EFFECT OF VARIOUS SELECTION PROCEDURES ON POPULATION STRUCTURE AND THEIR RELATIVE EFFICIENCY IN SUNFLOWER (*Helianthus annuus* L.)

By

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M Sc , (Ag)

THESIS SUBMITTED TO THE
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CERTIFICATE

Mr. B. Narendra has satisfactorily prosecuted the course of research and that the thesis entitled **"EFFECT OF VARIOUS SELECTION PROCEDURES ON POPULATION STRUCTURE AND THEIR RELATIVE EFFICIENCY IN SUNFLOWER (*Helianthus annuus* L.)"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

Major Advisor

Date :

Place :

(Dr. G. LAKSHMI KANTHA REDDY)

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF VARIOUS SELECTION PROCEDURES ON POPULATION STRUCTURE AND THEIR RELATIVE EFFICIENCY IN SUNFLOWER (*Helianthus annuus* L.)"** submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Acharya N.G.Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. B. Narendra** 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 investigations have been duly acknowledged by the author of the thesis.

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DECLARATION

I, **B. NARENDRA**, hereby declare that the thesis entitled **"EFFECT OF VARIOUS SELECTION PROCEDURES ON POPULATION STRUCTURE AND THEIR RELATIVE EFFICIENCY IN SUNFLOWER (*Helianthus annuus* L.)"** submitted to Acharya N.G. Ranga Agricultural University for the degree of **Doctor of Philosophy** in Agriculture is the result of original work done by me. I also declare that the materials contained in this thesis has not been published earlier.

B Narendra

Date : 29/6/02 **(B. NARENDRA)**

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Kilogram	:	kg
Heritability in broad sense	:	$h^2_{(b)}$

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ABSTRACT

The present investigation was carried out at Regional Agricultural Research Station, Nandyal, Andhra Pradesh to study the **effectiveness of various population improvement schemes in improving yield and yield attributes.** The study was also aimed at to find out stability of populations/ characters over different locations and dates of sowing. The Morden open pollinated population was chosen for imposing population schemes like mass selection, half sib, full sib selection and selfed progeny selection schemes.

The base population allotted for various selection schemes revealed that the attributed plant height, head diameter, 100-seed weight, oil per cent, oil yield and seed yield / plant exhibited wider variability in the form of mean, range, variance and coefficient of variation.

Increase in head diameter, oil per cent and seed yield / plant were found in MS_2 *kharif* and *rabi* seasons over that of MS_0 population. Whereas

in BS_2 population, in different seasons, the mean values of all the yield attributes were lower than BS_0 and BS_1 populations except 100-seed weight and oil percent in *summer* season.

The HS_2 and FS_2 population showed increased mean values in oil yield and seed yield / plant over the base population. However, HS_2 population further showed an improvement in the mean values in the attributes like head diameter, 100-seed weight and oil percent. However, in S_2 bulk population, oil yield and seed yield / plant were mostly affected characters when compared to S_0 and S_1 populations.

The variance and co-efficient of variation were reduced as the generations advanced in all the populations of mass selection, bulk sib selection, half sib, full sib selection and selfed progeny selection schemes.

The comparative efficiency study of various population improvement schemes revealed that full sib and half sib selection schemes have more effective in improving oil yield and seed yield / plant.

High heritability and genetic advance were found in 100-seed weight, oil yield and seed yield / plant in HS_1, FS_2 and S_1 generation populations and broader scope for further improvement.

The differences between GCV and PCV values were narrow in all the attributes when studied in the second generation over all populations. This has resulted in obtaining high heritability estimates. However, high heritability and genetic advances were found in plant height and seed yield only.

The character association and path analysis in different generation populations of various selection schemes revealed that oil yield/ plant showed strong significant positive association with seed yield / plant and also resulted in maximum direct effect.

The genotype and environmental (locations) study revealed that all populations expressed greater unpredictable behaviour and instability for all characters across different locations. However, the stability of characters observed in the populations were, selfed progenies for seed yield, head diameter and plant height, bulk sibs and half sibs for oil percent, stem thickness and maturity, full sibs for head diameter and maturity, mass selection for 100-seed weight. The full sibs for poor environment, half sibs and MSFH-17 for average environment and selfed progenies for favourable environment were found suitable.

The genotype and environments (dates of sowing) study revealed that populations were highly responsive to changes in different dates of sowing. The full sibs and half sibs were found promising for seed yield and oil yield for cultivation under average environment. Whereas mass selected progenies for maturity and selfed progenies for oil percent were promising under poor environment.

Chapter - I

Introduction

CHAPTER - I

INTRODUCTION

Sunflower (*Helianthus annuus* L.) cultivation in India started in 1969 with the introduction of four Russian and a Canadian variety i.e. VNIIMK 8931 (EC-68413), peredovic (EC-68414), Armavirskii 3497 (EC-68415). Armaverts (EC-69874) and Sunrise, respectively. These varieties were extensively tested under ICAR coordinating system during *Rabi* 1969-70 and *Kharif* 1970-71. The performance of these varieties under multilocations has given hope of cultivating sunflower successfully in the country on large scale. The two varieties EC-68414 and EC-68415 became popular among five varieties tested and are still under cultivation. Subsequently, one early maturing germplasm line EC-101495 (Cerniaka-66) was identified during screening and evaluation of germplasm collection at Bangalore. This line on its introduction from USSR into Canada was called by name 'Morden'. Later this was released as Morden variety in Karnataka in the year 1979.

There was a phenomenal increase in the area of Sunflower from 500 ha in 1972-73 to 2.00 million ha in 2000 with a production touched to 1.17 million tonnes (Anonymous, 2000). Rapid increase in the area of sunflower crop due to its wide adaptability, short duration, photo-insensitivity, high water use efficiency, high quality oil, high oil content, low seed rate, low cost of cultivation and relatively low pests and diseases.

There were some constraints in the crop at the early stage of introduction viz., poor seed filling, susceptibility to bird damage, lack of high self fertile lines, non-availability of good varieties / hybrids, lack of good agronomic practices, lack of resistance to pests and diseases, lack of tolerance to drought, supply of inadequate and poor quality seed and lack of perfect seed production technology (nucleus and breeders seed). To over come these constraints intensive research programmes have been initiated with multi-disciplinary coordinated approach and encouraging results have been achieved in collaboration with different organizations like ICAR, SAU and other private agencies.

However, much emphasis was given for exploitation of heterosis in the hybrid development programmes using available cytoplasmic male sterility and genetic fertility restoration systems and less importance for the development of open pollinated varieties with a high genetic potential of yield on par with hybrid varieties. This has resulted inaccessibility of majority of poor farmers in the country for cultivation of hybrids because of its high cost. Not only that, the farmers of this country have a habit of saving the seed of the crop for future sowings. At this juncture, if critically analysed the overall situation in the country, there is need to concentrate the breeding efforts towards development of open pollinated sunflower varieties keeping the majority of the poor farmers in the country inview. The Morden variety was released in

1979 in Karnataka and even today this variety is widely grown in the country. This is the best example to indicate not much of breeding programmes were oriented towards varietal development programme. This is to be considered as a research gap. Whatever efforts have been made sofar in the varietal improvement programmes, several population improvement methods have been devised, tested and adopted in several parts of the world to exploit genetic variability in the base material. The most prominent methods enumerated by Virupakshappa, 1994 were (1) mass selection (2) pustovoit method (3) half sib family (4) full sib family and (5) selfed progeny evaluation. All these methods have been imposed individually on the base material and improvements were studied. However, the studies on relative efficiency of all these methods on a single base material are meagre and needs to be thoroughly investigated to launch a massive programme for improvement of open pollinated varieties in sunflower for seed and oil yield. This is the primary responsibility of a breeder to ensure that the production and qualitative value of seed for commercial exploitation should be consistently monitored to make the crop highly competitive for farm earnings and sustaining basic objective of self-sufficiency in vegetative oil consumption demand of Indian Population.

Apart from this, assessing the stability of populations described by imposing different population schemes is all the more necessary to identify suitable population derived by a particular scheme which interact favourably with the environments.

In the present investigation, Morden variety was chosen for imposing various population improvement selection schemes as this variety is the most stable, early, short stature and dependable variety grown with varying managerial skills and input capacities of the farmers in different environments.

Thus the present investigation aimed at in open pollinated Morden variety with the following objectives.

* To study mean, range, variance and coefficient of variation for yield and yield attributes in different populations derived by imposing various selection schemes.

* To compare the efficiency of mass selection (MS), bulk sib (BS), half sib (HS), full sib (FS) and selfed progeny (S) selection schemes in improving yield and yield attributes.

* To estimate various genetic parameters in various populations derived by different selection schemes.

* To study the effect of imposition of various selection schemes on the character association of yield and yield attributes.

* To study the effect of imposition of various selection schemes on direct and indirect effects of yield and yield attributes.

* To findout stable populations derived by various population improvement schemes in different locations / dates of sowing.

Chapter - II

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

Population improvement was the earliest method applied to cross pollinated crops. The interest in population improvement methods declined with the development of hybrids and synthetics. However, breeders are now paying more attention to population improvement programmes especially after establishing All India Co-ordinated Research Projects on various crops more specifically in cross pollinated crops like Sunflower.

The success of any plant breeding programme mainly depends on several factors like variability in the population, intensity of selection, genetic structure of the traits and more specifically the selection scheme employed. In the present investigation five selection methods viz., mass selection, bulk-sib selection, half sib selection, full sib selection and selfed progeny were compared for their 'relative efficiency in improving yield and yield attributes in an open pollinated population Morden. The literature pertaining to these studies has been reviewed under the following headings.

1. Relative efficiency of selection schemes
2. Genetic parameters
3. Correlation and path analysis
4. Stability

2.1 RELATIVE EFFICIENCY OF SELECTION SCHEMES

In sunflower relevant literature on selection methods is very meagre. Hence pertinent studies in maize and other cross pollinated crops like niger, brassica and pearlmillet have been reviewed.

2.1.1 *Sun flower* :

According to Marozov (1944 and 1947) the varieties derived from the closely related material has limited variability that lead to failure in increased 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 system of selection resulted in the production of two varieties with high (59%) oil content.

Semihnenko and Kamennobrodskaja (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.

Kloczowski (1975) predicted greatest genetic advance for plant height, 100 seed weight and seed yield per plant with 30% selection intensity. Expected genetic advance was moderate for husk content, where as it was low for oil content (2.2%).

Cull *et al* (1977) calculated heritability estimates, phenotype correlation and expected responses after one cycle of full sib and mass selection as well as the combination of both the methods. They observed that when heritability estimates were correlated for the effects of inbreeding and assortative mating with cross pollination, the later produced marked decrease in the heritability estimates necessitating to take these effects into account in sunflower breeding.

Miller *et al* (1977) obtained an increment of 12.2% is oil content after three cycles of recurrent selection. They opined that the selection for oil content in the early generations would be effective to improve oil content as the heritability estimates for the trait was sufficiently high.

The results of Harinarayana *et al* (1980) after three cycles of mass selection based on oil yield and oil content in three diverse populations, SF_1A, SF_2A and SF_3A showed that seed yield decreased in SF_1A and SF_2A in cycle 2 but increased in SF_3A. Response to selection for seed yield in

SF_3A was greater in cycle 3 than in cycle 2, oil content increased in SF_1A and SF_2A in cycle 2 but there after the rate of increase slowed down the SF_3A population. The SF_2A which had highest oil content initially, exhibited slower response to selection for oil content.

Miller and Hammond (1985) reported an increase in seed yield by 6.3 percent per cycle after three cycles of reciprocal full sib selection.

Pandey *et al* (1988) reported an increase in seed yield of 28 percent over the base population at the end of third cycles of modified mass selection.

After two cycles of recurrent selection for GCA, Mamonov (1991) obtained an increment in yield by 13.9 percent and oil content by 16 per cent in the improved sunflower population 27860. Nearly 18 percent of the selected families had higher GCA in the second cycle of selection as compared to the first cycle.

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

According to Telli *et al.* (1996) when sunflower cultivar subjected to open pollination followed by mass selection in 2 successive growing seasons to evaluate the genetic progress obtained by 2 selection cycles per year. He observed that spring selections were superior to *summer* ones.

2.1.2 *Maize*

Gardner (1968) applied ten years of mass selection on thermal neutron seed treated and untreated populations of maize variety. Hays golden thermal neutron irradiation applied to seeds for two generations increased the genetic variability but reduced the grain yield. Selections in both irradiated and control populations resulted in an increased seed yield by 3% per year and the final populations were more prolific, late maturing and taller than the original Hays golden variety. It was concluded that the additive genetic variance had increased in the irradiated populations.

Silva (1969) imposed two cycles of half sib selection on a broad genetic based maize composite cateto Columbia compost and the results indicated that simultaneous selection for grain yield and number of ears per plant would be effective and in cycle II the mean yield was increased by 8.8 to 10.9%.

EL-Rouby *et al* (1971) reported that both modified mass selection and ear-to-row selection schemes were effective in increasing the grain yield by 8.9 + 1.2 per cycle in an open pollinated variety American Early. Although the grain yield increased with ear to row selection but the genetic co-efficient of variability decreased.

Empig *et al* (1971) worked out expected genetic progress from mass, S_1, half sib, full sib, modified ear to row, top cross and reciprocal full sib selections in a random mating population. Based on the ratio of amount of additive genetic variance to the number of generations per cycle of selection, it was concluded that the most efficient intra population selection scheme was mass selection with pollen control followed by modified ear to row selection and S_1 progeny selection.

Paterniani (1973) revealed that reciprocal recurrent selection scheme in improving the combining ability after one cycle of selection. When the half sib progenies were test crossed, the scheme required three generations per cycle and test crossing of individual open pollinated plants required two generations per cycle. Improvement in combining ability was 6 and 4 percent, respectively for these schemes.

Bulow (1974) worked out for plant efficiency (grain/stover) ratio, grain yield and earliness in two composites L and V for three generations of mass selection and observed 0.65 + 3.6 percent increased grain yield per cycle.

Osuna (1974) observed that a selection intensity of 5 percent led to an improvement in grain yield and other agronomically valuable traits after two cycles of stratified mass selection applied on two broad genetic based flint and dent populations.

Poblete and Galan (1974) studied the effect of six cycles of mass selection for ear weight, grain yield and various yield components in three maize varieties. A significant response to selection for ear weight was noticed in Mexico group 10 and Xolache composites but when selection for grain weight was practiced, only Mexico group 10 responded to selection.

Rivera and Crompton (1974) revealed that three sub populations of Mezcla varieties Amarillos population when subjected for mass selection for prolificacy and grain yield, differential response to selection under different seasons indicated that when three cycles of selection were made during rainy season, the increase in yield was 10.5 and 0.8 percent per cycle when the progress was assessed during rainy and dry seasons, respectively. For ears per plant, the corresponding responses were 8.8 and 1.0 percent, respectively.

Results of two experiments conducted by Yap and Chiow (1974) to ascertain the effect of bulking superior full sib or their open pollinated progenies indicated that bulking of superior full sibs yielded 14.4 percent more in local flint and 11.9 per cent in metro variety. Further they noticed some improvement in yield components due to selection for yield but no significant effects were evident for plant and ear heights and days to tasselling.

Ismail (1975) observed that wide variability for several yield and yield attributes over two cycles of selection among full sib families of synthetic Laposta and progenies of Tuxp PB X AED populations.

Morales and Larangal (1975) observed that after three cycles of mass selection, number of ears per plant increased by 11.3 percent and grain yield by 7.3 percent per cycle in the crosses involving variety UPCA-2 while number of days for silking was reduced in crosses with UPCA-2 and UPCA-3.

Ayala (1976) applied mass selection with a selection intensity of 10 percent on two heterogeneous Brazilian maize populations and obtained an estimated gain of 2.82 percent per cycle for yield in dent composite and 3.45 percent in flint composite.

Hoegemeyer and Hallauer (1976) made selections among and with in full sib families and effected crosses among the selected and unselected lines from Iowa two year synthetic and pioneer prolific composite. Evaluation of the interpopulation indicated that 7.4 per cent higher than intra population crosses while the crosses of selected lines gave yields 11.2% higher than the unselected line crosses. They found that selection among and with in the full sib families was an efficient method to draw superior parental lines for hybrids.

Josephson and Kincer (1976) carried out mass selection for 14 generations in a maize variety jellicorse. Maximum increase in grain yield was 13.1% recorded between fifth and nineth generations of selection. Total increase in ears per plant and ear weight were 22.1 and 21.6% respectively, after 14 generations of selection. Mean yield of the selected plants increased by 9.2% from third to eighth cycle of selection.

Improvement in grain yield was found to be greater from sib family selection (5% per year) followed by mass selection (4.4%) and S_1 selection (4%) applied in a population Suceava-1 (Funduianu, 1977). However, selection of half sib families and selection based on crosses of S_1 lines x tester were least effective in improving the yield.

Mukherjee *et al* (1980) observed that among full sib, half sib and S1 selection practiced on four different genetically broad based and divergent populations, composites derived from half sib families gave no gain in yield but two of the four full sib families programs yielded 5 percent gain. Peixoto (1980) obtained improvement in yield and yield components by one cycle of selection among and with in half sib families of two composites. Response to selection was found to be greater for selection among families than the selection within them.

Osuna *et al* (1981) worked out 70 half sib families derived from a flint composite, against two control varieties and found that 26 half sib families surpassed the over all mean yield by more than 11 percent. Similarly, an increase of 18 percent for yield was recorded after eight cycles of mass selection exercised on synthetic variety 31A by Van and Illia (1981).

Zorilla and Crane (1982) observed an increase in grain yield by 2.86 q/ha or 5.46 per cent per cycle of full sib family selection in colus synthetic variety. Average gain from among and within family selection as 2.63q/ha or 4.1 percent per cycle compared to unimproved variety gain from selection was found to be highest in first of the three selection cycles.

Lima *et al* (1977) observed high yield and good agronomic performance in dentato composto MF-HS II after one cycle of mass selection and three cycles of selection with in and between half sib families and further expected gain of 10 percent for grain yield was observed of which 7% was attributed to selection between families and 8% with in family selection.

Kauffmann and Dudley (1979) evaluated the effectiveness of mass selection and half sib family selection for increasing protein percentage in two maize populations and observed that mass selection was as effective as half sib family selection.

Selection among full-sib families experimented by Zorilla (1979) in a maize synthetic opaque yielded a total gain of 20.9 percent (7% per cycle) for grain yield over the original variety .

Analysis of data on grain yield, oil content and oil yield revealed that the selection of full-sib families was more effective than half sib or mass selection for oil content in maize population Suceava-1 (Funduianu and Moga 1980). However, for oil yield, half sib or full sib families selection were equally effective.

A substantially lower genetic advance of 6.6 percent was realised after two cycles of full-sib selection made in Isla cultivar Ageti by Dhillon *et al* (1983).

Variation among half sib and full sib families for grain yield was studied by Dhillon *et al* (1984) in a random mating population J-663. Additive variance was significant for grain yield and hence resulted in improvement of the trait.

Moll and Hanson (1984) worked out the response to ten cycles of full sib family selection and ten cycles reciprocal recurrent selection for grain yield in two maize populations Jarvis and Indian chief. Average response to selection per cycle was 3.5 and 1.4 percent from full sib selection in Jarvis and Indian chief, respectively and average response from reciprocal recurrent selection was 2.4 and 0.3 percent for Jarvis and Indian chief, respectively.

Khehra *et al* (1985) worked out expected genetic advance per cycle of selection and reported highest for full-sib selection (12.44%) followed by half-sib (11.23%) and mass selection (4.47%) in 64 half sib and 256 full sib families of Makki–safed-1 variety when they were evaluated for grain yield.

Pal *et al* (1986) studied 115 each full sib and S_1 families for yield and its related traits at 10 percent selection intensity and noticed that the realized gain from full sib selection was comparable to expected gains for grain yield but lower gains were realised for other traits. Realised gain per cycle was higher through full-sib selection than through S_1 family selection for grain yield. Thus full-sib selection was better than S_1 selection in intra population improvement.

Wright and Cockerham (1986) expressed that on the basis of progeny tests it is revealed that both progeny testing and family selection schemes (full sib or half sib) were superior than mass selection. Whenever the rate of self fertilization was low, family selections were found to yield greater permanent gains over range of heritability values than the mass selection.

In maize crop Pandey *et al* (1987) evaluated four different populations employed by full sib selection at different environments. Per cent gain per cycle of selection averaged over populations and environments were statistically significant indicating the efficiency of full-sib selection for improving the maize populations.

Based on results generated from two selections schemes Arha *et al* (1990) concluded that selection of full sib families were superior to mass selection.

Reddy and Agarwal (1992) predicted the genetic gain from full-sib family selection applied to a maize composite D-742. Full sib family selection with the advantage of selecting more than one character at a time showed expected response approximately three times more than mass selection.

Byrne *et al* (1995) subjected population Tuxpeno Sequia (TS) to eight cycles of full sib recurrent selection at one location with managed drought stress while Tuxpeno I (T_1) to six cycles of modified half sib selection scheme that relied on multilocation trial data. When studied over 12 environments both TS and T_1 populations revealed significant differences in rates of change per cycle for grain yield ears per plant, plant height and anthesis and silking interval.

The interaction of environments with the linear rate of gain in grain yield was not significant in either populations, indicating similar progress across the range of environmental conditions sampled. They concluded that selection under managed level of drought stress at one location together with multi location testing would be desirable components of maize breeding programmes for Ist drought prone tropical areas.

2.1.3 *Brassica SPP*

Two cycles of mass selection improved seed yield to the extent of 31.8 percent over the base population and 26.6 percent over the check variety T_9.

Das and Arunachalam (1985) selected early and late mating plants from each of six populations studied and their progenies were full sib to produce early and late fullsibbed populations. They noticed significant yield advance over the parental populations depending on the initial genetic variability between the populations.

Schweiger and Rudloff (1987) performed four to five generations of recurrent selection for high oil content in two breeding stocks of winter rape BNW9 and BNW11. Selection of 5 percent of plants with highest oil content led to an increase in mean oil content by 0.6 percent per cycle in BNW9 while little effect was noticed in BNW11.

2.1.4 *Pearl millet*

Gupta and Choubey (1984) observed that two cycles of mass selection with 3.3 percent selection intensity increased forage yield per plant, stem thickness and tiller number per plant by 21.34, 9.60 and 8.98 per cent, respectively in a population JFB 801 while one cycle of visual S_1 progeny selection with 3.1 per cent selection intensity increased forage yield per plant, leaf breadth and tiller number per plant, by 11.04, 13.09 and 15.57 per cent, respectively.

Response to selection based on single and multitrait criteria in two pearl millet populations, PSB–7 and PSB–3 was studied by Zaveri *et al* (1989). Analysis of data from S_1, half sib and full sib family selections indicated that the genetic advance was greater among S_1 families than half sib and full sib families.

2.1.5 *Niger*

Two cycles of mass selection was carried out by Virupakshappa *et al* (1986) in four local populations of niger. Response to selection for seed yield was 29 percent in population 1 and 31 percent in population 2. Increase in yield was attributed to increase in capitula per plant. Oil content increased by 2.14 per cent in population 1 and 9.62 percent in population 2 although selection was not exercised for oil content *per se*.

2.2 GENETIC PARAMETERS :

Success of any selection programme mainly depends on the extent of variability and the nature of genetic variance controlling the population under selection. Thus it is imperative to study the genetics of various characters. Here an attempt has been made to review the pertinent literature in sunflower.

High heritability (73%) for seed set and greater environmental influence with low heritability (21%) for oil percent were identified by Habura (1958).

Pinthus (1963) noticed significant influence of the environment on 1000 seed weight, per cent normal seeds per head and oil content. But Pawlowski (1964), Schuster (1964), Miller *et al* (1977) and Thomson *et al* (1979) observed that oil content was heritable and was determined by maternal parent than by the pollen parent.

Piquemal (1968) recorded high heritability for seed weight suggesting the usefulness of using this trait as selection criterion for improving seed yield.

Kovacik and Skaloud (1972) reported the influence of environment was high on achene oil content, considerable on head diameter and low on plant height, number and weight of a achene per head and 1000 seed weight.

Volf and Kasyanenko (1972) observed low heritability for all the characters except one character oil content of achenes had a heritability value of 0.436.

Naskar *et al* (1982) computed selection indices using dispersion matrices and reported that maximum genetic gain could be achieved when all the seven characters under study were considered for selection and selection for yield component traits was more profitable than selection for yield alone.

Sivaram (1982) recorded that head diameter, yield per plant and plot yield were primarily under the influence of dominant and non-allelic interactions. Though additive gene action was also prevalent. The predominance of additive gene action was noticed for 1000-seed weight.

Sivaram (1982) reported heritability estimate was moderate for head diameter and 1000 seed weight where it was low for yield per plant and plot yield.

Shinde *et al* (1983)reported high heritability with additive genetic variance for plant height, head diameter, seed yield per plant and 100 seed weight.

The study of Rostova *et al* (1984) revealed that achene yield, oil yield, capitulum diameter and 1000 achene weight were determined by environment to large extent.

Fick (1973) estimated the broad and narrow sense heritability for oil content and reported to be 0.72 and 0.61, respectively. The ratio of narrow to broad sense heritability indicated that the additive genetic was significant for oil content. Similarly, Volf and Dumacheva (1973) observed highest heritability for oil content and 1000-seed weight.

From the parent-off spring regression analysis, Oka and Campos (1974) noticed that the heritability was higher (50%) for days to flowering and plant height, but was low for head diameter.

Luczkiewicz (1975) noticed that the most variable traits were the achene yield on selfing and the number of branches per plant. The most stable ones were duration of vegetative period and oil content of the achene. In all the selfed lines, heritability was highest with respect to number of leaves and the number of florets in the capitulum. Leaf area and seed yield under self pollination were prone to environmental influence. From a diallel study, Zali *et al* (1977) recorded low heritability for oil content.

Asawa (1977) estimated that the variability in 27 varieties of different origins accounted to 97 per cent of the total variance from four characters viz head diameter, stem circumstance at maturity, height and seed yield while seed weight alone accounted for 56.3 per cent.

Singh *et al* (1977) observed high genetic variability for seed yield. 1000 seed weight plant height and seed filling and low for oil content. Expected genetic gain was highest for seed yield followed by 1000 seed weight, oil content and seed filling. However, Varshney and Singh (1977) observed high heritability for oil content alone and the exploitable genetic variability and genetic advance for seed yield, plant height and 1000 seed weight were found to be high.

Heritability ranged from 36.15 to 91.05 percent for various characters studied by Reddy and Reddy (1979), the highest values of being 91.05 per cent for days to maturity and 51.35 percent for stem diameter.

According to Venkateswarulu *et al* (1980) percent heritability was higher for days to flowering (68.80) followed by plant height (67.70) seed set and head diameter (21.90), leaf area index (20.60) and leaf area (19.40).

Furedi and Frank (1981) reported greater heritability (0.76) for seed yield per 10 plants. Shrinivasa (1982) recorded that non additive gene effects more for yield while additive and epistatic effects for oil content and reported highest genetic advance for yield per plant and for oil content the genetic advance was less.

2.3 CORRELATION AND PATH ANALYSIS STUDIES :

The literature on correlation and path effects in different populations derived by various selection schemes in sunflower is scanty. Hence, in order to derive some inferences, literature on other studies were reviewed here under.

High positive correlation between seed yield, height and head diameter was noticed by Schuster (1964). Correlation's between the length of growing period, height and head diameter were also positive.

Correlation coefficients in two high and two low oil content type sunflower varieties were estimated by D'jakov (1966 and 1969). It varied from 0.80 to 0.91 for kernel yield and oil content and 0.934 to 0.998 for kernel and oil yields. Hence, he suggested that oil yield could be improved through selection for kernel yield. When correlation of individual plants within a variety was calculated, it was 0.8 for oil yield and kernel oil content. Correlation between seed yield per head and head diameter was 0.95. Identical result of 0.95 correlation between seed yield and head diameter was obtained by Burns (1970), thus concluding that yield estimation based on head diameter would be more accurate than actual seed weight whenever the yield to be recorded in a plot with severe bird damage.

Piquemal (1968) reported that the selection for large flower heads, which was correlated with number of florets, would lead to better yield. He also reported a positive correlation between plant height and head size. Similarly, positive correlation between seed weight and oil content was observed by Ratkovick *et al* (1968).

Natali and Shaikh (1970) reported that seed yield was strongly and positively correlated with the number of florets per head but the head diameter was negatively correlated with seed yield. Partial and multiple correlation coefficient analyses revealed a positive relationship between seed yield and plant height, number of flowers, growth period and 1000-seed weight.

Kovacik and Skaloud (1972) found that the length of growing period, size of the achenes and husk percentage were negatively correlated. They also found that taller and late maturing plants produced large number of small achenes but yielded high. Fick *et al* (1974) noticed a positive correlation of seed oil content with number of days to 50 per cent flowering and plant height. Significant positive correlation between plant height and days to flowering was reported by Oka and Campos (1974) also.

Observations recorded by Pathak (1975) on 71 varieties of diverse origin revealed that tall varieties generally yielded high and seed yield per plant showed highly significant positive correlation with total dry matter, head diameter, 100-seed weight, plant height, stem diameter and husk weight, in that order.

Shabana (1975) observed that the most important traits influencing seed yield were 1000-seed weight, seed number per head and plant height. While the ones influencing oil percentage were plant height, seed number per head, 1000-seed weight and seed yield.

Among the ten traits under study, Skoric (1975) found that seed yield and seed oil content had greater influence on oil yield per hectare.

Correlation and regression analysis carried out by Ayyasamy *et al* (1977) indicated that head diameter had the most significant effect on yield.

Chandra and Anand (1977) observed that yield was positively correlated both phenotypically and genotypically with plant height.

Singh *et al* (1977) suggested that more emphasis to be laid on seed weight and head diameter while selecting for increased seed yield as they were positively associated.

Significant positive correlation of seed yield with plant height, days to maturity, head diameter and 100-seed weight was reported by Varshney and Singh (1977). Path analysis revealed that plant height, head diameter and seed filling influenced yield directly, while days to maturity and 1000-seed weight had shown indirect influence through plant height. Direct effect of days to maturity on seed yield was negative which suggested the possibility of selection for earliness couples with high yield.

Oil content was found to be positively correlated with height and number of embryos while negatively correlated with seed yield, head diameter and number of leaves per plant (Zali *et al* 1977)

Lakshmanaiah (1978) recorded a significant positive association of seed yield with capitulum diameter (0.611), 100-seed weight (0.505), seed number per capitulum (0.483), stem girth (0.424), plant height (0.369), seed filling (0.276), seed volume weight (0.337) and oil content (0.218). Maximum direct effect of head diameter on seed yield and indirect effect via seed weight, stem girth, seed number per capitulum, plant height, seed filling and oil content were elucidated by path coefficient analysis. Similarly, Alba E and Greco (1979) observed positive correlation between capitulum diameter and plant height which directly influenced the yield.

Anand and Chandra (1979) noticed that the correlations between seed yield and plant height, head diameter and 100-seed weight were positive. Whereas it was negative between oil content and pericarp thickness.

Giriraj *et al* (1979) found that achene weight, plant height and head diameter were the characters that influenced the achene yield most directly. Other characters positively associated with yield were leaf number and oil content. Results obtained by Omran *et al* (1979) also revealed a positive correlation of seed yield per plant with head diameter and 100-seed weight.

Velkov (1980) recorded high correlation between yield and head diameter, while head diameter was correlated with achene weight. Path coefficient analysis showed that head diameter had significant direct effect on achene yield, while 1000-achene weight had indirect effect on yield via head diameter.

Ghanavathi and Nahavandi (1981) observed that the correlation coefficients between oil yield and its components – achene yield and oil content were significant. Capitulum diameter was significantly correlated with achene yield and oil yield, and early maturity was associated with short stem and lower oil content.

D'jakov (1982) based on the study of six varieties concluded that positive correlation between yield and growth period duration, as for every one day's reduction in growth period, seed yield per plant dropped by one gram. Negative association existed between oil content and growth period.

Shrinivasa (1982) reported that yield per plant was negatively correlated with 100-achene weight and oil content, while it had positive significant correlation with head diameter. Oil content was positively correlated with 100-achene weight and negatively correlated with seed yield per plant and hull content.

Rao (1983) noticed that achene yield was positively correlated with capitulum diameter, achene oil content, 100-achene weight and total dry matter and negatively correlated with days to maturity and husk percentage. Kernel oil content showed negative direct effect on seed yield, while plant height and total dry matter had positive indirect effects.

Based on the character association study, Shinde *et al* (1983) opined that the selection based on characters like yield per plant, head diameter and 100-grain weight would be effective.

Caylak and Emiroglu (1984) noticed that seed yield per head was strongly correlated with height, stem thickness, head diameter and 100-achene weight.

Chaudhary and Anand (1985) reported strong direct effect of days to flowering and plant height at flowering on seed yield.

From the analysis of data on yield and yield attributes of 20 diverse varieties, Dhaduk *et al* (1985) recommended that for improving seed yield, selections could be based on capitulum diameter, 1000-filled seed weight and number of filled seeds per capitulum. Mishra *et al* (1985) and Singh *et al* (1985) reported that head diameter, per cent of filled seeds per head and 100-seed weight were positively correlated and had direct positive effect on seed yield per plant.

Sen *et al* (1985a) also recorded significant positive association between seed yield per plant and number of filled seeds per head, while association between seed yield per plant and oil content was negative.

Diaz *et al* (1986) observed that closest positive correlation of achene yield per plant existed with head diameter and number of achenes per head. They also observed that the number of achenes per head and achene weight had the greatest direct effects on seed yield.

Significant association of seed yield with stem diameter, dry matter content, head diameter and number of seeds per capitulum was reported by Sheriff *et al* (1986 and 1987). The Correlation and path analysis study emphasized the importance of stem girth, head diameter and number of seeds per capitulum in increasing the seed yield.

Path coefficient study by Sivaram (1986) indicated that the seed yield per plant had the strongest direct effect on yield per plot followed by percent achene set. Head diameter and 1000-achene weight had negative direct effects on yield per plot.

Vannozzi *et al* (1986) recorded a close correlation between achene yield and oil yield. Further, plant height and head diameter had direct positive effects on oil yield. The days to maturity had direct positive effect on oil content and oil yield.

Highly significant phenotypic correlation of oil yield per plant with seed yield per plant, 100 seed weight, and plant height was noticed by Abdel *et al* (1987). They also noticed highly significant correlation of seed yield with number of seeds per capitulum.

Significant correlation between seed yield and head diameter, stem diameter, 100-seed weight, number of leaves per plant and plant height observed by Vanisree *et al* (1988).

Niranjanamurthy and Shambulingappa (1989) observed that the seed yield could be improved by increasing the stem circumference, capitulum diameter, seed filling percentage and 100-seed weight.

In a study of the interrelation of eight yields related characters and their effect on achene yield and oil content, Visic (1989 and 1991) noticed a close correlation between achene yield and 1000-achene weight.

Pathak and Dixit (1990) found that seed yield per plant was significantly and positively correlated with stem girth and 100-seed weight. Head diameter followed by days to maturity and 100-seed weight exerted maximum direct effect on seed yield, while plant height and stem girth had indirect effects through other characters.

Singh and Labana (1990) noticed that seed yield was positively correlated with days to maturity, plant height, head diameter, grain filling percentage and 1000-grain weight.

A positive correlation between yield and yield components such as plant height, head diameter and 100-seed weight was observed by Khan and Islam (1991).

Tariq *et al* (1992) reported significant negative association between seed yield and 100-seed weight and days to maturity.

From a line x tester analysis, Chaudhary and Anand (1993) inferred that seed yield was significantly and positively correlated with number of leaves per plant, plant height, head diameter and 1000-achene weight in both F_1 and F_2 progenies. Oil content had a positive significant association with seed yield in F_2 only.

Correlation studies by Mogali (1993) implied that seed yield per plant had highly significant positive correlation with number of filled seeds per plant, seed filling percentage and head diameter. Oil yield per plant was positively correlated with seed yield per plant and number of filled seeds per head. Path coefficient analysis indicated that plant height, stem diameter, head diameter, days to 50 per cent flowering, number of leaves per plant, test weight, number of filled seeds per head and seed filling percentage had maximum direct effect on oil yield per plant. Patil (1993) observed that seed yield exhibited highest positive association with number of seeds per plant followed by plant height.

