds ($r=0.8701^{**}$), oil content ($r=0.8754^{**}$), plant height ($r=0.3221^{**}$) and head diameter ($r=0.2802^{**}$) showed significant positive correlation with seed yield per plant. The character number of unfilled-seeds ($r=-0.1674^{**}$) exhibited significant negative correlation with seed yield per plant.

4.5.2 203 Progenies

The phenotypic and genotypic correlation among seed yield and yield attributes are presented in Table-17. In general values for genotypic correlations were on par with phenotypic correlations. Hence, genotypic correlations are discussed below :

Days to maturity ($r_g=0.3816^{**}$), plant height ($r_g=0.6979^{**}$) and head diameter ($r_g=0.6142^{**}$) showed significant positive correlation with days to 50 per cent flowering.

Days to 50 per cent flowering ($r_g=0.3816^{**}$), plant height ($r_g = 0.4365^{**}$) and head diameter ($r_g=-0.2932^{**}$), seed yield per plant ($r_g=0.2873^{**}$), oil content ($r_g=0.2437^{**}$) and oil yield per plant ($r_g=0.3179^{**}$) exhibited significant positive correlation with days to maturity.

Plant height showed significant positive correlation with all the characters. High association of plant height was observed with days to 50 per cent flowering ($r_g=0.6979^{**}$), head diameter ($r_g=0.6608^{**}$) and days to maturity ($r_g=0.4365^{**}$). Seed yield per plant ($r_g=0.3652^{**}$), oil yield per plant ($r_g=0.3989^{**}$), oil content

($r_g=0.2802^{**}$) and 100 seed weight ($r_g=0.1426^*$) showed moderate correlation with plant height.

Days to 50 per cent flowering ($r_g=0.6142^{**}$), plant height ($r_g=0.6608^{**}$), days to maturity ($r_g=0.2932^*$), 100 seed weight ($r_g=0.2118^{**}$), seed yield per plant ($r_g=0.5855^{**}$) and oil yield per plant ($r_g=0.5147^{**}$) showed significant positive correlation with head diameter.

Plant height ($r_g=0.1426^*$) and head diameter ($r_g=0.2118^{**}$) showed significant positive correlation with 100 seed weight.

Oil yield per plant ($r_g=0.9894^{**}$), oil content ($r_g=0.2479^{**}$), head diameter ($r_g=0.5855^{**}$), plant height ($r_g=0.3652^{**}$) and days to maturity ($r_g=0.2873^{**}$) displayed significant positive correlation with seed yield per plant

Oil content showed significant positive correlation with oil yield per plant ($r_g=0.4012^{**}$), seed yield per plant ($r_g=0.2479^{**}$), plant height ($r_g=0.2803^{**}$) and days to maturity ($r_g=0.2437^{**}$).

Oil yield per plant exhibited significant positive correlation with seed yield per plant ($r_g=0.9894^{**}$), oil content ($r_g=0.4012^{**}$), days to maturity ($r_g=0.3179^{**}$), plant height ($r_g=0.3989^{**}$) and head diameter ($r_g=0.5147^{**}$).

4.6 SELECTION OF ELITE GENOTYPES FOR INTERMATING

The selected 50 genotypes on the *per se* performance of the 200 progenies, which may be to utilized for intermating to develop the base population for next

selection cycle (C5) and their performances for seed yield and yield attributing characters are presented in Table-18 and 19.

Number of days taken for maturity ranged from 85 to 109 days with a mean of 96.42 days. The mean plant height ranged from 100 to 180 cm with a mean of 136.84 cm and head diameter ranged from 8 to 17 cm with a mean of 12.88 cm.

The character, number of filled-seeds per plant, recorded a range from 823 – 1326 with a mean of 961.66, while number of unfilled seeds per plant showed a range from 0 – 419 with a mean of 115.94.

Seed yield per plant showed a narrow range from 23.8-60.0 g with a mean of 33.89 g. Oil content recorded a range from 40.5-45.8 per cent with a mean of 43.6 per cent, whereas oil yield per plant showed a mean of 14.74 g with a range of 10.30-27.24 g.

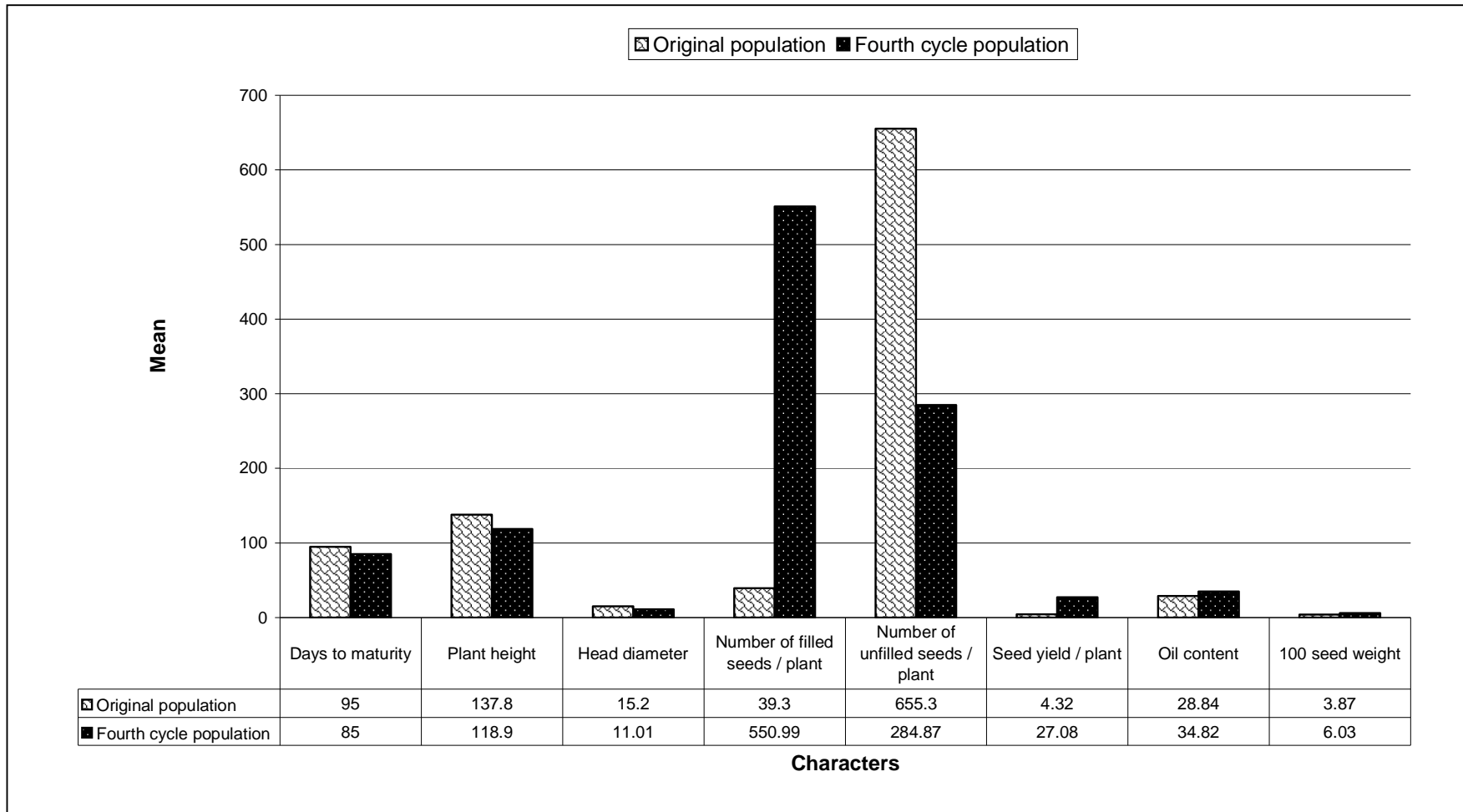


Fig. – 2 : Response to selection for seed yield and yield attributes

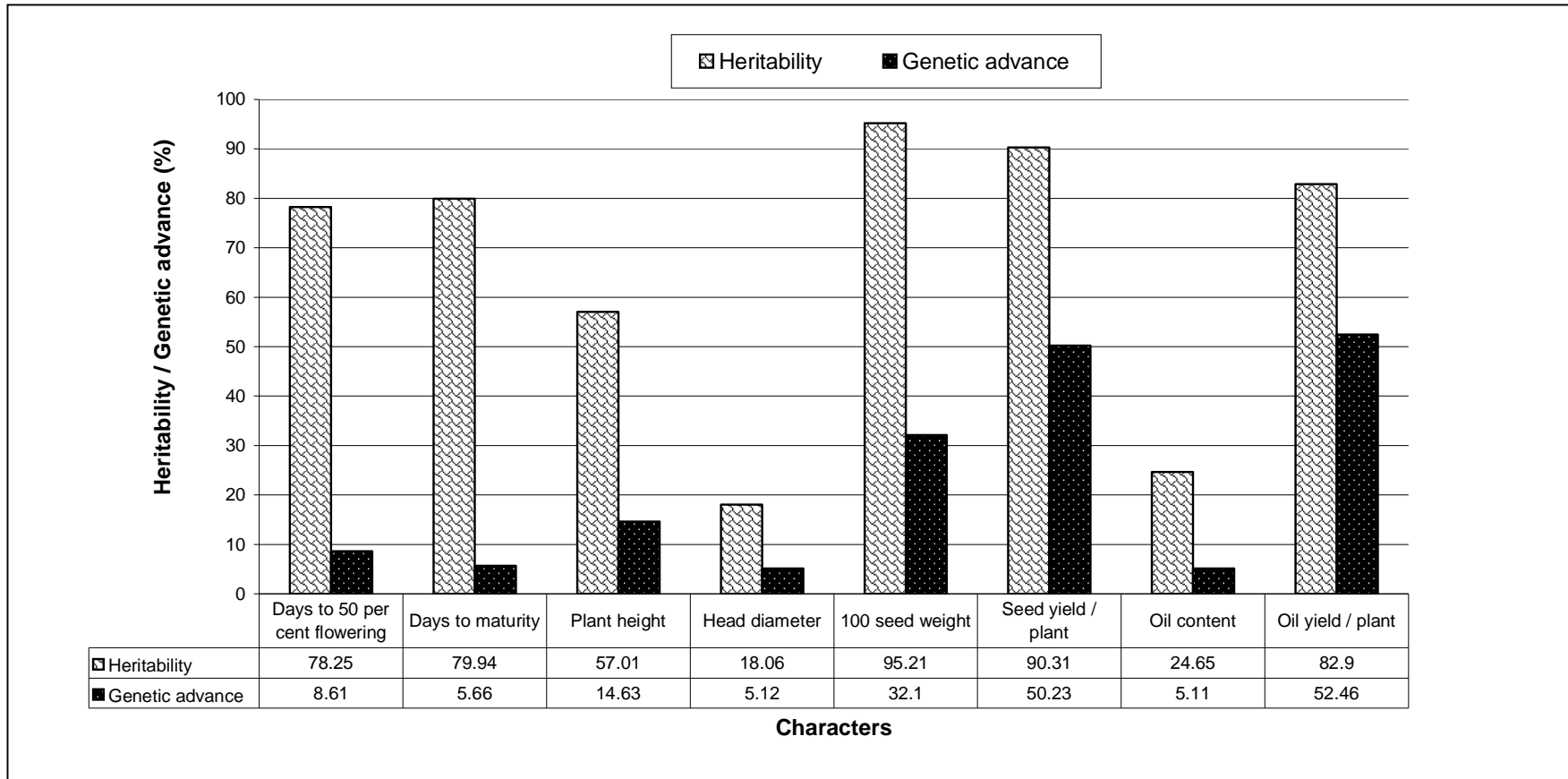


Fig. – 4 : Heritability and genetic advance as per cent of mean for seed yield and yield contributing characters

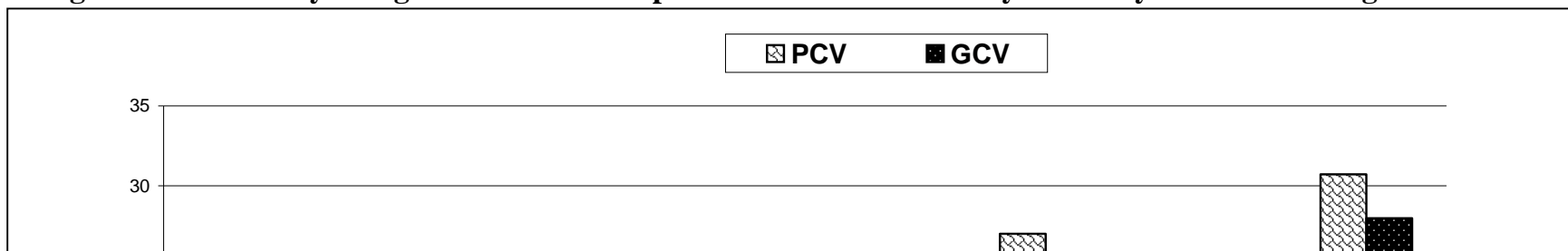


Table – 2 : Variability parameters of the fourth cycle (C₄) base population in sunflower

Character	Mean	Range
Days to maturity	95.45	80-109
Plant height (cm)	116.14	50-185
Head diameter (cm)	10.88	4-20
Number of filled-seeds per plant	550.99	0-1326
Number of unfilled-seeds per plant	284.87	0-793
Seed yield per plant (g)	11.84	0-60
Oil content (%)	42.86	38.8-46.4

Table – 10 : Mean performance of 200 sunflower progenies and 3 checks for seed yield and yield attributes

Sl.No.	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
1	GP ₂ -197	53.0	83.0	116.40	10.10	4.55	20.65	35.20	7.26
2	GP ₂ -218	56.0	86.0	102.70	10.20	6.45	21.85	38.50	8.43
3	GP ₂ -219	57.5	87.5	103.60	11.50	4.60	26.20	30.95	8.10
4	GP ₂ -234	56.0	86.0	102.50	9.10	5.80	16.90	30.85	5.20
5	GP ₂ -243	53.5	83.5	107.85	11.90	4.30	30.70	34.90	10.73
6	GP ₂ -320	55.0	85.0	109.80	11.00	4.60	24.25	30.85	7.46
7	GP ₂ -334	54.0	84.0	114.70	12.40	4.65	21.60	31.35	6.78
8	GP ₂ -337	48.0	78.0	103.20	9.10	5.40	22.45	32.90	7.36
9	GP ₂ -357	59.0	89.0	91.80	8.20	5.90	15.25	38.95	5.96
10	GP ₂ -374	54.5	84.5	105.00	10.80	5.90	19.40	35.70	6.91
11	GP ₂ -382	57.5	87.5	102.25	9.40	6.85	23.30	32.70	7.77
12	GP ₂ -414	58.0	88.0	112.40	10.30	5.05	31.70	38.70	12.20
13	GP ₂ -457	52.5	82.5	106.50	11.50	5.15	26.25	32.35	8.51
14	GP ₂ -511	54.5	84.5	125.90	10.70	4.80	35.75	36.70	13.25
15	GP ₂ -516	58.0	88.0	127.30	11.60	5.50	19.10	34.95	5.89
16	GP ₂ -527	55.5	85.5	112.00	11.30	6.25	23.55	33.20	7.82
17	GP ₂ -607	55.0	85.0	107.10	10.90	5.05	19.15	37.00	7.08
18	GP ₂ -618	53.5	83.5	126.50	11.70	6.45	32.50	37.65	12.11
19	GP ₂ -629	54.0	84.0	134.70	11.20	5.70	28.20	28.85	8.17
20	GP ₂ -631	47.0	77.0	119.80	9.80	5.35	32.00	34.25	10.97
21	GP ₂ -637	54.5	84.5	91.90	9.50	5.70	19.00	34.15	6.51
22	GP ₂ -653	57.0	87.0	113.80	10.60	4.95	30.25	34.45	10.47
23	GP ₂ -662	54.5	84.5	122.30	12.10	5.05	27.15	38.30	10.39
24	GP ₂ -669	54.0	84.0	124.15	11.00	6.20	23.60	31.65	7.50
25	GP ₂ -671	53.5	83.5	110.50	7.50	5.75	25.85	31.85	8.46
26	GP ₂ -681	53.0	83.0	108.50	10.80	4.45	32.00	34.75	11.17
27	GP ₂ -687	54.5	84.5	116.60	10.50	5.40	22.65	29.30	6.64
28	GP ₂ -688	54.0	84.0	137.80	12.30	4.80	23.65	32.70	7.78
29	GP ₂ -701	53.5	83.5	98.80	10.00	6.35	20.60	34.45	7.05
30	GP ₂ -713	56.5	86.5	84.50	10.30	7.60	25.95	41.35	10.73
31	GP ₂ -722	51.0	81.0	86.50	9.80	5.70	28.10	32.40	9.12
32	GP ₂ -724	53.5	83.5	113.00	10.10	5.20	20.05	31.40	6.19
33	GP ₂ -737	54.5	84.5	130.50	10.20	4.85	28.95	37.05	10.67
34	GP ₂ -747	51.5	81.5	109.30	9.80	5.35	23.75	34.25	8.11
35	GP ₂ -750	50.0	80.0	108.70	10.50	5.60	27.95	33.30	9.43
36	GP ₂ -761	53.5	83.5	116.60	10.90	7.00	22.70	33.05	7.49
37	GP ₂ -777	54.0	84.0	107.70	10.90	6.40	31.70	37.20	11.84
38	GP ₂ -778	54.0	84.0	120.40	10.40	7.25	33.20	28.80	9.56
39	GP ₂ -779	53.5	83.5	137.60	10.00	5.60	32.00	35.80	11.46
40	GP ₂ -782	53.0	83.0	106.90	11.20	6.40	30.75	37.40	11.50
41	GP ₂ -793	53.5	83.5	104.10	11.50	5.60	16.50	36.10	5.95
42	GP ₂ -796	54.0	84.0	104.30	10.70	6.00	33.20	34.70	11.53
43	GP ₂ -831	57.0	87.0	109.20	9.40	4.05	31.50	37.10	11.67
44	GP ₂ -854	53.5	83.5	108.70	11.20	6.60	27.90	35.65	9.85

Sl.No.	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
45	GP ₂ -862	52.5	82.5	105.80	11.60	6.00	20.45	33.70	6.90
46	GP ₂ -866	57.0	87.0	112.85	9.70	5.35	32.25	35.40	11.43
47	GP ₂ -874	57.5	87.5	100.70	8.90	5.90	24.40	36.50	8.91
48	GP ₂ -890	59.0	89.0	114.10	9.90	4.95	18.20	33.50	6.07
49	GP ₂ -899	47.5	77.5	104.80	9.50	5.10	25.65	34.15	8.90
50	GP ₂ -920	62.0	92.0	113.90	9.60	5.20	19.90	27.05	5.37
51	GP ₂ -924	53.0	83.0	101.10	8.30	5.00	16.70	30.95	5.16
52	GP ₂ -936	52.5	82.5	117.50	10.50	5.75	25.20	32.80	8.36
53	GP ₂ -944	56.5	86.5	127.60	12.00	6.40	25.40	38.20	9.71
54	GP ₂ -946	66.5	96.5	110.00	11.60	5.40	28.20	33.65	9.49
55	GP ₂ -957	59.0	89.0	115.80	9.60	5.10	18.85	40.00	8.54
56	GP ₂ -971	56.0	86.0	114.60	11.50	5.55	19.25	35.70	6.87
57	GP ₂ -975	52.0	82.0	120.60	11.60	5.00	28.30	34.70	9.82
58	GP ₂ -985	54.5	84.5	131.70	11.80	4.80	29.25	34.80	10.17
59	GP ₂ -1001	54.0	84.0	103.80	10.05	4.65	21.40	36.95	7.91
60	GP ₂ -1025	59.5	89.5	109.60	9.90	5.45	21.45	33.90	7.16
61	GP ₂ -1032	63.0	93.0	107.00	9.90	6.10	30.75	31.85	9.79
62	GP ₂ -1048	61.0	91.0	106.50	9.75	6.95	19.10	31.75	6.05
63	GP ₂ -1049	53.5	83.5	133.70	14.10	4.85	39.65	30.90	12.24
64	GP ₂ -1065	61.0	91.0	118.70	11.00	4.80	29.65	36.05	10.71
65	GP ₂ -1074	57.5	87.5	107.50	9.50	4.75	20.60	32.70	6.82
66	GP ₂ -1082	53.5	83.5	126.60	11.30	4.30	30.95	35.75	11.12
67	GP ₂ -1087	49.5	79.5	110.90	9.10	5.15	23.97	35.80	8.53
68	GP ₂ -1111	55.5	85.5	102.70	10.00	5.80	25.65	35.40	9.08
69	GP ₂ -1138	52.0	82.0	123.95	10.30	6.75	25.65	31.35	8.11
70	GP ₂ -1144	54.0	84.0	115.10	11.30	5.65	22.80	32.30	7.38
71	GP ₂ -1146	50.0	80.0	132.40	12.40	5.50	39.90	33.75	13.47
72	GP ₂ -1158	54.5	84.5	128.90	9.60	5.40	17.20	31.05	5.34
73	GP ₂ -1163	58.0	88.0	101.20	10.90	5.85	35.20	35.30	12.47
74	GP ₂ -1168	50.5	80.5	141.40	12.10	5.60	30.25	32.65	9.86
75	GP ₂ -1177	50.5	80.5	100.70	10.20	4.35	21.80	37.35	7.67
76	GP ₂ -1180	58.5	88.5	114.40	10.00	4.80	41.30	33.35	13.81
77	GP ₂ -1205	50.5	80.5	122.30	10.80	7.80	20.40	32.90	6.70
78	GP ₂ -1217	49.0	79.0	144.80	14.70	5.10	45.10	34.20	17.45
79	GP ₂ -1230	53.5	83.5	112.50	10.00	7.30	28.70	35.60	10.21
80	GP ₂ -1231	57.5	87.5	112.30	10.90	6.00	22.90	35.70	8.13
81	GP ₂ -1235	55.5	85.5	109.30	10.50	7.00	17.60	33.20	5.83
82	GP ₂ -1237	54.5	84.5	107.00	10.70	6.20	21.00	33.85	7.11
83	GP ₂ -1257	52.5	82.5	115.20	10.70	7.10	25.65	28.20	7.22
84	GP ₂ -1258	58.0	88.0	114.60	11.70	5.85	24.10	38.55	9.31
85	GP ₂ -1259	50.0	80.0	108.50	10.40	6.50	23.03	35.65	8.18
86	GP ₂ -1284	50.0	80.0	115.80	10.00	6.45	23.30	35.10	8.18
87	GP ₂ -1291	56.0	86.0	108.00	10.90	6.30	29.90	35.70	10.69
88	GP ₂ -1301	56.0	86.0	109.10	11.40	4.55	23.67	36.75	8.69
89	GP ₂ -1304	55.5	85.5	107.00	10.70	7.65	22.00	35.70	7.86
90	GP ₂ -1305	55.5	85.5	110.10	10.80	6.25	26.20	32.10	8.38
91	GP ₂ -1307	56.5	86.5	131.40	11.60	4.30	19.50	39.00	7.57