Gangappa and Virupakshappa (1994) reported that seed yield was positively and significantly associated with all the characters studied except days to 50% flowering. Path co-efficient analysis revealed that total dry weight of the head had direct effect on seed yield followed by stem weight per plant, plant height and stem diameter.

2.4 STABILITY

The information on genotype x environmental interaction is presented below.

Pathak and Dixit (1984) evaluated five popular varieties of sunflower over five seasons under semi arid conditions of Rajasthan and they observed that significant differences due to genotype and environments. Genotype x environment interaction variance significant that denotes differential performance of the genotypes in varied environments. The genotype, EC-68415 exhibited specific adoption for both favourable environments and seed yield.

The five genotypes of sunflower when studied for their stability over 10 different environments observed significant differences among the genotypes for grain and oil yield. It was observed by Rangaswamy *et al* (1984) and also found that all the genotypes were stable for grain and oil yield.

Sen *et al* (1985b) found that seven sunflower varieties when tested for stability over five seasons were not only significant among themselves but also significant for seed yield.

Shinde *et al* (1992) tested 15 sunflower genotypes across the seasons (*Kharif, rabi* and *summer*) and concluded that all 10 characters were significant for environmental effects and genotype x environment interaction. But Madrap *et al* (1994) found that the hybrids performed well during *rabi* and *summer* seasons than *kharif.*

Kandalkar (1997) observed significant mean square differences due to genotypes and genotype x environment interaction for seed yield and regression co-efficient indicate Latur 9917, Surya to be the most suitable genotypes for favourable environment. These results were observed when they evaluated 15 open pollinated varieties of sunflower genotypes at four dates of sowing under two locations. Late maturing genotypes expressed average response and stability under different sowing dates having higher yield performance.

October sown crop gave the lowest yields where as February sown crop gave higher yields. This was observed by Sharma *et al* (1997) when nine genotypes of sunflower evaluated under six sowing dates for eight yield components. Cultivar 14 was observed as most stable one for seed yield, test weight and head diameter.

Chapter - III

Materials and Methods

CHAPTER - III

MATERIALS AND METHODS

The present investigation was carried out from *Kharif* 1997 to *Rabi* 1999 at the Regional Agricultural Research Station, Nandyal, Andhra Pradesh situated at an altitude of 211 metres above mean sea level and with a latitude of 15.29°N. The soils are deep black cotton soils with pH of 8.0.

3.1 MATERIALS

The experimental material for the study was an open pollinated variety of sunflower, Morden which was one of the introductions into India from erst while USSR. Morden is a short duration variety (75-80 days) suitable as a catch crop in paddy fallows, as double cropping in rainfed areas, in multiple cropping in assured irrigation areas, as a contingent crop for delayed sowing and as a mixed crop in several crops. Besides, as this cultivar possess enormous amount of variability for seed yield, oil content and other qualitative characters, it was considered as an ideal population to apply different selection schemes of population improvement programmes.

3.2 METHODS

Five selection schemes viz., mass selection (MS), bulk sib (BS), half sib (HS), full sib (FS) and selfed progeny selection (S) were imposed on an open pollinated variety of Morden to evaluate their relative efficiency in improving yield and yield attributes.

The outline procedure of various selection schemes are presented in Table 1.

3.3 FIELD PLOT TECHNIQUE DURING *Kharif*, 1997

During *Kharif* 1997, the open pollinated base population of Morden was sown in isolation at Regional Agricultural Research Station, Nandyal, Andhra Pradesh in an area of 1800 square metres. Nearly 10,000 plants were raised by adopting a spacing of 60 cm between rows and 30 cm between plants with in a row. Out of the recommended dose of fertilizers (60: 60: 30 kg / N. P. K / ha), 50 per cent of nitrogen and entire dose of phosphorous and potassium were applied as basal dress and the remaining 50 per cent of nitrogen as top dress after 30 days of sowing. Within 15 days of sowing excess seedlings were removed retaining only one healthy seedling per hill. Inter cultural and other recommended package of practices for sunflower were followed to raise a good crop.

Before flowering, the experimental plot was divided into 20 grids of equal size (about 500 plants in a grid). Four grids were randomly allotted to each of the five selection methods.

Table 1 : Base population of Morden open pollinated variety (Selection schemes applied)

Seasons	Mass selection (MS)	Bulk sib selection (BS)	Half sib selection (HS)	Full sib selection (FS)	Selfed progeny (S)
1997 *Kharif*	1. 500 phenotypically superior plants selected from the base population	1. 500 phenotypically superior plants individually bagged	1. 500 phenotypically superior open pollinated plants selected and labelled and allowed for random pollination	1. Before flowering all the plants in the designated grids were bagged duly eliminating inferior and weak plants	1. In the designated grids, 500 plants bagged duly eliminating inferior and weak plants
	2. Based on seed yield and oil yield, 100 top ranking plants selected	2. At the time of flowering pollen is collected from all these plants and dusted to on all 500 plants and bagged. This process continued till flowering was completed	2. Based on seed yield and oil yield top ranking 115 plants selected.	2. Based on plants stature 500 pairs of plants were identified, labeled and bagged, in a given pair of plants. one plant is designated as female and other as male.	2. Based on seed yield and oil yield, 66 top ranking plants were selected and the seeds of these plants separated individually to raise as S_1 generation in the next season.
	3. Equal quantity of seed of all these plants were mixed to raise as MS_1 generation in the next season.	3. Based on seed yield and oil yield 100 top ranking plants selected	3 The seed of these plants maintained separately to raise in half sib progeny HS_1 in the next season.	3. Similar procedure was followed in all 500 pairs.	
		4 Equal quantity of seed of all these plants mixed to raise as BS_1 generation in the next season.		4 During flowering, pollen was collected from the male and dusted on its corresponding female plant. This is continued till flowering was completed	
				5. This procedure was followed in the rest of the pairs selected for crossing.	
				6. Based on seed and oil yield. 123 top ranking superior plants were identified.	
				7. The seed of 123 plants separately preserved for sowing as full sib families (FS_1) in the next season.	
1997 *Rabi*	1 The selected bulk of mass selection made during *Kharif* 1997 was raised as MS_1	1 The selected bulk of bulk sib selection made during 1997 *Kharif* was raised as BS_1	1 After retaining 50% of the seed as remnant, selected 115 HS_1 plants seed planted in randomized block design with two replications in a separate trial.	1. After retaining 50 per cent of the seed as remnant 123 FS_1 progenies were planted in randomized block design with two replications in a separate trial	1. Sixty six S_1 progenies were raised in a randomized block design with 2 replications.

	2. Similar procedure as described in the last season was followed.	2. Similar procedure as described in the last season was followed.	2. Each progeny was represented by a row.	2. Each progeny was represented by a row of 15 plants and observations recorded on randomly selected 5 plants.	2. *Prior to flowering* five plants in each progeny line were selfed and remaining plants left for yield evaluation.
	3. The bulk of this generation harvested separately and raised in next season as MS_2.	3. The bulk of this generation harvested separately and raised in next season as BS_2.	3. Based on seed yield and oil yield top progeny lines were identified.	3. Based on seed and oil yield top ranking progenies were identified	3. At maturity, the data was recorded on each of the progenies left for yield evaluation line.
	(The seed preserved in cold storage to maintain viability)	(The seed preserved in cold storage to maintain viability)	4. Based on this data, the corresponding remnant seed of these lines were taken and mixed to raise as HS_1 generation in next season.	4. Based on data the corresponding remnant seed of these lines were taken and mixed to raise as FS_1 generation	4. Based on seed and yield, superior progenies were identified and then the corresponding selfed lines seed was taken and bulked to raise as S_2 bulk population in the next season
1998 *Kharif* sowing could not be taken due to continuous rains					
1998 *Rabi*			1. HS_1 generation was raised in isolation	1. FS_1 were raised in isolation and at the time of flowering, plants were bagged and crossed *interse*.	
			2. The entire population was left for random pollination.	2. At maturity equal quantity of seed from each cross was taken without going on progeny testing and mixed to raise as FS_2 in the next season.	
			3. At maturity the entire plot was harvested to raise it as HS_2 in the next season.		

I. Final evaluation trial

I. The population of MS_2, BS_2, HS_2, FS_2, S_2 bulk and open pollinated variety Morden as check were raised during 1998-99 *summer*, 1999 *kharif* and *1999 rabi* in a randomized block design with four replications with a spacing of 60 cm between rows and 30 cm plant to plant within a row. Each population in a replication was sown in ten rows each with a 3 metres row length. Recommended fertilizer application and cultural operations were followed. The data recorded on individual plants was used to work out mean, range, variance and co-efficient of variation in all seasons. Analysis of variance was performed to find out significant differences among population and used to estimate genetic parameters in different seasons.

II. The seed material obtained from various populations viz., MS_2, BS_2, HS_2, FS_2 and S_2 during *kharif* 1999 were tested along with two checks Morden and MSFH-17 in different locations and also in different dates of sowing to find out genotype x environmental interactions.

3.3.1 *Mass selection*

From the grids earmarked for mass selection, 500 phenotypically superior plants were selected at the time of maturity from the base population. From each of the selected plants, observations on eight quantitative traits were recorded. These eight quantitative traits were indicated in the dissertation elsewhere. Based on seed yield and oil yield / plant, 100 top ranking plants were finally selected. Equal quantities of seed from each of the selected plants were bulked to form the seed material to raise it as MS_1 in the next season.

3.3.2 *Bulk sib selection*

This method is akin to mass selection but with pollen control. Just before flowering, 500 phenotypically superior plants were individually bagged with cloth bags. During flowering, pollen was collected in a petriplate from the cloth - bagged plants. Collected pollen was mixed and applied to all the individually bagged plants. After pollination the ear heads were covered again with the cloth bags to prevent out crossing. This procedure was repeated every alternate day till the completion of flowering. At the time of harvest, observations on eight quantitative traits were recorded. Finally based on seed yield and oil yield, 100 top ranking plants were selected. Equal quantities of seed from selected plants were bulked to raise as BS_1 in the next season.

3.3.3 *Half sib selection*

500 phenotypically superior open pollinated plants were selected from the grids allotted to this selection scheme and labeled. At the time of harvest, the data on all these selected plants were recorded. Finally based on seed yield and oil yield, 115 top ranking plants were selected. The seed of these plants maintained separately to raise in half sib progeny testing trial (HS_1) in the next season.

3.3.4 *Full sib selection*

Before flowering all the plants in the designated grids were bagged duly eliminating inferior and weak plants. The plants, which were in proximity, were labeled as a pair. Before flowering 500 such pairs of plants were identified, labeled and bagged. In a given pair of plants, one plant is designated as female and other as male. Similar procedure was followed in all 500 pairs. At the time of flowering, pollen is collected from the designated male parent and dusted on to its corresponding female parent. This has been carried out till the completion of flowering. Similar procedure was followed in the rest of the pairs selected for crossing. Every care has been taken to bag the plants immediately after crossing in all pairs of plants selected.

At the time of maturity, observations on yield and yield attributes were recorded on 400 selected plants and harvested separately. Based on laboratory analysis for seed yield and oil yield, 123 top ranking superior plants were identified. The seed of 123 plants separately preserved for sowing as full sib families (FS_1) in the next season.

3.3.5 *Selfed progeny*

In the designated grids, 500 plants were bagged before flowering duly eliminating inferior and weak plants. At the time of maturity, data on eight quantitative characters were recorded on each plant. Based on seed yield and oil yield, top ranking 66 plants were selected and the seeds of these plants separated individually to raise as S_1 generation in the next season.

3.4 FIELD PLOT TECHNIQUE DURING *Rabi* 1997

The selected bulks of mass and bulk sib selections made during *Kharif* 1997 were advanced to raise as MS_1 and BS_1 populations during *rabi* 1997. Recommended cultural practices were followed to maintain good plant stand and healthy crop. Similar procedure as described in the previous season followed to maintain good plant stand and healthy crop. The procedure as described in the previous season was followed in mass and bulk sib material in MS_1 and BS_1 generation. The seed of these generations harvested separately and designated as MS_2 and BS_2 for sowing in the next season.

Sixty six S_1 progenies were grown in a randomized block design with two replications. Recommended cultural practices were followed to maintain good stand and healthy crop. Prior to flowering, five plants in each progeny line were bagged to enforce selfing and remaining plants in each progeny line were left for recording data. At maturity, the data was recorded on each of the left over plants in each of the progeny line. Based on yield data, superior progenies were identified and seeds of corresponding saelfed plants were bulked to raise it as S_2 bulk progeny in the next season.

After retaining 50 per cent of the seed as remnant, selected 115 HS_1 and 123 FS_1 progenies were planted in separate trials in randomized block design with two replications. Each progeny was represented by a row of 15 plants. Recommended cultural practices were followed. In these two experiments, in each of progeny line, observations were recorded on five randomly selected plants. Based on seed yield and oil yield, top five per cent of progeny lines were identified. Based on this data, the corresponding remnant seeds of the lines were taken and mixed to raise as HS_1 and FS_1 generations.

Due to continuous rains and delay in the season, *Kharif* 1998 sowings could not be taken up.

3.5 FIELD PLOT TECHNIQUE DURING *Rabi*, 1998

The HS_1 generation was raised in isolation duly followed by recommended cultural practices to maintain good plant stand and healthy crop. The entire population was left for random pollination and at maturity the entire population was harvested as bulk and preserved to raise it as HS_2 in the next season.

Similarly FS_1 were raised in isolation and plants were bagged and crossed *interse*. At maturity equal quantity of seed from each cross was taken and mixed to raise as FS_2 in the next season.

3.6 FIELD PLOT TECHNIQUE DURING *Summer* 1999 AND 1999 *Kharif* AND *Rabi*

The populations of MS_2, BS_2, HS_2, FS_2, S_2 and open pollinated variety Morden were raised during 1998-99 *summer*, 1999 *kharif* and 1999 *rabi* in a randomized block design with four replications with a spacing 60 cm between rows and 30 cm plant to plant with in a row. Each population in a replication was sown in ten rows each with a 3 metres row length. Recommended fertilizer application and cultural operations were followed to raise a good crop. The data was recorded in twenty plants on eight quantitative traits.

3.7 COLLECTION OF DATA

The following observations were recorded from all the generation populations derived by applying various selections schemes.

3.7.1 *Plant height (cm)*

The height of the plant was measured in cm from the base of the stem at ground level to the point of attachment of the capitulum of the stem and expressed in cm.

3.7.2 *Head diameter (cm)*

Head diameter was measured in cm at the maximum width of the capitulum and expressed in cm.

3.7.3 *Stem thickness (cm)*

Stem thickness was measured in cm at the basal node using vernier callipers and expressed in cm.

3.7.4 *Days to maturity*

This was measured as the number of days taken from sowing to physiological maturity as evidenced by the change in the Thalamus colour from green to lemon yellow.

3.7.5 *Seed yield / plant (g)*

Filled seeds from individual plants after threshing were dried thoroughly and the weight was recorded in grams.

3.7.6 *100-Seed weight (g)*

One hundred well filled seeds from each plant were randomly taken and the weight was recorded in grams.

3.7.7 *Oil per cent*

About 5 g seeds from individual heads were taken to determine the oil content by using Nuclear Magnetic Resonance (NMR) spectrometer installed at National Seed Project, Rajendranagar, ANGRAU, Hyderabad, A.P. The instrument directly gives the per cent of oil in the seeds.

3.7.9 *Oil yield / plant (g)*

This was calculated by multiplying the seed yield with oil per cent of the seeds in individual plant.

Oil yield / plant (g) = Seed yield / plant X Oil percent

3.8. STATISTICAL ANALYSIS

1. The data obtained from MS_0, BS_0, HS_0, FS_0, S_0, MS_1, BS_1, HS_1, FS_1, S_1 and MS_2, BS_2, HS_2, FS_2 and S_2 in different seasons were used to estimate range, mean, variance and co-efficient of variation.
2. The data obtained on HS_1, FS_1 and S_1 progeny lines was utilized to estimate various genetics parameters like heritability, genetic advance, phenotypic coefficient of variation and genotypic coefficient of variation.
3. Simple correlation coefficients and path coefficients were worked out on all populations of various generations and also in different seasons.
4. Analysis of variance was worked out on second generations populations of all selection schemes in different seasons to test the significance and also to work out various genetic parameters.

3.8.1 *Statistical parameters*

3.8.1.1 ***Mean :*** Mean is defined as the sum of all observations in a sample divided by their number. It is denoted by $\bar{X}$ and calculated as follows

$$\bar{X} = (\Sigma x) \div N$$

Where $\bar{X}$ = Mean

Σ = Summation

X = An observation

N = Number of observations in a sample

3.8.1.2 ***Range :*** Range is the difference between the lowest and highest values present in the observations in a sample. It is measure of spread of variation in a sample. It is commonly used as a measure of variability in plant breeding populations.

3.8.1.3 ***Variance :*** Variance is defined as the average of the squared deviations or individual observations from the mean or it is square of standard deviation. It is expressed as the sum of squares of the deviations of all the observations of a sample from its mean and divided by degrees of freedom (N-1). It is an effective measure of variability, which permits partition of variation into various components. It is estimated by the following formula.

$$\text{Variance} = \left[\Sigma X^2 - \frac{(\Sigma X)^2}{N}\right] \div N - 1$$

Where Σ, X, X^2 and N = summation, an observation, square of an observation and number of observations. respectively.

Phenotypic variance and Genotypic variance : These two were computed as per the formulae suggested by Burton and Devane (1953).

Phenotypic variance σ_p^2 = Genotypic variance + Error variance

Genotypic variance σ_g^2 =

$$\frac{\text{Mean sum of squares due to treatment} - \text{Mean sum of squares due to error}}{\text{Number of replications}}$$

3.8.1.4 ***Coefficient of variation :*** The standard deviation is an absolute measure of variation and is expressed in terms of the unit of the variable. For purpose of comparative studies a relative measure of dispersion or variation is required. Coefficient of variation serves this purpose as it does not have any unit. The ratio of standard deviation of a sample to its mean expressed in percentage is called coefficient of variation. Thus,

$$\text{Coefficient of variation (CV)} = \frac{SD}{\bar{X}} X\ 100$$

Where

SD = Standard deviation

$\bar{X}$ = Mean of that character

The phenotypic σ_p^2 and genotypic (σ_g^2) variances were utilized for calculation of phenotypic coefficient of variations (PCV) and genotypic coefficient of variation (GCV) as per Burton (1952).

$$\text{Phenotypic coefficient of variation (PCV\%)} = \frac{\sigma_p}{\bar{X}} X\ 100$$

$$\text{Genotypic coefficient of variation (GCV\%)} = \frac{\sigma_g}{\bar{X}} X\ 100$$

σ_p = Phenotypic standard deviation

σ_g = Genotypic standard deviation

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

3.8.1.5 ***Heritability (broad sense) :*** Heritability in broad sense was calculated as per Hanson (1963).

$$\text{Heritability (broad sense)}\ h^2_{(b)} = \frac{\sigma^2_g}{\sigma^2_p} X\ 100$$

Where

σ^2_p = Phenotypic variance

σ^2_g = Genotypic variance

The heritability classification as high, moderate and low was followed as proposed by Robinson *et al.*, (1949).

Low	=	0-30%
Moderate	=	30-60%
High	=	Above 60%

3.8.1.6 ***Expected Genetic Advance :*** This can be calculated as per the formula proposed by Allard (1960).

$$GA = (K) \cdot \sigma_p \cdot H$$

Where,

GA = Expected genetic advance under selection

K = Selection differential in standard units which is 2.06 at 5% selection intensity

σ_p = Phenotypic standard deviation

H = Heritability coefficient

Expected genetic advance as per cent of mean calculated as follows

$$\text{GA as per cent of mean} = \frac{GA}{\bar{X}} X\ 100$$

Where, GA = expected genetic advance under selection

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

Genetic advance as per cent of mean was categorized as low, medium and high as suggested by Johnson *et al.* (1955b).

Low	0-10%
Medium	10-20%
High	20% and above

3.8.1.7 ***Simple correlations :*** Correlation refers to the degree and directions of association between two or more than two variables. It however, does not measure the dependence of one variable over the other. It is represented by r and is estimated as follows.

$$r_{xy} = \frac{Cov.\ (XY)}{\sqrt{Var\,X \cdot Var\,Y}}$$

Where,

r_{xy} = correlation coefficients between x and y

Cov. (xy) = covariance of characters x and y

Var x = Variance of character x

Var y = Variance of character y

The significance of correlation was tested by comparing the observed values of correlation coefficients with table values of correlation coefficients given by Fisher and Yates (1963) for n-2 degrees of freedom at 5 per cent and 1 per cent levels of probability.

3.8.1.8 ***Path coefficient analysis :*** With a view to partition the correlation coefficients between dependent and independent variables into direct and indirect effects and to assess the relative importance of each causal factor effecting seed yield and oil yield in different generations of the populations derived by various selection schemes, path coefficient analysis was carried out by the procedure originally proposed by Wright (1934) and subsequently elaborated by Dewey, and Lu (1959).

$$R1y = P1y + r12P2y + r13P3y \dots r1kpky$$

Where

R1y = Simple correlation coefficient between x_1 and y the dependent character

P1y	=	Direct effect of x_1 on y the dependent character
R12P2y	=	Indirect coefficient between x_1 on y through x_2
r12	=	Correlation coefficient between x_1 and x_2
r1k pky	=	Indirect effect of x_1 on y through k variables.

In the same way equations for r2y, r3y, upto r11y were written and path coefficients viz., direct and indirect effects were calculated by solving the simultaneous equations. Besides the direct and indirect effects, the residual effect was computed by using the formula.

$$PRy = 1 - (P1y\ r1y + P2y\ r2y + P3y\ r3y\ ...)^2$$

Where

PRy	=	Residual effect
p1y	=	Direct effect of X1 on Y
r1y	=	Correlation coefficient of x and y

The following scales as suggested by Lenk and Mishra (1973) were followed for categorization of direct and indirect effects.

Values of direct and indirect effects	**Rate of Scale**
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
More than one	Very high

3.8.1.9 ***Analysis of variance :*** Differences between the populations for various traits were tested for significance by using analysis of variance technique proposed by Panse and Sukhatme (1957).

$$Yij = M + gi + rj + eij$$

Where,

Yij = Phenotypic observation of i^{th} populations in j^{th} replication

M = General mean

gi = Effect of i^{th} population

rj = Effect of j^{th} replication

eij = Random error associated with ith genotype and j^{th} replication

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

Source	**d.f**	**M.S**	**F-ratio**
Replications	(r-1)	Mr	Mr / Me
Populations (genotypes)	g-1	Mg	Mg / Me
Error	(r-1) (g-1)	Me	
Total	(rg-1)		

Where

r = number of replications

g = number of genotypes (populations)

Mr, Mg and Me are the mean squares due to replication, genotype and error, respectively.

The F ratio was compared with table value at corresponding degrees of freedom to test the significance.

3.9 GENOTYPE X ENVIRONMENTAL INTERACTION STUDIES

The *Kharif* 1999 seed material of MS_2, BS_2, HS_2, FS_2, S_2 were used to study genotype x environmental interaction along with Morden and MSFH-17 in different locations and also in different dates of sowings as detailed below.

Experiment - I

The *Kharif* 1999 seed material of MS_2, BS_2, HS_2, FS_2, S_2 and checks Morden and MSFH-17 were raised in a randomized block design with five replications at five locations i.e. Nandyal and Sirivella (Kurnool District), Badvel (Cuddapah district), Penukonda and Mundla Mothukapalli (Anantapur district) during November 1999. The data was recorded at all locations in all the treatments at maturity and subjected for analysis.

Experiment - II

The *Kharif* 1999 seed material of the populations MS_2, BS_2, HS_2, FS_2, S_2 and checks Morden and MSFH-17 were raised in a randomized block design in five replications in five dates of sowings with 15 days interval at November 15, December 1 and 16th, 2nd January and 16th January at

Regional Agricultural Research Station, Nandyal, Andhra Pradesh. The package of practices were similar as that applied to previous experiments. The data was recorded on eight quantitative characters from all the treatments from different dates of sowings.

3.9.1 *Stability analysis studies*

The data obtained on eight quantitative traits from 5 populations and two checks over five locations in one experiment and five different dates of sowings in another experiment were subjected to as per the model suggested by Eberhart and Russell (1966).

3.9.1.1 ***Stability parameters :*** The linear regression model suggested by Eberhart and Russell is presented below

$$Yij = u + biIj + Sij$$

Where

Yij	=	Mean of ith genotype in jth environment
μ	=	Mean of all genotypes over all environments.
bi	=	Regression coefficient of ith genotype on the environmental index which measures the response of this genotype to varying environments.
Ij	=	The environmental index which is defined as the deviation of the mean of all the entries at a given environment from the overall mean.

$$Ij = \frac{\sum_i Yij}{g} - \frac{\sum_i \sum_j Yij}{ge} \text{ with}$$

$\sum_j Ij = 0$ and δij = deviation from regression of the i^{th} genotype at j^{th} environment.

Based on this model, the mean (μ), the regression coefficient (bi) and the mean square deviation from linear regression line (s^2di) are the stability parameters as proposed by Eberhart and Russell (1966) in their model. These parameters were estimated as follows.

μ_1 (Mean) = $\Sigma Yij / n$

bi (Regression coefficient) = $\sum_j Yij \,.\, Ij \;/\; \sum_j I_j^2$

s^2di (Deviation from linear regression)

$$\left[\sum_j S^2ij \;/\; e\text{-}2\right] - \left[S^2e \;/\; r\right]$$

Where, $\sum_j S^2ij = \left[\sum_j Y^2ij - Y^2i. \;/\; g\right] - \left[(\sum_j Yij \cdot ij)^2 \;/\; (\sum_j I^2j)\right]$

Where,

ΣS^2ij	=	Variance due to deviation from regression for a genotype.
$\Sigma Y^2ij \cdot Y^2i \;/\; g$	=	Variance due to independent variable
$(\Sigma Yij \,.\, ij)^2 \;/\; (\sum_j I^2j)$	=	Variance due to regression
s^2_e	=	Estimate of pooled error
e	=	Number of environments
g	=	Number of genotypes (populations)
r	=	Number of replications

$\sum_j Ij = 0$ and δij = deviation from regression of the i^{th} genotype at j^{th} environment.

Based on this model, the mean (μ), the regression coefficient (bi) and the mean square deviation from linear regression line (s^2di) are the stability parameters as proposed by Eberhart and Russell (1966) in their model. These parameters were estimated as follows.

μ_i (Mean) = $\Sigma Yij / n$

bi (Regression coefficient) = $\sum_j Yij \cdot Ij / \sum_j I_j^2$

s^2di (Deviation from linear regression)

$$\left[\sum_j S^2ij / e\text{-}2\right] - \left[S^2e / r\right]$$

Where, $\sum_j S^2ij = \left[\sum_j Y^2ij - Y^2i. / g\right] - \left[(\sum_j Yij \cdot ij)^2 / (\sum_j I^2j)\right]$

Where,

ΣS^2ij	=	Variance due to deviation from regression for a genotype.
$\Sigma Y^2ij - Y^2i / g$	=	Variance due to independent variable
$(\Sigma Yij \cdot ij)^2 / (\sum_j I^2j)$	=	Variance due to regression
s^2e	=	Estimate of pooled error
e	=	Number of environments
g	=	Number of genotypes (populations)
r	=	Number of replications

Pooled analysis of variance (Eberhart and Russell, 1966)

Source	d.f.	S.S	MS	F.cal
Total	(ge-1)	$\Sigma i \Sigma j Y^2 ij - CF$		
Genotypes	g-1	$\Sigma i \Sigma j Y^2 i - CF$	M_1	M_1 / MS_3
Env + (genotype x envi)	g (e-1)	$\Sigma_i \Sigma_j Y^2 ij \quad \Sigma_i Y^2 i/e$		
Env (linear)	1	$\frac{1}{g}(\Sigma j Yi \quad I^2 j) / \Sigma j I^2 j$		
Genotype x Env. (linear)	g-1	$\Sigma j \lvert (\Sigma j Yi \quad I^2 j) / \Sigma j I^2 j) \rvert$	MS_2	MS_2 / MS_3
Pooled deviation	g (e-2)	$\Sigma i \Sigma j S^2 ij$	MS_3	MS_3 / M_4
Deviation due to genotype i	(e-2)	$(\Sigma j Y^2 ij - \Sigma i Y^2 i/e)$ $(\Sigma j Yj . Ij)^2 / \Sigma j I^2 j =$ $\Sigma i \Sigma i S^2 ij$		
Pooled error	eg (r-1)		M_4	

g = genotype e = environment r = replication

3.9.1.2 ***Tests of significance*** : The following tests of significance were carried out.

1. To test the significance of difference among genotypes means namely

$$H_0 = \mu_1 = \mu_2 = \mu_3 = \ldots.. \mu n$$

$$F = \frac{\text{Mean square due to genotypes}}{\text{Mean square due to pooled deviation}} = \frac{MS_1}{MS_3}$$

2. To test that the genotypes did not differ for their regression on the environmental index i.e.

$H_0 = b_1 = b_2 = b_3 = ... bn$

$$F = \frac{\text{Mean square due to genotypes x environment (linear)}}{\text{Mean square due to pooled deviation}} = \frac{MS_2}{MS_3}$$

3. Any regression coefficient does not differ from unity was tested by the appropriate 't' test

$$t = \frac{|1 - bi|}{SE(bi)}$$

Significant was tested at 1% and 5% levels for (e^{-2}) degrees of freedom

4. Individual deviation from linear regression was tested as follows.

$$F = (\Sigma S_j^2 ij \ / \ e-2) \ / \text{ pooled error}$$

F value for (e-2), pooled error degrees of freedom at 1% and 5% levels.

3.9.1.3 ***Stable genotype :*** As a genotype with unit regression coefficient bi = 1 and the deviation not significantly differing from zero ($S^2di = 0$) is said to be stable genotype.

3.9.1.4 ***Ranking of genotypes based on different stability parameters***

3.9.1.4.1 ***Mean :*** The genotype with greater mean performance was ranked first and least as last.

3.9.1.4.2 ***Regression coefficient (bi values of Eberhart and Russell (1966) :*** The deviation of bi values from unity (b = 1) was ranked such that least deviation was ranked first and larger deviation was ranked last.

3.9.1.4.3 ***Deviation from regression (S^2_{di}) values of Eberhart and Russell (1966) :*** The genotype was least S^2di (greater stability) was ranked as first whereas the genotype with maximum S^2di (least stability) was ranked last.

Chapter - IV

Results

CHAPTER - IV

RESULTS

The data collected on eight quantitative traits viz., plant height (cm), stem thickness (cm), head diameter (cm), days to maturity, 100 seed weight (g), oil percent, oil yield and seed yield / plant (g) in different generations of mass selection, bulk sib selection, half sib selection, full sib selection and selfed progeny schemes were utilized to calculate mean, range, variance and coefficient of variation. The data obtained on the progeny trials of half sib selection (HS_1), full sib selection (FS_1) and S_1 selection were utilized to test the significance of the progenies selected for yield and yield attributes and also to calculate genetic parameters viz., genotypic coefficient of variation, phenotypic coefficient of variation, heritability (broad sense) and genetic advance as percent of mean.

The data on yield trails of the populations derived from the various selection schemes in second generation in different seasons were subjected to analysis of variance, to test the significance and also to calculate variability parameters. The seed material obtained from second generation populations of various selection schemes were subjected to genotype x environmental interaction. Finally the data of all generations of various selection schemes were utilized to compute correlation coefficients and path coefficients to study the association of yield and yield attributes in various generations of selection schemes. The results of the present investigation are presented under the following heads.

1. Mean, range, variance and coefficient of variation in the base, first generation and second generation populations in different seasons.
2. Analysis of variance and estimation of genetic parameters in HS_1, FS_1 and S_1 populations.
3. Analysis of variance and estimation of genetic parameters in second generation populations / seasons.
4. Character association of yield and yield attributes in different generations / seasons.
5. Direct and indirect effects of yield attributes on yield in different generations / seasons.
6. Genotype x Environmental interactions.

4.1 MEAN, RANGE, VARIANCE AND COEFFICIENT OF VARIATION FOR EIGHT QUANTITATIVE CHARACTERS IN THE BASE POPULATIONS ALLOTTED TO DIFFERENT SELECTION SCHEMES

The mean, range, variance and coefficient of variation for eight quantitative characters in the base population allotted to different selection schemes are presented in Table Numbers 2 to 9.

4.1.1 *Plant height (cm)*

The plants in the base populations earmarked for different selection schemes for plant height ranged from 66.3-139.3 (M_0), 69.3-127.6 (BS_0), 77.6-134.7 (HS_0), 69.6-117.5 (FS_0) and 63.8-109.6 (S_0). The mean plant heights in the ascending order were 80.1 (S_0), 84.1 (FS_0), 90.2 (BS_0), 93.5 (MS_0) and 95.2 (HS_0). The maximum variance was recorded in the base population of HS_0 (219.04) followed by S_0 (193.21) and FS_0 (174.24) and the least by MS_0 (36.00). Where as maximum coefficient of variation was recorded in the base population allotted to S_0 (17.4) followed by FS_0 (15.7), HS_0 (15.5) and the lowest by MS_0 (6.42) (Table 2).