Sl.No.	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
92	GP ₂ -1308	54.0	84.0	108.10	10.70	6.20	22.00	32.75	7.24
93	GP ₂ -1312	49.5	79.5	112.50	11.30	5.95	24.70	36.00	8.88
94	GP ₂ -1314	55.0	85.0	139.05	10.20	6.25	28.05	36.70	10.26
95	GP ₂ -1316	52.0	82.0	127.50	11.30	4.80	28.05	35.05	9.69
96	GP ₂ -1317	52.0	82.0	116.70	9.40	5.15	20.80	33.50	6.94
97	GP ₂ -1327	54.5	84.5	126.10	12.40	5.45	28.50	35.75	10.20
98	GP ₂ -1335	51.0	81.0	105.70	9.00	5.40	20.95	33.60	7.03
99	GP ₂ -1346	57.5	87.5	123.70	11.50	5.80	26.25	35.05	9.18
100	GP ₂ -1347	54.5	84.5	115.13	9.30	4.50	29.90	33.40	9.98
101	GP ₂ -1348	51.5	81.5	117.75	11.60	4.25	29.20	35.35	10.30
102	GP ₂ -1353	58.0	88.0	104.40	9.50	5.80	22.85	33.05	7.57
103	GP ₂ -1354	57.0	87.0	101.60	9.50	7.85	19.60	35.20	6.88
104	GP ₂ -1355	64.5	94.5	119.40	13.10	7.20	30.10	33.20	10.00
105	GP ₂ -1365	53.5	83.5	114.35	9.75	6.05	30.70	35.00	10.79
106	GP ₂ -1382	56.5	86.5	121.10	12.70	5.75	41.76	32.70	13.67
107	GP ₂ -1386	51.5	81.5	118.90	12.15	6.80	17.95	32.50	6.09
108	GP ₂ -1387	58.0	88.0	111.30	10.20	5.95	20.40	30.60	6.23
109	GP ₂ -1396	54.0	84.0	117.50	11.60	6.15	28.70	32.50	9.34
110	GP ₂ -1397	56.0	86.0	110.40	10.90	6.80	20.55	40.75	8.23
111	GP ₂ -1400	58.0	88.0	119.20	10.30	5.80	20.10	36.40	7.32
112	GP ₂ -1402	52.0	82.0	108.70	10.50	6.05	32.65	35.80	11.67
113	GP ₂ -1406	55.5	85.5	114.00	10.80	7.80	37.30	37.85	14.13
114	GP ₂ -1435	54.5	84.5	127.50	10.30	7.15	34.35	37.55	12.89
115	GP ₂ -1431	54.0	84.0	88.20	9.60	5.55	27.35	33.05	9.04
116	GP ₂ -1449	56.0	86.0	120.10	10.80	7.00	37.40	37.60	14.05
117	GP ₂ -1451	66.0	96.0	129.85	10.85	6.20	21.20	35.70	7.55
118	GP ₂ -1455	58.0	88.0	113.70	11.60	8.10	32.10	32.00	10.29
119	GP ₂ -1460	55.5	85.5	137.20	11.80	6.55	26.00	35.10	9.14
120	GP ₂ -1466	53.5	83.5	105.30	11.60	6.45	30.85	37.80	11.66
121	GP ₂ -1470	57.5	87.5	117.00	11.40	6.80	21.35	31.70	6.76
122	GP ₂ -1481	52.5	82.5	106.65	8.60	6.05	17.35	41.95	7.28
123	GP ₂ -1491	56.0	86.0	111.60	11.10	5.15	45.35	37.60	17.04
124	GP ₂ -1497	58.0	88.0	112.90	9.70	5.30	21.00	34.65	7.28
125	GP ₂ -1502	56.0	86.0	114.00	11.20	7.15	28.80	34.20	9.90
126	GP ₂ -1503	55.0	85.0	130.60	12.50	5.10	23.50	40.15	7.09
127	GP ₂ -1515	55.5	85.5	130.00	12.60	5.20	41.35	35.80	14.80
128	GP ₂ -1516	54.0	84.0	121.40	11.30	5.70	18.80	33.05	6.18
129	GP ₂ -1526	56.5	86.5	131.90	12.00	6.50	30.75	33.60	10.33
130	GP ₂ -1528	57.0	87.0	124.60	10.70	7.45	23.15	32.85	7.65
131	GP ₂ -1583	58.5	88.5	135.50	11.70	5.70	30.82	33.95	10.50
132	GP ₂ -1619	58.0	88.0	123.50	12.90	8.40	31.20	32.55	9.80
133	GP ₂ -1625	53.5	83.5	145.80	12.70	4.65	24.10	40.55	9.77
134	GP ₂ -1645	56.0	86.0	135.70	10.50	5.50	24.05	31.80	7.66
135	GP ₂ -1676	52.0	82.0	115.80	10.30	5.40	19.20	33.70	6.42
136	GP ₂ -1690	52.5	82.5	128.10	10.90	6.25	37.70	39.10	14.72
137	GP ₂ -1696	54.5	84.5	131.50	11.60	4.20	30.65	37.80	11.59
138	GP ₂ -1736	55.5	85.5	120.00	11.50	7.40	23.80	40.25	9.54

Sl.No.	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
139	GP ₂ -1746	53.5	83.5	128.90	13.60	7.35	44.30	37.70	16.55
140	GP ₂ -1779	52.5	82.5	107.40	9.60	7.50	29.90	32.85	9.78
141	GP ₂ -1782	54.5	84.5	131.20	12.85	6.95	28.10	28.70	8.08
142	GP ₂ -1783	48.5	78.5	112.50	11.35	6.85	40.65	35.45	14.40
143	GP ₂ -1819	54.5	84.5	137.10	12.10	5.30	28.15	35.45	9.99
144	GP ₂ -1821	50.5	80.5	136.70	9.60	7.10	18.90	32.10	6.04
145	GP ₂ -1824	53.5	83.5	133.40	10.90	6.30	27.85	35.60	9.90
146	GP ₂ -1827	53.0	83.0	112.50	9.20	6.60	21.60	34.20	7.41
147	GP ₂ -1836	56.0	86.0	114.40	11.10	8.20	17.30	36.85	6.37
148	GP ₂ -1856	59.0	89.0	136.60	11.10	6.55	34.80	32.75	11.38
149	GP ₂ -1862	55.0	85.0	132.00	10.00	7.50	23.10	33.40	7.72
150	GP ₂ -1867	56.0	86.0	121.70	9.50	5.60	31.50	36.60	11.50
151	GP ₂ -1886	54.0	84.0	116.20	12.20	6.20	21.65	30.35	6.62
152	GP ₂ -1894	57.5	87.5	129.30	10.10	6.30	41.35	33.25	13.76
153	GP ₂ -1895	58.0	88.0	117.40	10.80	6.40	20.90	36.50	7.63
154	GP ₂ -1902	52.0	82.0	119.00	12.50	7.25	23.00	34.95	8.04
155	GP ₂ -1905	55.5	85.5	120.40	12.30	4.95	21.25	30.90	6.55
156	GP ₂ -1914	54.5	84.5	117.30	13.30	5.45	23.60	35.20	8.31
157	GP ₂ -1943	51.5	81.5	137.80	10.30	5.80	24.25	38.20	9.29
158	GP ₂ -1944	56.5	86.5	122.30	12.10	5.20	19.15	37.95	7.27
159	GP ₂ -1979	56.5	86.5	105.40	12.30	6.95	21.80	38.20	8.37
160	GP ₂ -1991	54.5	84.5	113.20	10.20	6.30	17.25	37.85	6.57
161	GP ₂ -1992	51.5	81.5	132.10	12.00	6.80	25.90	36.65	9.47
162	GP ₂ -2000	52.5	82.5	116.80	10.30	5.60	23.40	37.90	8.83
163	GP ₂ -2006	56.5	86.5	142.60	12.00	5.65	46.70	36.35	16.97
164	GP ₂ -2008	57.5	87.5	125.80	11.80	6.30	28.70	35.70	10.25
165	GP ₂ -2030	55.5	85.5	118.60	11.20	6.15	29.20	34.60	10.03
166	GP ₂ -2035	52.5	82.5	150.15	15.00	5.30	40.45	40.60	16.43
167	GP ₂ -2038	53.5	83.5	127.60	11.20	5.10	46.65	38.25	17.85
168	GP ₂ -2072	54.0	84.0	129.40	12.30	7.05	40.35	37.00	14.93
169	GP ₂ -2109	59.0	89.0	135.40	11.20	6.90	33.05	33.80	11.13
170	GP ₂ -2114	54.0	84.0	136.00	11.70	6.00	17.60	33.15	5.85
171	GP ₂ -2140	54.0	84.0	128.30	10.70	4.80	28.70	34.80	9.99
172	GP ₂ -2165	53.0	83.0	117.70	10.80	7.75	37.30	38.80	14.47
173	GP ₂ -2170	57.0	87.0	102.40	11.20	5.80	25.55	34.15	8.71
174	GP ₂ -2226	63.5	93.5	128.60	11.70	6.80	30.95	34.75	10.77
175	GP ₂ -2227	51.0	81.0	124.00	11.90	6.75	21.00	28.70	6.04
176	GP ₂ -2240	61.5	91.5	127.60	11.90	7.50	28.60	38.05	10.85
177	GP ₂ -2249	55.0	85.0	117.30	11.50	6.45	25.45	31.65	8.03
178	GP ₂ -2250	57.5	87.5	118.40	11.60	6.90	28.20	32.95	9.30
179	GP ₂ -2273	52.5	82.5	129.80	12.30	7.80	21.15	31.80	6.65
180	GP ₂ -2275	61.5	91.5	120.90	11.40	7.55	46.70	36.35	16.98
181	GP ₂ -2279	53.0	83.0	129.90	10.40	6.40	16.30	29.95	4.93
182	GP ₂ -2280	49.0	79.0	117.10	10.20	6.60	27.95	34.85	9.78
183	GP ₂ -2328	58.0	88.0	131.60	11.90	7.35	24.65	33.30	8.22
184	GP ₂ -2339	50.5	80.5	146.90	12.70	6.55	39.65	35.45	14.05
185	GP ₂ -2355	63.5	93.5	137.80	11.60	7.55	31.05	35.60	11.04