4.1.2 *Head diameter (cm)*

The plants in the base population allotted for different selection schemes had wide range of variation for head diameter from 9.23-25.83. The base population allotted to S_0 scheme had wide range for head diameter (9.23-21.64) followed by the population allotted to BS_0 (13.92-25.80) and HS_0 (14.32-25.83). The lowest range was observed in the base population allotted to MS_0 scheme (9.34-18.54). The mean of base population allotted to BS_0, HS_0 and FS_0 recorded almost similar mean for head diameter 17.78, 17.72 and 17.43 respectively. Where as base population allotted to MS_0 and S_0 recorded comparatively lower mean values when compared to other. The variance values of the base populations of S_0 (10.82), MS_0 (9.79) and HS_0

Table 2 : **Mean, range, variance and coefficient of variation for plant height (cm) in the base population allotted for different selection schemes during *Kharif*, 1997**

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	93.51	66.3-139.3	36.00	6.42
2	BS_0	90.2	69.3-127.6	136.99	12.9
3	HS_0	95.2	77.6-134.7	219.04	15.5
4	FS_0	84.1	69.6-117.5	174.24	15.7
5	S_0	80.1	63.8-109.6	193.21	17.4

Table 3 : **Mean, range, variance and coefficient of variation for head diameter (cm) in the base population allotted for different selection schemes during *Kharif*, 1997**

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	13.32	9.34-18.54	9.79	23.49
2	BS_0	17.78	13.92-25.80	7.89	15.80
3	HS_0	17.72	14.32-25.83	8.58	16.47
4	FS_0	17.43	11.84-21.63	2.66	9.35
5	S_0	14.26	9.23-21.64	10.82	23.07

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

(8.58) were comparatively higher than the variances recorded in FS_0 (2.66) and BS_0 (7.89). Similar trends were observed with regard to coefficient of variation where is S_0 base population recorded 23.07 followed by MS_0 with 23.49. (Table 3)

4.1.3 *Stem thickness (cm) :*

Maximum range of stem thickness was observed in the base population allotted to S_0 (1.04-4.23) followed by BS_0 population (2.73-5.21). The lowest range was observed in the base population allotted for MS_0 (1.82-3.73). The base populations allotted for BS_0 and HS_0 and FS_0 have recorded comparatively similar mean values for stem thickness. S_0 population recorded lowest mean value of 1.96. The variances of base populations of MS_0, BS_0 and HS_0 recorded almost similar values. Where as the coefficient of variation was maximum in S_0 population (27.06) followed by MS_0 base population (21.80). (Table 4)

4.1.4 *Days to maturity*

Maximum range for days to maturity was observed in the base population of S_0 (78-87). In the rest of the base populations range was narrow. Where as the same S_0 population recorded less number of days to maturity 82.69 and maximum number of days to maturity was observed in the base population of MS_0 (87.52). With regard to variance and coefficient of

Table 4 : **Mean, range, variance and coefficient of variation for stem thickness (cm) in the base population allotted for different selection schemes during *Kharif*, 1997**

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	2.66	1.82-3.73	0.34	21.80
2	BS_0	3.54	2.73-5.21	0.30	15.53
3	HS_0	3.55	2.24-4.53	0.32	16.06
4	FS_0	3.24	2.54-4.23	0.20	13.86
5	S_0	1.96	1.04-4.23	0.28	27.06

Table 5 : **Mean, range variance and coefficient of variation for days to maturity in the base population allotted for different selection schemes during *Kharif*, 1997**

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	87.52	86-89	0.50	0.81
2	BS_0	85.91	84-88	2.28	1.71
3	HS_0	85.81	82-87	1.27	1.32
4	FS_0	85.21	84-87	47.74	8.10
5	S_0	82.69	78-87	4.04	2.43

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

variation, the base population allotted for FS_0 recorded maximum values 47.24 and 8.10, respectively. The lowest values of variance and coefficient of variation was observed in the base population allotted for S_0. (Table 5)

4.1.5 *100 Seed weight (g)*

The range of values for 100 seed weight was maximum in the base populations allotted for BS_0 (3.62-8.13) followed by S_0 (4.32-8.13) and FS_0 (3.93-7.73). The lowest range was observed in the base population of MS_0 (4.06-7.23). The mean values for 100-seed weight ranged from 3.55 (HS_0) to 6.17 (S_0). Maximum variance and coefficient of variation was recorded in the base population allotted for BS_0 with a variance of 1.53 and coefficient of variation 24.60. (Table 6)

4.1.6 *Seed yield / plant (g)*

The maximum range of 16.13-36.72 for seed yield was recorded in the base population allotted for HS_0 and in the different base populations allotted for different selection schemes, the differences were comparatively low. The HS_0 base population has recorded maximum mean seed yield of 24.08 followed by BS_0 population with mean seed yield of 22.38. While the rest of the populations were recorded almost similar mean seed yield. The base population of BS_0 recorded maximum variance (39.94) and coefficient of variation (28.23) followed by HS_0 population with a variance of 27.56 and

Table 6 : Mean, range, variance and coefficient of variation for 100 seed weight (g) in the base population allotted for different selection schemes during *Kharif*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	6.11	4.06-7.23	0.46	11.13
2	BS_0	5.04	3.62-8.13	1.53	24.60
3	HS_0	3.55	2.63-6.12	0.36	16.90
4	FS_0	5.11	3.93-7.73	0.81	17.61
5	S_0	6.17	4.32-8.13	1.28	18.37

Table 7 : Mean, range, variance and coefficient of variation for seed yield / plant (g) in the base population allotted for different selection schemes during *Kharif*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	18.49	15.44-29.23	8.91	15.68
2	BS_0	22.38	17.83-32.72	39.94	28.23
3	HS_0	24.08	16.13-36.72	27.56	21.80
4	FS_0	19.08	13.93-26.72	16.16	21.06
5	S_0	18.41	15.24-25.83	13.39	19.88

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

coefficient of variation 21.80. Where as in MS_0 population low values of variance 8.91 and coefficient of variation 15.68 was recorded. (Table 7)

4.1.7 *Oil per cent*

The base population allotted for BS_0 showed maximum range of 27.63-40.21 oil per cent. Where as in the rest of base populations allotted for different selection schemes the differences were narrow. The mean oil per cent value ranged from 31.28 (BS_0) - 33.40 (S_0) and there by indicated not much differences existed in the base populations allotted for various selection schemes. However, maximum variance (16.89) and coefficient of variation (13.13) was found in the base population allotted for BS_0 and in the rest of the base populations, variances and coefficient of variations trends differed. (Table 8)

4.1.8 *Oil yield / plant (g)*

The base population allotted for HS_0 recorded maximum range (5.64-11.23), mean (7.82), variance (3.96) and coefficient of variation (25.44). Where as the base population of MS_0 recorded mean oil yield (6.06), variance (1.06) and coefficient of variation (16.90). (Table 9)

Table 8 : Mean, range, variance and coefficient of variation for oil percent in the base population allotted for various selection schemes during *Kharif*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	32.85	29.23-39.42	7.45	8.31
2	BS_0	31.28	27.63-40.21	16.89	13.13
3	HS_0	32.46	28.83-38.94	11.16	10.28
4	FS_0	32.87	28.93-40.42	5.71	7.27
5	S_0	33.40	29.62-40.23	6.10	7.39

Table 9 : Mean, range, variance and coefficient of variation for oil yield / plant (g) in the base population allotted for various selection schemes during *Kharif*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_0	6.06	4.43-9.42	1.06	16.90
2	BS_0	6.93	5.24-10.31	1.96	27.41
3	HS_0	7.82	5.64-11.23	3.96	25.44
4	FS_0	6.24	4.34-9.23	1.93	22.27
5	S_0	6.10	4.93-9.23	1.61	20.81

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

4.2 MEAN, RANGE, VARIANCE AND COEFFICIENT OF VARIATION IN THE FIRST GENERATION POPULATIONS DERIVED BY DIFFERENT SELECTION SCHEMES

The mean, range, variance and coefficient of variation in the first generation populations derived by different selection schemes are presented in Table Numbers 10 to 17.

4.2.1 *Plant height (cm)*

The maximum range for plant height was observed in BS_1 population (63.6-119.7) followed by MS_1 populations (65.3-119.2). The lowest range for plant height was recorded in the population of HS_1 (77.3-99.6). The maximum mean plant height of 87.5 in the FS_1 population followed by HS_1 population (85.3) was observed. Where as in the rest of the populations means were almost on par with each other. The maximum variance (114.49) and coefficient of variation (12.90) was found in BS_1 populations followed by MS_1 populations with a variance of 112.36 and coefficient of variability 12.84. The S_1 population recorded low variance (0.49) and coefficient of variation (0.82). The coefficient of variation in the populations of HS_1 and FS_1 was not differed much. (Table 10)

Table 10 : Mean, range, variance and coefficient of variation for plant height (cm) in the first generation populations of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	82.5	65.3-119.2	112.36	12.84
2	BS_1	83.0	63.6-119.7	114.49	12.90
3	HS_1	85.3	77.3-99.6	96.04	11.49
4	FS_1	87.5	71.2-111.3	81.00	10.28
5	S_1	84.5	60.6-99.5	0.49	0.82

Table 11 : Mean, range, variance and coefficient of variation for head diameter (cm) in the first generation population of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	12.18	9.23-20.34	4.88	18.44
2	BS_1	13.00	9.32-19.42	10.11	24.46
3	HS_1	11.36	10.23-14.92	1.29	10.04
4	FS_1	9.87	7.34-13.23	1.44	12.17
5	S_1	9.76	8.34-11.63	0.92	9.88

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

4.2.2 *Head diameter (cm)*

The MS_1 and BS_1 populations showed wide range of values 9.23-20.34 and 9.32-19.42 for head diameter. Next in order were FS_1, HS_1 and S_1 populations. The mean head diameter was maximum (13) in BS_1 followed by MS_1 population. Similar trends just like that of range values were observed even for mean head diameter values in HS_1, FS_1, and S_1 populations. These populations recorded mean values of 11.36, 9.87 and 9.76, respectively. (Table 11)

4.2.3 *Stem thickness (cm)*

The maximum range for stem thickness was recorded in the population of MS_1 (1.82-3.63). In the rest of the populations viz., BS_1, HS_1 and FS_1 ranges for stem thickness were almost similar. However, S_1 population showed lowest range of 1.44-2.33 when compared to other populations. However, mean stem thickness was maximum in HS_1 population (2.97) followed by BS_1 population (2.67). The lowest mean stem thickness was observed in S_1 population (1.89). Maximum variance (0.36) and coefficient of variation (20.20) was recorded in the population of HS_1 followed by MS_1 population with a variance of 0.16 and coefficient of variation 16.67. The lowest variance (0.05) and coefficient of variation (8.23) was recorded in the BS_1 population. (Table 12)

Table 12 : Mean, range, variance and coefficient of variation for stem thickness (cm) in the first generation populations of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	2.40	1.82-3.63	0.16	16.67
2	BS_1	2.67	1.81-3.23	0.05	8.23
3	HS_1	2.97	1.73-3.23	0.36	20.20
4	FS_1	2.00	1.63-3.12	0.07	13.26
5	S_1	1.89	1.44-2.23	0.06	12.72

Table 13 : Mean, range, variance and coefficient of variation for days to maturity in the first generation populations of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	86.41	84-89	0.82	1.05
2	BS_1	87.41	82-89	2.22	1.61
3	HS_1	80.97	77-84	6.45	3.14
4	FS_1	81.45	78-86	3.42	2.25
5	S_1	81.42	77-84	3.42	2.25

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

4.2.4 *Days to maturity*

The FS_1 population recorded maximum range (78-86) and the lowest in the MS_1 population (84-89) for days to maturity. Where as in the rest of the populations the differences in the range of values were similar. The mean number of days taken to maturity were maximum in the populations of BS_1 and MS_1 with 87.41 and 86.41, respectively. Where as in the populations of HS_1, FS_1 and S_1 mean values for days to maturity were on par with each other. However, the variance and coefficient of variation was maximum in the population of HS_1 followed FS_1 and S_1. The lowest variance and coefficient of variation was recorded in the population of MS_1. (Table 13)

4.2.5 *100 Seed weight (g)*

The maximum range for 100 seed weight was recorded in the population of FS_1 (1.04-6.63) followed by HS_1 population (2.46-6.24). In the rest of the populations similar range values were recorded. Maximum 100 seed weight was recorded in MS_1 population (6.07) and the lowest in FS_1 (3.49). The 100 seed weight of BS_1 and S_1 populations were on par with each other. Maximum variance (14.97) and coefficient of variation (74.35) was recorded in the population of BS_1. Whereas the lowest variance (0.39) and coefficient of variation (10.38) was recorded in the population of MS_1. In the rest of the populations viz., HS_1, FS_1 and S_1, the variances were not differed much. (Table 14)

Table 14 : Mean, range, variance and coefficient of variation for 100 seed weight (g) in the first generation populations of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	6.07	4.23-7.34	0.39	10.38
2	BS_1	5.21	3.62-6.63	14.97	74.35
3	HS_1	4.04	2.46-6.24	2.07	35.77
4	FS_1	3.49	1.04-6.63	2.92	49.00
5	S_1	5.23	3.12-5.93	2.10	27.80

Table 15 : Mean, range, variance and coefficient of variation for seed yield / plant (g) in the first generation populations of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	15.14	9.32-24.23	13.98	24.70
2	BS_1	11.98	9.32-20.34	92.16	80.09
3	HS_1	10.81	11.63-16.12	3.53	17.41
4	FS_1	5.26	3.03-13.43	7.89	23.42
5	S_1	6.01	3.23-13.34	7.56	45.70

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

4.2.6 *Seed yield / plant (g)*

The MS_1 population showed wide range for seed yield per plant (9.32-24.23) where as HS_1 population recorded narrow range (11.63-16.12). The FS_1 and S_1 populations recorded similar range values of 3.03-13.43 and 3.23-13.34 respectively. The mean seed yield per plant was maximum in MS_1 population (15.14). Where as BS_1 and HS_1 recorded 11.98 and 10.81, respectively. The lower mean seed values were recorded in the population of FS_1 (5.26) and S_1 (6.01). The maximum variance (92.16) and coefficient of variation (80.09) were found in BS_1 populations. Where as HS_1 population recorded lowest variance (3.53) and coefficient of variation (17.41) when compared to the rest of the populations. (Table 15)

4.2.7 *Oil per cent*

The maximum range for oil per cent was recorded in the BS_1 population (20.63-46.24) followed by MS_1 population (15.23-37.34). The lowest range for oil per cent was observed in FS_1 population (28.83-35.64) followed by HS_1 population (26.64-37.72). The BS_1 population also recorded maximum mean of oil per cent 35.02, variance of 52.27 and coefficient of variation 20.66. The mean oil per cent values of MS_1 (28.31) and S_1 population (28.52) and HS_1 (30.11) and FS_1 (30.01) were on par with each other. The variance and coefficient of variation were on par in the populations of HS_1 and FS_1. (Table 16)

Table 16 : Mean, range, variance and coefficient of variation for oil percent in the first generation populations of various selection schemes during *rabi*, 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	28.31	15-23-37.34	16.97	14.55
2	BS_1	35.02	20.63-46.24	52.27	20.66
3	HS_1	30.11	26.64-37.72	7.78	9.29
4	FS_1	31.01	28.83-35.64	6.25	8.06
5	S_1	28.52	20.23-39.84	23.72	17.09

Table 17 : Mean, range, variance and coefficient of variation for oil yield / plant (g) in the first generation populations of various selection schemes during *rabi* 1997

S.No.	Populations	Mean	Range	Variance	C.V
1	MS_1	4.21	2.83-7.14	1.51	29.22
2	BS_1	3.83	2.23-8.24	1.53	32.52
3	HS_1	3.24	2.13-5.24	0.41	19.86
4	FS_1	3.11	0.64-2.63	2.78	5.35
5	S_1	3.89	0.93-5.24	2.13	77.24

Note: Abbreviation's expansions given in the list of symbols and abbreviations used

4.2.8 *Oil yield / plant (g)*

The maximum range for oil yield per plant was observed in the BS_1 population (2.23-8.24). The MS_1 and S_1 populations showed similar differences in the range of values. Whereas FS_1 population showed a range of 0.64-2.63 for oil yield per plant. The maximum mean oil yield per plant was recorded in the population of MS_1 (4.21) followed by BS_1 (3.83), HS_1 (3.24), FS_1 (3.11) and S_1 (3.89). Maximum variance (2.78) was recorded in the population of FS_1 and the lowest was in the population of HS_1 with 0.41. Though the variance is low in S_1 population compared to FS_1, but recorded maximum coefficient of variation (77.24). (Table 17)

4.3 MEAN, RANGE, VARIANCE AND COEFFICIENT OF VARIATION IN SECOND GENERATION POPULATIONS OF DIFFERENT SELECTION SCHEMES IN DIFFERENT SEASONS

In order to study the effects of different seasons in influencing mean, range, variance and coefficient of variation in second generations populations derived by various selection schemes and to identify the best season and population, the data on different traits were collected and presented in Table Numbers 18 to 25.

4.3.1 *Plant height (cm)*

In *summer* 1998-99, maximum range of 58.8-98.6 was observed in the FS_2 population followed by BS_2 population with 52.6-89.8. The lowest range of 50.3-73.4 and 50.8-74.3 was observed in the populations of MS_2 and S_2 respectively. During the same *summer* season, the mean plant height was maximum in FS_2 population (66.4) followed by BS_2 (65.7) and S_2 (64.2). Where as in MS_2 and HS_2 the mean plant heights were comparatively low. The maximum variance and coefficient of variations were recorded in the populations of FS_2 and BS_2 followed by S_2. The lowest variance and coefficient of variation was recorded in the population of MS_2. (Table 18)

Where as in *Kharif* season, maximum range for plant height (62.6-90.7) was recorded in the BS_2 population and lowest in MS_2. The maximum mean plant height was found in FS_2 (95.8) followed by HS_2 (88.7) population. The lowest mean plant height was found in S_2 populations (68.1). Whereas the variance was maximum in BS_2 (43.56) followed by FS_2 (30.25) populations. The lowest variance was found in MS_2 population (5.76). The coefficient of variation was maximum in BS_2 population (7.5) and the least in MS_2 population (3.1).

During *Rabi* season, maximum range for plant height was found in HS_2 population (82.6-95.8) and the least in S_2 population (68.3-74.2). The

Table 18 : Mean, range, variance and coefficient of variation for plant height (cm) in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	58.6	53.3-73.4	40.96	7.92
	K	79.6	73.3-85.6	5.76	3.1
	R	74.0	69.3-76.2	3.61	2.4
	Mean	70.7		16.77	4.46
BS_2	S	65.7	52.6-89.8	108.16	15.9
	K	80.6	62.6-90.7	43.56	7.5
	R	81.3	76.7-84.3	4.00	2.5
	Mean	75.9		51.90	25.9
HS_2	S	60.3	49.3-75.8	75.69	14.5
	K	88.7	79.2-94.8	21.16	5.2
	R	89.6	82.6-95.8	19.36	2.5
	Mean	79.5		38.73	7.4
FS_2	S	66.4	58.8-98.6	193.21	20.9
	K	95.8	87.6-105.8	30.25	5.7
	R	92.8	87.8-95.6	3.24	2.1
	Mean	85.0		75.56	9.56
S_2	S	64.2	50.8-74.3	94.09	15.1
	K	68.1	60.3-73.6	15.84	5.6
	R	71.3	68.3-74.2	3.24	2.1
	Mean	67.9		37.72	7.6
	Mean over 'S'	63.04		102.42	14.86
	Mean over 'K'	82.56		23.31	5.42
	Mean over 'R'	81.08		6.69	2.32

S : *Summer*, 1998-99

K : *Kharif*, 1999

R : *Rabi*, 1999

maximum mean plant height was recorded in the populations of FS_2 (92.8) followed by HS_2 (86.0) and the lowest in S_2 (71.3) population. The variance was maximum in HS_2 population (19.36) and in the rest of the populations the variance values were not differed much. The coefficient of variation among different populations not differed very much.

Over the seasons (*Summer*, *Kharif* and *Rabi*), maximum mean plant height values were recorded in the population of FS_2 (85) followed by HS_2 (79.5). Where as S_2 population recorded the lowest mean value of (67.9). The maximum mean variance of 75.56 was found in the population of FS_2. However, the coefficient of variation in FS_2 was next in to BS_2 population. The MS_2 population over the seasons recorded lowest variance (16.72) and coefficient of variation (4.46).

The overall mean values of all the seasons indicated that *Kharif*, 1999 and *Rabi*, 1999 were the best seasons for all the populations for maximum expression of plant height.

4.3.2 *Head diameter (cm)*

During *summer* season, FS_2 population showed maximum range 6.54-15.8 for head diameter followed by S_2 population (4.53-10.74). In the rest of the populations not much of differences observed in the range values. The mean head diameter values recorded by different populations were HS_2 (8.93), FS_2 (8.90), BS_2 (8.46), S_2 (8.04) and MS_2 (7.65), thereby indicated that summer season has not influenced much. The variance and coefficient of variation were maximum in FS_2 population followed by S_2 population. Where as the variance of MS_2, BS_2 and HS_2 were 1.56, 1.02 and 1.32, respectively. (Table 19)

Similarly during *Kharif*, FS_2 population recorded maximum range of 19.64-24.23 for head diameter. Where as in the rest of the populations not exhibited wider differences in the range of values. For mean head diameter, the FS_2 population showed maximum value of 22.03 followed by HS_2 population 19.03. Where as S_2 population recorded lowest mean head diameter of 10.50. Maximum variance and coefficient of variation was found in FS_2 population and the lowest by S_2 population.

During *Rabi*, range values were not wider in the different populations studied. The FS_2 population showed maximum mean head diameter (21.60) followed HS_2 population (20.66). The S_2 population showed the lowest mean head diameter (10.98). As that in *Kharif*, wider differences in variance values were observed even in *Rabi* season among the populations. Similarly with regard to coefficient of variation.

Table 19 : Mean, range, variance and coefficient of variation for head diameter (cm) in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	7.65	6.32-10.44	1.56	16.39
	K	17.09	15.34-18.23	0.58	4.45
	R	17.62	15.32-18.34	1.16	6.17
	Mean	14.12		1.10	9.00
BS_2	S	8.46	6.93-10.21	1.02	11.99
	K	15.60	14.23-16.45	0.31	3.61
	R	16.78	15.83-17.62	0.30	3.33
	Mean	13.61		0.54	6.31
HS_2	S	8.93	6.84-11.93	1.32	12.89
	K	19.03	17.63-19.62	0.25	2.65
	R	20.66	19.63-22.24	0.33	3.33
	Mean	16.21		0.63	6.29
FS_2	S	8.90	6.54-15.8	3.72	21.71
	K	22.03	19.64-24.23	1.37	5.33
	R	21.60	20.63-22.34	0.18	4.27
	Mean	17.51		1.76	10.43
S_2	S	8.04	4.53-10.74	2.46	19.52
	K	10.50	10.23-11.80	0.16	3.88
	R	10.98	10.23-11.53	0.18	4.27
	Mean	9.84		0.93	9.22
	Mean over 'S'	8.39		2.02	16.50
	Mean over 'K'	16.85		0.53	3.98
	Mean over 'R'	17.53		0.43	4.27

S : *Summer*, 1998-99
K : *Kharif*, 1999
R : *Rabi*, 1999

Over the populations, in a particular season maximum head diameter was found in FS_2 (17.51) followed by HS_2 (16.21) population and the lowest S_2 (9.84). Similar trends were observed with variance and coefficient of variation.

In general, *Kharif* and *Rabi* 1999 were found to be more favourable for all populations for maximum head diameter expression.

4.3.3 *Stem thickness (cm)*

In *summer* season, maximum range was recorded in the population of HS_2 (0.72-2.13) followed by BS_2 population (0.92-1.93). Maximum mean value for stem thickness was also recorded in HS_2 population (0.93). However the variance was maximum in MS_2 population (158.26). Where as the coefficient of variation was maximum in HS_2 population (34.19) followed by FS_2 (26.96) population. (Table 20)

In *Kharif* season, maximum range for stem thickness was found in BS_2 and HS_2 populations. However, in the rest of the populations not much of variation was found. Maximum mean of 4.39 was found in FS_2 population followed by HS_2 population. Wide differences were not recorded in the variance values in the populations studied during *Kharif* season. They coefficient of variation was maximum in BS_2 population (21.89) followed by S_2 population (20.91).

Table 20 : Mean, range, variance and coefficient of variation for stem thickness (cm) in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	0.76	0.62-1.34	158.26	16.56
	K	1.81	1.23-2.24	0.05	12.38
	R	3.48	3.23-3.71	0.02	3.97
	Mean	2.02		52.77	10.97
BS_2	S	0.83	0.92-1.93	0.01	11.90
	K	1.79	1.23-2.42	0.15	21.89
	R	2.60	2.43-2.84	0.02	5.95
	Mean	1.74		0.06	13.25
HS_2	S	0.93	0.72-2.13	1.10	34.19
	K	2.99	2.44-3.63	0.18	14.66
	R	4.36	3.63-4.92	0.17	5.95
	Mean	2.76		0.15	18.27
FS_2	S	0.86	0.73-1.24	0.05	26.96
	K	4.39	3.84-4.83	0.08	6.70
	R	4.64	4.34-4.93	0.02	14.24
	Mean	3.29		0.05	15.97
S_2	S	0.77	0.44-1.13	0.02	20.53
	K	1.40	1.23-1.94	0.08	20.91
	R	1.60	1.24-1.93	0.02	14.24
	Mean	1.25		0.04	18.56
	Mean over 'S'	0.83		31.29	22.03
	Mean over 'K'	2.48		0.11	15.31
	Mean over 'R'	3.34		0.05	8.87

S : *Summer*, 1998-99
K : *Kharif*, 1999
R : *Rabi*, 1999

The range values during *rabi* season were maximum in HS_2 population (3.63-4.92) and the least was in BS_2 population. Maximum mean values for stem thickness were found in FS_2 (4.64) and HS_2 (4.36) populations. Similar trend as that of *Kharif* season observed with regard to variance values. However, coefficient of variation was found maximum in the populations of FS_2 and S_2.

When it was taken overall mean, mean variance and mean of coefficient of variation of a particular population over all seasons, it was found that FS_2 population recorded maximum over all mean (3.29) followed by HS_2 (2.76). The mean variance was maximum in MS_2 population and in the mean coefficient of variation, HS_2 and S_2 recorded maximum values.

For all the populations, *rabi* season showed maximum overall mean (3.34) followed by *Kharif* season (2.48). However, maximum mean variance and coefficient of variation were found in summer season.

4.3.4 *Days to maturity*

In *summer* FS_2 population recorded maximum range (80-87) for days to maturity followed by HS_2 (80-85). The mean number of days taken to maturity were 84.32, 84 and 83.04 in S_2, FS_2 and HS_2, respectively. The variance was maximum in HS_2 followed by FS_2. The coefficient of variation was maximum in FS_2 (1.94) followed by HS_2 (1.75). (Table 21)

Table 21 : Mean, range, variance and coefficient of variation for days to maturity in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	81.23	80-82	0.41	0.89
	K	81.41	79-83	1.17	1.32
	R	81.20	80-83	0.41	0.70
	Mean	81.28		0.66	0.97
BS_2	S	81.51	80-83	0.92	1.12
	K	81.20	80-83	0.83	1.06
	R	80.91	80-82	0.50	0.91
	Mean	81.20		0.75	1.03
HS_2	S	83.04	80-85	3.09	1.75
	K	81.43	80-83	0.55	0.91
	R	81.44	80-84	1.08	0.99
	Mean	81.97		1.57	1.22
FS_2	S	84.00	80-87	2.66	1.94
	K	81.34	80-83	0.55	0.91
	R	80.93	80-82	1.54	1.11
	Mean	82.09		1.58	1.32
S_2	S	84.32	83-86	0.64	0.92
	K	79.92	76-82	2.19	1.72
	R	80.84	79-83	1.54	1.11
	Mean	81.69		1.46	1.25
	Mean over 'S'	82.82		1.54	1.32
	Mean over 'K'	81.06		1.06	1.18
	Mean over 'R'	81.06		1.01	0.96

S : *Summer*, 1998-99
K : *Kharif*, 1999
R : *Rabi*, 1999

In *Kharif*, the range for days to maturity was maximum in S_2 (76-82) and the rest of the populations not differed very much and similarly with mean number of days taken to maturity. The variance was maximum in S_2 population (2.19) followed by MS_2 (1.17) and in the rest of the populations almost similar variance values were observed.

In *rabi* season, not much differences were observed in the range and mean values for days to maturity. The variance was maximum in S_2 and FS_2 populations and similarly with coefficient of variation.

The overall mean of populations in different seasons not differed very much and also similar variance and coefficient of variation were observed.

4.3.5 ***100 Seed weight (g)***

During *summer* season, maximum range for 100 seed weight was recorded in FS_2 population and MS_2 and S_2 had similar range values. Maximum 100 seed weight was found in FS_2 population (6.40). The lowest 100 seed weight was found in S_2 population (4.58). The maximum variance and coefficient of variation was also found FS_2 population. (Table 22)

The maximum range of 2.43-4.42 was recorded in BS_2 population during *Kharif* followed by FS_2 and S_2 populations. The 100 seed weight was

Table 22 : Mean, range, variance and coefficient of variation for 100 seed weight (g) in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	5.23	4.04-6.23	0.22	9.09
	K	3.92	3.43-4.24	0.03	4.82
	R	3.41	3.23-3.71	0.05	6.57
	Mean	4.18		0.10	6.83
BS_2	S	5.80	5.32-6.64	0.27	9.12
	K	3.72	2.43-4.42	0.21	12.36
	R	3.13	3.23-3.62	0.03	5.19
	Mean	4.22		0.17	8.89
HS_2	S	5.40	4.93-6.14	0.15	7.39
	K	5.13	5.14-5.63	0.03	3.50
	R	4.53	4.24-.533	0.08	5.19
	Mean	5.02		0.09	5.36
FS_2	S	6.40	5.14-8.43	1.32	18.06
	K	6.57	5.83-7.62	0.32	8.71
	R	6.89	6.23-7.24	0.06	5.58
	Mean	6.62		0.57	10.78
S_2	S	4.58	2.83-5.34	0.72	0.92
	K	2.48	2.14-3.83	0.13	14.66
	R	3.30	3.14-3.83	0.06	5.58
	Mean	3.45		0.30	7.05
	Mean over 'S'	5.48		0.54	8.92
	Mean over 'K'	4.36		0.14	8.81
	Mean over 'R'	4.25		0.06	5.62

S : *Summer*, 1998-99

K : *Kharif*, 1999

R : *Rabi*, 1999

maximum in FS_2 population followed by HS_2 population. The variances of all the populations during *Kharif* were almost similar. Where as the maximum coefficient of variation was found in S_2 (14.66) followed by BS_2 (12.36) population.

During *rabi* season, range values were maximum in HS_2 and FS_2 populations. Hundred seed weight was maximum in FS_2 population (6.89) and variance and co-efficient of variation were similar in almost all populations.

The mean of FS_2 population over three seasons was greater than the rest of the populations. Next in order was HS_2 population. The mean 100 seed weight of all the populations in *summer* season recorded maximum value (5.48) than the other seasons. Similar results were obtained for variance and coefficient of variation.

4.3.6 ***Seed yield / plant (g)***

During *summer* season, the maximum range was recorded in the FS_2 population (7.93-16.42) followed by HS_2 population (9.83-16.42). The mean seed yield of HS_2 population (13.16) was greater than BS_2 population (10.89) followed by FS_2, S_2 and MS_2 populations. The variance and coefficient of variation were maximum in HS_2 population when compared to the rest of the populations. (Table 23)

Table 23 : Mean, range, variance and coefficient of variation for seed yield / plant (g) in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	6.23	5.01-7.32	0.30	8.85
	K	20.06	19.23-20.61	0.35	6.67
	R	22.64	3.23-3.71	0.05	6.57
	Mean	16.31		0.23	7.36
BS_2	S	10.89	9.63-12.92	0.44	6.13
	K	16.31	15.53-16.82	0.09	1.91
	R	18.20	16.43-18.84	0.45	3.70
	Mean	15.13		0.33	3.91
HS_2	S	13.16	9.83-16.42	3.53	14.34
	K	30.57	29.83-32.34	0.26	1.67
	R	32.44	31.23-33.44	0.34	0.67
	Mean	25.39		1.38	5.56
FS_2	S	8.47	7.93-16.42	0.59	9.19
	K	39.85	39.24-40.63	0.30	1.39
	R	41.98	40.63-42.65	0.01	2.13
	Mean	30.10		0.30	4.24
S_2	S	7.55	6.63-8.12	0.21	6.02
	K	7.49	6.83-8.04	0.11	4.41
	R	6.76	6.63-7.03	0.25	2.13
	Mean	7.27		0.19	4.18
	Mean over 'S'	9.26		0.01	8.91
	Mean over 'K'	22.85		0.22	3.21
	Mean over 'R'	24.40		0.22	3.04

S : *Summer*, 1998-99
K : *Kharif*, 1999
R : *Rabi*, 1999

In *Kharif* season, maximum range values were found in HS_2 population (29.83-32.34) and in the rest of the populations the differences were minimum. However, maximum mean seed yield was found in F_2 population (39.85) followed by HS_2 population with 30.57. Maximum variance (0.35) and coefficient of variation (6.67) were recorded by the MS_2 population.

Maximum range for seed yield was recorded in BS_2 population (16.43-18.84) followed by HS_2 and FS_2 population in *rabi* season. The least range values were found in S_2 and MS_2 populations. Highest mean seed yield was found in FS_2 (41.98) followed by HS_2 (32.44) population. The variance was maximum in BS_2 population (0.45) but the coefficient of the variation was highest in MS_2 population.

The mean seed yield of a population over all the seasons was maximum in FS_2 (30.10) followed by HS_2 population (25.39). The average yield of all populations over different seasons were found to be better in *rabi* season followed by *kharif* season. But the same thing has not reflected in variance and coefficient of variation. *Summer* season appeared favourable for variance and coefficient of variation.

4.3.7 *Oil per cent*

In *summer* season, maximum range for oil per cent was found in BS_2 population (30.43-43.24) followed by MS_2 and S_2 populations. Whereas the mean oil per cent value were higher in BS_2 population (36.71) followed by HS_2 (34.43) and FS_2 (33.80). Where as the variance (17.14) and coefficient of variation (15.13) were higher in MS_2 population. (Table 24)

In *rabi* season, maximum range for oil per cent was found in MS_2 population (30.24-36.32). The mean per cent values were higher in FS_2 (48.36) followed by HS_2 and S_2. The variance was maximum in HS_2 (115.56) followed by BS_2 population (111.94). However, the coefficient of variation was maximum in MS_2 population.

Maximum oil per cent over all the seasons was found in the population of FS_2 (43.27) followed by HS_2 (39.42) population. The mean oil per cent of all the populations in a particular season is considered, *kharif* and *rabi* seasons recorded maximum oil per cent of 40.74 and 38.97, respectively. However, mean variance of all the populations was maximum in *rabi* (46.13) but coefficient of variation was maximum in *summer* season (10.17).

Table 24 : Mean, range, variance and coefficient of variation oil percent in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	27.41	20.33-31.24	17.14	15.13
	K	39.70	33.42-42.34	4.16	5.14
	R	33.68	30.24-36.32	2.62	4.82
	Mean	33.59		7.97	8.36
BS_2	S	36.71	30.43-43.24	16.97	11.23
	K	33.44	30.53-35.24	0.21	3.88
	R	31.00	30.32-32.14	111.94	1.88
	Mean	33.72		43.04	5.66
HS_2	S	34.43	29.52-39.23	9.36	8.91
	K	42.76	39.63-44.24	0.96	2.31
	R	41.08	39.62-42.14	115.56	0.58
	Mean	39.42		41.96	3.93
FS_2	S	33.80	29.64-37.83	7.95	8.35
	K	47.66	45.63-48.42	0.92	2.03
	R	48.36	48.13-49.04	0.53	1.81
	Mean	43.27		3.13	4.06
S_2	S	32.77	30.12-36.54	5.57	7.21
	K	40.12	37.63-41.82	0.69	2.07
	R	40.72	39.63-41.82	0.03	1.81
	Mean	37.87		2.09	3.69
	Mean over 'S'	33.02		11.39	10.17
	Mean over 'K'	40.74		1.38	3.08
	Mean over 'R'	38.97		46.13	2.18

S : *Summer*, 1998-99
K : *Kharif*, 1999
R : *Rabi*, 1999

4.3.8 *Oil yield / plant (g)*

In *summer* season, maximum range for oil yield / plant was found in HS_2 population (3.34-6.04) followed by FS_2 population (2.14-3.93). Similarly mean oil yield / plant was found in HS_2 population (4.53) followed by BS_2 population (3.97). Where as coefficient of variation was highest in MS_2 population (19.08) followed by HS_2 population (16.69). (Table 25)

For oil yield / plant in *kharif* season, maximum range was found in FS_2 population (17.46-20.23) followed by MS_2 (6.63-8.42). Where as mean oil yield per plant was maximum in FS_2 population (18.96) followed by HS_2 population (12.79). The variance for oil yield / plant was maximum in BS_2 (1.66) where as coefficient of variation was high in MS_2 and BS_2 populations.

In *rabi* season, wide range was found in two population viz., BS_2 and FS_2 with 6.43-8.84 and 17.23-19.46, respectively. Mean oil yield per plant was highest in FS_2 population (18.62) followed by HS_2 (13.10). Maximum variance was found in FS_2 (0.56) where as for coefficient of variation S_2 population recorded highest value of 6.28.

Over all the seasons, FS_2 population recorded maximum mean oil yield / plant (13.47) followed by HS_2 population (10.14). Both *kharif* and *rabi* seasons were in general favourable for the expression of oil yield per

Table 25 : Mean, range, variance and coefficient of variation for oil yield / plant (g) in second generation populations in different seasons

Population / Generation	Season	Mean	Range	Variance	C.V
MS_2	S	1.69	1.23-2.24	0.10	19.08
	K	7.70	6.63-8.42	0.26	6.67
	R	7.07	6.31-7.92	0.14	5.27
	Mean	5.49		0.17	10.34
BS_2	S	3.97	3.24-4.63	0.17	10.72
	K	5.06	4.63-5.34	1.66	6.67
	R	5.48	6.43-8.84	0.04	3.91
	Mean	4.84		0.62	7.10
HS_2	S	4.53	3.34-6.04	0.56	16.69
	K	12.79	12.24-13.56	0.13	2.93
	R	13.10	12.43-13.64	0.16	3.10
	Mean	10.14		0.28	7.57
FS_2	S	2.84	2.14-3.93	0.14	13.53
	K	18.96	17.64-20.23	0.29	2.86
	R	18.62	17.23-19.64	0.56	4.05
	Mean	13.47		0.33	6.81
S_2	S	2.47	2.13-3.14	0.07	11.68
	K	2.90	2.53-3.24	0.03	5.54
	R	2.79	2.63-3.12	0.03	6.28
	Mean	2.72		0.04	7.83
	Mean over 'S'	3.10		0.21	14.34
	Mean over 'K'	9.48		0.47	4.93
	Mean over 'R'	9.41		0.19	4.52

S : *Summer*, 1998-99

K : *Kharif*, 1999

R : *Rabi*, 1999

plant by all the populations. However, maximum mean coefficient of variation was recorded in the *summer* season by all the populations.