Sl.No.	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
186	GP ₂ -2385	55.5	85.5	116.70	12.40	6.85	28.95	35.65	10.31
187	GP ₂ -2401	54.5	84.5	131.20	11.70	5.50	20.15	32.95	6.61
188	GP ₂ -2419	56.5	86.5	140.50	12.50	7.20	33.70	40.80	13.74
189	GP ₂ -2445	54.5	84.5	126.50	11.80	6.55	37.80	40.05	15.15
190	GP ₂ -2446	56.5	86.5	121.40	12.40	5.75	19.25	34.00	6.55
191	GP ₂ -2451	52.5	82.5	143.60	11.30	7.65	20.65	36.35	7.51
192	GP ₂ -2460	57.0	87.0	140.20	12.50	7.50	33.20	36.40	12.05
193	GP ₂ -2484	61.5	91.5	148.60	13.50	8.20	39.95	35.35	14.12
194	GP ₂ -2489	55.0	85.0	123.20	12.60	7.50	23.60	32.95	7.83
195	GP ₂ -2527	53.0	83.0	143.40	11.40	6.05	36.70	38.60	14.26
196	GP ₂ -2545	56.5	86.5	144.30	10.40	5.25	26.65	36.10	9.62
197	GP ₂ -2567	58.5	88.5	116.50	10.40	6.80	18.55	40.65	7.53
198	GP ₂ -2640	53.5	83.5	115.30	12.80	6.45	29.85	34.75	10.40
199	GP ₂ -2657	57.5	87.5	142.00	11.40	8.35	30.05	35.80	10.76
200	GP ₂ -2663	54.0	84.0	134.20	10.20	7.50	20.75	36.90	7.65
	Inbred mean	55.0	85.0	119.01	11.00	6.04	26.90	34.85	9.40
201	Morden	48	78	73.15	11.00	5.00	31.65	29.45	9.35
202	GAUSUF-15	53	83	132.05	12.35	5.55	39.25	33.30	16.41
203	KBSH-1	53	83	129.35	11.70	5.95	36.55	37.30	13.61
	General Mean	54.95	84.95	118.90	11.01	6.03	27.08	34.82	9.46
	CV%	2.92	1.8	8.17	12.46	3.58	8.41	8.74	12.70
	S.Em±	1.6	1.53	6.87	0.97	0.15	1.61	2.15	0.85
	CD at 5%	3.14	3.0	19.03	2.69	0.42	4.46	5.97	2.35

Table – 4 : Variability spectrum of the selections of population with reference to plant height

Entry	Plant Height (cm)	Head Diameter (cm)	Days to maturity	No. of filled-seeds	No. of unfilled - eeds	Yield per plant (g)	Oil content (%)
GP ₂ -53	50	5	94	413	98	17.1	--
GP ₂ -421	50	5	85	410	231	17.4	--
GP ₂ -248	53	5	87	412	129	16.8	--
GP ₂ -54	56	5	85	410	220	17.2	--
GP ₂ -458	60	6	85	571	269	27.1	32.8
GP ₂ -509	62	5	84	495	356	20.6	29.7
GP ₂ -96	67	5	92	449	355	20.5	30.1
GP ₂ -521	67	5	85	395	119	15.1	--
GP ₂ -43	70	5	92	418	360	13.2	--
GP ₂ -474	70	5	85	452	185	17.0	--
GP ₂ -663	72	6	88	599	246	27.2	30.7
GP ₂ -343	74	7	87	527	218	26.2	29.9
GP ₂ -725	74	10	93	899	303	41.2	42.8
GP ₂ -259	77	5	87	326	111	11.2	--
GP ₂ -424	77	5	85	449	119	14.2	--
GP ₂ -430	77	8	86	809	119	33.7	40.7
GP ₂ -40	78	5	85	420	230	12.1	--
GP ₂ -81	78	5	93	392	171	12.1	--
GP ₂ -335	78	6	85	426	251	25.3	34.8
GP ₂ -401	78	5	85	412	111	11.5	--
GP ₂ -1347	120	11	82	851	0	24.0	43.0
GP ₂ -1382	120	11	96	836	43	24.4	42.8
GP ₂ -1402	120	12	96	937	112	32.8	43.5
GP ₂ -1406	120	15	98	846	216	25.0	31.2
GP ₂ -1431	120	10	99	733	327	23.6	30.9
GP ₂ -218	174	14	83	881	38	26.5	43.4
GP ₂ -12.03	175	11	94	756	21	20.6	28.1
GP ₂ -1645	180	15	95	1231	62	56.0	41.2
GP ₂ -2075	180	13	107	602	82	24.2	31.9
GP ₂ -973	185	14	85	836	32	22.1	30.2

Table – 5 : Variability spectrum of the selections of population with reference to head diameter

Entry	Head diameter (cm)	Plant height (cm)	Days to maturity	No. of filled-seeds	No. of unfilled-seeds	Seed yield / Plant (g)	Oil content (%)
GP ₂ -2094	20	155	107	821	179	35.2	40.7
GP ₂ -2453	20	142	105	796	162	26.2	32.8
GP ₂ -1360	19	144	99	676	269	22.6	30.0
GP ₂ -1557	19	170	99	657	218	23.6	29.8
GP ₂ -1657	18	136	100	738	172	27.8	34.6
GP ₂ -1667	18	156	98	878	146	28.0	38.2
GP ₂ -1816	18	140	103	868	164	27.1	32.9
GP ₂ -1853	18	158	102	773	277	17.1	--
GP ₂ -12.19	18	140	109	735	233	15.1	--
GP ₂ -2493	18	160	105	689	212	27.8	36.9
GP ₂ -1944	17	138	97	1326	0	60.0	45.4
GP ₂ -1983	17	159	98	853	222	25.8	30.9
GP ₂ -2072	17	150	109	977	216	36.8	44.6
GP ₂ -2086	17	180	107	733	277	20.4	24.7
GP ₂ -2384	17	134	105	926	200	33.4	41.6
GP ₂ -2459	17	126	107	846	226	25.9	26.8
GP ₂ -2061	16	150	109	641	229	13.6	--
GP ₂ -2084	16	150	105	787	133	25.1	29.7
GP ₂ -2249	15	135	106	926	113	31.5	40.2
GP ₂ -2250	15	135	103	951	112	34.6	41.0
GP ₂ -662	10	110	94	956	41	36.0	44.3
GP ₂ -671	10	136	89	755	109	26.0	42.7
GP ₂ -681	10	118	95	719	129	18.7	41.8
GP ₂ -686	10	114	97	522	188	34.4	42.1
GP ₂ -687	10	115	96	972	104	36.0	41.9
GP ₂ -27	5	88	94	450	380	11.7	--
GP ₂ -28	5	90	94	410	319	12.1	--
GP ₂ -30	5	90	93	420	313	12.0	--
GP ₂ -165	4	88	94	426	189	14.2	--
GP ₂ -376	4	18	86	447	82	13.9	--

Table – 8 : Variability spectrum of the selections of population with reference to seed yield

Entry	Seed yield / plant (g)	Plant height (cm)	Head diameter (cm)	Days to maturity	No. of filled-seeds	No. of unfilled-seeds	Oil content (%)
GP ₂ -1944	60.0	138	17	97	1326	0	45.4
GP ₂ -1645	56.0	180	15	95	1231	62	41.2
GP ₂ -957	48.0	155	13	91	1199	12	43.5
GP ₂ -1690	48.0	115	14	97	1197	0	43.4
GP ₂ -713	46.0	117	14	91	1129	13	40.8
GP ₂ -1307	46.0	138	15	92	1176	0	45.8
GP ₂ -2226	44.8	120	14	103	1096	10	44.2
GP ₂ -1048	43.9	125	13	89	1109	86	42.4
GP ₂ -2481	43.5	150	15	103	1026	26	44.0
GP ₂ -527	43.4	124	14	95	1103	9	41.5
GP ₂ -629	43.3	140	14	97	1106	0	40.7
GP ₂ -1316	43.3	137	14	95	1109	76	44.0
GP ₂ -516	42.0	134	14	94	1093	71	43.1
GP ₂ -1011	42.0	140	15	87	1021	55	43.8
GP ₂ -1304	42.0	140	15	93	1062	18	43.8
GP ₂ -1291	41.9	141	15	96	1081	16	40.3
GP ₂ -374	40.7	139	14	98	1082	6	43.5
GP ₂ -2415	40.6	148	15	106	808	89	44.2
GP ₂ -2339	40.5	130	15	106	1043	41	44.2
GP ₂ -2279	40.2	135	14	103	1009	21	44.6
GP ₂ -899	16.8	130	11	91	781	286	44.3
GP ₂ -2401	16.3	100	12	104	546	221	42.4
GP ₂ -2140	16.2	125	13	103	729	216	38.8
GP ₂ -890	16.0	137	10	86	719	147	40.6
GP ₂ -1779	16.0	122	14	102	612	316	41.0
GP ₂ -780	0	104	5	87	0	376	--
GP ₂ -810	0	104	5	85	0	309	--
GP ₂ -1121	0	134	10	94	0	649	--
GP ₂ -1200	0	123	7	91	0	238	--
GP ₂ -1478	0	106	10	96	0	626	--

Table – 6 : Variability spectrum of the selections of population with reference to number of filled-seeds

Entry	No. of filled - seeds	No. of unfilled- seeds	Plant height (cm)	Head diameter (cm)	Days to maturity	Seed yield / plant (g)	Oil content (%)
GP ₂ -1944	1326	0	138	17	97	60.0	45.4
GP ₂ -1645	1231	62	180	15	95	56.0	41.2
GP ₂ -957	1199	12	155	13	91	48.0	43.5
GP ₂ -1690	1197	0	115	14	97	48.0	43.4
GP ₂ -1307	1176	0	138	15	92	46.0	45.8
GP ₂ -713	1129	13	117	14	91	46.0	40.8
GP ₂ -1048	1109	86	125	13	89	43.9	42.4
GP ₂ -1316	1109	76	137	14	95	43.3	44.0
GP ₂ -629	1106	0	140	14	97	43.3	40.7
GP ₂ -527	1103	9	124	14	95	43.4	41.5
GP ₂ -2226	1096	10	120	14	103	44.8	44.2
GP ₂ -516	1093	71	134	14	94	42.0	43.1
GP ₂ -374	1082	6	139	14	98	40.7	43.5
GP ₂ -1291	1081	16	141	15	96	41.9	40.3
GP ₂ -1042	1073	0	143	13	89	42.3	40.2
GP ₂ -1304	1062	18	140	15	93	42.0	43.8
GP ₂ -1821	1061	0	150	14	97	40.0	44.6
GP ₂ -1138	1044	41	148	10	89	40.0	40.5
GP ₂ -2339	1043	41	130	15	106	40.5	44.2
GP ₂ -1225	1039	21	150	15	99	44.0	44.1
GP ₂ -1353	500	209	102	9	91	20.0	43.7
GP ₂ -1397	500	189	122	14	101	20.0	41.9
GP ₂ -1405	500	289	115	12	101	20.0	40.5
GP ₂ -1441	500	302	118	10	97	20.0	41.1
GP ₂ -1497	500	264	119	11	97	20.0	44.3
GP ₂ -2028	5	642	120	12	96	0.2	--
GP ₂ -2201	3	401	140	10	106	0.1	--
GP ₂ -346	0	729	84	8	84	0	--
GP ₂ -780	0	376	104	5	87	0	--
GP ₂ -810	0	709	94	5	85	0	--

Table – 7: Variability spectrum of the selections of population with reference to number of unfilled-seeds