4.4 ANALYSIS OF VARIANCE

The populations of HS_1 (115), FS_1 (123) and S_1 (66) were raised in three separate experiments in a randomized block design with two replications in each. The data obtained in each of the experiments were subjected to analysis of variance.

Analysis of variance for eight quantitative traits studied in HS_1, FS_1 and S_1 progenies showed significant differences among the progenies in each of the experiments (Table 26-28). It indicated that considerable variation existed in the progenies selected in each of these populations.

4.4.1 *Genetic parameters*

4.4.1.1 ***HS_1 progenies :*** The genotypic coefficient of variation in all the characters studied ranged from 3.0 (days to maturity) to 35.67 (100-seed weight). The phenotypic coefficient of variation ranged from 3.64 (days to maturity) to 35.6 (100-seed weight). Days to maturity, plant height, stem thickness, oil per cent and head diameter recorded low genotypic coefficient of variation. High genotypic coefficient of variation values were found in 100-seed weight, oil yield and seed yield. Low phenotypic coefficient of

Table 26 : Analysis of variance for eight quantitative traits in HS_1 generation progenies in sunflower

Source	df	Mean squares (M.S)							
		Plant height	Head diameter	Stem thickness	Days to Maturity	100-Seed weight	Oil percent	Oil yield / plant	Seed yield / plant
Replications	1	29.2870	1.2331	0.0257	3.9065	2.5272**	32.8829**	0.2006	1.0374
Treatments	114	95.8333**	3.1602**	0.1152**	14.6206**	3.9941**	15.1073**	0.9875**	9.7890**
Error	114	20.7475	0.6922	0.0413	2.7991	0.0110	0.0971	0.0904	0.8764
S.Ed.		4.5549	0.8320	0.2033	1.6730	0.1047	0.3116	0.3007	0.9362
C.D. (0.05)		9.0279	1.6490	0.4029	3.3160	0.2075	0.6176	0.5960	1.8555
C.D (0.01)		11.9339	2.1798	0.5325	4.3834	0.2743	0.8164	0.7879	2.4527

* Significant at 5% level
** Significant at 1% level

Table 27 : Analysis of variance for eight quantitative traits in FS_1 generation progenies in sunflower

Source	df	Mean sum of squares (M.S)							
		Plant height	Head diameter	Stem thickness	Days to Maturity	100-Seed weight	Oil percent	Oil yield / plant	Seed yield / plant
Replications	1	2212.2847**	14.1122**	0.6765**	19.4685**	0.8209**	16.7040**	0.1892	2.9654
Treatments	122	407.3576**	1.6239**	0.0752**	2.8445**	3.6117**	11.9331**	0.9730**	9.6333**
Error	122	50.9546	0.7655	0.0374	2.736	0.0497	0.1534	0.1454	1.4587
S.Ed.		7.1383	0.8749	0.1933	1.6654	0.2230	0.3917	0.3813	1.2078
C.D. (0.05)		14.1552	1.7350	0.3833	3.3025	0.4423	0.7767	0.7561	2.3950
C.D (0.01)		18.6808	2.2896	0.5058	4.3584	0.5837	1.0251	0.9978	3.1608

* Significant at 5% level
** Significant at 1% level

Table 28 : **Analysis of variance for eight quantitative traits in S_1 generation progenies in sunflower**

Source	df	Mean squares (M.S)							
		Plant height	Head diameter	Stem thickness	Days to Maturity	100-Seed weight	Oil percent	Oil yield / plant	Seed yield / plant
Replications	1	181.3201**	5.0003**	0.3236**	3.9886*	1.1666**	2.4886*	0.0123*	0.1018
Treatments	65	152.1163**	1.8598**	0.1018**	5.6233**	4.0970**	44.9477**	1.5891**	14.5072**
Error	65	6.6835	0.2159	0.0301	3.6788	0.0173	0.2233	0.0499	0.3290
S.Ed.		2.5853	0.4647	0.1736	1.9180	0.1315	0.4725	0.2234	0.5736
C.D. (0.05)		5.1628	0.9280	0.3466	3.8303	0.2627	0.9436	0.4461	1.1455
C.D (0.01)		6.8613	1.2333	0.4607	5.0905	0.3491	1.2540	0.5928	1.5224

* Significant at 5% level
** Significant at 1% level

variation values were found in days to maturity (3.64), plant height (8.84) and oil per cent (9.25). Head diameter and stem thickness showed medium phenotypic coefficient of variation values i.e. 12.32 and 12.42, respectively. High phenotypic coefficient of variation values were recorded by the characters viz., seed weight (35.77), oil yield (24.01) and seed yield (22.19).

All the characters studied recorded high heritability estimates that is more than 60% except stem thickness (0.47 or 47%). Days to maturity exhibited low genetic advance (5.09). Whereas moderate genetic advance was found in plant height, head diameter, stem thickness and oil per cent. Hundred seed weight, oil yield and seed yield recorded high genetic advance, 73.28, 41.16 and 30.21, respectively. (Table 29)

4.4.1.2 ***FS_1 Progenies :*** Days to maturity, head diameter, stem thickness and oil per cent recorded low genotypic coefficient of variation. Moderate genotypic coefficient of variation was found in plant height (15.30). The characters such as 100-seed weight, oil yield and seed yield recorded high genotypic and phenotypic coefficient of variation. Moderate phenotypic coefficient of variation were found in plant height, stem thickness and head diameter. High heritability and genetic advance were found in seed yield, oil yield, plant height and seed weight. Moderate heritability and low genetic advance recorded in head diameter and stem thickness. (Table 30)

Table 29 : Estimates of genetic variability parameters for eight quantitative traits in HS_1 generation progenies in sunflower

S.No	Character	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Heritability (broad sense) $h^2_{(b)}$	Genetic advance as percent of mean
1.	Plant height (cm)	7.09	8.84	0.64	11.73
2.	Head diameter (cm)	9.86	12.32	0.64	16.27
3.	Stem thickness (cm)	8.53	12.42	0.47	12.08
4.	Days to maturity	3.00	3.64	0.67	5.09
5.	100-Seed weight (g)	35.67	35.77	0.99	73.28
6.	Oil percent	9.19	9.25	0.98	18.81
7.	Oil yield / plant (g)	21.90	24.01	0.83	41.16
8.	Seed yield / plant (g)	20.29	22.19	0.83	30.21

* Significant at 5% level
** Significant at 1% level

Table 30 : Estimates of genetic variability parameters for eight quantitative traits in FS_1 generation progenies in sunflower

S.No	Character	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Heritabilty (broad sense) $h^2_{(b)}$	Genetic advance as percent of mean
1.	Plant height (cm)	15.30	17.35	0.77	27.80
2.	Head diameter (cm)	6.81	11.37	0.35	8.41
3.	Stem thickness (cm)	7.06	12.19	0.33	8.44
4.	Days to maturity	0.23	2.04	0.12	0.53
5.	100-Seed weight (g)	40.49	41.05	0.97	82.26
6.	Oil percent	7.89	7.99	0.97	16.05
7.	Oil yield / plant (g)	41.20	47.90	0.74	73.02
8.	Seed yield / plant (g)	38.69	45.06	0.73	68.42

* Significant at 5% level
** Significant at 1% level

4.4.1.3 ***S_1 Progenies :*** Days to maturity and head diameter recorded low genotypic coefficient of variation. Where as the plant height (10.10), stem thickness (10.10) and oil per cent grouped under moderate group. As in the other populations, the characters oil yield and seed yield recorded high genotypic and phenotypic coefficient of variation. Days to maturity also showed low phenotypic coefficient of variation (2.64). Moderate phenotypic coefficient of variation was found in plant height, head diameter, stem thickness and oil per cent. High heritability and genetic advance were found in seed yield, oil yield, oil per cent and 100-seed weight. Low heritability and low genetic advance in the days to maturity. High heritability and moderate genetic advance recorded in the plant height, head diameter and stem thickness. (Table 31)

4.5 ANALYSIS OF VARIANCE AND GENETIC PARAMETERS IN SECOND GENERATION POPULATIONS

The analysis of variance and genetic parameters for yield and yield attributes in the second generation populations of mass selection, bulk sib selection, half sib, full sib and selfed progeny along with check Morden in different seasons of *summer* 1998-99, *kharif* 1999 and *rabi* 1999 are furnished in Table numbers 32 to 38.

Table 31 : Estimates of genetic parameters for eight quantitative traits in S_1 generation progenies in sunflower

S.No	Character	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Heritabilty (broad sense) $h^2_{(b)}$	Genetic advance as percent of mean
1.	Plant height (cm)	10.10	10.56	0.91	19.92
2.	Head diameter (cm)	9.27	10.42	0.79	17.00
3.	Stem thickness (cm)	10.10	13.70	0.54	15.33
4.	Days to maturity	1.20	2.64	0.20	1.13
5.	100-Seed weight (g)	27.82	27.94	0.99	57.07
6.	Oil percent	16.66	16.74	0.99	34.15
7.	Oil yield / plant (g)	53.76	55.48	0.93	107.33
8.	Seed yield / plant (g)	42.94	43.92	0.95	86.48

* Significant at 5% level
** Significant at 1% level

Table 32 : Analysis of variance for yield and yield attributes in the second generation populations during *summer*, 1998-99

Source	df	Mean squares (M.S)							
		Plant height	Head diameter	Stem thickness	Days to maturity	100 Seed weight	Oil percent	Oil yield/ plant	Seed yield / plant
Replications	4	12.28	0.72	0.002	3.93	0.02	9.79	0.014	0.84
Populations	5	694.48**	21.44**	1.114**	42.88**	5.67**	71.25**	6.96**	59.40**
Error	20	6.88	0.44	0.003	3.04	0.02	6.24	0.02	0.59

* Significant at 5% level
** Significant at 1% level

Table 33 : Analysis of variance for yield and yield attributes in the second generation populations during *kharif*, 1999

Source	df	Mean squares (M.S)							
		Plant height	Head diameter	Stem thickness	Days to maturity	100 Seed weight	Oil percent	Oil yield/ plant	Seed yield / plant
Replications	4	0.57	1.29	0.01	1.00	0.08	2.80	0.23	0.40
Populations	5	489.16**	72.99**	6.15**	3.15**	10.10**	120.97**	171.59*	635.41**
Error	20	3.16	0.77	0.01	0.62	0.22	0.92	0.26	0.87

* Significant at 5% level
** Significant at 1% level

Table 34 : Analysis of variance for yield and yield attributes in the second generation populations during *rabi*, 1999

Source	df	Mean squares (M.S)							
		Plant height	Head diameter	Stem thickness	Days to maturity	100 Seed weight	Oil percent	Oil yield/ plant	Seed yield / plant
Replications	4	4.99	0.38	0.01	1.20	0.01	1.23	0.16	1.25
Populations	5	349.42**	72.49**	6.49**	2.22**	10.02**	207.76**	167.52**	731.94**
Error	20	4.48	2.85	0.05	0.71	0.01	2.65	0.18	0.48

* Significant at 5% level
** Significant at 1% level

Analysis of variance in different seasons revealed significant differences among various populations for all the yield and yield attributes studied. This indicated considerable variability among the populations derived by various selection schemes.

4.5.1 *Summer*, 1998-99

The MS_2 and HS_2 populations recorded significantly lower mean values for plant height than BS_2, FS_2, S_2 and Morden variety. Where as for head diameter BS_2, HS_2 and FS_2 populations recorded significantly higher mean values than the check variety Morden. The stem thickness was minimum (0.76) in MS_2 population followed by S_2 population (0.77). The HS_2 population recorded maximum stem thickness value of 0.93 when compared to all the populations. MS_2 and BS_2 populations taken comparatively less number of days to maturity. Maximum 100 seed weight was found in FS_2 population (6.40) followed by BS_2 population and the least in Morden check variety (3.78). BS_2 population recorded maximum oil per cent (36.71) and the least in MS_2 population (27.41). For oil yield and seed yield / plant, HS_2 population recorded maximum mean values and minimum in MS_2 population (Table 35).

During *summer* season, all the attributes studied showed high heritability estimates, where as only plant height, showed high expected

Table 35 : Mean values of various populations for yield and yield attributes during *summer*, 1998-99

S. No.	Character	MS_2	BS_2	HS_2	FS_2	S_2	Morden (check)	S.Em
1	Plant height (cm)	58.6	65.7	60.3	66.4	64.2	65.00	1.66
2	Head diameter (cm)	7.65	8.46	8.93	8.90	8.04	7.53	0.42
3	Stem thickness (cm)	0.76	0.83	0.93	0.86	0.77	0.85	0.04
4	Days to maturity	81.23	81.51	83.04	84.00	84.32	84.60	1.10
5	100 Seed weight (g)	5.23	5.80	5.40	6.40	4.58	3.78	0.09
6	Oil percent	27.41	36.71	34.43	33.80	32.77	32.50	1.57
7	Oil yield / plant (g)	1.69	3.97	4.53	2.84	2.47	2.60	0.09
8	Seed yield / plant (g)	6.23	10.89	13.16	8.47	7.55	7.45	0.48

genetic advance (22.40) and the rest of the attributes recorded low values. The differences between genotypic and phenotypic variances were narrow for most of the characters except days to maturity and oil per cent. (Table 38)

4.5.2 *Kharif* 1999

The FS_2 population recorded maximum plant height (95.8) and none of the other populations showed higher values than Morden. Where as for head diameter only two population HS_2 and FS_2 showed significantly superior mean value than Morden variety. For stem thickness, FS_2 population showed maximum mean value of 4.39 and minimum in S_2 population 1.40. When it comes to days to maturity, MS_2 population taken more number of days 87.41 and the rest of the populations recorded less number of days when compared to Morden variety. Maximum oil per cent (47.66), oil yield (18.96) and seed yield / plant (39.85) were found in FS_2 population followed by HS_2 population (Table 36).

During *Kharif* 1999, high heritability estimates were found in all the attributes studied. However, the expected genetic advance values were moderate for plant height, oil yield and seed yield / plant. The differences between genotypic and phenotypic variances were narrow in all the attributes. (Table 38)

Table 36 : Mean values of various populations for yield and yield attributes during *kharif*, 1999

S. No.	Character	MS_2	BS_2	HS_2	FS_2	S_2	Morden (check)	S.Em
1	Plant height (cm)	79.6	80.6	88.7	95.8	68.1	90.7	1.12
2	Head diameter (cm)	17.09	15.6	19.03	22.03	10.5	16.2	0.55
3	Stem thickness (cm)	1.81	1.79	2.99	4.39	1.4	2.94	0.07
4	Days to maturity	87.41	81.2	81.43	81.34	79.92	82.4	0.49
5	100 Seed weight (g)	3.92	3.72	5.13	6.57	2.48	3.6	0.29
6	Oil percent	39.7	33.44	42.76	47.66	40.12	36.6	0.61
7	Oil yield / plant (g)	7.7	5.06	12.79	18.96	2.9	7.08	0.32
8	Seed yield / plant (g)	20.06	16.31	30.57	39.85	7.49	22.4	0.59

4.5.3 *Rabi* 1999

The maximum plant height was found in FS_2 (92.8) followed by HS_2 (86.0) and BS_2 (81.30) where as minimum in S_2 (71.3) population. The mean head diameter ranged from 10.98 (S_2) to 21.60 (FS_2). The maximum stem thickness was found in FS_2 (4.64) and minimum in S_2 with 1.60. Narrow range values were found for days to maturity. The maximum 100 seed weight was found in FS_2 (6.89) and minimum in BS_2 (3.13) population. FS_2 population recorded maximum oil per cent with 48.36 and minimum in BS_2 population (31.00). Wide range was found in oil yield / plant from 2.79 (S_2) to 18.62 (FS_2). In seed yield also FS_2 recorded maximum mean value of 41.98 followed by HS_2 with 32.44 and MS_2 with 22.64 and the lowest in S_2 (6.76) (Table 37).

The differences between genotypic and phenotypic variances were narrow for most of the characters except head diameter and days to maturity. Heritability estimates were high for all the attributes studied. However, it has not reflected in the expected genetic advance. Where in moderate expected genetic advance values were found in plant height, oil per cent, oil yield and seed yield / plant. (Table 38)

Table 37 : Mean values of various populations for yield and yield attributes during *rabi*, 1999

S. No.	Character	MS_2	BS_2	HS_2	FS_2	S_2	Morden (check)	S.Em
1	Plant height (cm)	74.06	81.3	86	92.8	71.3	80	1.33
2	Head diameter (cm)	17.62	16.78	20.66	21.6	10.98	15.78	1.06
3	Stem thickness (cm)	3.48	2.6	4.36	4.64	1.6	2.84	0.14
4	Days to maturity	81.2	80.91	81.44	80.93	80.84	83.2	0.53
5	100 Seed weight (g)	3.41	3.13	4.53	6.89	3.3	3.96	0.06
6	Oil percent	33.68	31	41.08	48.36	40.72	36.6	1.03
7	Oil yield / plant (g)	7.07	5.48	13.1	18.62	2.79	6.9	0.26
8	Seed yield / plant (g)	22.64	18.2	32.44	41.98	6.76	21.8	0.43

Table 38 : Genetic parameters of yield and yield attributes over various second generation populations in different seasons

S. No.	Characters	Season	Genetic parameters			
			σg^2	σp^2	$h^2_{(b)}$	GAM%
1.	Plant height	*summer* 1998-99	137.52	144.40	95	23.40
		kharif 1999	97.20	100.35	98	19.90
		rabi 1999	68.78	73.26	93	16.31
2	Head diameter	*summer* 1998-99	4.20	4.64	94	3.93
		kharif 1999	14.44	15.21	96	7.65
		rabi 1999	13.92	16.77	83	6.97
3.	Stem thickness	*summer* 1998-99	0.22	0.22	98	0.95
		kharif 1999	1.20	1.22	99	2.23
		rabi 1999	1.28	1.33	96	2.26
4.	Days to maturity	*summer* 1998-99	7.96	11.01	72	4.88
		kharif 1999	0.48	1.10	44	0.94
		rabi 1999	0.30	1.04	29	0.61
5.	100 Seed weight	*summer* 1998-99	1.01	1.03	98	2.02
		kharif 1999	1.97	2.19	89	2.70
		rabi 1999	2.00	2.01	99	2.4
6	Oil percent	*summer* 1998-99	13.00	19.24	68	6.10
		kharif 1999	24.09	25.01	96	9.85
		rabi 1999	41.02	43.67	93	12.59
7	Oil yield / plant	*summer* 1998-99	1.39	1.40	99	2.39
		kharif 1999	34.26	35.52	99	11.91
		rabi 1999	33.46	33.64	99	11.77
8	Seed yield / plant	*summer* 1998-99	11.76	12.35	95	6.83
		kharif 1999	126.90	127.78	99	11.30
		rabi 1999	146.29	146.77	99	24.58

σg^2 = Genotypic variance
σp^2 = Phenotypic variance
$h^2_{(b)}$ = Heritability
GAM% = Expected genetic advance as percent of mean

4.6 CHARACTER ASSOCIATION

4.6.1 *Mass Selection*

The data on character association among yield and yield attributes in different generations of mass selection and also over different seasons are presented in Tables 39 to 43.

4.6.1.1 ***MS_0 population :*** In the base population allotted for mass selection, oil yield / plant showed significant positive association with seed yield / plant (0.86985) and all the rest of the traits showed non significant and negative association with seed yield except plant height. Among the yield attributes, plant height showed positive and significant association with head diameter (0.28721) and stem thickness (0.27269). Plant height showed negative non-significant association with days to maturity and 100 seed weight. Head diameter with stem thickness (0.99370) and oil per cent with oil yield per plant (0.41346) showed negative significant positive association. The rest of the associations among yield attributes may be negative or positive but non-significant. (Table 39)

4.6.1.2 ***MS_1 population :*** Head diameter and oil yield / plant showed significant positive association with seed yield / plant 0.23788 and 0.86116, respectively. Where as days to maturity showed negative significant association with seed yield / plant (-0.21527). Head diameter, stem thickness

Table 39 : Simple correlation coefficients among yield and yield attributes in the base population allotted for mass selection (MS_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.28721**	0.27269**	-0.01080	-0.12290	0.07343	0.06800	0.03408
Head diameter (cm)		1.00000	0.99370**	-0.03997	-0.10344	0.06101	-0.01011	-0.04253
Stem thickness (cm)			1.00000	-0.04106	-0.09853	0.05509	-0.00946	-0.03863
Days to maturity				1.00000	-0.14889	-0.17776*	-0.10816	-0.02273
100 Seed weight (g)					1.00000	0.11732	-0.02554	-0.08294
Oil percent						1.00000	0.41346**	-0.07855
Oil yield / plant (g)							1.00000	0.86985**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

and oil per cent showed significant and positive association with oil yield / plant. Oil per cent with head diameter (0.25550) and stem thickness (0.28259) and stem thickness with head diameter showed highly significant and positive association (0.93471). (Table 40)

4.6.1.3 ***MS_2* *Population :*** In *summer* season, oil yield per plant only showed significant positive association with seed yield (0.6800). Where as the trait, 100 seed weight showed negative significant association with seed yield (-0.55555). Oil yield per plant showed highly significant positive association with oil per cent (0.88597). Similarly, the stem thickness with plant height and head diameter with plant height showed significant positive association. The rest of the associations among yield attributes showed either negative or positive but non-significant. (Table 41)

In *kharif* season, none of the yield attributes showed significant positive association with seed yield / plant. However, plant height recorded significant and negative association with seed yield / plant (-0.41491). But for oil yield/ plant, the yield attributes namely head diameter, stem thickness, 100 seed weight and oil per cent showed significant and positive association. Oil per cent with plant height (0.41783), stem thickness (0.50117), and 100 seed weight (0.61625) showed significant and positive association. 100 seed weight with plant height and stem thickness showed significant positive association.

Table 40 : Simple correlation coefficients among yield and yield attributes in MS_1 generation population

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.06916	0.06606	0.16733	-0.01507	-0.13616	-0.15102	-0.08079
Head diameter (cm)		1.00000	0.93471**	0.05357	0.05694	0.25550*	0.34587**	0.23788*
Stem thickness (cm)			1.00000	0.09479	0.04780	0.28259**	0.30337**	0.17288
Days to maturity				1.00000	0.07545	0.11667	-0.13753	-0.21527*
100 Seed weight (g)					1.00000	-0.08351	-0.06148	-0.03916
Oil percent						1.00000	0.45553**	-0.03327
Oil yield / plant (g)							1.00000	0.86116**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 41 : Simple correlation coefficients among yield and yield attributes in MS_2 generation population during *summer*, 1998-99

	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.45287*	0.43087*	0.02606	0.02190	-0.07394	-0.21110	-0.32234
Head diameter (cm)		1.00000	0.98046**	-0.07612	0.20373	0.35084	0.20018	-0.16023
Stem thickness (cm)			1.00000	-0.05130	0.14014	0.36259	0.23806	-0.10822
Days to maturity				1.00000	-0.25952	-0.32618	-0.15030	0.22268
100 Seed weight (g)					1.00000	0.14029	-0.18651	-0.55550**
Oil percent						1.00000	0.88597**	0.22733
Oil yield / plant (g)							1.00000	0.64800**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Days to maturity with stem thickness (0.41857) and stem thickness with plan height (0.52349) showed significant positive association. (Table 42)

In *rabi* season, none of the traits showed significant positive association with seed yield / plant. Where as pant height and head diameter showed negative and significant association with seed yield / plant. Oil yield was positively and significantly correlated with 100 seed weight (0.69547) and also with oil per cent (0.58399). Plant height with head diameter positively and negatively with days to maturity was significantly associated. (Table 43)

4.6.2 *Bulk sib selection*

The data on character association among yield and yield attributes in different cycles of bulk sib selection and also in different seasons are presented in Table Numbers 44 to 48.

4.6.2.1 ***BS_0 Population :*** In the base population allotted for bulk sib selection, the seed yield was significantly and positively associated with oil yield per plant, oil per cent, stem thickness and head diameter. Where as oil yield per plant was positively and significantly associated with oil per cent, stem thickness and head diameter. The 100 seed weight with head diameter and stem thickness showed significant positive association with correlation

Table 42 : Simple correlation coefficients among yield and yield attributes in MS_2 generation population during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	-0.31110	0.52349**	0.43429*	0.52231**	0.41783*	0.18320	-0.41491*
Head diameter (cm)		1.00000	0.14875	-0.09418	0.10985	-0.19011	0.41394*	0.28678
Stem thickness (cm)			1.00000	0.41857*	0.66949**	0.50117**	0.56240**	-0.08613
Days to maturity				1.00000	0.39527	0.22416	0.13510	-0.36097
100 Seed weight (g)					1.00000	0.61625**	0.75881**	-0.10553
Oil percent						1.00000	0.45824*	0.13141
Oil yield / plant (g)							1.00000	0.30588
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 43 : Simple correlation coefficients among yield and yield attributes in MS_2 generation population during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.52674**	0.13530	-0.43529*	-0.08355	0.07201	-0.28221	-0.55662**
Head diameter (cm)		1.00000	0.21887	-0.12565	0.08409	0.27749	-0.02619	-0.39836*
Stem thickness (cm)			1.00000	0.04663	0.35707	0.21103	0.22409	0.00795
Days to maturity				1.00000	0.35701	-0.09529	0.05532	0.23870
100 Seed weight (g)					1.00000	0.28531	0.69547**	0.14923
Oil percent						1.00000	0.58399**	0.10560
Oil yield / plant (g)							1.00000	0.29241
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

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values 0.2369 and 0.23980, respectively. Stem thickness with head diameter also showed highly significant positive association (0.96991). The oil per cent showed significant positive association with head diameter and days to maturity. (Table 44)

4.6.2.2 ***BS_1 Population :*** The seed yield / plant was positively and significantly associated with many characters viz., head diameter, stem thickness, 100-seed weight, oil per cent and oil yield / plant, oil yield was positively and significantly associated with head diameter, stem thickness, 100-seed weight. Where as stem thickness and oil per cent plant with head diameter was highly significant and positive. Only one association between days to maturity and stem thickness was negative and significant (-0.22674). (Table 45)

4.6.2.3 ***BS_2 Population :*** During *summer* in BS_2 population only days to maturity showed significant positive association with seed yield (0.46075) and the rest of the traits were neither positive nor negative but non-significant. Head diameter with stem thickness (0.87956) and oil per cent with oil yield (0.87136) exhibited significant positive associations. (Table 46)

During *kharif* season, oil yield and oil per cent were significantly and positively associated with seed yield. Where as oil yield was positively and

Table 44 : Simple correlation coefficients among yield and yield attributes in the base population allotted for bulk sib selection (BS_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	-0.04476	-0.00121	0.02020	-0.02572	-0.01198	0.07795	0.06924
Head diameter (cm)		1.00000	0.96991**	-0.04289	0.23169**	0.18709*	0.60292**	0.63023**
Stem thickness (cm)			1.00000	-0.02240	0.23980**	0.17803*	0.63082**	0.66752**
Days to maturity				1.00000	-0.07795	0.02065	0.03131	0.04893
100 Seed weight (g)					1.00000	-0.06402	-0.00622	0.03509
Oil percent						1.00000	0.50699**	0.19750*
Oil yield / plant (g)							1.00000	0.92162**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 45 : Simple correlation coefficients among yield and yield attributes in BS_1 generation population

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.09153	0.12473	-0.06148	0.17837	-0.17313	-0.16603	-0.11767
Head diameter (cm)		1.00000	0.91130**	-0.19307	-0.01644	0.06751	0.26280**	0.37775**
Stem thickness (cm)			1.00000	-0.22674*	-0.03211	0.07397	0.24954*	0.33558**
Days to maturity				1.00000	-0.02818	0.05151	-0.05834	-0.13904
100 Seed weight (g)					1.00000	0.16902	0.22662*	0.21607*
Oil percent						1.00000	0.75039**	0.19854*
Oil yield / plant (g)							1.00000	0.76125**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 46 : Simple correlation coefficients among yield and yield attributes in BS_2 population during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.30673	0.18856	0.21968	0.17859	0.02038	-0.00086	-0.07524
Head diameter (cm)		1.00000	0.87956**	0.33817	-0.18739	-0.16444	-0.16749	0.09309
Stem thickness (cm)			1.00000	0.24709	-0.27748	-0.19814	-0.25867	0.01040
Days to maturity				1.00000	-0.02636	-0.09915	0.13630	0.46075*
100 Seed weight (g)					1.00000	0.12810	0.19699	0.09812
Oil percent						1.00000	0.87136**	-0.37239
Oil yield / plant (g)							1.00000	0.11836
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

significantly associated with stem thickness and oil per cent. The rest of the associations were non-significant. (Table 47)

Oil yield with seed yield (0.99211) and head diameter with oil per cent (0.52642) showed significant positive association during *rabi* season. The rest of the combinations showed non-significant negative or positive association. (Table 48)

4.6.3 *Half Sib Selection*

The data on character association among yield and yield attributes in different cycles of half sib selection and seasons are present in Table Numbers 49 to 53.

4.6.3.1 ***HS_0* *Population* :** In the base population allotted for HS_0, the head diameter, stem thickness and oil yield per plant exhibited positive and significant association with seed yield. Where as head diameter, stem thickness and oil per cent exhibited significant and positive association with oil yield. Similarly head diameter and stem thickness with 100 seed weight and head diameter with stem thickness (0.93921) showed significant and positive association. (Table 49)

Table 47 : Simple correlation coefficients among yield and yield attributes in BS_2 generation population during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.33932	0.29170	0.34806	0.39460	0.29163	0.36354	0.15700
Head diameter (cm)		1.00000	0.33610	-0.01023	0.27720	0.09163	0.10948	-0.01216
Stem thickness (cm)			1.00000	-0.38916	0.16171	0.37430	0.64165**	-0.07053
Days to maturity				1.00000	0.02092	-0.23446	-0.26112	0.00307
100 Seed weight (g)					1.00000	0.16401	0.15838	0.13650
Oil percent						1.00000	0.82504**	0.61064**
Oil yield / plant (g)							1.00000	0.41241*
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 48 : Simple correlation coefficients among yield and yield attributes in BS_2 generation population during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	-0.13139	-0.36007	0.26270	-0.13718	0.07936	-0.15087	-0.07601
Head diameter (cm)		1.00000	-0.25321	-0.38355	0.22894	0.52642**	-0.11279	0.05991
Stem thickness (cm)			1.00000	0.00888	0.12150	-0.05524	-0.14715	0.16649
Days to maturity				1.00000	0.24578	0.15754	-0.24323	-0.33845
100 Seed weight (g)					1.00000	0.28129	-0.48219**	-0.18481
Oil percent						1.00000	-0.37099	-0.21189
Oil yield / plant (g)							1.00000	0.99211**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 49 : Simple correlation coefficients among yield and yield attributes in the base population allotted for half sib selection (HS_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.07739	0.10432	-0.01410	-0.10043	0.06751	0.08853	0.05980
Head diameter (cm)		1.00000	0.93921**	0.05878	0.21667*	0.09293	0.42619**	0.42722**
Stem thickness (cm)			1.00000	0.06103	0.19174*	0.02010	0.36273**	0.39114**
Days to maturity				1.00000	0.08804	-0.09690	-0.02764	0.00388
100 Seed weight (g)					1.00000	-0.03860	0.05284	0.07282
Oil percent						1.00000	0.47005**	0.07872
Oil yield / plant (g)							1.00000	0.90453**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

4.6.3.2 ***HS_1 population*** : In the HS_1 population, head diameter stem thickness and oil yield showed significant and positive association with yield. The rest of the characters showed either positive nor negative non-significant association with seed yield. Where as head diameter, stem thickness and oil per cent exhibited significant and positive association with oil yield. The hundred seed weight with oil per cent, head diameter with stem thickness and showed significant and positive association. Where as plant height with days to maturity showed negative significant association (-0.35103). (Table 50)

4.6.3.3 ***HS_2 Population*** : In *summer* HS_2 population, only oil yield was significantly and positively associated with seed yield (0.82474) and many of the characters have shown non-significant negative association with seed yield. The oil per cent with oil yield (0.53275), 100 seed weight with oil per cent (0.69226) head diameter with stem thickness (0.80334) and plant height with head diameter (0.46349) showed significant and positive association. (Table 51)

During *kharif* in the same HS_2 population, non of the characters exhibited significant association with seed yield either in positive or negative direction. However, oil per cent with oil yield (0.65944) and plant height with head diameter (0.44154) showed significant positive association. (Table 52)

Table 50 : Simple correlation coefficients among yield and yield attributes in HS_1 generation population

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.17880	0.07273	-0.35103**	0.09877	-0.04346	0.06008	0.11968
Head diameter (cm)		1.00000	0.74756**	-0.18228	0.07272	0.08728	0.42023**	0.43663*
Stem thickness (cm)			1.00000	-0.08846	0.08835	0.10729	0.37949**	0.36551**
Days to maturity				1.00000	-0.00762	-0.06300	-0.12960	-0.11868
100 Seed weight (g)					1.00000	0.20457*	0.08264	-0.03895
Oil percent						1.00000	0.49589**	0.02755
Oil yield / plant (g)							1.00000	0.87146**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 51 : Simple correlation coefficients among yield and yield attributes in HS_2 generation population during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.46349*	0.34897	0.03025	0.37814	0.19726	0.17710	0.07231
Head diameter (cm)		1.00000	0.80334**	-0.01936	0.28880	0.32005	0.17219	-0.02651
Stem thickness (cm)			1.00000	-0.08904	0.23352	0.25066	-0.06920	-0.23409
Days to maturity				1.00000	0.06066	0.30022	0.00659	-0.20655
100 Seed weight (g)					1.00000	0.69226**	0.27642	-0.12531
Oil percent						1.00000	0.53275**	-0.02824
Oil yield / plant (g)							1.00000	0.82474**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 52 : Simple correlation coefficients among yield and yield attributes in HS_2 generation population during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.44154*	0.04770	0.00233	-0.25037	0.12005	-0.12042	-0.09325
Head diameter (cm)		1.00000	0.15222	-0.13541	-0.22382	0.00248	-0.28989	0.00449
Stem thickness (cm)			1.00000	-0.00244	0.17902	-0.01362	-0.34697	0.30482
Days to maturity				1.00000	0.00398	0.01565	0.013360	-0.22306
100 Seed weight (g)					1.00000	-0.10980	-0.09080	-0.09485
Oil percent						1.00000	0.65944**	0.07045
Oil yield / plant (g)							1.00000	0.21452
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

In *rabi* HS_2 population, only one character, oil yield significantly and positively associated with seed yield (0.58497). Plant height with 100 seed weight, stem thickness with days to maturity exhibited significant positive association. Significant and negative associations were found between stem thickness and 100 seed weight (-0.50685) and plant height with stem thickness (-0.57952) and days to maturity (-0.47816). (Table 53)

4.6.4 *Full Sib Selection*

The results of the character association among yield and yield attributes in different cycles of full sib selection and season are presented in tables 54 to 58.