Entry	No. of unfilled-seeds	Plant height (cm)	Head diameter (cm)	Days to maturity	Seed yield / plant (g)	No. of filled-seeds	Oil content (%)
GP ₂ -148	0	124	11	85	25.0	819	38.2
GP ₂ -214	0	137	11	91	32.0	926	40.6
GP ₂ -243	0	127	14	91	31.5	921	39.5
GP ₂ -573	0	116	12	87	24.1	829	42.4
GP ₂ -629	0	140	14	97	43.3	1106	40.7
GP ₂ -631	0	146	11	94	34.4	927	43.0
GP ₂ -738	0	112	10	97	34.0	939	43.2
GP ₂ -782	0	117	10	89	29.2	889	43.6
GP ₂ -892	0	142	11	89	34.0	940	43.1
GP ₂ -920	0	127	10	90	28.5	883	40.3
GP ₂ -924	0	125	12	95	36.2	957	41.6
GP ₂ -965	0	134	13	93	34.8	938	40.9
GP ₂ -1039	0	130	6	90	21.0	611	30.6
GP ₂ -1042	0	143	13	89	42.3	1073	34.9
GP ₂ -1044	0	136	11	87	33.9	938	38.6
GP ₂ -1231	0	110	11	94	28.3	896	40.9
GP ₂ -1347	0	120	11	92	24.0	851	43.0
GP ₂ -1690	0	145	14	97	48.0	1197	43.4
GP ₂ -1944	0	138	17	97	60.0	1326	45.4
GP ₂ -2055	0	135	14	102	21.3	811	34.9
GP ₂ -2384	300	134	17	105	33.4	926	41.6
GP ₂ -2385	300	114	14	104	27.3	976	44.9
GP ₂ -2402	300	125	12	105	19.2	788	24.9
GP ₂ -2444	300	132	14	107	23.1	724	34.2
GP ₂ -2446	300	140	14	104	20.9	816	29.8
GP ₂ -1652	764	140	18	103	7.1	68	--
GP ₂ -2045	771	150	18	107	6.6	286	--
GP ₂ -1972	787	163	13	97	0.2	12	--
GP ₂ -2416	792	117	13	106	12.8	279	--
GP ₂ -2316	793	140	18	106	0	0	--

Table – 3 : Variability spectrum of the selections of population with reference to days to maturity

Entry	Days to maturity	Plant height (cm)	Head diameter (cm)	No. of filled-seeds	No. of unfilled-seeds	Seed yield / plant (g)	Oil content (%)
GP ₂ -151	80	104	8	829	196	28.7	30.6
GP ₂ -854	89	107	9	789	286	18.4	43.4
GP ₂ -862	89	123	11	859	8	25.7	40.2
GP ₂ -864	89	114	10	784	116	18.4	22.4
GP ₂ -865	89	132	10	762	179	22.0	28.6
GP ₂ -891	89	126	10	820	232	22.0	26.0
GP ₂ -892	89	142	11	940	0	34.0	39.8
GP ₂ -894	89	139	11	808	337	20.8	31.0
GP ₂ -895	89	130	10	701	124	27.8	34.2
GP ₂ -914	89	122	10	854	181	25.7	29.8
GP ₂ -928	89	125	9	622	223	13.2	--
GP ₂ -952	89	113	9	742	234	15.2	--
GP ₂ -1010	89	112	9	732	172	13.7	--
GP ₂ -1030	89	156	11	924	101	30.8	40.8
GP ₂ -1035	89	109	8	731	112	13.1	--
GP ₂ -1048	89	125	13	1109	86	43.9	42.4
GP ₂ -1064	89	96	7	891	194	19.2	26.4
GP ₂ -1074	89	140	10	923	79	32.0	42.8
GP ₂ -1082	89	134	8	909	71	30.2	44.7
GP ₂ -1088	89	92	7	787	197	15.2	--
GP ₂ -1312	95	129	13	936	31	32.1	44.4
GP ₂ -1316	95	137	14	1109	76	43.3	44.0
GP ₂ -1354	95	124	15	841	131	23.0	40.3
GP ₂ -1365	95	124	12	896	219	28.3	40.1
GP ₂ -1373	95	100	8	874	21	27.4	40.2
GP ₂ -2058	109	140	13	808	399	18.2	--
GP ₂ -2060	109	145	13	741	241	13.3	--
GP ₂ -2061	109	150	16	729	241	13.6	--
GP ₂ -2067	109	135	15	868	189	16.3	--
GP ₂ -2072	109	150	17	977	216	36.8	44.6

Table – 9 : Variability spectrum of the selections of population with reference to oil per cent

Entry	Oil Content (%)	Plant height (cm)	Head diameter (cm)	Days to maturity	No. of filled-seeds	No. of unfilled-seeds	Seed yield / plant (g)
GP ₂ -1992	46.4	133	13	97	826	229	23.2
GP ₂ -1307	45.8	138	15	92	1176	0	46.0
GP ₂ -1308	45.7	126	11	94	829	216	24.6
GP ₂ -1400	45.7	130	14	104	942	21	37.2
GP ₂ -1894	45.7	136	14	96	917	76	30.7
GP ₂ -2038	45.6	140	12	99	886	316	28.7
GP ₂ -950	45.5	126	10	91	909	192	30.0
GP ₂ -1481	45.5	140	13	93	872	289	25.5
GP ₂ -1944	45.4	138	17	97	1326	0	60.0
GP ₂ -1284	45.3	120	12	92	866	41	25.8
GP ₂ -1503	45.2	105	10	95	916	17	10.0
GP ₂ -1515	45.2	112	12	96	988	21	38.0
GP ₂ -1736	45.2	126	12	100	862	169	25.4
GP ₂ -2000	47.2	126	11	101	910	69	30.0
GP ₂ -1032	44.9	132	11	90	913	179	31.0
GP ₂ -1991	44.9	140	13	96	843	286	23.4
GP ₂ -2385	44.9	114	14	104	976	300	27.3
GP ₂ -1168	44.8	119	14	99	989	281	38.0
GP ₂ -1258	44.8	12.7	12	89	912	66	31.0
GP ₂ -1163	42.9	132	13	96	809	308	20.0
GP ₂ -1230	42.8	144	15	95	917	219	31.4
GP ₂ -1257	42.8	130	13	92	987	76	38.8
GP ₂ -1382	42.8	120	11	96	836	43	24.4
GP ₂ -1466	42.6	130	12	84	941	126	32.0
GP ₂ -920	40.3	12.7	10	90	883	0	28.5
GP ₂ -750	40.2	110	9	92	853	179	26.9
GP ₂ -862	40.2	123	11	89	859	8	25.7
GP ₂ -747	40.0	129	13	93	981	217	36.4
GP ₂ -2140	38.8	125	13	103	729	216	16.2

Table - 11 : Variability parameters for seed yield and its attributes in 203 lines in sunflower

Character	Mean	Range	Variance
Days to 50 per cent flowering	54.95	46-67	12.50
Days to maturity	84.95	76-97	12.71
Plant height (cm)	118.90	73.15-150.15	219.37
Head diameter (cm)	11.01	7.50-15.0	2.30
100 seed weight (g)	6.03	4.05-8.40	0.97
Seed yield / plant (g)	27.08	15.25-49.25	53.49
Oil content (%)	34.82	27.05-41.95	12.30
Oil yield / plant (g)	9.46	4.93-17.85	8.44

Table - 12 : Range, mean and selection differential for seed yield and its attributes in sunflower

Character		Range	Mean	Selection differential
Days to maturity	BP	80-109	95.45	-10.50
	S ₁	76-97	84.95	
Plant height (cm)	BP	50-185	116.14	2.76
	S ₁	73.15-150.15	118.90	
Head diameter (cm)	BP	4-20	10.88	0.13
	S ₁	7.50-15.0	11.01	
Seed yield / plant (g)	BP	0-60	11.84	15.24
	S ₁	15.25-49.25	27.08	
Oil content (%)	BP	38.8-46.4	42.86	-8.04
	S ₁	27.05-41.95	34.82	
Oil yield / plant (g)	BP	0-13.25	5.63	3.83
	S ₁	4.93-17.85	9.46	

BP = base population of the fourth cycle
S₁ = progenies of the selected plants

Table – 13 : ANOVA for seed yield and yield attributes in 203 sunflower genotypes

Character	Mean sum of squares		
	Replications	Treatments	Error
Days to 50 per cent flowering	1.36	21.07**	2.57
Days to maturity	2.00	21.07**	2.57
Plant height (cm)	374.13*	344.44**	94.31
Head diameter (cm)	28.67	2.71**	1.88
100 seed weight (g)	0.003	1.90**	0.47
Seed yield / plant (g)	1.49	101.80**	5.18
Oil content (%)	6.29	15.33**	9.27
Oil yield/plant (g)	0.47	15.44**	1.44

* Significant at 5% level

** Significant at 1% level

Table – 18 : Selected 60 elite genotypes and their mean performance

Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
GP ₂ -218	53.00	94.50	102.70	10.20	6.45	21.85	38.50	8.43
GP ₂ -357	53.50	95.00	91.80	8.20	5.90	15.25	38.95	5.96
GP ₂ -374	56.00	94.50	105.00	10.80	5.90	19.40	35.70	6.91
GP ₂ -414	52.50	90.00	112.40	10.30	5.05	31.70	38.70	12.20
GP ₂ -511	55.50	96.00	125.90	10.70	4.80	35.75	36.70	13.25
GP ₂ -607	53.50	93.00	107.10	10.90	5.05	19.15	37.00	7.08
GP ₂ -618	58.00	97.00	126.50	11.70	6.45	32.50	37.65	12.11
GP ₂ -662	56.00	94.00	122.30	12.10	5.05	27.15	38.30	10.39
GP ₂ -713	51.00	93.50	84.50	10.30	7.60	25.95	41.35	10.73
GP ₂ -737	56.50	99.50	130.50	10.20	4.85	28.95	37.05	10.67
GP ₂ -777	55.00	94.50	107.70	10.90	6.40	31.70	37.20	11.84
GP ₂ -779	54.00	94.00	137.60	10.00	5.60	32.00	35.80	11.46
GP ₂ -782	53.00	99.00	106.90	11.20	6.40	30.75	37.40	11.50
GP ₂ -793	52.00	96.00	104.10	11.50	5.60	16.50	36.10	5.95
GP ₂ -874	51.50	89.00	100.70	8.90	5.90	24.40	36.50	8.91
GP ₂ -944	61.50	99.50	127.60	12.00	6.40	25.40	38.20	9.71
GP ₂ -957	58.00	92.50	115.80	9.60	5.10	18.85	40.00	8.54
GP ₂ -1001	54.50	94.50	103.80	10.05	4.65	21.40	36.95	7.91
GP ₂ -1082	60.50	99.50	126.60	11.30	4.30	30.95	35.75	11.12
GP ₂ -1138	58.00	98.50	123.95	10.30	6.75	25.65	31.35	8.11
GP ₂ -1146	55.50	94.00	132.40	12.40	5.50	39.90	33.75	13.47
GP ₂ -1177	56.50	97.50	100.70	10.20	4.35	21.80	37.35	7.67
GP ₂ -1217	59.50	101.50	144.80	14.70	5.10	45.10	34.20	17.45
GP ₂ -1258	53.50	96.00	114.60	11.70	5.85	24.10	38.55	9.31
GP ₂ -1307	56.50	98.50	131.40	11.60	4.30	19.50	39.00	7.57
GP ₂ -1327	58.00	100.50	126.10	12.40	5.45	28.50	35.75	10.20
GP ₂ -1397	55.00	96.50	110.40	10.90	6.80	20.55	40.75	8.23
GP ₂ -1406	50.00	96.00	114.00	10.80	7.80	37.30	37.85	14.13
GP ₂ -1435	54.50	95.00	127.50	10.30	7.15	34.35	37.55	12.89
GP ₂ -1449	50.50	95.50	120.10	10.80	7.00	37.40	37.60	14.05
GP ₂ -1466	51.00	91.00	105.30	11.60	6.45	30.85	37.80	11.66
GP ₂ -1481	55.50	101.50	106.65	8.60	6.05	17.35	41.95	7.28
GP ₂ -1491	50.00	97.50	111.60	11.10	5.15	45.35	37.60	17.04
GP ₂ -1515	58.50	98.00	130.00	12.60	5.20	41.35	35.80	14.80
GP ₂ -1625	59.50	96.50	145.80	12.70	4.65	24.10	40.55	9.77
GP ₂ -1690	56.00	100.00	128.10	10.90	6.25	37.70	39.10	14.72
GP ₂ -1696	60.50	97.00	131.50	11.60	4.20	30.65	37.80	11.59
GP ₂ -1736	55.50	97.50	120.00	11.50	7.40	23.80	40.25	9.54
GP ₂ -1746	56.50	100.50	128.90	13.60	7.35	44.30	37.70	16.55
GP ₂ -1867	58.50	94.50	121.70	9.50	5.60	31.50	36.60	11.50
GP ₂ -1894	56.50	99.00	129.30	10.10	6.30	41.35	33.25	13.76
GP ₂ -1943	59.50	97.50	137.80	10.30	5.80	24.25	38.20	9.29
GP ₂ -1944	60.00	99.00	122.30	12.10	5.20	19.15	37.95	7.27
GP ₂ -1979	52.00	96.00	105.40	12.30	6.95	21.80	38.20	8.37
GP ₂ -2006	60.50	97.50	142.60	12.00	5.65	46.70	36.35	16.97

Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Yield per plant (g)	Oil content (%)	Oil yield per plant (g)
GP ₂ -2035	57.50	98.50	150.15	15.00	5.30	40.45	40.60	16.43
GP ₂ -2038	55.50	98.50	127.60	11.20	5.10	46.65	38.25	17.85
GP ₂ -2072	52.50	99.50	129.40	12.30	7.05	40.35	37.00	14.93
GP ₂ -2165	54.00	98.50	117.70	10.80	7.75	37.30	38.80	14.47
GP ₂ -2240	52.50	95.00	127.60	11.90	7.50	28.60	38.05	10.85
GP ₂ -2275	54.00	97.50	120.90	11.40	7.55	46.70	36.35	16.98
GP ₂ -2280	55.00	98.50	117.10	10.20	6.60	27.95	34.85	9.78
GP ₂ -2339	58.50	93.00	146.90	12.70	6.55	39.65	35.45	14.05
GP ₂ -2385	54.50	92.50	116.70	12.40	6.85	28.95	35.65	10.31
GP ₂ -2401	61.50	95.50	131.20	11.70	5.50	20.15	32.95	6.61
GP ₂ -2419	57.50	96.00	140.50	12.50	7.20	33.70	40.80	13.74
GP ₂ -2445	61.00	96.00	126.50	11.80	6.55	37.80	40.05	15.15
GP ₂ -2484	56.00	98.50	148.60	13.50	8.20	39.95	35.35	14.12
GP ₂ -2527	62.00	101.00	143.40	11.40	6.05	36.70	38.60	14.26
GP ₂ -2567	54.50	96.00	116.50	10.40	6.80	18.55	40.65	7.53
GP ₂ -2657	56.50	92.50	142.00	11.40	8.35	30.05	35.80	10.76
General Mean	55.74	96.48	122.07	11.27	6.08	30.62	37.55	11.48
Morden	52.00	91.00	73.15	11.00	5.00	31.65	29.45	9.35
GAUSUF-15	57.50	94.50	132.05	12.35	5.55	49.25	33.30	16.41
KBSH-1	54.50	99.00	129.35	11.70	5.95	36.55	37.30	13.61

Table – 19 : Variability parameters for seed yield and yield attributes of selected 50 plants for intermating

Character	Mean	Range
Days to maturity	96.42	85-109
Plant height (cm)	136.84	100-180
Head diameter (cm)	12.88	8-17
No. of filled-seeds/plant	961.66	823-1326
No. of unfilled-seeds /plant	115.94	0-419
Seed yield / plant (g)	33.89	23.8-60.0
Oil content (%)	43.60	40.5-45.8
Oil yield / plant (g)	14.74	10.30-27.24

Table – 18 : Mean performance of 50 selected genotypes for seed yield and yield attributes

Genotype	Days to maturity	Plant height (cm)	Head diameter (cm)	No. of filled-seeds per plant	No. of unfilled-seeds per plant	Seed yield per plant	Oil content (%)	Oil yield per plant (%)
GP ₂ -1944	97	138	17	1326	0	60.0	45.4	27.24
GP ₂ - 1645	95	180	15	1231	62	56.0	41.2	23.08
GP ₂ -1307	92	138	15	1176	0	46.0	45.8	21.04
GP ₂ -957	91	155	13	1199	12	48.0	43.5	20.86
GP ₂ -1690	97	145	14	1197	0	48.0	43.4	20.83
GP ₂ -2226	103	120	14	1096	210	44.8	44.2	19.79
GP ₂ -713	91	117	14	1129	113	46.0	40.8	18.95
GP ₂ -2339	106	130	15	1043	41	40.5	44.2	17.89
GP ₂ -1696	93	140	10	1026	6	40.0	44.5	17.79
GP ₂ -374	98	139	14	1082	6	40.7	43.5	17.72
GP ₂ -793	88	132	11	1003	95	40.0	43.8	17.51
GP ₂ -1515	96	112	12	988	21	38.0	45.2	17.17
GP ₂ -2072	109	150	17	977	216	36.8	44.6	16.41
GP ₂ -1138	89	148	10	1044	41	40.0	40.5	16.19
GP ₂ -2484	107	140	14	971	26	36.1	44.8	16.17
GP ₂ -1491	95	115	14	988	121	38.0	42.3	16.08
GP ₂ -662	94	110	10	956	41	36.0	44.3	15.94
GP ₂ -2275	103	140	14	967	9	37.0	42.6	15.76
GP ₂ -1867	96	130	12	949	61	35.9	43.5	15.62
GP ₂ -1001	85	138	11	949	7	34.1	41.9	14.27
GP ₂ -1894	96	136	14	917	76	30.7	45.7	14.03
GP ₂ -2165	103	140	11	921	196	32.2	43.5	14.00
GP ₂ -1625	96	172	12	981	22	32.0	43.5	13.94
GP ₂ -1258	89	127	12	912	66	31.0	44.8	13.89
GP ₂ -1466	94	130	12	941	126	32.0	42.6	13.62
GP ₂ -1082	89	134	8	909	71	30.2	44.7	13.48
GP ₂ -944	95	140	13	922	419	31.3	43.0	13.46
GP ₂ -357	97	111	12	909	9	30.0	43.9	13.16
GP ₂ -1449	97	125	15	932	216	32.2	40.8	13.12
GP ₂ -2038	99	140	12	886	316	28.7	45.6	13.07
GP ₂ -2419	107	140	14	917	219	30.3	42.9	12.98
GP ₂ -511	85	100	11	910	46	30.0	43.0	12.80
GP ₂ -782	89	117	10	889	0	29.2	43.6	12.73
GP ₂ -1327	96	128	15	889	8	29.8	42.4	12.66
GP ₂ -2240	103	134	12	896	8	28.6	44.2	12.61

Genotype	Days to maturity	Plant height (cm)	Head diameter (cm)	No. of filled-seeds per plant	No. of unfilled-seeds per plant	Seed yield per plant	Oil content (%)	Oil yield per plant (%)
GP ₂ - 2280	102	128	11	897	216	29.7	42.9	12.44
GP ₂ -2385	104	114	14	976	300	27.3	44.9	12.25
GP ₂ -1217	96	124	12	912	316	30.5	41.5	12.16
GP ₂ -1746	99	137	15	886	69	28.0	43.2	12.08
GP ₂ -777	97	114	14	877	326	28.9	41.5	11.97
GP ₂ -1435	99	134	15	872	119	26.0	44.7	11.63
GP ₂ -1481	93	140	13	872	289	25.5	45.5	11.59
GP ₂ -1736	100	126	12	862	169	25.4	45.2	11.47
GP ₂ -218	93	174	14	881	38	26.5	43.4	11.46
GP ₂ -1943	101	150	13	856	41	26.0	44.1	11.46
GP ₂ -2244	105	133	13	829	389	23.9	44.6	10.66
GP ₂ -779	91	128	11	837	187	24.1	44.1	10.61
GP ₂ -1177	96	114	13	823	19	23.8	44.5	10.60
GP ₂ -874	87	115	10	829	217	23.8	44.3	10.55
GP ₂ -1406	98	120	15	846	216	25.0	41.2	10.30

Table – 17 : Phenotypic (r_p) and genotypic (r_g) correlations of seed yield and yield contributing characters

		Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Seed yield / plant (g)	Oil content (%)	Oil yield/ plant (g)
Days to 50% flowering	r_p	1	0.2634**	0.4873**	0.5925**	-0.0538	0.0430	0.0758	0.0704
	r_g	1	0.3816**	0.6979**	0.6142**	-0.0598	0.0694	0.0842	0.0831
Days to maturity	r_p		1	0.2999**	0.1291	0.0273	0.2244**	0.1963**	0.2647**
	r_g		1	0.4365**	0.2932**	0.0326	0.2873**	0.2437**	0.3179**
Plant height (cm)	r_p			1	0.4921**	0.1070*	0.3066**	0.1463**	0.2957**
	r_g			1	0.6608**	0.1426*	0.3652**	0.2802**	0.3989**
Head diameter (cm)	r_p				1	0.1984**	0.3418**	-0.1215	0.3496**
	r_g				1	0.2118**	0.5855**	-0.1018	0.5147**
100 seed weight (g)	r_p					1	0.0332	0.0659	0.0335
	r_g					1	0.0442	0.0727	0.0548
Seed yield / plant (g)	r_p						1	0.1457*	0.9432**
	r_g						1	0.2479**	0.9894**
Oil content (%)	r_p							1	0.4265**
	r_g							1	0.4012**
Oil yield/plant	r_p								1
	r_g								1

* significant at 5% level

** significant at 1% level

r_p = phenotypic correlation coefficient

r_g = genotypic correlation coefficient

Table – 15 : Estimates of variability and genetic parameters for seed yield and its attributes

Character	Mean	Coefficient of variation (%)		Heritability (%) (Broad-sense)	Genetic advance	Genetic advance as per cent of mean
		Phenotypic	Genotypic			
Days to 50 per cent flowering	54.95	6.26	5.53	78.25	4.73	8.61
Days to maturity	84.95	4.03	3.60	79.94	4.81	5.66
Plant height (cm)	118.90	12.46	9.40	57.01	17.39	14.63
Head diameter (cm)	11.01	13.77	5.85	18.06	0.56	5.12
100 seed weight (g)	6.03	16.37	15.97	95.21	1.94	32.10
Seed yield / plant (g)	27.08	27.00	25.66	90.31	13.60	50.23
Oil content (%)	34.82	10.07	5.00	24.65	1.78	5.11
Oil yield / plant (g)	9.46	30.72	27.97	82.90	4.96	52.46