4.6.4.1 ***FS_0* Population :** In the FS_0 population, head diameter, stem thickness and oil yield were positively and significantly associated with seed yield. Where as oil yield exhibited significant and positive association with three characters viz., head diameter (0.20279), stem thickness (0.20814) and oil per cent (0.25693). The head diameter with stem thickness also showed significant positive association (0.94497). (Table 54)

4.6.4.2 ***FS_1* Population :** The three characters viz., plant height and 100 seed weight and oil yield / plant showed positive and significant association with seed yield / plant. Among character associations, head diameter with

Table 53 : Simple correlation coefficients among yield and yield attributes in HS_2 generation population during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.14137	-0.57952**	-0.47816**	0.72101**	-0.01006	0.03988	-0.06342
Head diameter (cm)		1.00000	0.27210	0.39039	0.26858	-0.37013	-0.04970	0.06087
Stem thickness (cm)			1.00000	0.62489**	-0.50685**	0.05069	0.09298	-0.09729
Days to maturity				1.00000	-0.10159	0.16397	0.20791	0.01095
100 Seed weight (g)					1.00000	-0.03046	0.16445	0.03580
Oil percent						1.00000	0.08167	-0.27101
Oil yield / plant (g)							1.00000	0.58497**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 54 : Simple correlation coefficients among yield and yield attributes in the base population allotted for full sib selection (FS_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.14332	0.13613	-0.05474	-0.03012	0.18193*	-0.04774	-0.04715
Head diameter (cm)		1.00000	0.94497**	0.14934	-0.06027	0.10019	0.20279*	0.21708*
Stem thickness (cm)			1.00000	0.14252	-0.08399	0.12903	0.20814*	0.23729**
Days to maturity				1.00000	-0.00506	0.03162	0.03859	0.03726
100 Seed weight (g)					1.00000	-0.14313	-0.07055	-0.00291
Oil percent						1.00000	0.25693**	-0.00774
Oil yield / plant (g)							1.00000	0.86309**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

stem thickness (0.93762) and plant height (0.32181) and plant height with 100-seed weight (0.23597) showed significant and positive association. Where as oil yield / plant showed significant positive association with plant height, 100 seed weight and oil per cent. (Table 55)

4.6.4.3 ***FS_2 Population :*** During *summer* none of the traits have shown significant positive association with seed yield. Where as oil yield was positively and significantly associated with plant height, head diameter, stem thickness, days to maturity and oil per cent. The 100 seed weight with plant height (0.66611), days to maturity with head diameter and stem thickness, stem thickness with plant height and head diameter showed significant and positive association. (Table 56)

In *kharif* season also none of the traits showed significant association with seed yield. However, oil yield showed significant positive association with oil per cent only (0.56785). There were positive significant association between oil per cent and days to maturity (0.46096) and negative significant associations between oil per cent and 100 seed weight (-0.58003). The 100-seed weight exhibited positive and significant association with the both characters head diameter and stem thickness. The stem thickness with head diameter and head diameter with plant height showed significant positive association. (Table 57)

Table 55 : Simple correlation coefficients among yield and yield attributes in FS_1 generation population

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.33571**	0.32181**	0.03935	0.23597**	-0.05137	0.20575*	0.18798*
Head diameter (cm)		1.00000	0.93762**	0.06354	0.09020	-0.00356	0.11777	0.07917
Stem thickness (cm)			1.00000	0.07427	0.09688	0.03075	0.15103	0.11149
Days to maturity				1.00000	-0.09827	-0.03657	-0.10231	-0.07677
100 Seed weight (g)					1.00000	0.09690	0.63516**	0.57327**
Oil percent						1.00000	0.24219**	0.11159
Oil yield / plant (g)							1.00000	0.92814**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 56 : Simple correlation coefficients among yield and yield attributes in FS_2 generation population during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.37283	0.47573**	0.31577	0.66611**	0.37061	0.61735**	0.00829
Head diameter (cm)		1.00000	0.92960**	0.59923**	0.15365	0.20890	0.55780**	0.16242
Stem thickness (cm)			1.00000	0.50154*	0.16715	0.40467*	0.68493**	0.22116
Days to maturity				1.00000	-0.03969	0.22167	0.50809**	-0.29573
100 Seed weight (g)					1.00000	-0.06545	0.15573	0.06159
Oil percent						1.00000	0.76630**	0.10929
Oil yield / plant (g)							1.00000	-0.06650
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 57 : Simple correlation coefficients among yield and yield attributes in FS_2 generation population during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.68523**	0.27374	-0.03466	0.29653	-0.37537	-0.35883	0.04918
Head diameter (cm)		1.00000	0.59233*	0.01478	0.60697**	-0.28580	-0.25081	0.08870
Stem thickness (cm)			1.00000	-0.10141	0.62663**	-0.35008	-0.08519	0.03090
Days to maturity				1.00000	-0.17268	0.46096*	0.38784	0.03529
100 Seed weight (g)					1.00000	-0.58003**	-0.20139	0.37985
Oil percent						1.00000	0.56785**	0.03176
Oil yield / plant (g)							1.00000	0.27185
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

The same FS_2 population in *rabi* season, showed significant positive association of seed yield with 100 seed weight and oil yield. Where as oil yield showed positive and significant association with 100 seed weight (0.73640). The rest of the character associations were either positive or negative but not significant. (Table 58)

4.6.5 *Selfed Population*

The results of the character association among yield and yield attributes and seasons are present in Table Nos. 59 to 63.

4.6.5.1 ***S_0 Population :*** In the plot allotted for selfing series, seed yield was positively and significantly associated with head diameter, stem thickness and oil yield / plant. Where as oil yield / plant showed positive and significant association with head diameter, stem thickness and oil per cent / plant. Days to maturity with stem thickness (0.29055) and stem thickness with head diameter (0.39704) showed significant and positive association. The rest of the associations were positive or negative but not significant. (Table 59)

4.6.5.2 ***S_1 Population :*** In S_1 population, seed yield with oil yield (0.35624), oil per cent with days to maturity (0.24740) and thickness with head diameter (0.62975) showed significant and positive association. (Table 60)

Table 58 : Simple correlation coefficients among yield and yield attributes in FS_2 generation population during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.29527	-0.13450	0.03564	-0.16899	-0.05522	-0.18884	-0.06663
Head diameter (cm)		1.00000	-0.13154	0.26125	-0.39512	-0.14986	-0.39437	-0.22580
Stem thickness (cm)			1.00000	0.24418	0.19068	0.08612	0.05790	-0.02321
Days to maturity				1.00000	-0.13020	-0.17267	-0.18254	-0.24007
100 Seed weight (g)					1.00000	0.09401	0.73640**	0.43009*
Oil percent						1.00000	0.23147	0.03298
Oil yield / plant (g)							1.00000	0.47095*
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 59 : **Simple correlation coefficients among yield and yield attributes in the base population allotted for selfed progeny (S_0)**

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	-0.06586	0.11999	0.07715	-0.00831	-0.03486	0.05080	0.05488
Head diameter (cm)		1.00000	0.39704	-0.03771	-0.07444	0.06949	0.44787**	0.45073**
Stem thickness (cm)			1.00000	0.29055*	0.10983	-0.02969	0.26873*	0.30152*
Days to maturity				1.00000	-0.05007	-0.05089	-0.13677	-0.11929
100 Seed weight (g)					1.00000	0.16527	0.07226	0.01510
Oil percent						1.00000	0.30174*	-0.05333
Oil yield / plant (g)							1.00000	0.93357**
Seed yield / plant (g)								1.00000

* Significant at 5% level
** Significant at 1% level

Table 60 : Simple correlation coefficients among yield and yield attributes in S_1 generation progenies

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.22464	0.12230	-0.00030	-0.19718	0.00169	0.09304	0.02606
Head diameter (cm)		1.00000	0.62975**	0.07436	0.02028	0.07007	0.19550	0.19387
Stem thickness (cm)			1.00000	-0.05154	0.21594	0.16794	0.10509	0.12635
Days to maturity				1.00000	0.21514	0.24740*	-0.09070	0.12679
100 Seed weight (g)					1.00000	0.14113	0.00817	0.17119
Oil percent						1.00000	0.10602	0.12214
Oil yield / plant (g)							1.00000	0.35624**
Seed yield / plant (g)								1.00000

* Significant at 5% level

** Significant at 1% level

4.6.5.3 ***S_2 Bulk Population :*** During *summer*, seed yield was positively and significantly associated with oil per cent (0.46959) and oil yield (0.77527). Where as oil yield / plant showed significant positive association with oil per cent (0.82278) only. The 100 seed weight showed negative significant association with days to maturity (-0.44324), stem thickness exhibited positive significant association with head diameter (0.75328). (Table 61)

In S_2 bulk population of *kharif* season, seed yield was positively and significantly associated with stem thickness (0.41815) and oil yield / plant (0.76242). Negative and significant association was observed between seed yield and oil per cent (-0.40235). Similarly, oil yield / plant showed negative and significant association with oil per cent (-0.43451). The character oil per cent / plant showed significant and positive association with head diameter (0.59029) and 100 seed weight (0.42327). The 100 seed weight with head diameter (0.87388) and head diameter with plant height (0.40260) showed significant and positive association. (Table 62)

During *rabi* season in the same S_2 bulk selfed population, seed yield was significantly and positively associated with 100 seed weight (0.52838) and oil yield (0.41473). Where as oil yield / plant positively and significantly associated with oil per cent (0.65871). The 100 seed weight with head

Table 61 : Simple correlation coefficients among yield and yield attributes in S_2 generation population during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	-0.04805	-0.10513	0.08075	0.07755	0.29730	0.27340	0.19470
Head diameter (cm)		1.00000	0.75328**	0.17033	-0.01057	0.12857	0.11454	0.27589
Stem thickness (cm)			1.00000	0.32526	-0.12578	-0.03289	0.23001	0.28165
Days to maturity				1.00000	-0.44324*	0.28215	0.38372	0.33313
100 Seed weight (g)					1.00000	0.16914	0.14844	0.18617
Oil percent						1.00000	0.82278**	0.46959*
Oil yield / plant (g)							1.00000	0.77527**
Seed yield / plant (g)								1.00000

* Significant at 5% level

** Significant at 1% level

Table 62 : Simple correlation coefficients among yield and yield attributes in S_2 generation population during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	0.40260*	0.06320	-0.45158*	0.35035	0.25935	0.11883	0.12634
Head diameter (cm)		1.00000	-0.06850	-0.06837	0.87388**	0.59029**	-0.02230	-0.16852
Stem thickness (cm)			1.00000	-0.07105	-0.21394	-0.03613	0.30223	0.41815*
Days to maturity				1.00000	-0.13681	0.04490	-0.18175	-0.15545
100 Seed weight (g)					1.00000	0.42327*	-0.13424	-0.33603
Oil percent						1.00000	-0.43451*	-0.40235*
Oil yield / plant (g)							1.00000	0.76242**
Seed yield / plant (g)								1.00000

* Significant at 5% level

** Significant at 1% level

diameter and stem thickness with plant height showed significant and positive association. The rest of the associations were neither positive or negative but not significant. (Table 63)

4.7 PATH COEFFICIENT ANALYSIS

Correlation coefficients do not project complete picture especially when the causal factors are inter-related. The correlation coefficients between seed yield and each of its component characters are partitioned into the corresponding direct and indirect effects through path co-efficient analysis.

4.7.1 *Mass selection*

Path coefficient analysis of different traits in various generation populations of mass selection are presented in Table Numbers 64 to 68.

4.7.1.1 ***MS_0 population :*** In the base population allotted for mass selection, oil yield / plant showed very high direct effect (1.0892) on seed yield / plant whereas oil per cent showed high negative direct effect on seed yield (-0.5294). The direct effects of head diameter, stem thickness, days to maturity and 100 seed weight on seed yield were negligible. (Table 64 and Fig. 1)

Table 63 : Simple correlation coefficients among yield and yield attributes in S_2 generation population during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Plant height (cm)	1.00000	-0.38006	0.64791**	0.49913*	-0.17297	-0.26266	-0.08236	-0.00497
Head diameter (cm)		1.00000	-0.16442	-0.35903	0.59029**	-0.05113	0.06263	0.12808
Stem thickness (cm)			1.00000	0.33064	-0.21836	-0.18366	0.04316	-0.20423
Days to maturity				1.00000	-0.29343	-0.19636	-0.24650	-0.14785
100 Seed weight (g)					1.00000	-0.16652	-0.01081	0.52838**
Oil percent						1.00000	0.65871**	0.24281
Oil yield / plant (g)							1.00000	0.41473*
Seed yield / plant (g)								1.00000

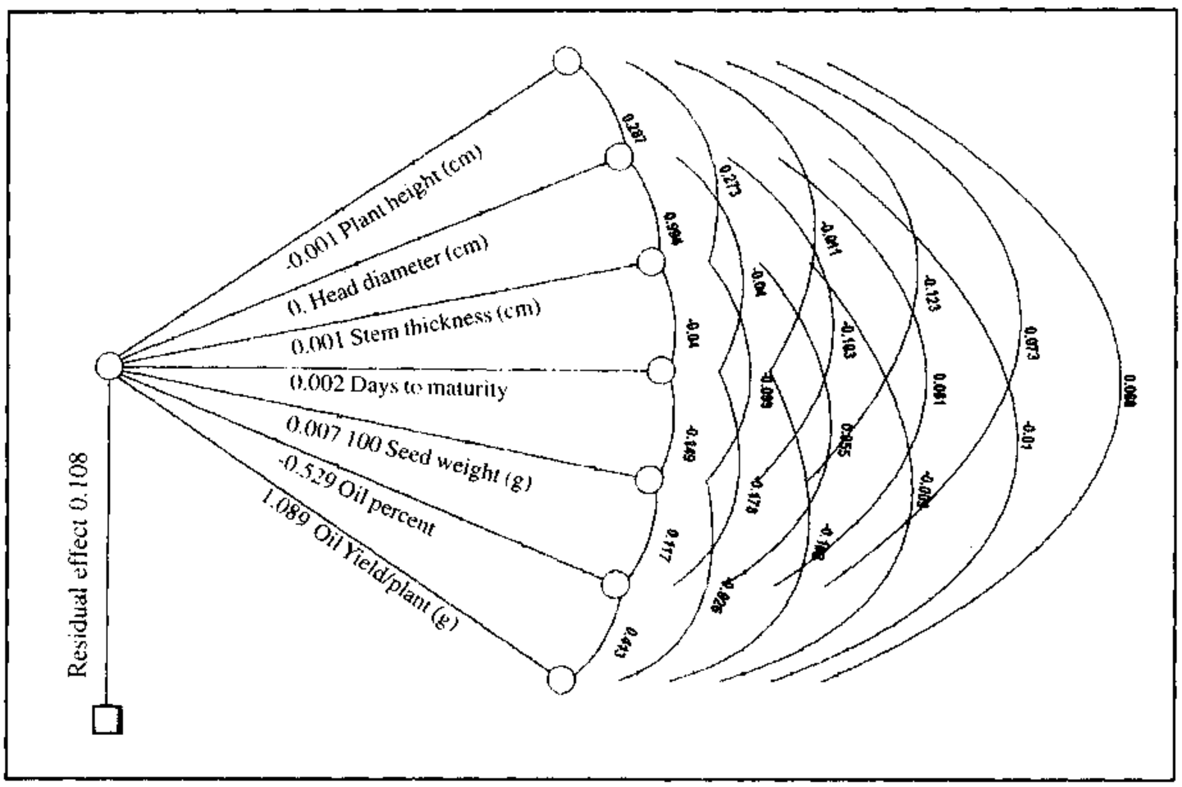
* Significant at 5% level
** Significant at 1% level

Table 64 : Path coefficient analysis of yield and yield attributes in the base population allotted for mass selection (MS_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0007**	-0.0002	-0.0002	0.0000	0.0001	-0.0001	0.0000
Head diameter (cm)	0.0001	**0.0004**	0.0004	0.0000	0.0000	0.0000	0.0000
Stem thickness (cm)	0.0004	0.0014	**0.0014**	-0.0001	-0.0001	0.0001	0.0000
Days to maturity	0.0000	-0.0001	-0.0001	**0.0021**	-0.0003	-0.0004	-0.0002
100 Seed weight (g)	-0.0009	-0.0008	-0.0007	-0.0011	**0.0074**	0.0009	-0.0002
Oil percent	-0.0389	-0.0323	-0.0292	0.0941	-0.0621	**-0.5294**	-0.2189
Oil yield / plant (g)	0.0741	-0.0110	-0.0103	-0.1178	-0.0278	0.4504	**1.0892**
Seed yield / plant (g)	0.0341	-0.0425	-0.0386	-0.0227	-0.0829	-0.0785	0.8699**
Partial R^2	0.0000	0.0000	-0.0001	0.0000	-0.006	0.0416	0.9475

R^2 = 0.9883 Residual effect = 0.1082

Fig 1 Path diagram for yield and yield attributes in the base population of Sunflower allotted for mass selection (MS_0)



4.7.1.2 ***MS_1 population :*** The oil yield / plant showed very high direct effect on seed yield / plant (1.1079). Plant height, head diameter and days to maturity exhibited negligible direct effects on seed yield / plant. The direct effect of oil per cent on seed yield / plant was negative and high (-0.5335). The 100 seed weight also showed negative direct effect but negligible. Though the direct effect of head diameter on seed yield is low (0.0215) but its significant positive correlation is due to indirect effect of oil yield / plant through head diameter. Similarly days to maturity showed negligible direct effect on seed yield / plant but its significant negative correlation is contributed indirectly by oil yield / plant through days to maturity. (Table 65 and Fig. 2)

4.7.1.3 ***MS_2 population :*** During *summer* season, oil yield / plant showed very high direct effect of 2.2530 on seed yield / plant. Though oil per cent exhibited very high negative direct effect (-1.7649) on seed yield, its effect was nullified by showing very high positive indirect effect through oil yield / plant. The 100 seed weight showed positive direct effect but its negative significant correlation with seed yield/ plant is due to moderate to high negative indirect effects of oil per cent and oil yield / plant through 100 seed weight. (Table 66 and Fig. 3)

Table 65 : Path coefficient analysis for yield and yield attributes in MS_1 generation population of sunflower

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.0143**	0.0010	0.0009	0.0024	-0.0002	-0.0020	-0.0022
Head diameter (cm)	0.0015	**0.0215**	0.0201	0.0012	0.0012	0.0055	0.0074
Stem thickness (cm)	-0.0022	-0.0306	**-0.0328**	-0.0031	-0.0016	-0.0093	-0.0099
Days to maturity	0.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000
100 Seed weight (g)	0.0002	-0.0009	-0.0007	-0.0011	**-0.0150**	0.0013	0.0009
Oil percent	0.0726	-0.1363	-0.1508	-0.0622	0.0446	**-0.5335**	-0.2430
Oil yield / plant (g)	-0.1673	0.3832	0.3361	-0.1524	0.0681	0.5047	**1.1079**
Seed yield / plant (g)	-0.0808	0.2379**	0.1729	-0.2153*	-0.0392	-0.0333	0.8612**
Partial R^2	-0.0012	0.0051	-0.0057	0.0000	0.0006	0.0177	0.9541

$R^2 = 0.9707$ Residual effect = 0.1711

Fig 2 Path diagram for yield and yield attributes in MS_1 generation population of sunflower

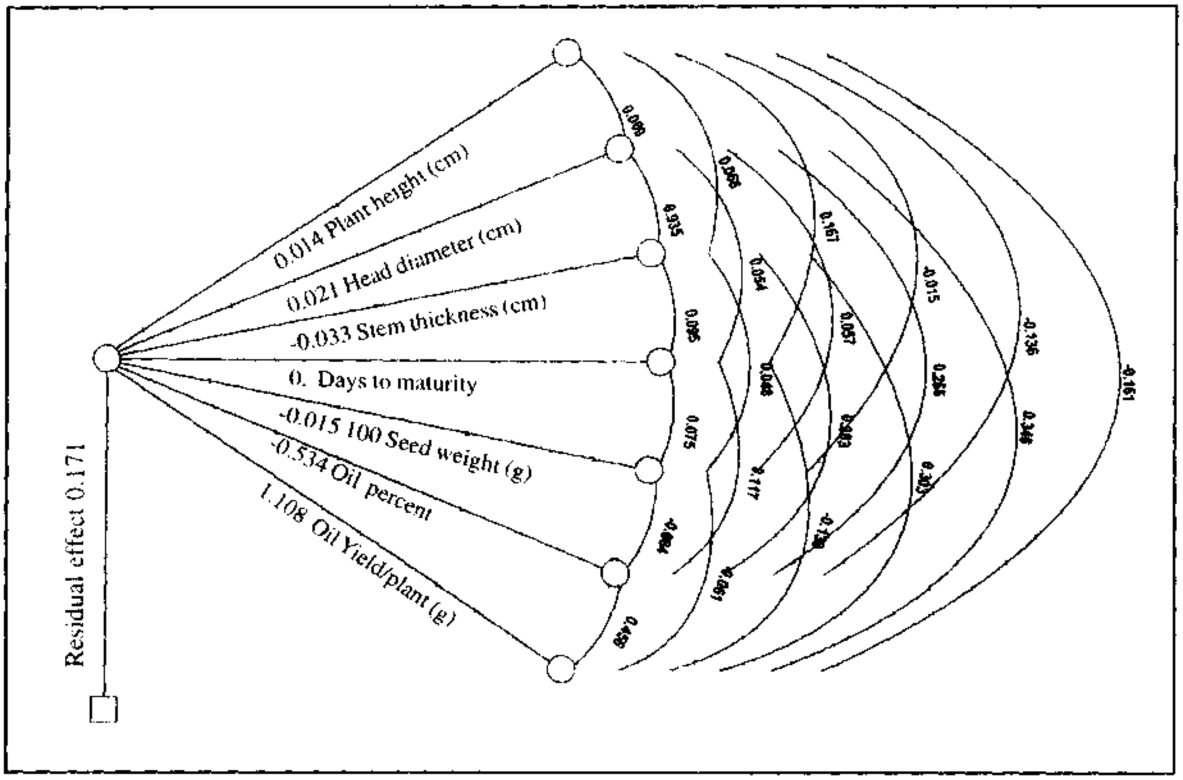
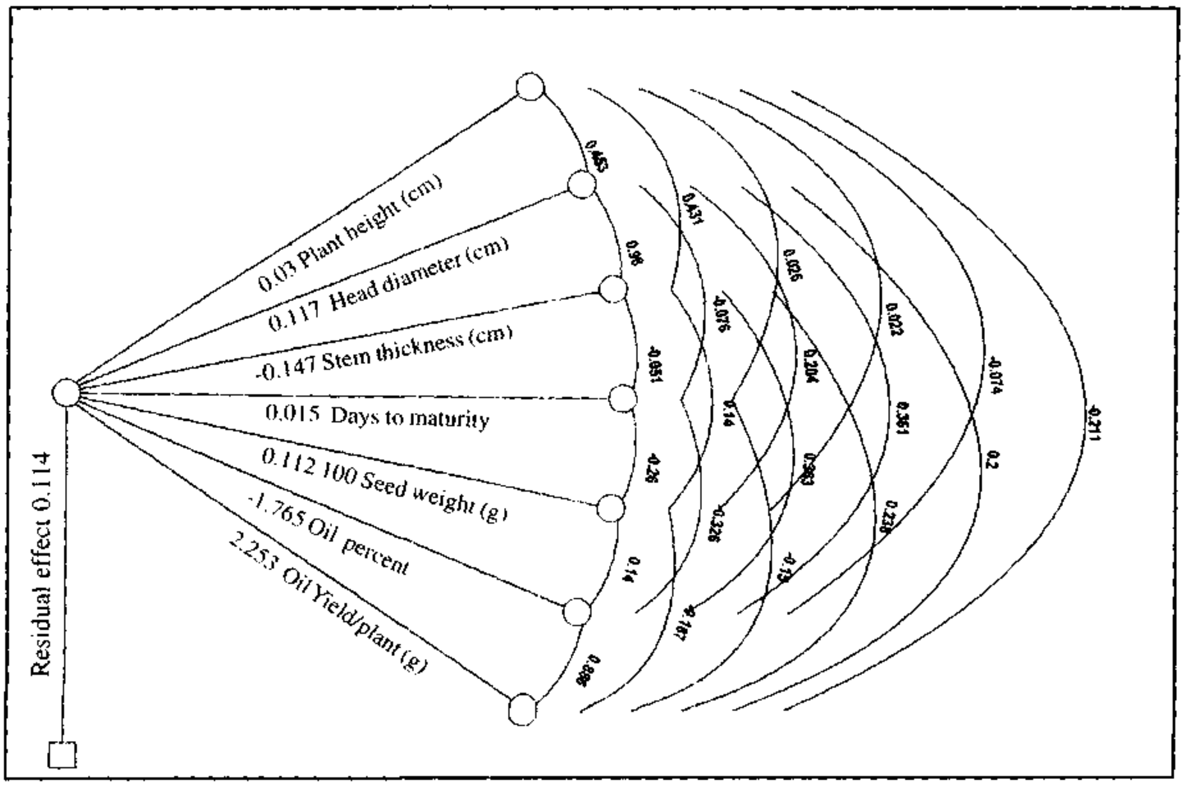


Table 66 : Path coefficient analysis of yield and yield attributes in the MS_2 generation population of sunflower during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.0305**	0.0138	0.0131	0.0008	0.0007	-0.0023	-0.0064
Head diameter (cm)	0.0528	**0.1166**	0.1143	-0.0089	0.0238	0.0409	0.0233
Stem thickness (cm)	-0.0634	-0.1442	**-0.1471**	0.0075	-0.0206	-0.0533	-0.0350
Days to maturity	0.0004	-0.0012	-0.0008	**0.0154**	-0.0040	-0.0050	-0.0023
100 Seed weight (g)	0.0025	0.0229	0.0158	-0.0292	**0.1125**	0.0158	-0.0210
Oil percent	0.1305	-0.6192	-0.6399	0.5757	-0.2476	**-1.7649**	-1.5636
Oil yield / plant (g)	-0.4756	0.4510	0.5364	-0.3386	-0.4202	1.9961	**2.2530**
Seed yield / plant (g)	-0.3223	-0.1602	-0.1082	0.2227	-0.5555**	0.2273	0.6480**
Partial R^2	-0.0098	-0.0187	0.0159	0.0034	-0.0625	-0.4012	1.4600

$R^2 = 0.9871$ Residual effect = 0.1136

Fig 3 Path diagram for yield and yield attributes in MS_2 generation population in sunflower during *summer*, 1998-99.



Where as in *kharif* season, oil yield / plant showed very high direct effect (0.6911) on seed yield / plant followed by oil per cent (0.3942). The significant negative correlation of plant height on seed yield is because of moderate negative direct effect of plant height on seed yield (-0.2563) followed by indirectly through head diameter, stem thickness, days to maturity and 100 seed weight. (Table 67 and Fig. 4)

During *rabi* season, none of the characters showed very high and high direct effects on seed yield / plant. However, the trait oil per cent showed low direct effect on seed yield / plant (0.1628). Highly negative direct effect was exhibited by plant height on seed yield (-0.4412) and that has resulted negative significant correlations between plant height and seed yield / plant. Similarly, significant negative correlations between head diameter and seed yield / plant is because of exhibition of moderate negative direct effect of head diameter on seed yield / plant. The direct effects of other characters on seed yield were negligible. (Table 68 and Fig. 5)

4.7.2 *Bulk sib selection*

Path coefficient analysis of different traits in various generation populations of bulk sib selection are presented in Table Numbers 69 to 73.

Table 67 : Path coefficient analysis of yield and yield attributes in the MS_2 generation population of sunflower during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.2563**	0.0797	-0.1342	-0.1113	-0.1339	-0.1071	-0.0469
Head diameter (cm)	-0.0190	**0.0612**	0.0091	-0.0058	0.0067	-0.0116	0.00253
Stem thickness (cm)	-0.0242	-0.0069	**-0.0461**	-0.0193	-0.0309	-0.0231	-0.0259
Days to maturity	-0.0637	0.0138	-0.0614	**-0.1467**	-0.0580	-0.0329	-0.0198
100 Seed weight (g)	-0.3431	-0.0722	-0.4398	-0.2596	**-0.6569**	-0.4048	-0.4984
Oil percent	0.1647	-0.0749	0.1976	0.0884	0.2429	**0.3942**	0.1807
Oil yield / plant (g)	0.1266	0.2861	0.3886	0.0934	0.5244	0.3167	**0.6911**
Seed yield / plant (g)	-0.4149*	0.2868	-0.0861	-0.3610	-0.1055	0.1314	0.3059
Partial R^2	0.1063	0.0175	0.0040	0.0530	0.0693	0.0518	0.2114

$R^2 = 0.5133$ Residual effect = 0.6976

Fig 4 Path diagram for yield and yield attributes in MS_2 generation population of sunflower during *Kharif*, 1999.

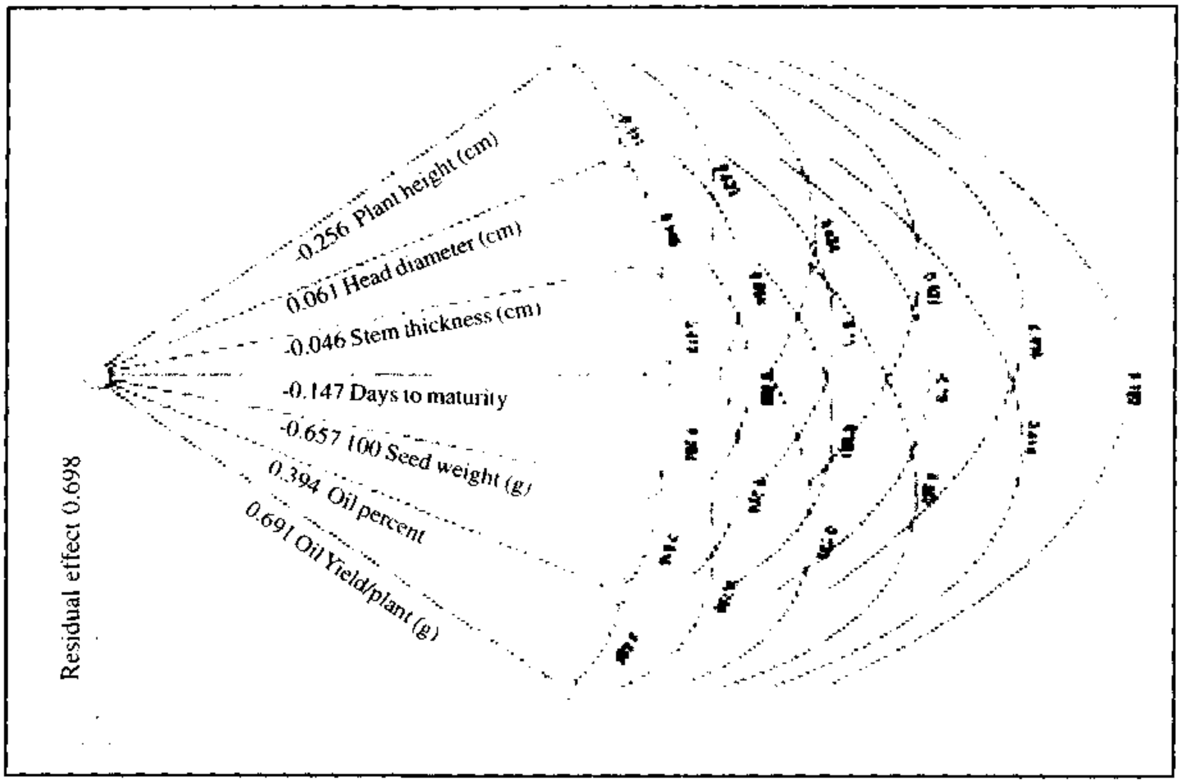
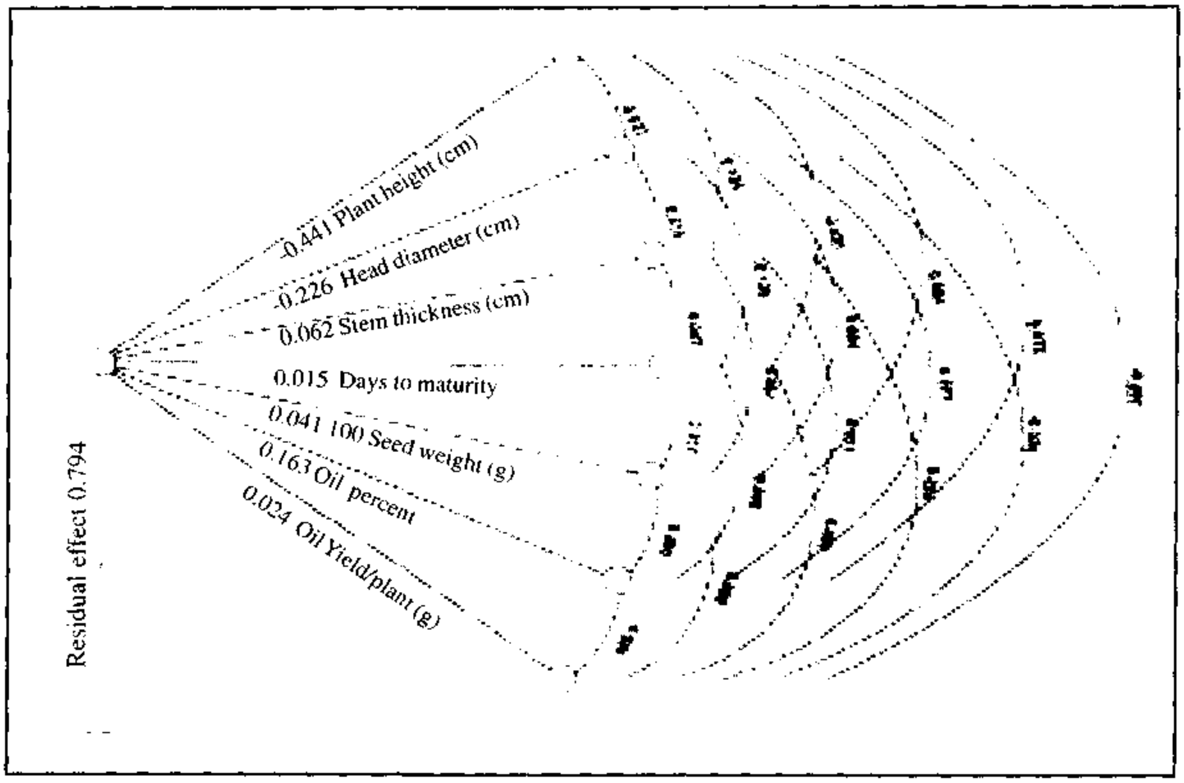


Table 68 : Path coefficient analysis of yield and yield attributes in the MS_2 generation population of sunflower during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.4412**	-0.2324	-0.0597	0.1921	0.0369	-0.0318	0.1245
Head diameter (cm)	-0.1188	**-0.2256**	-0.0494	0.0284	-0.0190	-0.0626	0.0059
Stem thickness (cm)	0.0084	0.0136	**0.0621**	0.0029	0.0222	0.0131	0.0139
Days to maturity	-0.0065	-0.0019	0.0007	**0.0150**	0.0054	-0.0014	0.0008
100 Seed weight (g)	-0.0034	0.0034	0.0146	0.0146	**0.0408**	0.0116	0.0284
Oil percent	0.0117	0.0452	0.0343	-0.0155	0.0464	**0.1628**	0.0951
Oil yield / plant (g)	-0.0067	-0.0006	0.0053	0.0013	0.0165	0.0139	**0.0238**
Seed yield / plant (g)	-0.5566**	-0.3984*	0.0079	0.2387	0.1492	0.1056	0.2924
Partial R^2	0.2456	0.0899	0.0005	0.0036	0.0061	0.0172	0.0070

R^2 = 0.3698 Residual effect = 0.7939

Fig 5 Path diagram for yield and yield attributes in MS_2 generation population of sunflower during *Rabi* 1999.