Table – 16 : Correlation coefficients for seed yield and yield attributes in base population of sunflower

	Days to maturity	Plant height (cm)	Head diameter (cm)	Number of filled-seeds	Number of unfilled-seeds	Oil content (%)	Seed yield / plant (g)
Days to maturity	1	0.1794**	0.1703**	0.0369	0.1165**	0.0121	0.0428
Plant height (cm)		1	0.4602**	0.3026**	0.2142**	0.1335**	0.3221**
Head diameter (cm)			1	0.2684**	0.1891**	0.1027**	0.2802**
Number of filled-seeds				1	-0.1369**	0.3276**	0.8701**
Number of unfilled-seeds					1	-0.1561**	-0.1674**
Oil content (%)						1	0.8754**
Seed yield/plant (g)							1

* significant at 5% level

** significant at 1% level

Table – 14 : Variability parameters for seed yield and yield attributes in original population and fourth cycle population and response to selection

Character	Range		Mean		Percentage increase or decrease	Response per cycle
	Original population	Fourth cycle population	Original population	Fourth cycle population		
Days to maturity	74-111	76-97	95.0	85.0	-10.53	-2.5
Plant height (cm)	49-215	73.15-150.15	137.8	118.90	-13.71	-4.72
Head diameter (cm)	3-27	7.5-15.0	15.2	11.01	-27.56	-1.04
Number of filled seeds / plant (g)	0-693	0-1326	39.3	550.99	1302.01	127.92
Number of unfilled seeds / plant (g)	0-1715	0-793	655.3	284.87	-56.53	-92.61
100 seed weight (g)	1.8-5.9	4.05-8.40	3.87	6.03	55.81	0.54
Seed yield / plant (g)	0-84.47	15.25-49.25	4.32	27.08	526.85	5.69
Oil content (%)	15.0-40.7	27.05-41.95	28.84	34.82	20.73	1.49

CHAPTER – V

DISCUSSION

Sunflower (*Helianthus annuus* L.) cultivation started in India from 1972 with the Russian introduced varieties EC68413 and EC 68414. The crop has contributed significantly to the total oilseed production because of the development of several high yielding hybrids and open pollinated varieties suitable for cultivation in different agroclimatic regions of the country.

Plant breeding aims at genetic improvement of yield characters making the genotypes to be of agronomically adaptable and economically superior in their performance. The main aim of plant breeding programmes is to increase the yield potential of the crop.

In the recent years, the yield levels of sunflower reached to stagnant level. There is a need to develop superior inbreds so that these inbreds can be utilized in further breeding programme. The development of superior inbreds from the population is not an easy process, but involves several cycles of selection in a population improvement programme.

Systemic population improvement programmes help the breeders to generate superior populations with improved performance of the concerned characters by imposing directional selection and intermating them for the development of elite inbred lines. It enables the plant breeder for developing superior hybrids, synthetics and composites for commercial cultivation.

The present study was undertaken with the fourth cycle base population by adopting simple recurrent selection. The fourth cycle base population was raised during *rabi*, 2002, superior 200 progenies were selected for progeny test in summer, 2003. Based on the performance of these progenies, best 50 plants (remnant seeds) will be selected for use in raising the fifth cycle population for further improvement. The extent of genetic variability in the base population is essential to subject a population for selection and to achieve improvement in a particular trait(s).

The present investigation was carried out with an objective of finding response to selection, genetic parameters *viz.*, variability, heritability (broad-sense), genetic advance as per cent of mean and character association. The results obtained from the present study are discussed hereunder:

5.1 MEAN PERFORMANCE OF ORIGINAL AND FOURTH CYCLE OF POPULATIONS

The study of original population exhibited wide variability for all the characters studied. Days to maturity exhibited a wide range of variability from 74 days to 111 days and plant height as short as 49 cm to as tall as 215 cm. While head diameter showed small head of 3 cm to as high as 27 cm. Number of filled-seeds exhibited a high range of zero to 693 seeds, the unfilled-seed number was from zero to as high as 1715. This population showed a wide range for oil content from a low value of 15 per cent to a high oil content of 40.7 per cent, whereas 100 seed weight showed a range of 1.8 to as high as 5.9 g.

Similarly, in the fourth population, the genotypes exhibited considerable variation for seed yield and yield contributing characters. The range of variation for the mean performance of genotypes recorded for different characters were, days to maturity exhibited a range from 80 to 109 days, plant height ranged from 50 cm to 185 cm, head diameter recorded the highest value of 20 cm while the lowest value of 4 cm, number of filled-seeds ranged from zero to 1326, number of unfilled-seeds ranged from zero to 793, seed yield from zero to very high of 60 g and oil content ranged from 38.8 to 46.4 per cent.

In the present study, out of 200 genotypes evaluated, all the genotypes were taller as compared to the check, Morden, while 96 showed larger head diameter, whereas two genotypes flowered and matured earlier, 170 genotypes showed more 100 seed weight, 193 with more oil content, 40 genotypes with more seed yield per plant and 91 with more oil yield per plant as compared to Morden.

Compared to the check, GAUSUF-15, 41 genotypes were matured and flowered earlier, 24 genotypes produced larger heads, 31 were taller, 133 genotypes with more 100 seed weight, 17 with more seed yield, 127 with more oil content and only five with more oil yield.

Whereas, 47 genotypes produced larger heads, 44 were taller, 41 matured and flowered earlier, 99 with more 100 seed weight, 40 with more oil content, 21 with more seed yield per plant and 22 with more oil yield per plant than the KBSH-1 check.

The study of 200 progenies, obtained by exercising selection in the fourth base population revealed narrowing down of variability for most of the characters studied. It was observed that the range in the variability was low for days to maturity (from 80-109 to 76-97 days), plant height (from 50 – 185 to 73.15 – 150.15 cm), head diameter (from 4 – 20 to 7.5 – 15.0 cm), and seed yield per plant (from 0 – 60 to 15.25 – 49.25 g) in the selected 200 progenies compared to the fourth cycle base population. The reason for this type of variability is due to directional selection which ultimately leads to the high mean.

Virupakshappa and Sindagi (1987) observed high range of variation for plant height, 100 seed weight, seed yield and oil content. High range of variation was reported for plant height by Sujatha *et al.* (2002), whereas Teklewold *et al.* (1999) recorded high range of values for the characters *viz.*, leaf area, number of filled-seeds per plant, per cent autogamy, seed yield per plant and per cent seed-set.

The genotypes GP₂-1944, GP₂-1645, GP₂-1307, GP₂-957 and GP₂-1690 were the highest oil yielders and seed yielders among the progenies. High oil content was recorded in GP₂-1944, GP₂-1307, GP₂-1515, GP₂-1894 and GP₂-2038 progenies.

5.2 RESPONSE TO SELECTION

The population improvement programmes result into improved gene pool because of more frequency of favourable alleles in favourable combinations. The system is dynamic as hybridization and selection are employed simultaneously so as to create new genetic variability along with desired response. The progress of

selection depends mainly upon the nature of gene effects operating in a particular population. The present study was practiced to improve the population of sunflower in its fourth selection cycle (C₄) following simple recurrent selection. The variability parameters for the original base population and fourth cycle population for the characters were studied.

The highest per cent increase was recorded for filled seed number (1302.01 per cent). It showed a positive response of 127.92 filled seeds per cycle. The other character which showed high per cent response was seed yield per plant. It recorded 526.85 per cent increase with a positive response of 5.69 g seeds per plant per cycle. The oil content (20.73%) and 100 seed weight (55.81%) also recorded positive response for the selection. The respective response to selection for oil content and 100 seed weight were 1.49 per cent and 0.54 g per cycle.

Semihnenko and Kamennobroadskaja (1962), Harinarayana *et al.* (1980), Miller and Hammond (1985), Pandey *et al.* (1988), Mamonov (1991) and Seneviratne (2002) also reported increase in seed yield due to cyclic selection. Positive response for oil content was showed by Marozov (1944 and 1947), Stojkovic and Gibsman (1949), Semihnenko and Kamennobroadskaja (1962), Miller *et al.* (1977), Harinarayana *et al.* (1980), Shivakumar (1995) and Seneviratne (2002).

On the other hand, negative response was recorded for the characters, days to maturity, plant height, head diameter and number of unfilled-seeds. Days to maturity reported -10.53 per cent response, reflecting an average response of -2.5 days per cycle. Whereas, the cyclic selection has responded to the plant height by -13.71 per cent. Thus it lead to -4.72 cm per cycle. Head diameter reported -

27.56 per cent response, reflecting an average response of -1.04 cm per cycle. Whereas, unfilled-seed number per plant showed a negative response by reducing the unfilled-seeds by -56.53 per cent per cycle. The average response recorded for this character was -92.61 seeds per cycle.

Seneviratne (2002) reported negative response for days to maturity, head diameter and number of unfilled-seeds after three cycles of simple recurrent selection.

5.3 VARIABILITY PARAMETERS

The range in mean performance reflects the extent of phenotypic variance present in the material. Thus, it would be erroneous to infer on the magnitude of variability present based on range as a parameter, since it is composed of genetic and non-genetic components. Hence, partitioning of the total variability into genetic and non-genetic variance is essential.

The phenotypic variance indicates the amount of variance which is due to differences in phenotypic value, whereas the genotypic variance indicate the magnitude of variance arising from the differences in genotypic values. But, the phenotypic variance and genotypic variance values can not be used for comparing variability for different characters, as the mean of the characters to be measured could also be different. Hence, the coefficient of variation which is calculated by considering the respective means have been used for comparison. Higher estimates of these coefficients indicate wider diversity and *vice versa*. At the same time, narrow differences between phenotypic and genotypic coefficients of variation implies low sensitivity to environment effects.

In the present study, the values of PCV and GCV were high for seed yield (27.00 and 25.66 per cent, respectively) and oil yield (30.72 and 27.97 per cent, respectively). These findings are in accordance with the results of other workers (Jayaramaiah *et al.*, 1993; Jayarame Gowda, 1994; Mogali and Virupakshappa, 1994; Satisha, 1995 and Teklewold *et al.*, 1999).

Gangappa (1991) observed high PCV and GCV values for seed yield. High PCV and GCV values were also reported for seed yield by Muhammad *et al.* (1992).

High PCV and GCV values were obtained for seed yield and oil yield (Jayaramaiah *et al.*, 1993 and Jayarame Gowda, 1994).

High PCV and GCV values for seed yield alone was given by Chakrapani (1997); Chikkadevaiah *et al.* (1998); Rukminidevi *et al.* (1999) and Ashok *et al.* (2000).

100 seed weight showed moderate PCV and GCV value in the present study. Moderate PCV and GCV values were reported for 100 seed weight by Saravanan *et al.* (1996).

Plant height, head diameter and oil content showed moderate PCV and low GCV values in the present study. Significant PCV and low GCV values were reported for head diameter by Alam *et al.* (1987).

Among the characters studied, days to 50 per cent flowering and days to maturity exhibited low PCV and GCV values. These results are in accordance with the results of Teklewold *et al.* (1999) and Ashok *et al.* (2000).