4.7.2.1 ***BS_0 population :*** In the base population allotted for bulk sib selection, oil yield per plant showed maximum direct effect of 1.0638 on seed yield / plant and that has resulted significant positive correlation between them. Though the direct effects of oil per cent, stem thickness and head diameter on seed yield / plant were low, the significant positive correlations exhibited by these characters is because of high indirect effects of oil yield/ plant through all these characters. (Table 69 and Fig. 6)

4.7.2.2 ***BS_1 population :*** Oil yield / plant showed very high direct effect on seed yield / plant and has resulted positive correlation. The other traits showed negligible, direct effects on seed yield either in positive or negative direction. The significant positive correlation between oil per cent and seed yield / plant resulted because of very high indirect effect of oil yield/ plant through oil per cent. The positive significant correlations of the traits like 100 seed weight, stem thickness and head diameter on seed yield / plant resulted through indirect effect of oil yield / plant through all these characters. (Table 70 and Fig. 7)

4.7.2.3 ***BS_2 population :*** During *summer*, oil yield / plant showed very high direct effect on seed yield / plant (1.8786). However, it has not resulted into significant positive correlations of very high negative indirect of oil per cent through oil yield / plant. The direct effects of other characters were

Table 69 : Path coefficient analysis of yield and yield attributes in the base population of sunflower allotted for bulk sib selection (BS_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0204**	0.0009	0.0000	-0.0004	0.0005	0.0002	-0.0016
Head diameter (cm)	0.0023	**-0.0509**	-0.0494	0.0022	-0.0118	-0.0095	-0.0307
Stem thickness (cm)	-0.0001	0.1042	**0.1074**	-0.0024	0.0258	0.0191	0.0677
Days to maturity	0.0005	-0.0010	-0.0005	**0.0240**	-0.0019	0.0005	0.0008
100 Seed weight (g)	-0.0002	0.0015	0.0016	-0.0005	**0.0066**	-0.0004	0.0000
Oil percent	0.0042	-0.0658	-0.0626	-0.0073	0.0225	**-0.3517**	-0.1783
Oil yield / plant (g)	0.0829	0.6414	0.6710	0.0333	-0.0066	0.5393	**1.0638**
Seed yield / plant (g)	0.0692	0.6302**	0.6675**	0.0489	0.0351	0.1975*	0.9216**
Partial R^2	-0.0014	-0.03212	0.0717	0.0012	0.0002	-0.0695	0.9804

$R^2 = 0.9505$ Residual effect = 0.2224

Fig 6 Path diagram for yield and yield attributes in the base population of sunflower alloted bulk sib selection (BS_0).

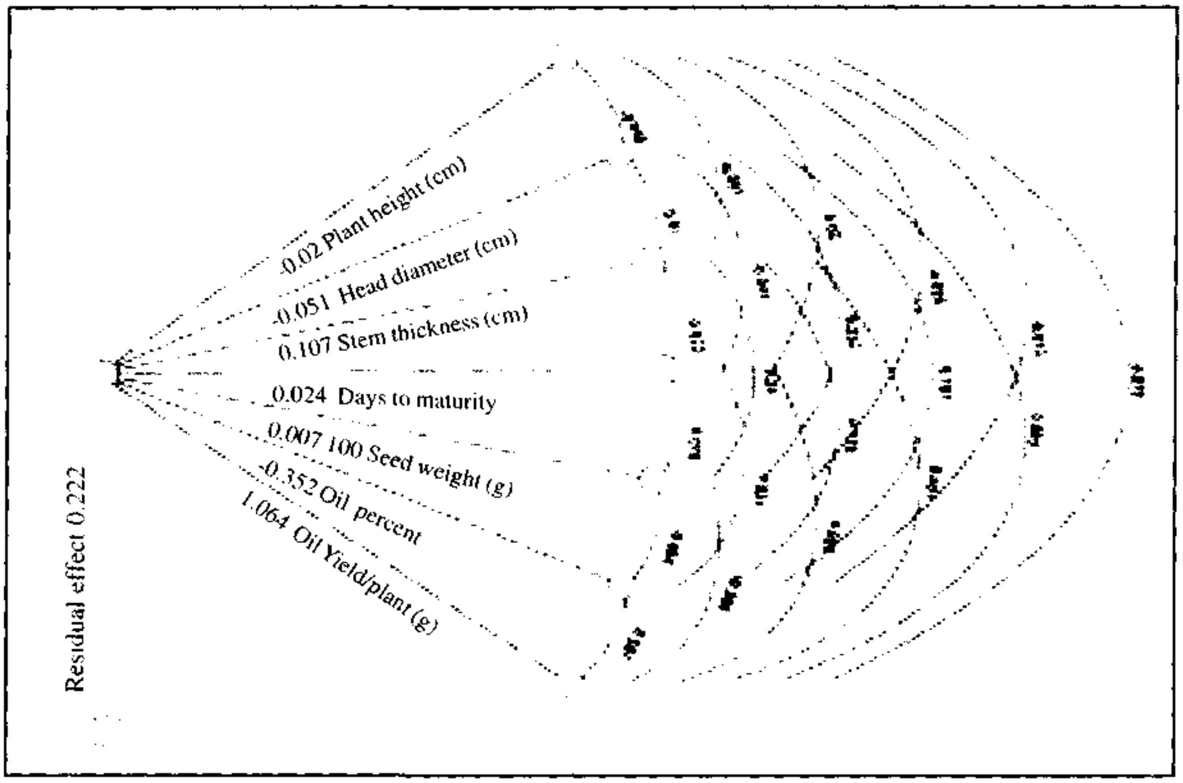
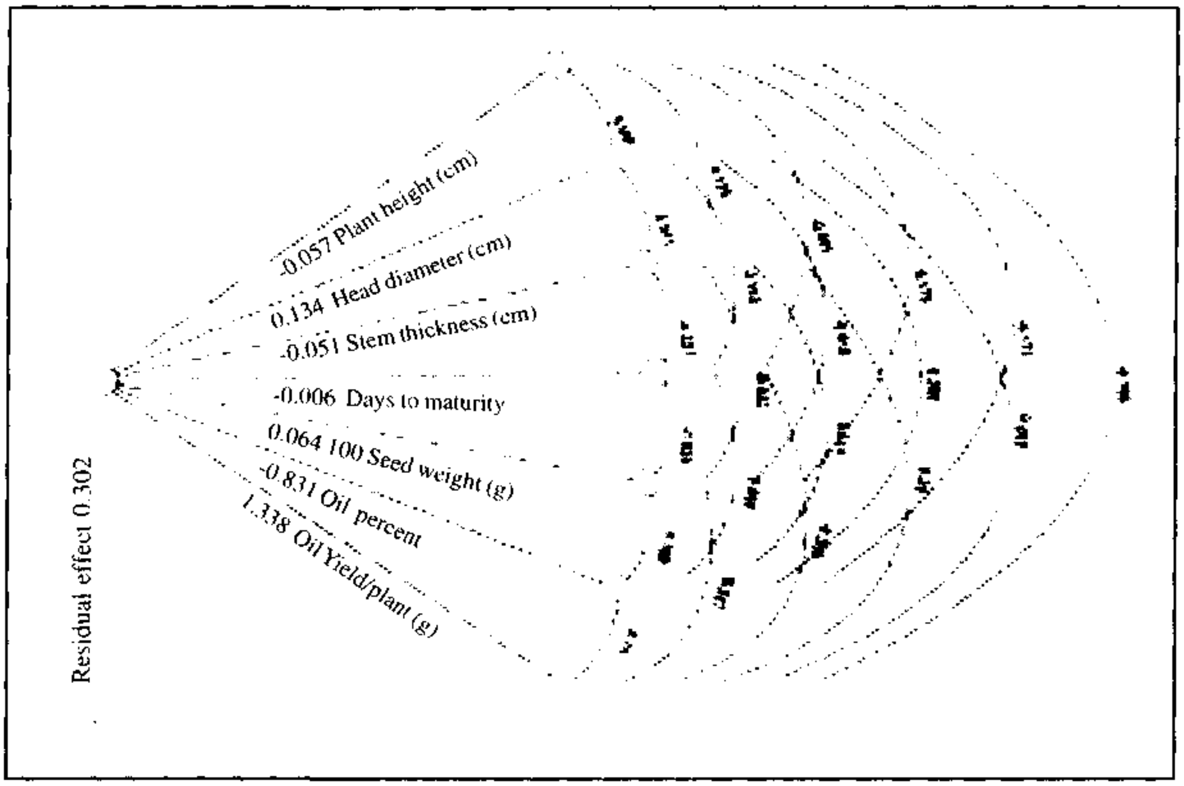


Table 70 : Path coefficient analysis of yield and yield attributes in BS_1 generation population of sunflower

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0570**	-0.0052	-0.0071	0.0035	-0.0102	0.0099	0.0095
Head diameter (cm)	0.0122	**0.1336**	0.1217	-0.0258	-0.0022	0.0090	0.0351
Stem thickness (cm)	-0.0063	-0.0462	**-0.0507**	0.0115	0.0016	-0.0038	-0.0127
Days to maturity	0.0003	0.0011	0.0013	**-0.0055**	0.0002	-0.0003	0.0003
100 Seed weight (g)	0.0114	-0.0011	-0.0021	-0.0018	**0.0639**	0.0108	0.0145
Oil percent	0.1440	-0.0561	-0.0615	-0.0428	-0.1405	**-0.8315**	-0.6239
Oil yield / plant (g)	-0.2222	0.3517	0.3340	-0.0781	0.3033	1.0044	**1.3385**
Seed yield / plant (g)	-0.1177	0.3777**	0.3356**	-0.1390	0.2161*	0.1985*	0.7613**
Partial R^2	0.0067	0.0505	-0.0170	0.0008	0.0138	-0.1651	1.0189

$R^2 = 0.9086$ Residual effect = 0.3024

Fig 7 Path diagram for yield and yield attributes in BS_1 generation population of Sunflower



negligible. The significant positive correlation of days to maturity with seed yield / plant is because of indirect effects of oil per cent and oil yield / plant through days to maturity. (Table 71 and Fig. 8)

During *kharif* season, oil per cent showed high direct effect on seed yield / plant (0.6429) followed by oil yield / plant (0.1450). The stem thickness also showed high direct effect on seed yield but in negative direction (-0.4082). The significant correlation between oil yield / plant with seed yield / plant is because of maximum indirect contribution of oil per cent through oil yield / plant. (Table 72 and Fig. 9)

In *rabi* season, oil yield / plant and stem thickness exhibited high direct effects on seed yield / plant followed by moderate direct effects by plant height and head diameter. The other characters showed negligible direct effects on seed yield / plant. (Table 73 and Fig. 10)

4.7.3 *Half sib selection*

Path coefficient analysis of different traits in various generation populations of half sib selection are presented in Table Numbers 74 to 78.

4.7.3.1 ***HS_0 population :*** In the base population allotted for half sib selection, oil yield / plant showed very high direct effect on seed yield / plant

Table 71 : Path coefficient analysis of yield and yield attributes in BS_2 generation population of sunflower during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0584**	-0.0179	-0.0110	-0.0128	-0.0104	-0.0012	0.0001
Head diameter (cm)	-0.0021	**-0.0070**	-0.0061	-0.0024	0.0013	0.0011	0.0012
Stem thickness (cm)	0.0244	0.1137	**0.1293**	0.0319	-0.0359	-0.0256	-0.0334
Days to maturity	-0.0019	-0.0029	-0.0021	**-0.0084**	0.0002	0.0008	-0.0011
100 Seed weight (g)	0.0049	-0.0052	-0.0076	-0.0007	**0.0275**	0.0035	0.0054
Oil percent	-0.0405	0.3269	0.3939	0.1971	-0.2547	**-1.9880**	-1.7323
Oil yield / plant (g)	-0.0016	-0.3146	-0.4859	0.2561	0.3701	1.6369	**1.8786**
Seed yield / plant (g)	-0.0752	0.0931	0.0104	0.4608*	0.0981	-0.3724	0.1184
Partial R^2	0.0044	-0.0006	0.0013	-0.0039	0.0027	0.7403	0.2224

R^2 = 0.9666 Residual effect = 0.1829

Fig 8 Path diagram for yield and yield attributes BS_2 generation population of Sunflower during *summer*, 1998-99.

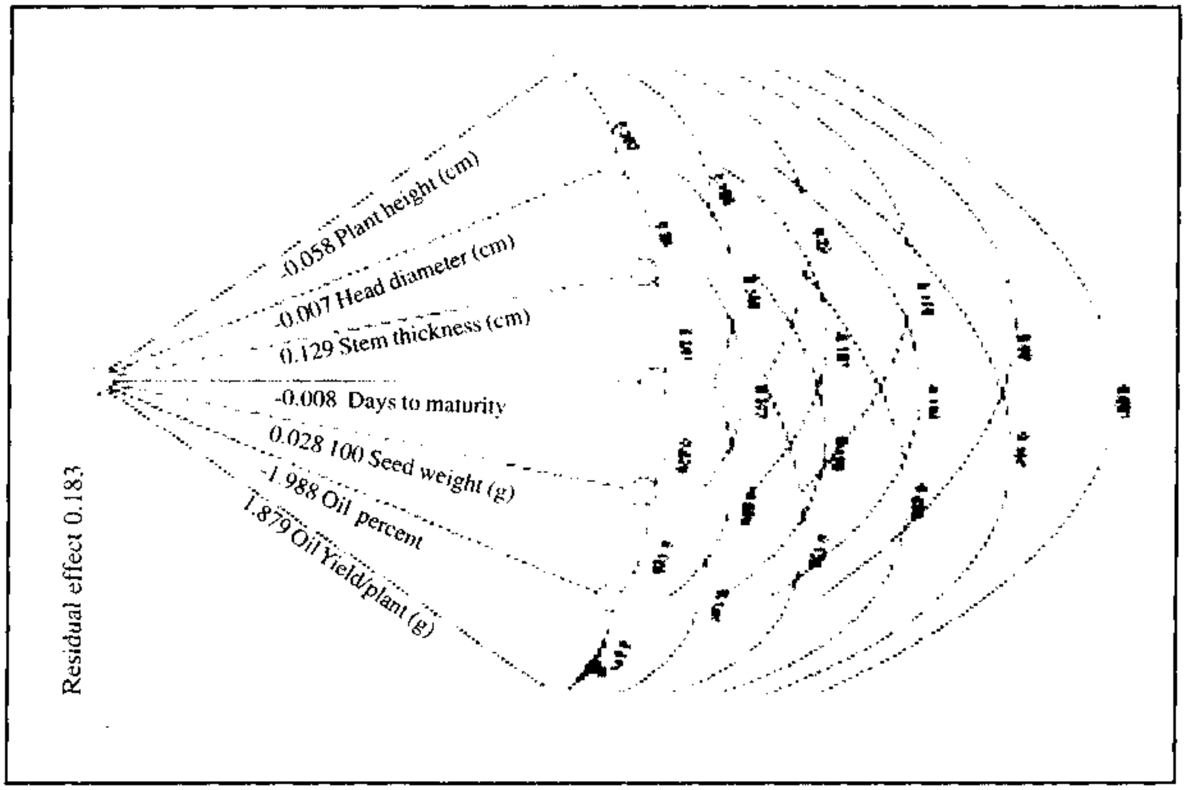


Table 72 : Path coefficient analysis of yield and yield attributes in BS_2 generation population of sunflower during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0175**	-0.0059	-0.0051	-0.0061	-0.0069	-0.0051	-0.0064
Head diameter (cm)	0.0126	**0.0372**	0.0125	-0.0004	0.0103	0.0034	0.0041
Stem thickness (cm)	-0.1191	-0.1372	**-0.4082**	0.1588	-0.0660	-0.1528	-0.2619
Days to maturity	0.0132	-0.0004	-0.0147	**0.0378**	0.0008	-0.0089	-0.0099
100 Seed weight (g)	0.0276	0.0194	0.0113	0.0015	**0.0699**	0.0115	0.0111
Oil percent	0.1875	0.0589	0.2406	-0.1507	0.1054	**0.6429**	0.5304
Oil yield / plant (g)	0.0527	0.0159	0.0930	-0.0379	0.0230	0.1196	**0.1450**
Seed yield / plant (g)	0.1570	-0.0122	-0.0705	0.0031	0.1365	0.6106**	0.4124*
Partial R^2	-0.0028	-0.0005	0.0288	0.0001	0.0095	0.3926	0.0598

R^2 = 0.4876 Residual effect = 0.7158

Fig 9 Path diagram for yield and yield attributes BS_2 generation population of Sunflower during *Kharif*, 1999.

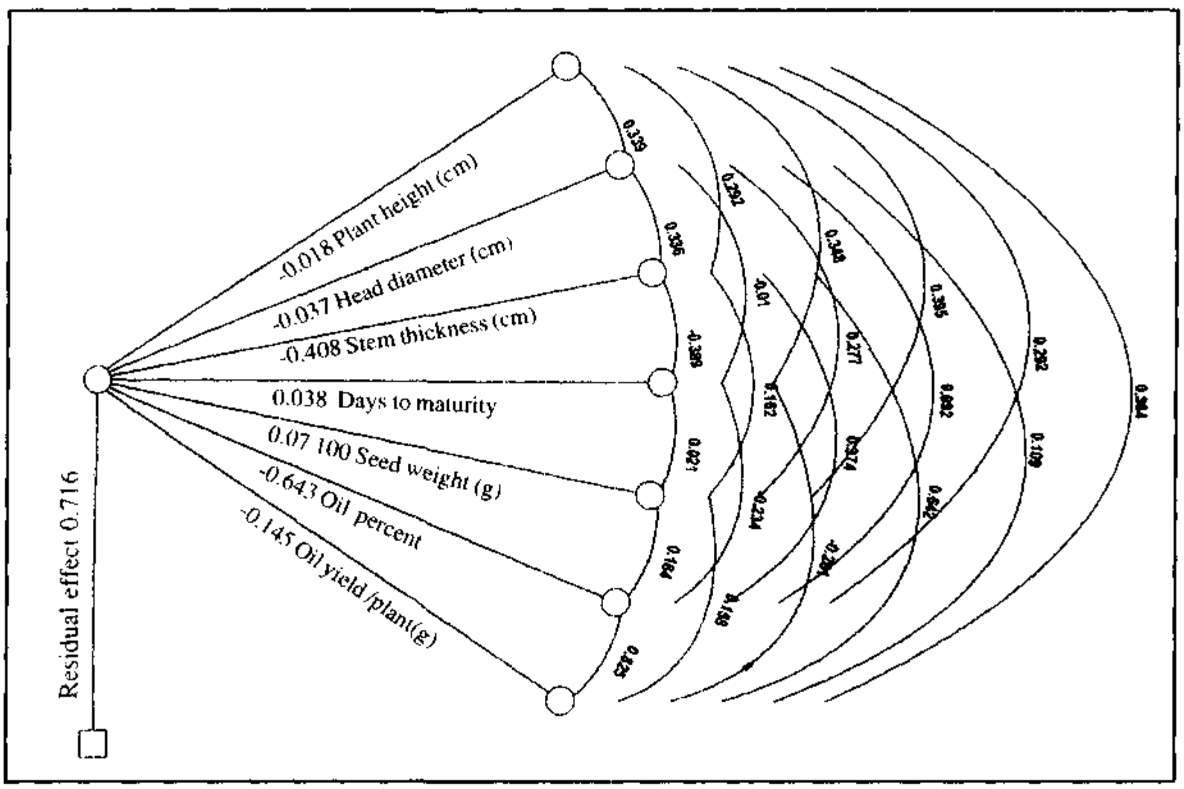
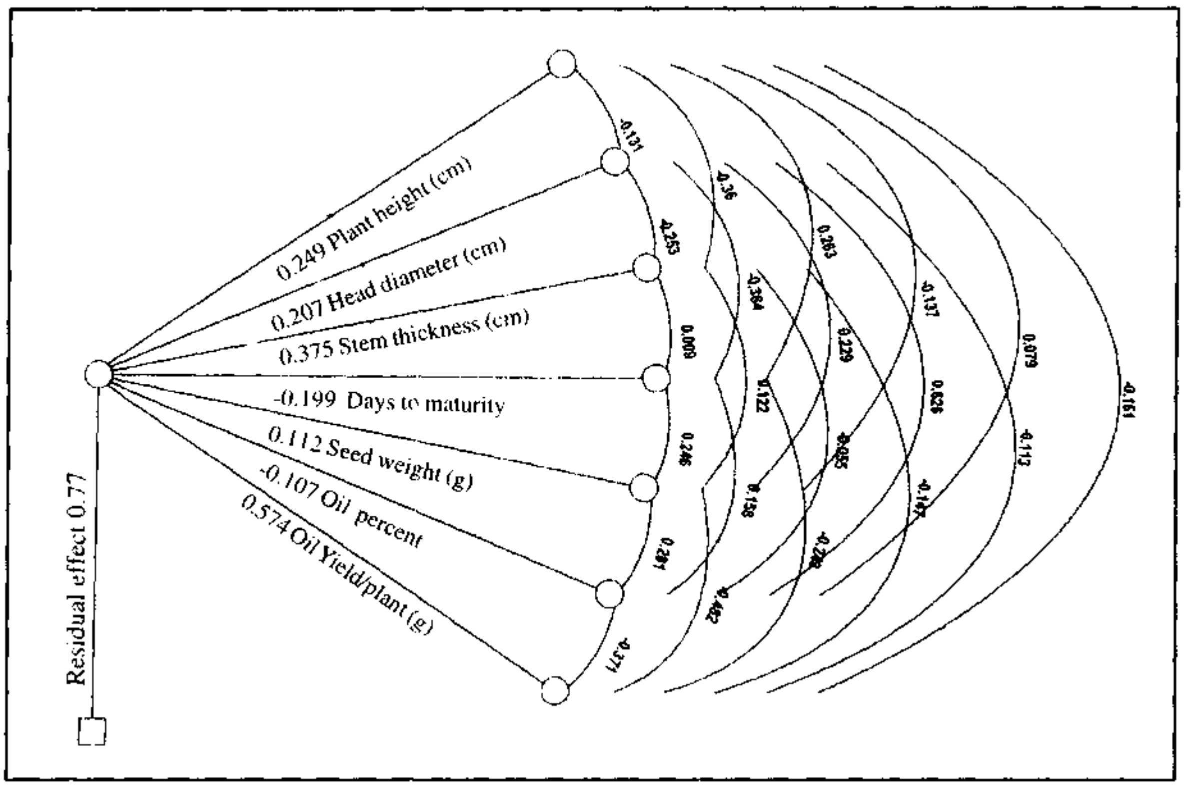


Table 73 : Path coefficient analysis of yield and yield attributes in BS_2 generation population of sunflower during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.2491**	-0.0327	-0.0897	0.0654	-0.0342	0.0198	-0.0376
Head diameter (cm)	-0.0271	**0.2066**	-0.0523	-0.0792	0.0473	0.0188	-0.0233
Stem thickness (cm)	-0.1351	-0.0950	**0.3752**	0.0033	0.0456	-0.0207	-0.0552
Days to maturity	-0.0523	0.0763	-0.0018	**-0.1991**	-0.0489	-0.0314	0.0484
100 Seed weight (g)	-0.0154	0.0257	0.0137	0.0276	**0.1124**	0.0316	-0.0542
Oil percent	-0.0085	-0.0563	0.0059	-0.0168	-0.0301	**-0.1069**	0.0396
Oil yield / plant (g)	-0.0866	-0.0648	-0.0845	-0.1397	-0.2769	-0.2131	**0.5743**
Seed yield / plant (g)	-0.0760	0.0599	0.1665	-0.3384	-0.1848	-0.2119	0.4921*
Partial R^2	-0.0189	0.0124	0.0625	0.0674	-0.0208	0.0226	0.2826

R^2 = 0.4078 Residual effect = 0.7695

Fig 10 Path diagram for yield and yield attributes BS_2 generation population of Sunflower during *Rabi*, 1999



and resulted in significant positive association. The oil per cent also traits high direct effect on seed yield / plant but negative in direction. The direct effects of the other traits were negligible. However, positive significant association of head diameter and stem thickness with seed yield resulted because of high indirect effects of oil yield / plant through head diameter and stem thickness (Table 74 and Fig. 11).

4.7.3.2 ***HS_1* population :** Oil yield / plant showed very high direct effect on seed yield / plant (1.1339) and that has resulted significant positive correlation. Oil per cent showed high negative direct effect on seed yield / plant (-0.5265) and its effect was nullified by positive indirect effect of oil yield / plant. The other characters showed negligible direct effects on seed yield / plant. The positive significant association of stem thickness and head diameter with seed yield / plant resulted due to high indirect effects of oil yield / plant. (Table 75 and Fig. 12)

4.7.3.3 ***HS_2* population :** During *summer* season, oil yield / plant showed very high direct effect on seed yield / plant (1.1952) and ultimately resulted in positive significant association. The attribute oil per cent showed high negative direct effect on seed yield / plant (-0.6584) and its effect is nullified by indirect effect of oil yield / plant. The rest of the characters direct effects showed little influence on seed yield / plant. (Table 76 and Fig. 13)

Table 74 : Path coefficient analysis for yield and yield attributes in the base population allotted for half sib selection (HS_0) in sunflower

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0096**	-0.0007	-0.0010	0.0001	0.0010	-0.0006	-0.0008
Head diameter (cm)	-0.0019	**-0.0244**	-0.0229	-0.0014	-0.0053	-0.0023	-0.0104
Stem thickness (cm)	0.0020	0.0183	**0.0195**	0.0012	0.0037	0.0004	0.0071
Days to maturity	0.0001	-0.0005	-0.0005	**-0.0081**	-0.0007	0.0008	0.0002
100 Seed weight (g)	0.0002	-0.0005	-0.0004	-0.0002	**-0.0021**	0.0001	-0.0001
Oil percent	-0.0300	-0.0414	-0.0089	0.0431	0.0172	**-0.4450**	-0.2092
Oil yield / plant (g)	0.0990	0.4764	0.4055	-0.0309	0.0591	0.5254	**1.1178**
Seed yield / plant (g)	0.0598	0.4272**	0.3911**	0.0039	0.0728	0.0787	0.9045**
Partial R^2	-0.0006	-0.0104	0.0076	0.0000	-0.0002	-0.0350	1.0111

$R^2 = 0.9725$ Residual effect = 0.1659

Fig 11 Path diagram for yield and yield attributes in the base population allotted for half sib selection (HS_0) in Sunflower.

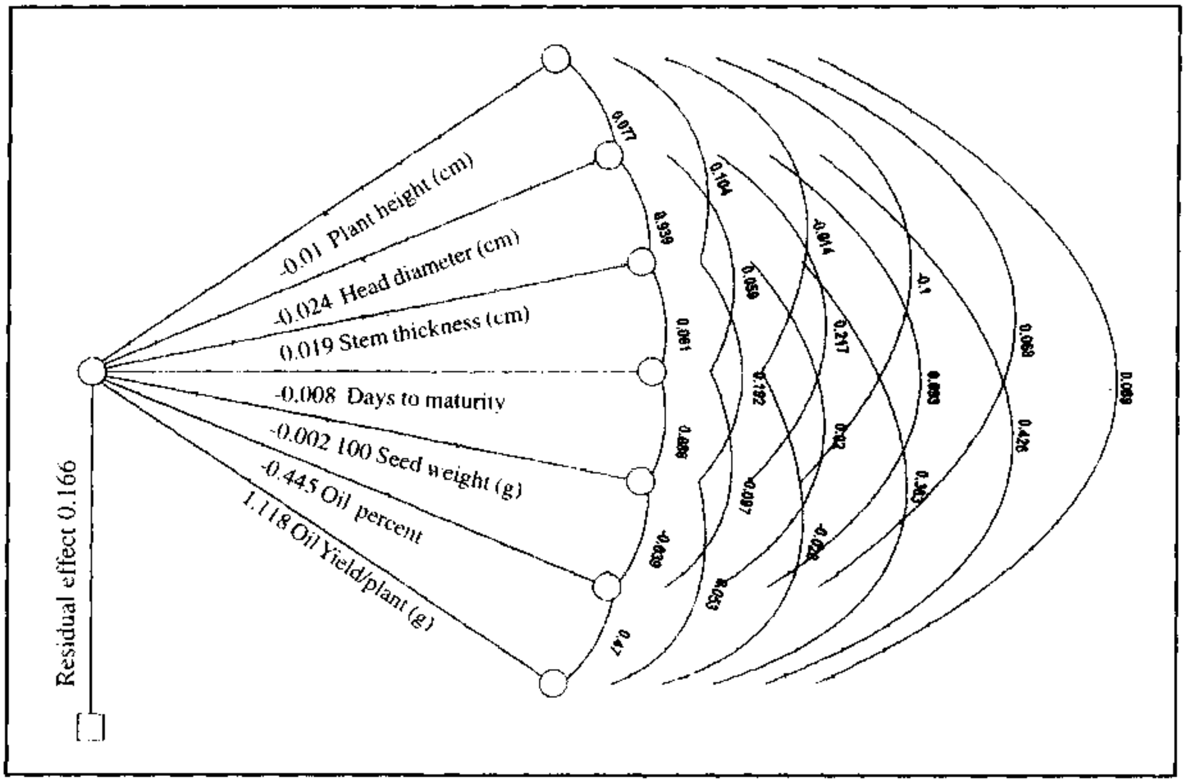


Table 75 : **Path coefficient analysis for yield and yield attributes in the HS_1 generation population of sunflower**

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.0321**	0.0057	0.0023	-0.0113	0.0032	-0.0014	0.0019
Head diameter (cm)	0.0038	**0.0214**	0.0160	-0.0039	0.0016	0.0019	0.0090
Stem thickness (cm)	-0.0017	-0.0175	**-0.0235**	0.0021	-0.0021	-0.0025	-0.0089
Days to maturity	-0.0028	-0.0015	-0.0007	**0.0080**	-0.0001	-0.0005	-0.0010
100 Seed weight (g)	-0.0027	-0.0020	-0.0024	0.0002	**-0.0275**	-0.0056	-0.0023
Oil percent	0.0229	-0.0460	-0.0565	0.0332	-0.1077	**-0.5265**	-0.2611
Oil yield / plant (g)	0.0681	0.4765	0.4303	-0.1470	0.0937	0.5623	**1.1339**
Seed yield / plant (g)	0.1197	0.4366**	0.3655**	-0.1187	-0.0390	0.0276	0.8715**
Partial R^2	0.0038	0.0093	-0.0086	-0.0009	0.0011	-0.0145	0.9881

$R^2 = 0.9783$ Residual effect = 0.1472

Fig 12 Path diagram for yield and yield attributes in the (HS_1) generation population of Sunflower.

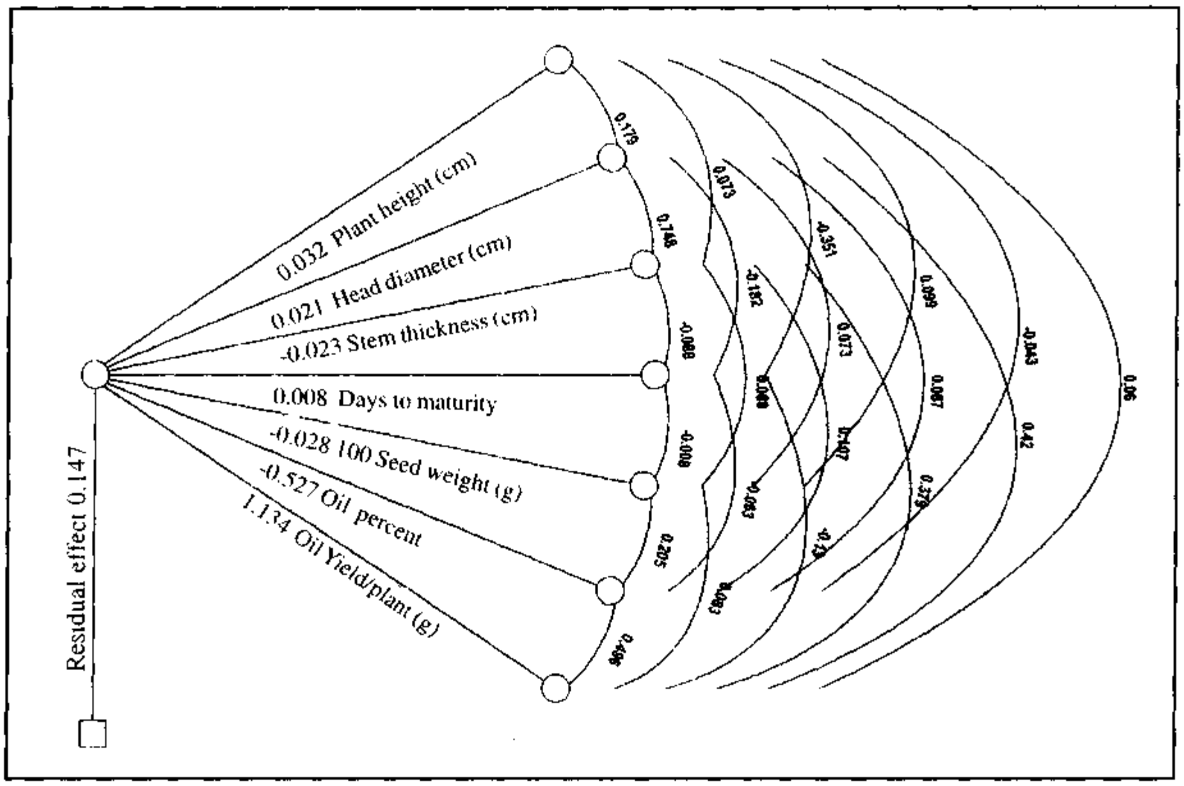
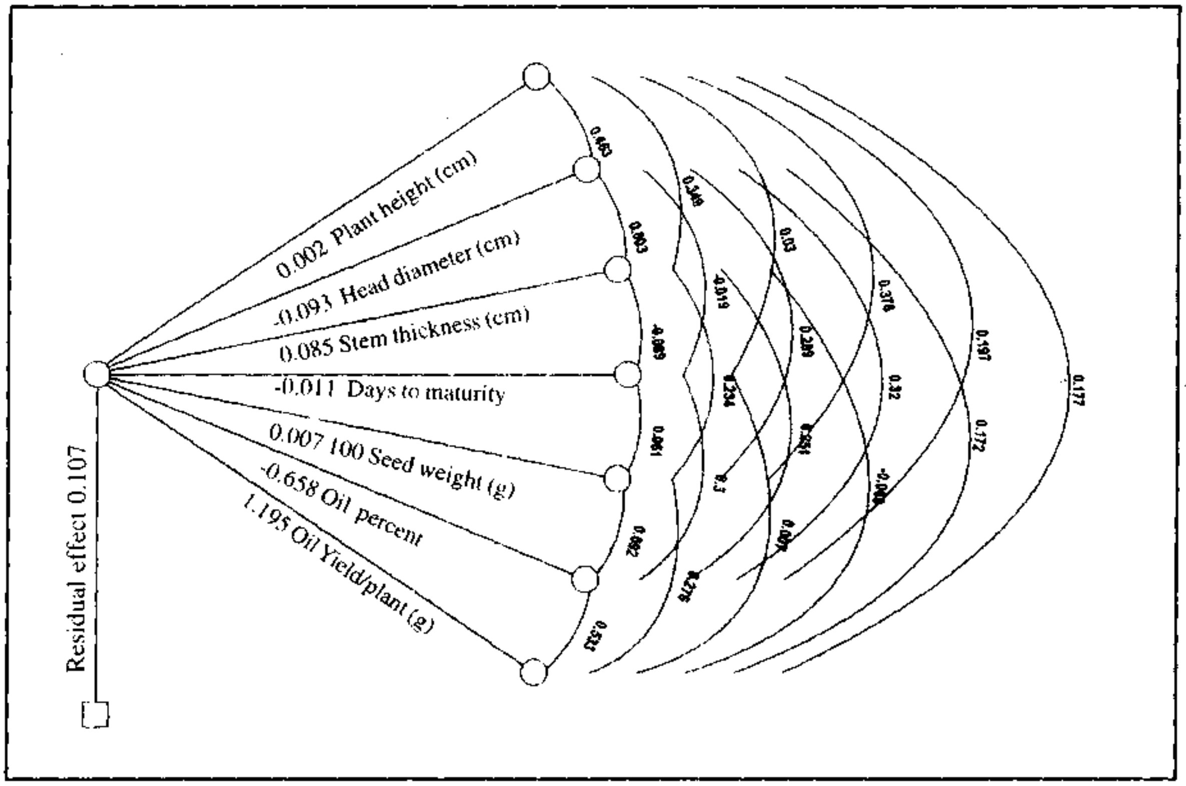


Table 76 : Path coefficient analysis for yield and yield attributes in the HS_2 generation population of sunflower during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.0015**	0.0007	0.0005	0.0000	0.0006	0.0003	0.0003
Head diameter (cm)	-0.0431	**-0.0930**	-0.0747	0.0018	-0.0269	-0.0298	-0.0160
Stem thickness (cm)	0.0297	0.0684	**0.0851**	-0.0076	0.0199	0.0213	-0.0059
Days to maturity	-0.0003	0.0002	0.0010	**-0.0115**	-0.0007	-0.0034	-0.0001
100 Seed weight (g)	0.0027	0.0021	0.0017	0.0004	**0.0072**	0.0050	0.0020
Oil percent	-0.1299	-0.2107	-0.1650	-0.1977	-0.4558	**-0.6584**	-0.3508
Oil yield / plant (g)	0.2117	0.2058	-0.0827	0.0079	0.3304	0.6368	**1.1952**
Seed yield / plant (g)	0.0723	-0.0265	-0.2341	-0.2065	-0.1253	-0.0282	0.8247**
Partial R^2	0.0001	0.0025	-0.0199	0.0024	-0.0009	0.0186	0.9858

$R^2 = 0.9885$ Residual effect = 0.1074

Fig 13 Path diagram for yield and yield attributes in the HS_2 generation population of Sunflower during *summer* 1998-99.



In *kharif*, oil yield / plant and stem thickness exhibited high direct effects on seed yield / plant and has not resulted in significant positive association because of many of indirect effects were negative in direction. The traits days to maturity and oil per cent exhibited negative indirect effects. (Table 77 and Fig. 14)

In *rabi* season, oil yield / plant exhibited high direct effect on seed yield / plant and resulted in significant positive correlation. Plant height and stem thickness showed high negative direct effects (-0.3207) and (-0.4144) respectively on seed yield / plant. The other characters direct effects had little influence on seed yield / plant. (Table 78 and Fig. 15)

4.7.4 *Full sib selection*

The direct and indirect effects of various traits on seed yield / plant in various traits on seed yield / plant in various generation populations of full sib selection are presented in Table Numbers 79 to 83.

4.7.4.1 ***FS_0 population*** : In the base population for full sib selection, oil yield / plant showed high direct effect on seed yield / plant and ultimately resulted in significant positive correlation. Significant positive correlation between stem thickness and seed yield / plant resulted due to direct effect of 0.2508 and indirect effect of 0.1913 of oil yield / plant through stem

Table 77 : **Path coefficient analysis of yield and yield attributes in the HS_2 generation population of sunflower during *kharif*, 1999**

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0617**	-0.0273	-0.0029	-0.0001	0.0155	-0.0074	0.0074
Head diameter (cm)	0.0325	**0.0735**	0.0112	-0.0100	-0.0165	0.0002	-0.0213
Stem thickness (cm)	0.0271	0.0866	**0.5691**	-0.0014	0.1019	-0.0078	-0.1975
Days to maturity	-0.0007	0.0406	0.0007	**-0.3000**	-0.0012	-0.0047	-0.0401
100 Seed weight (g)	0.0435	0.0389	-0.0311	-0.007	**-0.1736**	0.0191	0.0158
Oil percent	-0.0480	-0.0010	0.0054	-0.0063	0.00493	**-0.3995**	-0.2635
Oil yield / plant (g)	-0.0859	-0.2069	-0.2476	0.0953	-0.0648	0.4706	**0.7136**
Seed yield / plant (g)	-0.0933	0.0045	0.3048	-0.2231	-0.0949	0.0704	0.2145
Partial R^2	0.0058	0.0003	0.1735	0.0669	0.0165	-0.0281	0.1531

R^2 = 0.3879 Residual effect = 0.7824

Fig 14 Path diagram for yield and yield attributes in HS_2 generation population of Sunflower during *Kharif*, 1999.

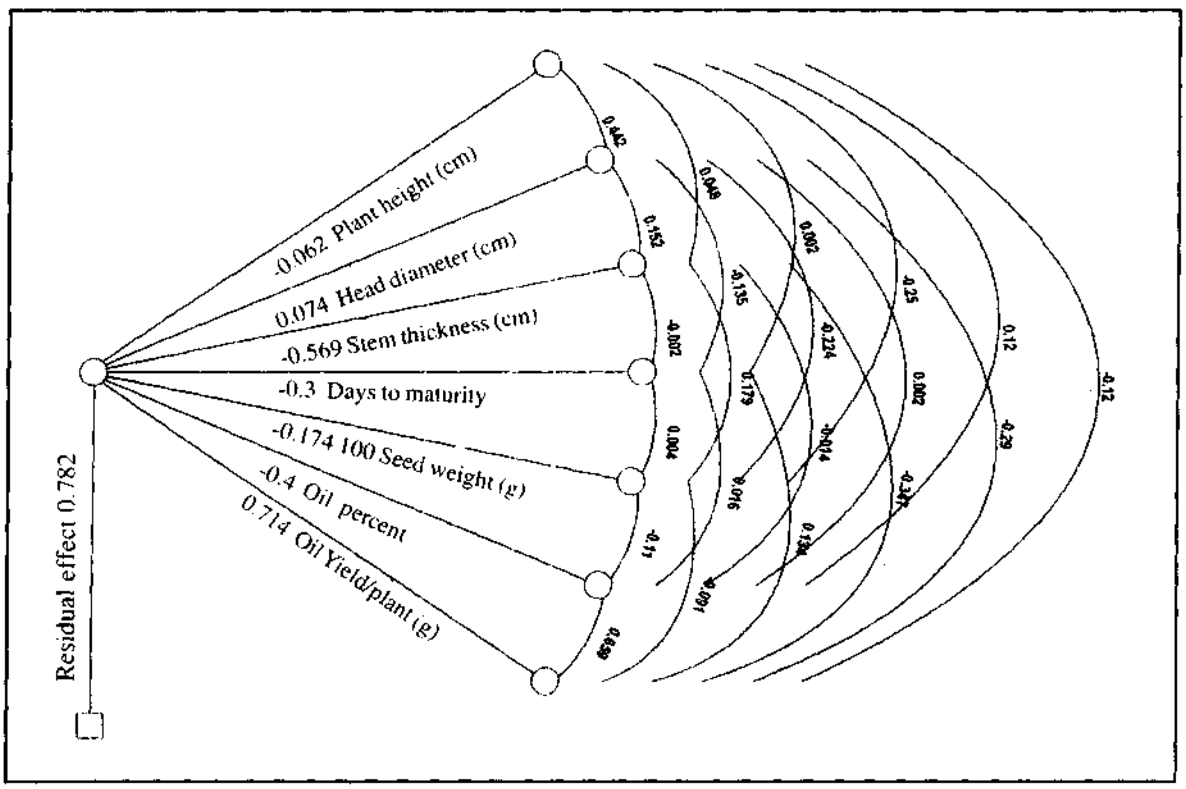
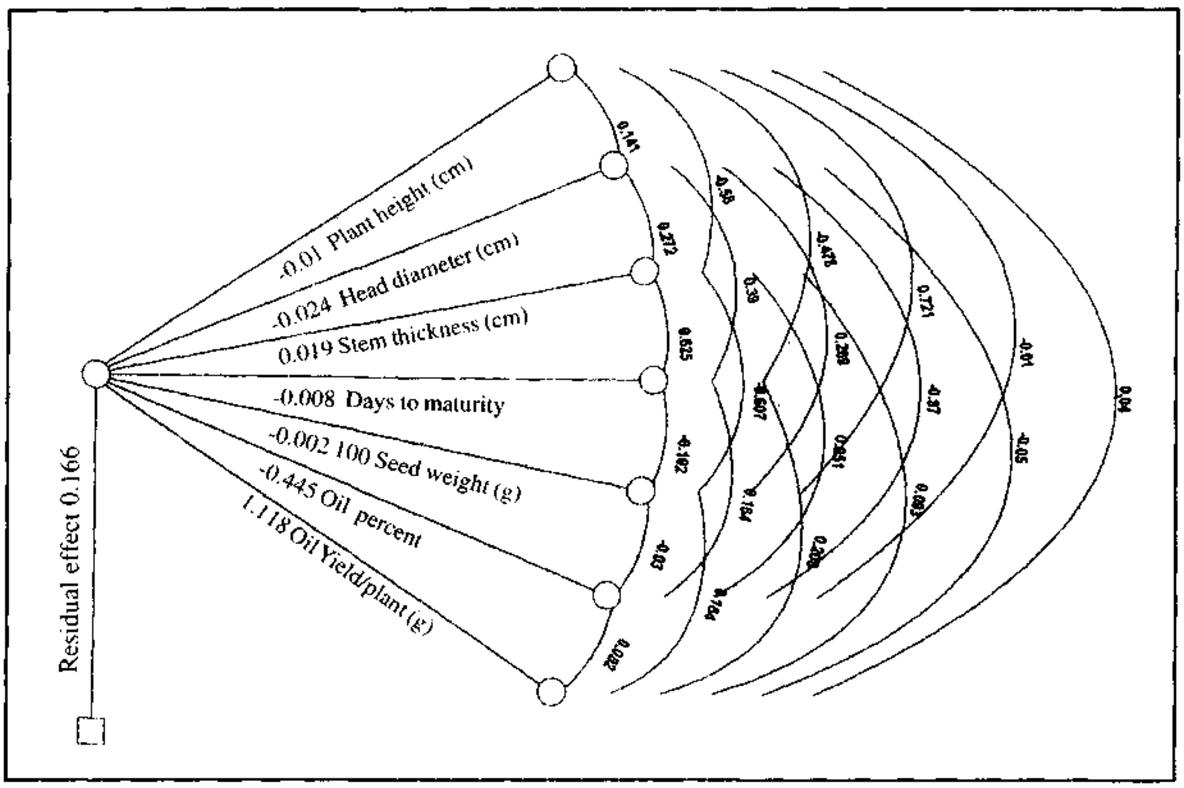


Table 78 : Path coefficient analysis for yield and yield attributes in the HS_2 generation population of sunflower during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.3207**	-0.0453	0.1859	0.1534	-0.2312	0.0032	-0.0128
Head diameter (cm)	0.0381	**0.2694**	0.0773	0.1052	0.0723	-0.0997	-0.0134
Stem thickness (cm)	0.2401	-0.1128	**-0.4144**	-0.2589	0.2100	-0.0210	-0.0385
Days to maturity	0.0576	-0.0470	-0.0753	**-0.1205**	0.0122	-0.0198	-0.0251
100 Seed weight (g)	-0.1091	-0.0406	0.0767	0.0154	**-0.1513**	0.0046	-0.0249
Oil percent	0.0020	0.0729	-0.0100	-0.0323	0.0060	**-0.1968**	-0.0161
Oil yield / plant (g)	0.0285	-0.0356	0.0665	0.1488	0.1177	0.0584	**0.7157**
Seed yield / plant (g)	-0.0634	0.0609	-0.0973	0.0110	0.0358	-0.2710	0.5850**
Partial R^2	0.0203	0.0164	0.0403	-0.0013	-0.0054	0.0533	0.4187

$R^2 = 0.5423$ Residual effect = 0.6765

Fig 15 Path diagram for yield and yield attributes HS_2 generation population of Sunflower during *Rabi,* 1999.



thickness. Though the direct effect of head diameter is negative (-0.1841) on seed yield / plant, but the positive significant association resulted as a result of maximum indirect effects of stem thickness (0.2370) and oil yield / plant through head diameter. (Table 79 and Fig. 16)

4.7.4.2 ***FS_1* population :** In the FS_1 population, oil yield / plant showed high direct effect on seed yield / plant (0.9872) and resulted in significant positive association. The other traits showed negligible direct effects. However, positive significant correlation was found between plant height and seed yield and 100 seed weight with seed yield / plant. This is due to maximum indirect contribution of oil yield through plant height and 100 seed weight. (Table 80 and Fig. 17)

4.7.4.3 ***FS_2* population :** During *summer* season, oil per cent (0.5424) and head diameter (0.4451) showed high direct effects on seed yield / plant. However, they have not influenced significant positive association mainly because of many of negative indirect effects of other characters. Oil yield / plant (-0.7676) and days to maturity (-0.4826) showed high negative direct effects on seed yield / plant. (Table 81 and Fig. 18)

During *kharif*, 100 seed weight showed high direct effect (0.9453) on seed yield / plant followed by medium direct effects by oil per cent, plant

Table 79 : Path coefficient analysis for yield and yield attributes in the base population allotted for full sib selection (FS_0) in sunflower

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.0375**	0.0054	0.0051	-0.0021	-0.0011	0.0068	-0.0018
Head diameter (cm)	-0.0264	**-0.1841**	-0.1740	-0.0275	0.0111	-0.0184	-0.0373
Stem thickness (cm)	0.0341	0.2370	**0.2508**	0.0357	-0.0211	0.0324	0.0522
Days to maturity	-0.0002	0.0006	0.0006	**0.0040**	0.0000	0.0001	0.0002
100 Seed weight (g)	-0.0011	-0.0022	-0.0030	-0.0002	**0.0359**	-0.0051	-0.0025
Oil percent	-0.0472	-0.0260	-0.0335	-0.0082	0.0372	**-0.2596**	-0.0667
Oil yield / plant (g)	-0.0439	0.1864	0.1913	0.0355	-0.0648	0.2361	**0.9191**
Seed yield / plant (g)	-0.0471	02.171*	0.2373**	0.0373	-0.0029	-0.0077	0.8631**
Partial R^2	-0.0018	-0.0400	0.0595	0.0001	-0.0001	0.0020	0.7933

R^2 = 0.8131 Residual effect = 0.4323

Fig 16 Path diagram for yield and yield attributes in the base population allotted for full sib selection (FS_0) in Sunflower.

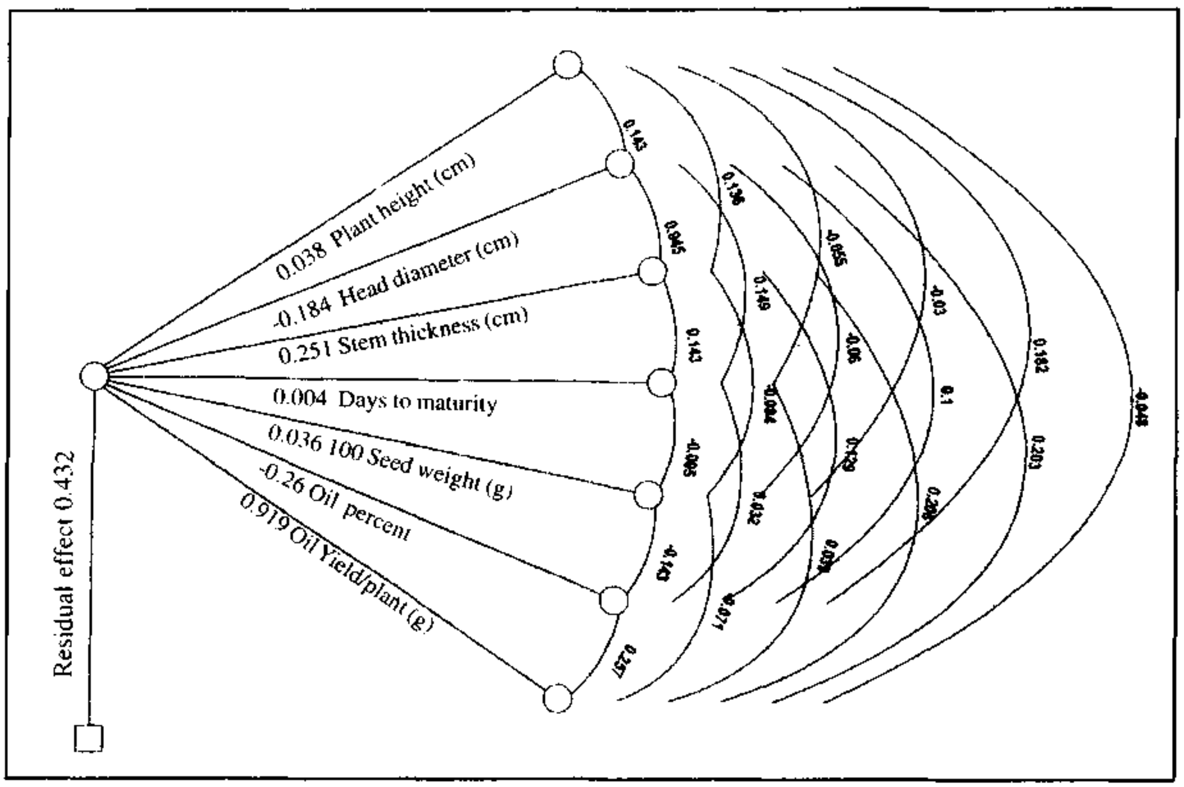


Table 80 : Path coefficient analysis of yield and yield attributes in FS_1 generation population of sunflower

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0020**	-0.0007	-0.0007	-0.0001	-0.0005	0.0001	-0.0004
Head diameter (cm)	-0.0158	**-0.0471**	-0.0442	-0.0030	-0.0043	0.0002	-0.0056
Stem thickness (cm)	0.0043	0.0124	**0.0132**	0.0010	0.0013	0.0004	0.0020
Days to maturity	0.0007	0.0012	0.0014	**0.0182**	-0.0018	-0.0007	-0.0019
100 Seed weight (g)	-0.0086	-0.0033	-0.0035	0.0036	**-0.0365**	-0.0035	-0.0232
Oil percent	0.0064	0.0004	-0.0038	0.0045	-0.0120	**-0.1240**	-0.0300
Oil yield / plant (g)	0.2031	0.1163	0.1491	-0.1010	0.6270	0.2391	**0.9872**
Seed yield / plant (g)	0.1880*	0.0792	0.1115	-0.0768	0.5733**	0.1116	0.9281**
Partial R^2	-0.0004	0.0037	0.0015	-0.0014	-0.0209	-0.0138	0.9162

$R^2 = 0.8774$ Residual effect = 0.3501

Fig 17 Path diagram for yield and yield attributes in FS_1 generation population of Sunflower.

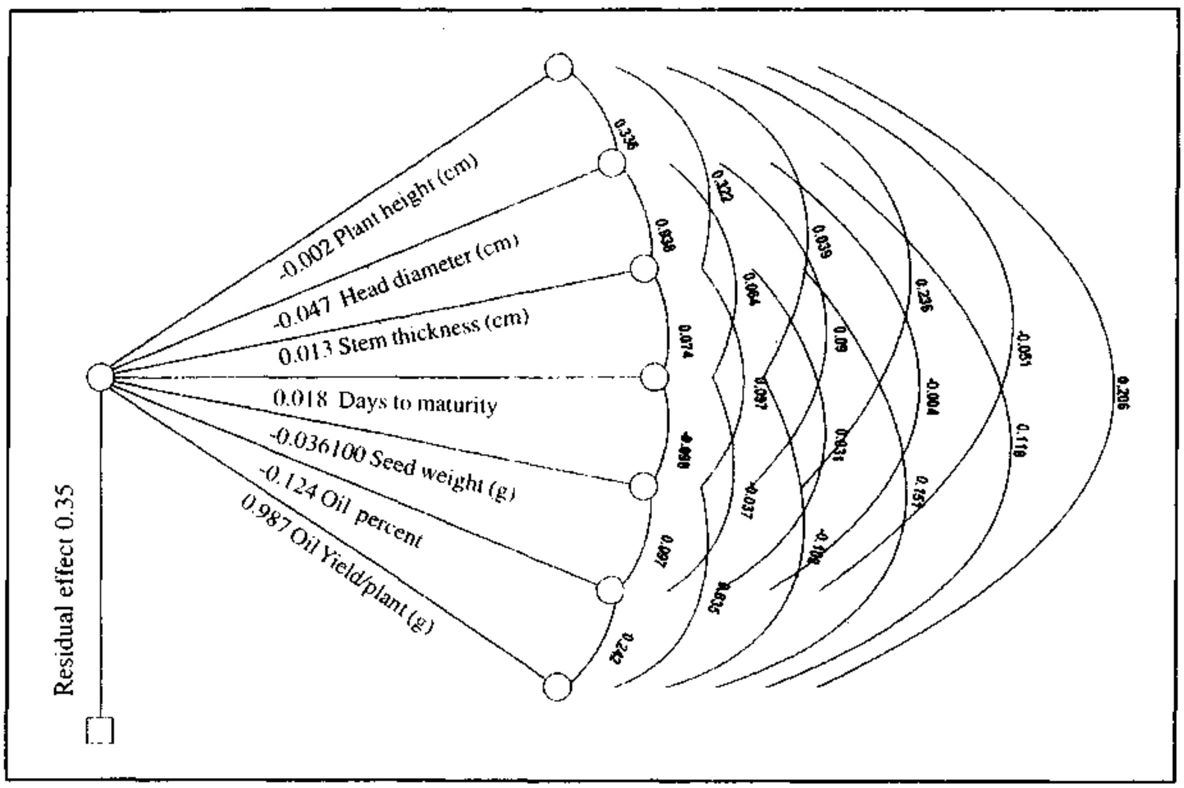
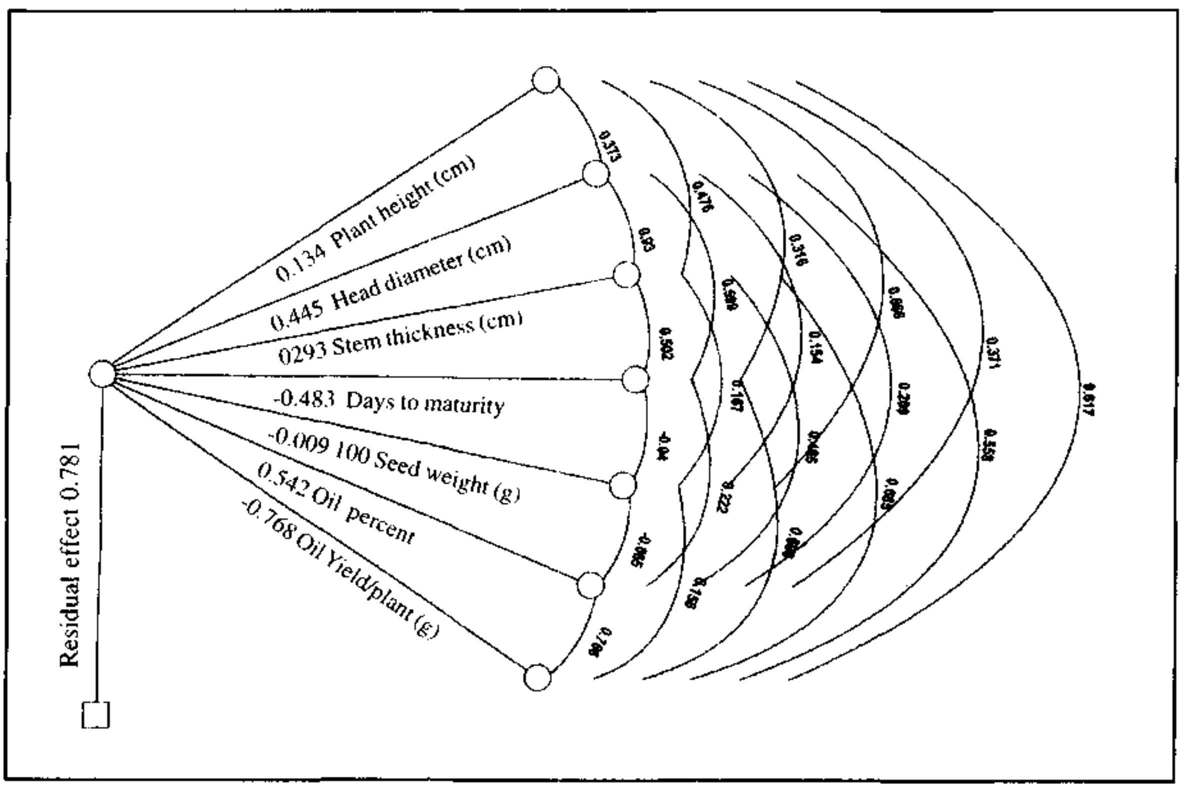


Table 81 : Path coefficient analysis of yield and yield attributes in FS_2 generation population of sunflower during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.1343**	0.0501	0.0639	0.0424	0.0894	0.0498	0.0829
Head diameter (cm)	0.1660	**0.4451**	0.4138	0.2667	0.0684	0.0930	0.2483
Stem thickness (cm)	0.1396	0.2727	**0.2933**	0.1471	0.0490	0.1187	0.2009
Days to maturity	-0.1524	-0.2892	-0.2420	**-0.4826**	0.0192	-0.1070	-0.2452
100 Seed weight (g)	-0.0063	-0.0014	-0.0016	0.0004	**-0.0094**	0.0006	-0.0015
Oil percent	0.2010	0.1133	0.2195	0.1202	-0.0355	**0.5424**	0.4156
Oil yield / plant (g)	-0.4739	-0.4281	-0.5257	-0.3900	-0.1195	-0.5882	**-0.7676**
Seed yield / plant (g)	0.0083	0.1624	0.2212	-0.2957	0.0616	0.1093	-0.0665
Partial R^2	0.0011	0.0723	0.0649	0.1427	-0.0006	0.0593	0.0510

$R^2 = 0.3907$ Residual effect = 0.7805

Fig 18 Path diagram for yield and yield attributes in FS_2 generation population of Sunflower during *summer* 1998-99.



height and oil yield / plant. However, none of the traits exhibited positive significant association with seed yield / plant. (Table 82 and Fig. 19)

In *rabi* season, oil yield / plant exhibited high direct effect of 0.3344 on seed yield/ plant. The negligible direct effect of 100 seed weight on seed yield / plant (0.1781) was recorded. However, significant positive correlations of 100 seed weight and oil yield / plant with seed yield/ plant was due to mainly by their direct effects. (Table 83 and Fig. 20)

4.7.5 *Selfed populations*

The direct and indirect effects of various traits on seed yield / plant in various generation populations of selfing series are presented in table numbers 84 to 88.

4.7.5.1 ***S_0* population :** In the base population allotted for selfing series, oil yield / plant showed very high direct effect on seed yield / plant and ultimately resulted in significant positive correlation. Where as oil per cent showed high negative direct effect on seed yield / plant (-0.3677). Significant positive association of head diameter an stem thickness with seed yield / plant resulted due to indirect influence of oil yield / plant. (Table 84 and Fig. 21)

Table 82 : Path coefficient analysis of yield and yield attributes in FS_2 generation population of sunflower during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.3427**	0.2348	0.0938	-0.0119	0.1016	-0.1286	-0.1230
Head diameter (cm)	-0.2485	**-0.3626**	-0.2148	-0.0054	-0.2201	0.1036	0.0910
Stem thickness (cm)	-0.0797	-0.1724	**-0.2911**	0.0295	-0.1824	0.1019	0.0248
Days to maturity	0.0036	-0.0015	0.0106	**-0.1046**	0.0181	-0.0482	-0.0405
100 Seed weight (g)	0.2803	0.5737	0.5923	-0.1632	**0.9453**	-0.5483	-0.1904
Oil percent	-0.1450	-0.1104	-0.1352	0.1781	-0.2241	**0.3863**	0.2194
Oil yield / plant (g)	-0.1043	-0.0729	-0.0248	0.1127	-0.0585	0.1650	**0.2906**
Seed yield / plant (g)	0.0492	0.0887	0.0309	0.0353	0.3799	0.0318	0.2719
Partial R^2	0.0169	-0.0322	-0.0090	-0.0037	0.3591	0.0123	0.0790

R^2 = 0.4223 Residual effect = 0.7600

Fig 19 Path diagram of yield and yield attributes in FS_2 generation population of sunflower during *Kharif* 1999.

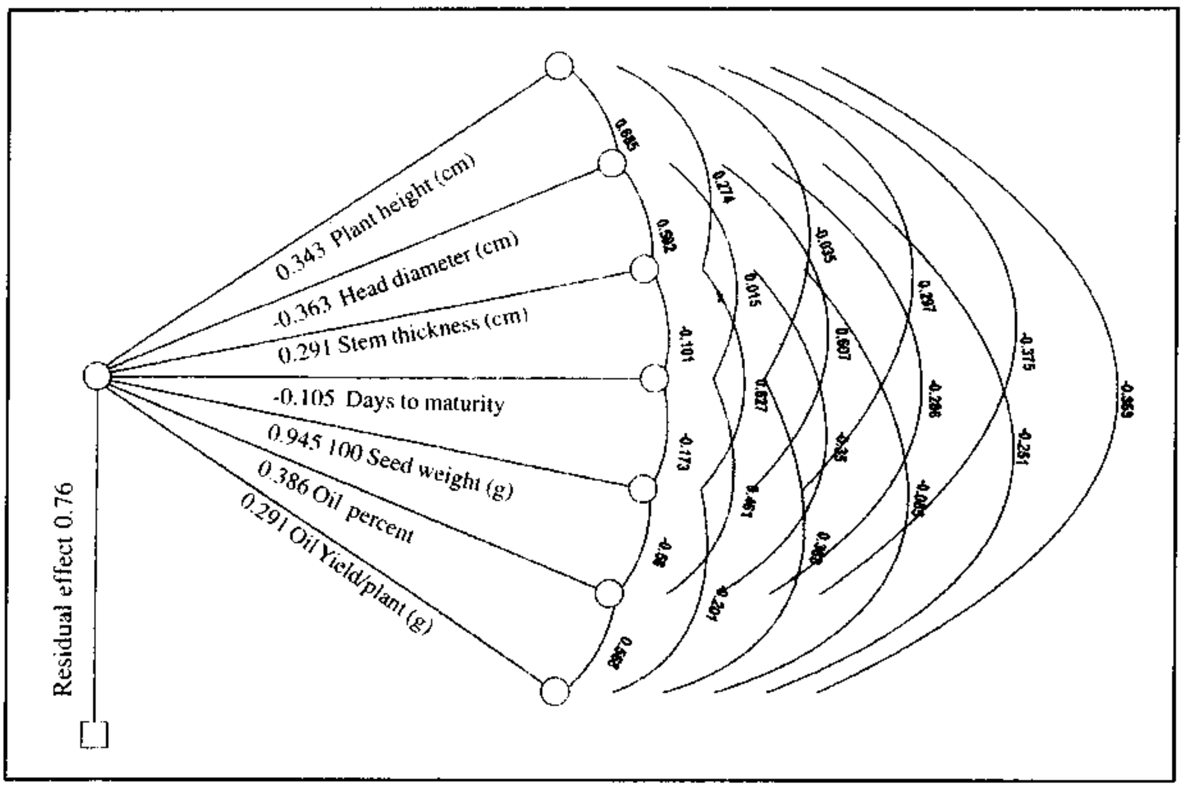


Table 83 : Path coefficient analysis of yield and yield attributes in FS_2 generation population of sunflower during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.0256**	0.0075	-0.0034	0.0009	-0.0043	-0.0014	-0.0048
Head diameter (cm)	-0.0014	**-0.0048**	0.0006	-0.0012	0.0019	0.0007	0.0019
Stem thickness (cm)	0.0035	0.0035	**-0.0262**	-0.0064	-0.0050	-0.0023	-0.0015
Days to maturity	-0.0058	-0.0429	-0.0401	**-0.1640**	0.0214	0.0283	0.0299
100 Seed weight (g)	-0.0301	-0.0704	0.0340	-0.0232	**0.1781**	0.0167	0.1311
Oil percent	0.0048	0.0130	-0.0075	0.0149	-0.0081	**-0.0865**	-0.0200
Oil yield / plant (g)	-0.0631	-0.1319	0.0194	-0.0610	0.2462	0.0774	**0.3344**
Seed yield / plant (g)	-0.0666	-0.2258	-0.0232	-0.2401	0.4301*	0.0330	0.4709*
Partial R^2	-0.0017	0.0011	0.0006	0.0394	0.0766	-0.0029	0.1575

R^2 = 0.2706 Residual effect = 0.8541

Fig 20 Path diagram of yield and yield attributes in FS_2 generation population of sunflower during *Rabi* 1999.