5.3.1 HERITABILITY AND GENETIC ADVANCE

The heritability estimates indicate accuracy of the expressivity of trait with which a genotype can be assessed by its phenotypic performance and its effective utilization in judging the phenotypic selection. In the present study, broad sense heritability was estimated for all the characters.

High heritability estimates were observed for days to 50 per cent flowering (78.25%), days to maturity (79.94%), plant height (57.01%), 100 seed weight (95.21%), seed yield per plant (90.31%) and oil yield per plant (82.90%).

Similar kind of high heritability were also reported for these characters by Madrap *et al.* (1998), Teklewold *et al.* (1999), Ashok *et al.* (2000) and Khan (2001).

Surendranath (1985) also observed high heritability for plant height Singh and Yadava (1986) recorded high heritability values for number of filled-seed, 100 seed weight and head diameter. High heritability estimates have been reported for seed yield (Alam *et al.*, 1987), plant height, days to 50 per cent flowering, 100 seed weight, oil content (Vanisree, 1987), plant height and seed yield (Narsaiah, 1995).

The high heritability estimates for plant height, head diameter and 100 seed weight were observed by Saravanan *et al.* (1996) and for days to 50 per cent flowering and oil content by Chikkadevaiah *et al.* (1998).

Low heritability estimates were observed for head diameter (18.06%) and oil content (24.65%). Low heritability was reported by Volif and Kasyaneko (1972) for characters like 100 seed weight and oil content. Srivastava and Mishra (1976) recorded low estimates of heritability for head diameter.

Zali *et al.* (1977) recorded low heritability for oil content. Shashikala (1992) also reported low heritability for characters like plant height, head diameter, number of filled seeds per head, oil per cent and oil yield.

Heritability values alone can not provide any indication of the amount of genetic progress that would result from selection of the best individuals because estimates of heritability in broad sense includes both additive and non-additive gene action. Therefore, high heritability estimates accompanied by high genetic advance as per cent of mean would be a reliable tool of selection.

High heritability associated with high genetic advance as per cent of mean were recorded for seed yield per plant (90.31% and 50.23%, respectively) and oil yield per plant (82.90% and 52.46%, respectively). This is an indication for the presence of negligible environmental influence on these characters and prevalence of additive gene action in their expression. It indicates that these characters are amenable for improvement through selection process. Similar kind of observations for seed yield per plant and oil yield per plant were reported by

Mogali and Virupakshappa (1994), Teklewold *et al.* (1999) and Ashok *et al.* (2000).

Singh and Yadav (1986), Gangappa (1991) and Muhammad *et al.* (1992) recorded high heritability coupled with high genetic advance for seed yield. Mogali and Virupakshappa (1994) and Teklewold *et al.* (1999) observed high heritability with high genetic advance for seed yield and oil yield.

Saravanan *et al.* (1996), Madrap *et al.* (1998) and Ashok *et al.* (2000) reported high heritability and high genetic advance for plant height, 100 seed weight and seed yield. High heritability coupled with high genetic advance observed for seed yield by Alam *et al.* (1987), number of seeds per plant and seed yield by Rukmini Devi *et al.* (1999).

High heritability estimates associated with moderate genetic advance as per cent of mean recorded for plant height and 100 seed weight suggest that these characters were less influenced by environment, however, governed by both additive and non-additive gene action. Hence, improvement of plant height and 100 seed weight is still possible by selection with the present material under cyclic selection process.

The above findings were in consonance with the results obtained by Patil *et al.* (1996). They also reported high heritability coupled with moderate genetic advance for plant height and oil content. Muhammad *et al.* (1992) observed high heritability with moderate genetic advance for plant height and head diameter.

High heritability estimates associated with low genetic advance as per cent of mean was recorded for days to 50 per cent flowering (78.25% and 8.61%, respectively) and days to maturity (79.94% and 5.66%, respectively) show that these characters are less influenced by the environment but governed by non-additive gene action.

Present findings are in accordance with the earlier findings of Roy and Mishra (2000), they reported low genetic advance for days to 50 per cent flowering and days to maturity. Similar results of low genetic advance for days to maturity (6.08%) was also reported by Rukmini Devi *et al.* (1999).

Low heritability coupled with low genetic advance as per cent of mean was observed for head diameter (18.06% and 5.12%, respectively) and oil content (24.65% and 5.11%, respectively) show that these characters are highly influenced by the environment.

Similar kind of results were also reported for these characters by Volif and Kasyaneko (1972), Klockzowskii (1975), Srivastava *et al.* (1976) and Zali *et al.* (1977).

A perusal of genetic parameters from the above discussion suggests that the two most important economic traits *viz.*, seed yield and oil yield exhibited high genetic advance coupled with high heritability, indicating the improvement for these characters can be made by following direct selection.

5.4 CHARACTER ASSOCIATION

Seed yield is a complex character governed by several contributing traits. Hence, it is important to understand the association of different characters with

seed yield for enhancing the usefulness of selection criterion to be followed while developing varieties.

For the fourth cycle (C₄) population, the correlation coefficient was computed for days to maturity, plant height, head diameter, number of filled seeds, number of unfilled seeds, oil content and seed yield.

Plant height ($r = 0.3221^{**}$), head diameter ($r = 0.8701^{**}$), number of filled-seeds ($r=0.8701^{**}$) and oil content ($r = 0.8754^{**}$) showed positive association with seed yield. These findings are in accordance with the results of other workers (Lawrence and Mohammed, 1993; Punia and Gill, 1994; Narasaiah, 1995; Amenla, 1996; Doddamani *et al.*, 1997 and Teklewold *et al.*, 2000).

The positive association of number of filled-seeds with seed yield was noticed and the finding is similar to the earlier findings by Dhaduk *et al.* (1985), Singh *et al.* (1985), Sheriff *et al.* (1987), Alvarez *et al.* (1992), Lawrence and Mohammed, (1993), Punia and Gill, (1994), Narsaiah, (1995), Venkateswara Rao, (1999), Satyanarayana, (2000), Teklewold *et al.* (2000) and Komuraiah, (2002).

Plant height and head diameter showed positive association with seed yield and this is in consonance with the previous findings of Chervet and Vear, (1990), Chidamabaram and Sundaresan, (1990), Lawrence and Mohammed, (1993), Punia and Gill, (1994), Narsaiah, (1995), Amenla *et al.* (1996), Doddamani *et al.* (1997) and Teklewold *et al.* (2000).

The positive association of oil content with seed yield was in agreement with the results reported by Sharma *et al.* (1987) and Amenla *et al.* (1996).

In the present study, phenotypic and genotypic correlations were carried for the 203 lines. The genotypic correlations were on par with the phenotypic correlations, suggesting the less influence of environment.

Head diameter, plant height, days to maturity, oil yield and oil content showed significant positive association with seed yield.

Similar type of results were observed by Madrap *et al.* (1998) for oil yield by head diameter and Venkateswara Rao (1999) for days to maturity and plant height, by Teklewold *et al.* (2000) for plant height and head diameter by Khan (2001) for days to maturity and head diameter.

Narsaiah (1995) showed the positive association of plant height, head diameter and days to maturity with seed yield. Amenla *et al.* (1996) observed positive association of plant height, head diameter and oil content with seed yield. Doddamani *et al.* (1997) showed positive association of plant height with seed yield.

The results obtained indicated that seed yield was increased whenever there was increase in characters that were positive and significantly associated with seed yield. These characters can be considered as criteria for selection for higher yield as these were mutually and directly associated with seed yield.

CHAPTER – VI

SUMMARY

The present investigations were taken-up to improve the sunflower population through cyclic selection at Directorate of Oilseeds Research, Hyderabad. The base gene pool was generated by crossing six promising lines at project coordinating unit (sunflower), Bangalore. The base population consisted of 20,000 plants for the fourth cycle of selection (C_4), which was raised during *Rabi*, 2002, phenotypically superior 2,000 plants were selected and selfed. Based on the filled seeds and oil content performance, top 200 lines were selected for progeny test. During summer, 2003, progeny test was conducted to evaluate the 200 lines along with three checks (Morden, GAUSUF-15 and KBSH-1) for seed yield and yield component characters.

The base population (C_4) exhibited, wide range of variability for days to maturity, plant height, head diameter, number of filled seeds per plant, number of unfilled-seeds, seed yield and oil content.

The analysis of variance revealed significant differences for days to 50 per cent flowering, days to maturity, plant height, head diameter, 100 seed weight, seed yield, oil content and oil yield per plant, suggesting considerable variability among the 200 progenies.

A positive trend of selection differential was reported for plant height, head diameter, seed yield and oil yield among progenies as compared to the base

population. Whereas, days to maturity and oil content showed negative values for selection differential.

Response to selection showed positive gain of 511.69 for number of filled seeds per plant (127.92 seeds per cycle), 22.76 g for seed yield per plant (5.69 g per cycle), 5.98 per cent for oil content (1.49% per cycle) and 2.16 g for 100 seed weight (0.54 g per cycle). Whereas, genetic gain was in negative direction for unfilled-seed number (-370.43 seeds and -92.61 seeds per cycle), head diameter (-4.19 cm and -1.04 cm per cycle), plant height (-18.9 cm and -4.72 cm per cycle) and days to maturity (-10 days and -2.5 days per cycle) after four cycles of selection over the base population.

The overall perusal of PCV and GCV revealed high values for seed yield and oil yield and moderate values for plant height, head diameter, 100 seed weight and oil content, whereas days to 50 per cent flowering and days to maturity recorded low values. Heritability in broad sense was high for days to 50 per cent flowering, days to maturity, plant height, 100 seed weight, seed yield and oil yield. High heritability coupled with high genetic advance as per cent of mean was observed for seed yield and oil yield indicating predominance of additive gene action controlling the inheritance of these characters.

Further, high heritability coupled with moderate genetic advance recorded for plant height and 100 seed weight indicated the less influence of environment on these traits; since both additive and non-additive genes govern the traits, the improvement is also possible through simple selection process.

High heritability with low genetic advance for days to 50 per cent flowering and days to maturity indicate the presence of non-additive gene action. These traits can be improved through intermating of selects thereby gene constellation can be broken and free variability can be released in the advanced cycles of selection.

Low heritability coupled with low genetic advance as per cent of mean was observed for head diameter and oil content which indicated the high influence of environment on these traits and selection was ineffective.

Correlation analysis for base population revealed that plant height, head diameter, filled-seed number and oil content showed strong positive correlation with seed yield. These characters also exhibited strong positive correlation among themselves indicating additive gene action in their expression.

Phenotypic and genotypic correlation analysis revealed that oil yield, oil content and plant height showed strong and positive correlation with seed yield and significant positive correlation among these traits in the progenies. Plant height showed significant positive correlation with head diameter, days to 50 per cent flowering and days to maturity and also correlation among themselves.

The overall selection followed for the improvement of sunflower population from C₁ to C₄ indicates that enormous amount of variability created helped the Plant Breeder to operate the directional selection effectively and recombination of selected individuals create further variability. This has made the cyclic selection more effective and recorded substantial amount of genetic gain

for the selected traits, specially for filled-seed number, seed yield, 100 seed weight and oil content.

The elite genotypes having high seed yield, number of filled-seeds and oil content along with desirable yield contributing characters can be identified and selfed continuously for 5-6 generations. Sibbing will help to develop superior inbreds which can be utilized as parents for the commercial exploitation of heterosis in sunflower.

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