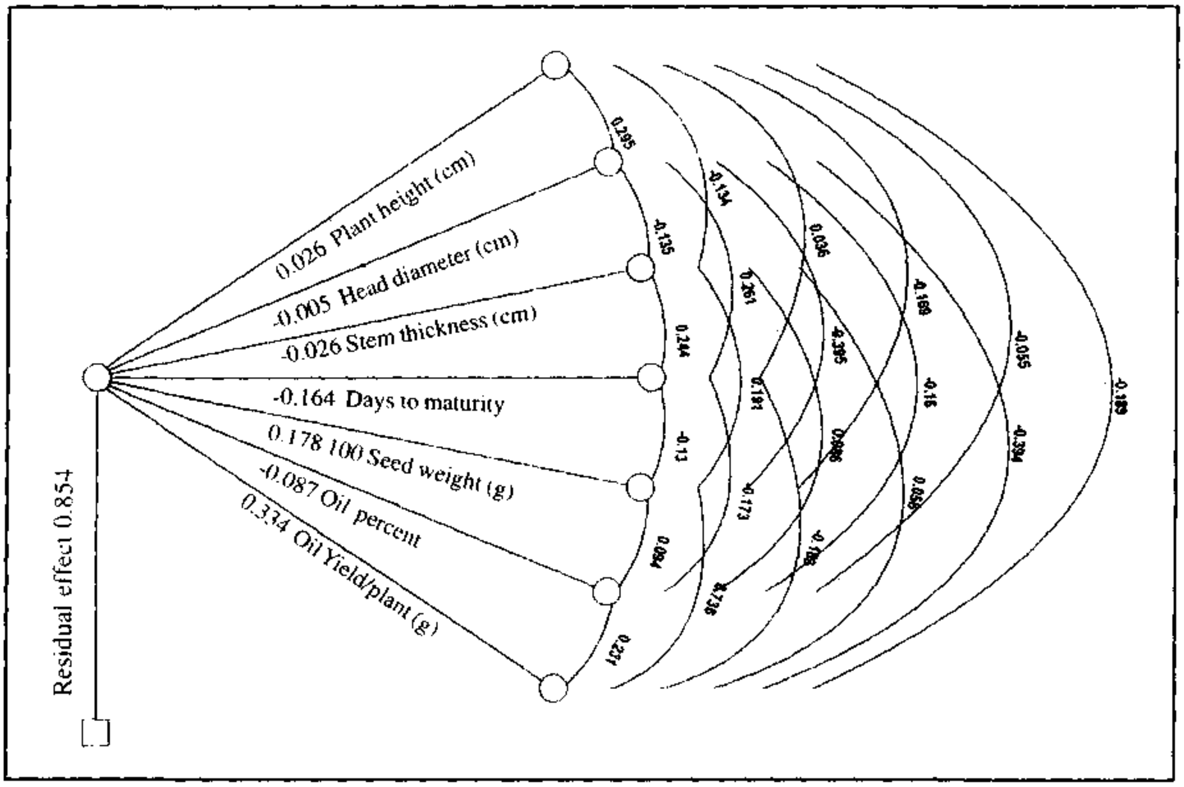
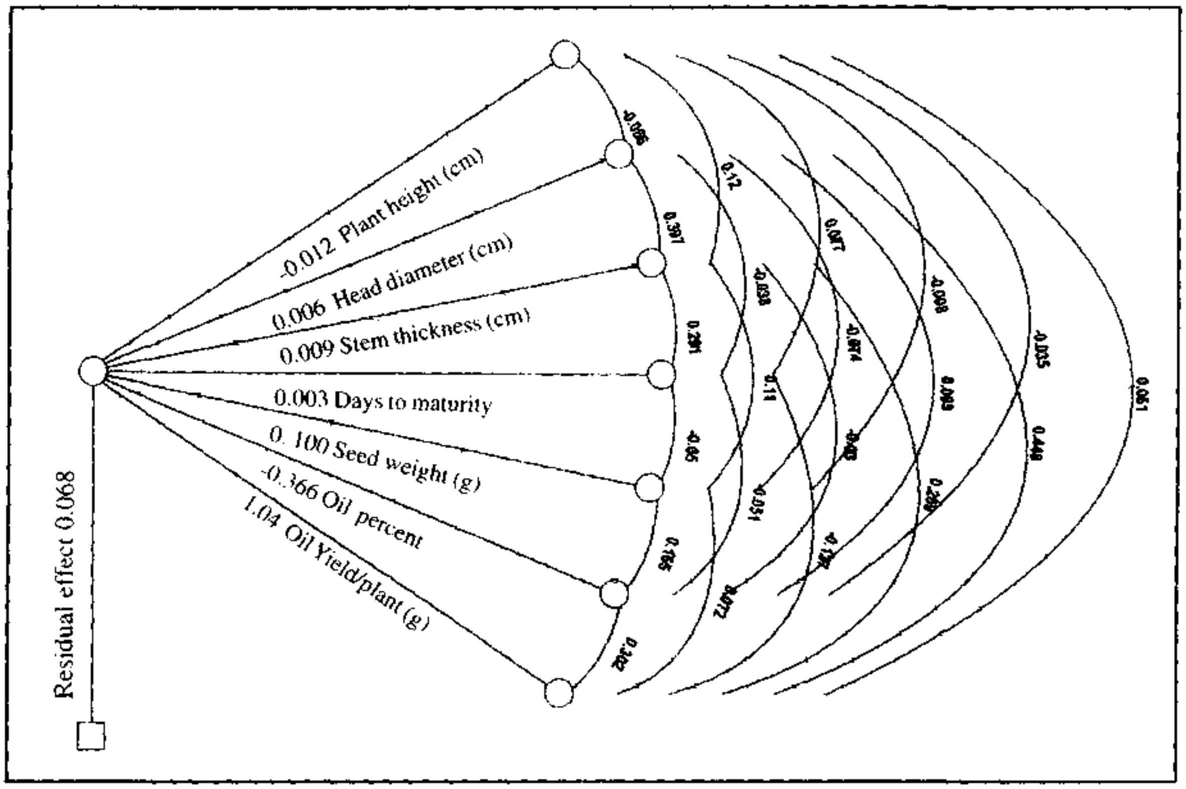


Table 84 : Path coefficient analysis of yield and yield attributes in the base population allotted for selfed progeny (S_0)

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0117**	0.0008	-0.0014	-0.0009	0.0001	0.0004	-0.0006
Head diameter (cm)	-0.0004	**0.0060**	0.0024	-0.0002	-0.0004	0.0004	0.0027
Stem thickness (cm)	0.0011	0.0037	**0.0092**	0.0027	0.0010	-0.0003	0.0025
Days to maturity	0.0002	-0.0001	0.0008	**0.0027**	-0.0001	-0.0001	-0.0004
100 Seed weight (g)	0.0000	0.0000	0.0000	0.0000	**0.0002**	0.0000	0.0000
Oil percent	0.0128	-0.0255	0.0109	0.0187	-0.0608	**-0.3677**	-0.1109
Oil yield / plant (g)	0.0528	0.4659	0.2796	-0.1423	0.0752	0.3139	**1.0403**
Seed yield / plant (g)	0.0549	0.4507**	0.3015*	-0.1193	0.0151	-0.0533	0.9336**
Partial R^2	-0.0006	0.0027	0.0028	-0.0003	0.0000	0.0196	0.9712

$R^2 = 0.9953$ Residual effect = 0.0684

Fig 21 Path diagram of yield and yield attributes in the population allotted for selfed progeny (S_0)



4.7.5.2 **S_1 population** : Only one trait oil yield / plant showed high direct effect on seed yield / plant and resulted in significant positive correlation. The other traits showed very low and negligible direct effects. (Table 85 and Fig. 22)

4.7.5.3 ***S_2 population*** : In *summer* season, in the S_2 bulk population, oil yield / plant showed very high direct effect (1.7409) on seed yield / plant. Where as oil per cent exhibited very high negative direct effect (-1.1527) on seed yield / plant. However, the oil per cent showed significant positive correlation with seed yield / plant because of very high indirect effect of oil yield / plant (1.4324) through oil per cent. The stem thickness also showed high negative direct effect (-0.7991) and its effects is nullified by indirect effect of head diameter through stem thickness. The head diameter itself showed high direct effect of 0.8004 on seed yield / plant. However, it had not showed significant positive correlation with seed yield / plant and this is because high negative indirect effect exhibited by stem thickness (-0.6020) through head diameter. (Table 86 and Fig. 23)

In *kharif* season, high direct effects were exhibited by oil yield / plant and head diameter. The significant association of oil yield / plant and stem thickness with seed yield / plant resulted due to direct effects mainly. The 100 seed weight showed high negative direct effect (-0.5045). Though head

Table 85 : Path analysis of yield and yield attributes in the S_1 generation population of sunflower

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0039**	-0.0009	-0.0005	0.0000	0.0008	0.0000	-0.0004
Head diameter (cm)	0.0287	**0.1277**	0.0804	0.0095	0.0026	0.0089	0.0250
Stem thickness (cm)	-0.0024	-0.0125	**-0.0198**	0.0010	-0.0043	-0.0033	-0.0021
Days to maturity	0.0000	0.0080	-0.0056	**0.1082**	0.0233	0.0268	-0.0098
100 Seed weight (g)	-0.0279	0.0029	0.0305	0.0304	**0.1413**	0.0199	0.0012
Oil percent	0.0001	0.0024	0.0057	0.0084	0.0048	**0.0339**	0.0036
Oil yield / plant (g)	0.0315	0.0662	0.0356	-0.0307	0.0028	0.0359	**0.3388**
Seed yield / plant (g)	0.0261	0.1939	0.1264	0.1268	0.1712	0.1221	0.3562**
Partial R^2	-0.0001	0.0248	-0.0025	0.0137	0.0242	0.0041	0.1207

$R^2 = 0.1849$ Residual effect = 0.9028

Fig 22 Path diagram of yield and yield attributes in the S_1 generation population of sunflower

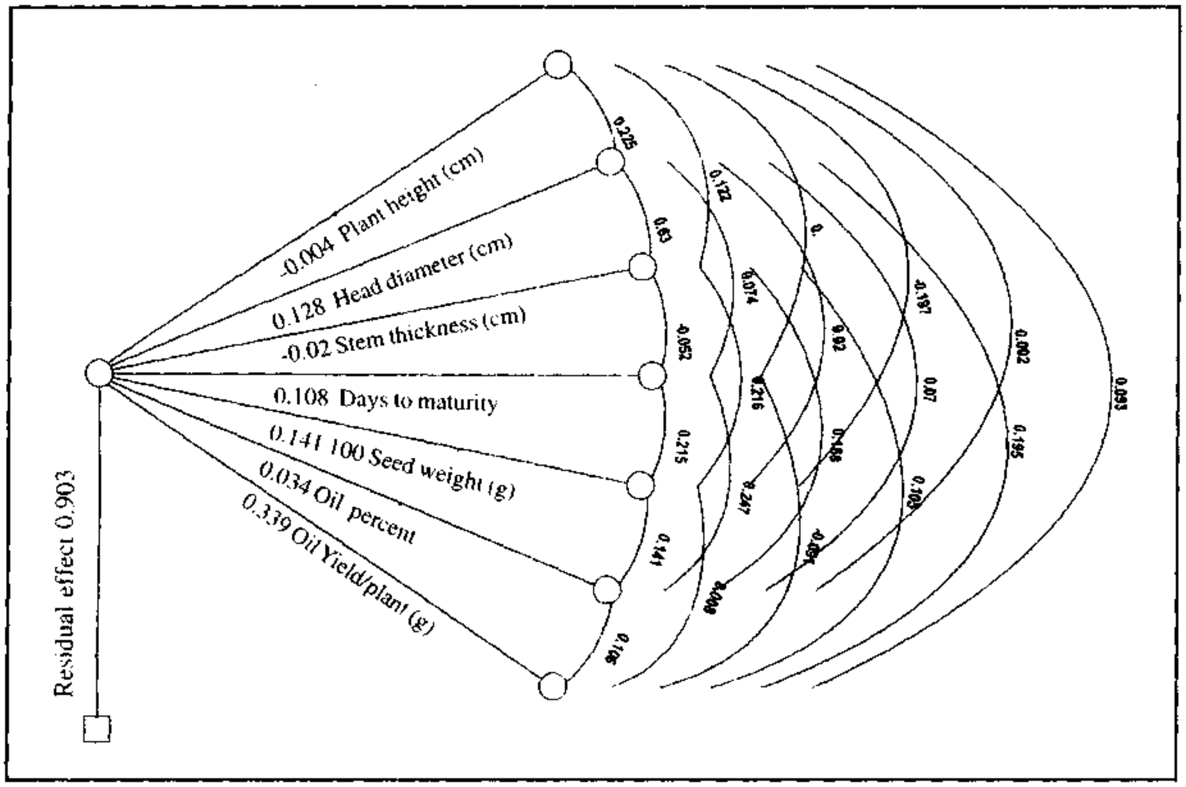


Table 86 : Path analysis of yield and yield attributes in the S_2 generation population of sunflower during *summer*, 1998-99

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**-0.0049**	0.0002	0.0005	-0.0004	-0.0004	-0.0015	-0.0013
Head diameter (cm)	-0.0385	**0.8004**	0.6029	0.1363	-0.0085	0.1029	0.0917
Stem thickness (cm)	0.0840	-0.6020	**-0.7991**	-0.2599	0.1005	0.0263	-0.1838
Days to maturity	0.0129	0.0272	0.0519	**0.1594**	-0.0707	0.0450	0.0612
100 Seed weight (g)	0.0079	-0.0011	-0.0128	-0.0451	**0.1017**	0.0172	0.0151
Oil percent	-0.3427	-0.1482	0.0379	-0.3252	-0.1950	**-1.1527**	-0.9484
Oil yield / plant (g)	0.4760	0.1994	0.4004	0.6680	0.2584	1.4324	**1.7409**
Seed yield / plant (g)	0.1947	0.2759	0.2817	0.3331	0.1862	0.4696*	0.7753**
Partial R^2	-0.0010	0.2208	-0.2251	0.0531	0.0189	-0.5413	1.3497

$R^2 = 0.8752$ Residual effect = 0.3533

908

Fig 23 Path diagram of yield and yield attributes in S_2 generation population of sunflower during *summer* 1998-99.

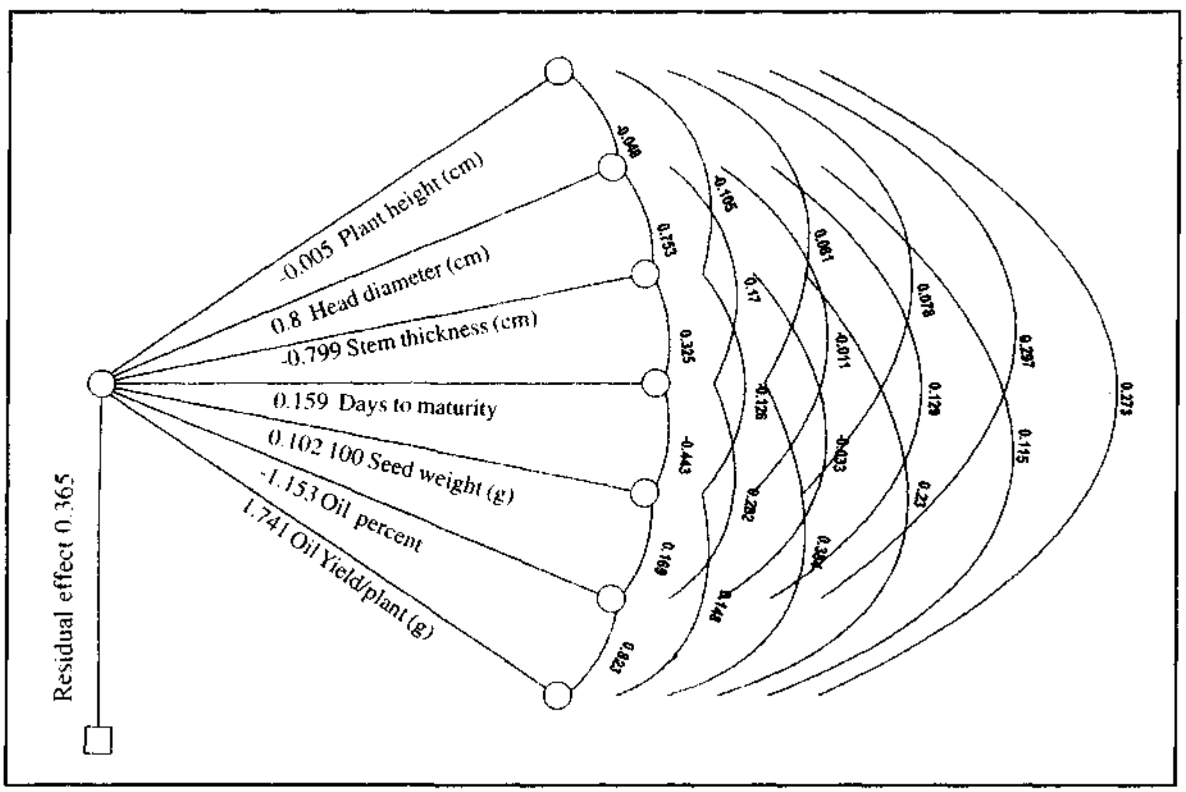


Table 87 : Path analysis of yield and yield attributes in the S_2 generation population of sunflower during *kharif*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.1205**	0.0485	0.0076	-0.0544	0.0422	0.0312	0.0143
Head diameter (cm)	0.1399	**0.3476**	-0.0238	-0.0238	0.3037	0.2052	-0.0078
Stem thickness (cm)	0.0094	-0.0101	**0.1481**	-0.0105	-0.0317	-0.0054	0.0448
Days to maturity	0.0116	0.0018	0.0018	**-0.0256**	0.0035	-0.0012	0.0047
100 Seed weight (g)	-0.1768	-0.4409	0.1079	0.0690	**-0.5045**	-0.2135	0.0677
Oil percent	-0.0451	-0.1027	0.0063	-0.0078	-0.0737	**-0.1740**	0.0756
Oil yield / plant (g)	0.0669	-0.0126	0.1702	-0.1023	-0.0756	-0.2447	**0.5631**
Seed yield / plant (g)	0.1263	-0.1685	0.4181*	-0.1554	-0.3360	-0.4023*	0.7624**
Partial R^2	0.0152	-0.0586	0.0619	0.0040	0.1695	0.0700	0.4293

$R^2 = 0.6914$ Residual effect = 0.5555

Fig 24 Path diagram of yield and yield attributes in S_2 generation population of sunflower during *Kharif*, 1999.

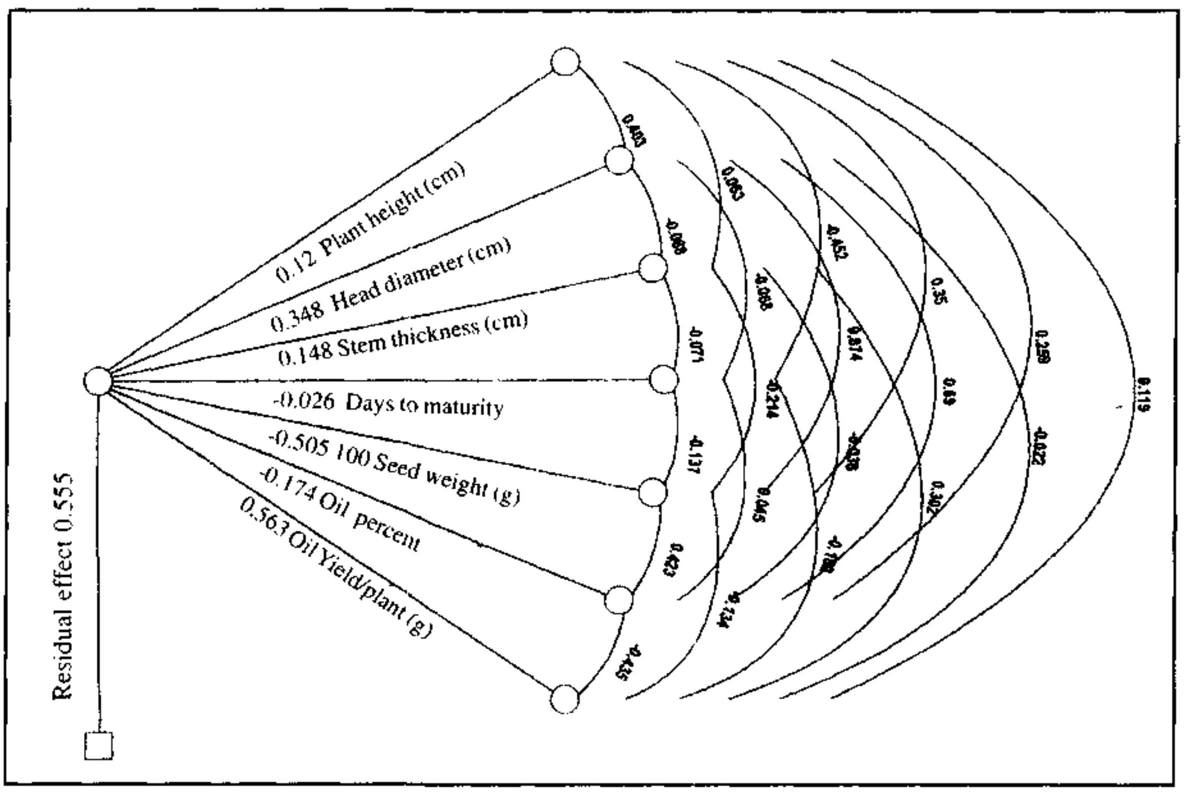
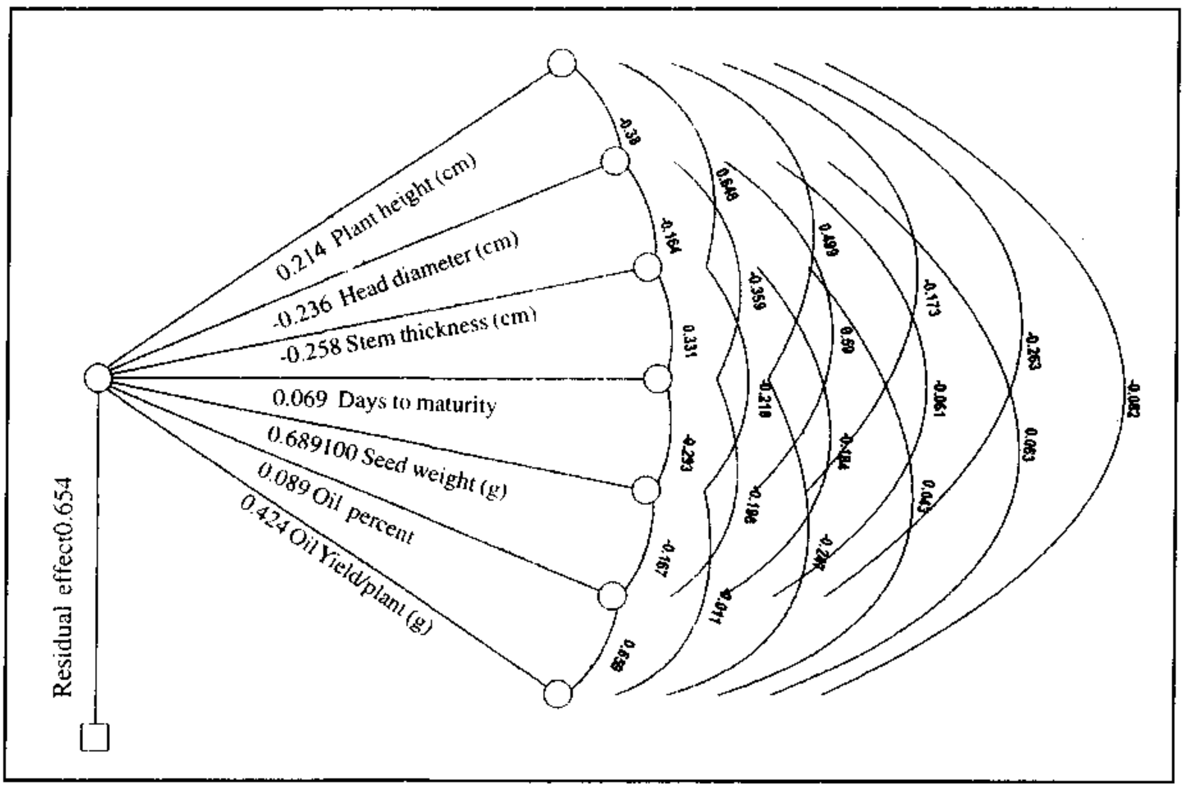


Table 88 : Path analysis of yield and yield attributes in the S_2 generation population of sunflower during *rabi*, 1999

Characters	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 Seed weight (g)	Oil percent	Oil yield / plant (g)
Plant height (cm)	**0.2140**	-0.0813	0.1387	0.1068	-0.0370	-0.0562	-0.0176
Head diameter (cm)	0.0898	**-0.2364**	0.0389	0.0849	-0.1395	0.0121	-0.0148
Stem thickness (cm)	-0.1661	0.0421	**-0.2564**	-0.0848	0.0560	0.0471	-0.0111
Days to maturity	0.0346	-0.0249	0.0229	**0.0693**	-0.0203	0.0136	-0.0171
100 Seed weight (g)	-0.1191	0.4065	-0.1504	-0.2021	**0.6886**	-0.1147	-0.0074
Oil percent	-0.0233	-0.0045	-0.0163	-0.0174	-0.0148	**0.0886**	0.0583
Oil yield / plant (g)	-0.0350	0.0266	0.0183	-0.1046	-0.0046	0.2796	**0.4244**
Seed yield / plant (g)	-0.0050	0.1281	-0.2042	-0.1478	0.5284**	0.2428	0.4147*
Partial R^2	-0.0011	-0.0303	0.0524	-0.0102	0.3639	0.0215	0.1760

R^2 = 0.5722 Residual effect = 0.6541

Fig 25 Path diagram of yield and yield attributes in S_2 generation population of sunflower during *Rabi* 1999.



diameter showed high direct effect (0.3476) on seed yield and its effect is nullified by negative indirect effect of 100-seed weight (-0.4409). (Table 87 and Fig. 24)

In *rabi* season, 100-seed weight (0.6886) and oil yield / plant (0.4244) showed high direct effects on seed yield / plant and ultimately resulted in significant positive association. The direct effects of other traits on seed yield/ plant were negligible. (Table 88 and Fig. 25)

4.8 GENOTYPE X ENVIRONMENT INTERACTION AND STABILITY ANALYSIS OVER THE LOCATIONS

The analysis of variance for stability as suggested by Eberhart and Russel (1966) was carried out for 7 populations of sunflower and the results are presented in Table 89.

Variance due to populations when tested against population X environment as well as pooled error were significant for all the characters under the study (Table 89). This indicated that the average performance of the populations in respect of eight characters varied significantly in different environments as well as the populations differed among themselves in average performance over all the environments.

There was a pronounced effect of five environments on head diameter and 100 seed weight. On contrary the remaining characters viz., plant height, stem thickness, days to maturity, oil percent, oil yield and seed yield did not vary significantly indicating the stability of these characters in all the populations over five environments.

Table 89 : Analysis of variance for 8 characters of 7 populations of sunflower over 5 environments (5 locations)

S. No.	Source of variation	df	Plant height	Head diameter	Stem thickness	Days to maturity	100-seed weight	Oil per cent	Oil yield	Seed yield / plot
1.	Replications within environments	20	13.46	0.30	0.01	0.37	0.01	0.02	0.03	0.10
2.	Populations	6	372.58**	46.12**	0.48**	13.66**	1.78**	60.27**	26.73	22.55**
3.	Environments	4	26.04	11.67**	0.05	1.76	0.36**	0.74	9.75	3.70
4.	Populations x Envts.	24	55.33	1.95	0.07	2.16	0.07	0.75	5.99	4.23
5.	Envt. + (popln +Envt.)	28	51.14	3.34	0.07	2.11	0.11	0.75	6.53	4.15
6.	Env. (Linear)	1	104.16**	46.70**	0.22*	7.05**	1.45**	2.97**	39.00**	14.82*
7.	Popln x Env. (Linear)	6	86.83**	2.06**	0.03	1.59*	0.05*	1.67**	10.03**	2.15**
8.	Pooled deviation	21	38.42**	1.64**	0.07**	20.02**	0.06**	0.38**	3.98**	4.21**
Populations										
9.	Mass selection	3	51.08**	1.87**	0.09**	6.84**	0.016	0.31**	4.33**	9.89**
10.	Bulk sib	3	27.82*	2.54**	0.02**	4.14**	0.05**	0.05**	4.22**	2.78**
11.	Half sib	3	17.16**	2.05**	0.02**	0.28	0.03*	0.39**	6.82**	5.15**
12.	Full sib	3	146.32**	0.44	0.15**	0.24**	0.05**	0.32**	2.40**	4.32**
13.	Selfed progeny	3	11.97*	0.36**	0.08**	0.93**	0.05**	0.34**	0.68**	0.20**
14.	Morden	3	0.49	3.15**	0.05**	0.46**	0.23**	0.70**	8.1**	5.00**
15.	MSFH-17	3	14.12	1.03**	0.06**	1.23**	0.03*	0.06*	1.27**	2.17**
16.	Pooled error	120	10.24	0.25	0.01	0.29	0.01	0.02	0.03	0.10
17	**Total**	**34**	**107.87**	**10.89**	**0.14**	**4.15**	**0.40**	**11.25**	**10.09**	**7.40**

*, ** Significant at 5 and 1 per cent levels when tested against pooled error

The populations X environment interaction was further partitioned into two sources i.e., linear and non-linear (Pooled deviation components) the mean squares due to population X environment (Linear) was significant for oil percent only where as it was non-significant for all the remaining characters. The individual population deviation for specific characters was significant indicating the instability of populations for most of the characters.

The non-linear interaction between population X environment revealed that all the populations exhibited significant differences over environment for head diameter, stem thickness, oil percent and oil yield. In case of plant height, Morden population has shown considerable stability where as half sib population exhibited stability for days to maturity over the environments. Similarly considerable stability among the populations i.e., mass selection, half sib, selfed progeny and Morden was revealed for 100 – seed weight whereas selfed progeny exhibited stability over environments for seed yield.

4.8.1 ***Stability analysis***

Seven populations of sunflower were grown in 5 environments i.e., Nandyal, Sirivella, Mundlamothukapalli, Penukonda and Badwel during *Rabi* 1999.

Table 91 : Mean performance and stability parameters of 7 genotypes over five environments (locations) for Plant height (cm)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	89.04	75.66	75.38	77.58	77.36	8.80	73.00	-2.518	40.38**
Bulk sib	83.76	76.54	72.86	72.86	87.54	6.87	80.29	1.845	17.11*
Half sib	87.32	76.94	84.30	84.30	84.14	4.05	82.27	1.241	6.46
Full sib	104.20	96.36	86.74	86.74	77.16	10.35	89.90	0.461	135.62**
Selfed progeny	70.50	63.58	72.12	73.12	73.12	4.01	70.67	1.512	1.26
Morden	74.44	78.20	78.14	75.74	75.74	1.65	76.46	-0.794**	-10.20
MSFH-17	102.50	80.66	106.82	87.82	93.28	10.64	94.21	5.253**	3.41

Table 92 : Mean performance and stability parameters of 7 genotypes over five environments (locations)

Head diameter

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	13.04	10.22	8.84	11.96	7.82	2.15	10.36	1.39*	1.61**
Bulk sib	13.04	13.68	10.46	14.06	14.84	1.67	13.21	0.72	2.29**
Half sib	15.34	16.94	11.60	15.76	15.50	2.01	15.02	1.23	1.79**
Full sib	19.54	17.34	13.56	19.32	16.36	2.44	17.22	1.84**	0.18
Selfed progeny	8.82	8.28	7.38	8.70	6.64	0.93	7.96	0.59*	0.10
Morden	11.96	14.18	10.52	12.46	8.76	2.04	11.57	1.04	2.89**
MSFH-17	14.0	11.68	13.00	13.76	13.00	0.90	13.10	0.16	0.77**

Table 93 : Mean performance and stability parameters of 7 genotypes over five environments (locations)

Stem thickness

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	0.760	0.84	1.14	1.38	1.30	0.27	1.08	0.74	0.084**
Bulk sib	1.540	1.52	1.60	1.86	1.58	0.14	1.62	0.68*	0.010
Half sib	1.920	1.34	1.94	1.88	1.86	0.25	1.78	2.41**	0.013
Full sib	2.20	1.80	2.26	1.38	1.78	0.35	1.88	1.21	0.145**
Selfed progeny	0.84	1.00	1.32	1.52	0.86	0.30	1.10	1.75**	0.077**
Morden	1.62	1.66	1.50	1.24	1.26	0.19	1.45	-0.44	0.039**
MSFH-17	1.92	1.44	1.34	1.58	1.44	0.23	1.53	0.63	0.054**

Table 94 : Mean performance and stability parameters of 7 genotypes over five environments (locations)

Days to maturity

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	77.4	77.8	81.8	83.2	77.40	2.76	79.52	3.17	6.53**
Bulk sib	80.4	79.8	83.6	78.2	80.0	1.97	80.4	1.77	3.83**
Half sib	80.6	80.0	81.8	80.6	82.0	0.99	81.0	1.44*	-0.019
Full sib	81.0	80.6	80.2	80.2	81.20	0.455	80.64	-0.31	-0.060
Selfed progeny	77.0	77.4	77.8	76.8	79.2	0.95	77.64	0.91	0.627*
Morden	80.2	79.6	79.0	80.4	80.4	0.61	79.92	-0.31	0.150
MSFH-17	82.0	83.4	82.2	83.8	84.2	0.84	83.12	0.31	0.931**

Table 95 : Mean performance and stability parameters of 7 genotypes over five environments (locations) for 100-Seed weight (g)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	3.98	3.90	4.0	3.80	3.64	0.39	3.864	0.424	0.0037
Bulk sib	3.58	3.50	3.14	2.96	3.32	0.25	3.300	0.736	0.036**
Half sib	4.28	3.92	4.04	3.56	3.50	0.32	3.860	1.271*	0.019*
Full sib	5.34	4.50	5.22	4.32	4.36	0.49	4.748	1.978**	0.03**
Selfed progeny	3.20	2.78	2.80	2.60	2.90	0.818	2.856	0.31	0.005**
Morden	3.14	3.36	3.80	2.78	3.84	0.45	3.384	0.716	0.22**
MSFH-17	3.98	3.26	3.54	3.30	3.44	0.29	3.504	1.057*	0.02*

Table 96 : Mean performance and stability parameters of 7 genotypes over five environments (locations)

See yield / plot (kg)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	Seed yield / plant (g)	bi	S^2di
Mass selection	4.88	9.98	8.92	2.88	4.98	2.991	6.32	23.2	1.7	9.79**
Bulk sib	7.55	6	9.66	7.24	9	1.45	7.88	29.4	0.252	2.68**
Half sib	9.12	12.64	6.76	9.8	10.54	2.143	9.76	33.8	1.185	5.05**
Full sib	10.94	7.3	11.14	11.82	11.86	1.894	10.61	39.2	-0.814	4.22**
Selfed progeny	3.66	5.78	3.92	2.3	6.18	1.6	4.36	16.9	2.135**	0.1
Morden	7.92	8.4	3.02	5.94	8.22	2.28	6.70	24.5	1.65	4.90**
MSFH-17	9.38	6.82	9.16	6.54	9.3	1.43	8.24	32.3	0.88	2.07**

Table 97 : Mean performance and stability parameters of 7 genotypes over five environments (locations) for Oil per cent

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	30.20	31.50	30.32	29.94	28.84	1.02	30.06	2.69*	0.29**
Bulk sib	36.52	35.24	34.30	33.60	33.24	1.32	34.58	3.60**	0.48
Half sib	33.48	32.24	31.50	31.50	31.16	0.920	31.97	2.30	0.38**
Full sib	32.58	33.48	34.40	34.44	34.50	0.84	33.88	-2.08	0.30**
Selfed progeny	39.88	39.00	38.44	39.46	38.78	0.56	39.11	0.76	0.32**
Morden	33.64	35.38	35.44	34.86	34.58	0.73	34.78	-0.181	0.69**
MSFH-17	28.72	28.46	283.0	28.86	28.64	0.4	28.59	-0.114	0.04*

Table 98 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (locations) for Oil yield / plant (g)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	5.78	11.50	8.38	2.84	6.40	3.2	6.98	2.253*	4.3080**
Bulk sib	9.88	8.38	13.30	9.24	10.26	1.86	10.21	-0.477	4.19**
Half sib	11.24	15.46	7.94	10.6	9.52	2.8	10.95	1.417	6.79**
Full sib	11.90	10.42	14.36	15.30	14.42	2.06	13.28	-1.299	2.37**
Selfed progeny	6.06	9.12	5.48	3.68	9.20	2.40	6.70	1.944**	0.65**
Morden	10.54	11.12	3.52	7.18	10.14	3.17	8.50	1.692	8.07**
MSFH-17	9.84	10.46	9.46	5.74	10.54	2.00	9.20	1.469*	1.23**

94.21 cm (MSFH-17). The regression values ranged form -2.518 (mass selection) to 5.253 (MSFH-17) and only the two populations i.e., Morden and MSFH-17 recorded significant regression values as well as significantly different from unit values i.e., bi=1.0 (Table 91). The deviation from regression ranged form -10.20 (Morden) to 40.38 (mass selection) and only three genotypes (mass selection, full sibs and bulk sibs) showed significant deviation from zero.

4.8.2.2 ***Head diameter :*** The population recorded a range of mean in head diameter form 7.96 cm (Selfed progeny) to 17.22 cm (full sibs) with a general mean of 12.63 cm over five environments (Table 92). The regression of head diameter on environmental index was in the range of 0.16 (MSFH-17) to 1.84 (fullsibs) of which the three genotypes i.e., selfed progeny mass selection and fullsib populations recorded significant bi values. Only one population i.e., fullsibs showed significant deviation from unity. The deviation from regression had shown significant difference form zero in five populations whereas in the other two genotypes it was not significant form zero.

4.8.2.3 ***Stem thickness :*** This trait recorded a general mean of 1.49 cm thickness and the individual population means ranged from 1.08 cm (mass selection) to 1.88 cm (full sibs). The regression of stem diameter on environmental index was significantly different form unity in two genotypes i.e., half sibs and Morden whereas the remaining genotypes recorded non-significant deviation from unity (Table 93). The deviations from regression were significant in all the populations except bulksib and half sib populations. Significant regression values were recorded for half sib, selfed progeny and bulksib populations.

4.8.2.4 ***Days to maturity :*** The seven populations had a mean maturity duration of 80.32 days over the five environments (Table 94) and the mean maturity of individual populations ranged from 77.64 days (selfed progeny) to 83.12 days (MSFH-17). The regression values on environmental index ranged from -0.44 (Morden) to 2.41 (half sibs) but only three populations i.e. half sibs, self progeny and bulk sibs expressed significant regressions. Only the full sib population had the significant deviation of regression from unity. The deviations from regression (S^2_{di}) ranged from -0.060 (full sibs) to 6.53 (mass selection) and these were significant in all the genotypes except half sib, full sibs, and Morden populations.

4.8.2.5 **100-Seed weight :** The mean seed weight among the seven populations ranged from 2.85 g (selfed progeny) to 4.748 g (full sibs) with a general mean of 3.64 g (Table 95). The regression co-efficients were significant for full sibs, half sibs and MSFH-17 but none of the regressions exhibited significant deviation from unity. The mean square deviations form regression were not significant in mass selection while these were significant for all the remaining populations.

4.8.2.6 ***Oil per cent :*** An average oil per cent of 33.28 per cent was recorded over the populations with the mean oil per cent of populations were in the range of 28.59% (MSFH-17) and 39.11% (selfed progeny). The regression co-efficients of genotypes ranged from -0.208 (full sibs) to 3.60 (bulk sibs) and were significant for bulk sibs and mass selection genotypes (Table 96). The regression co-efficients of full sibs, MSFH-17 and bulk sibs were found to be significant from unity where as the remaining regressions of genotypes were not significant from unity. However, the mean square deviations from regression were found significantly different form zero in all the populations except bulk sibs.

4.8.2.7 ***Oil yield :*** The genotypes recorded a range of oil yield from 6.98 g (mass selection) to 13.28 g (full sibs) with a mean oil yield of 9.40 g over the five environments (Table 97). The regression coefficients were registered in a range of -1.299 (full sibs) to 2.253 (mass selection). The regression co-efficients of three populations i.e. mass selection (2.253), selfed progeny (1.944) and MSFH-17 (1.469) were significant while the remaining regressions were non-significant. However, the regression co-efficients of full sibs and selfed progeny genotypes were found to be significantly different from unity and the squared deviations from regression were significant in all the populations.

4.8.2.8 ***Seed yield :*** An average seed yield of 7.760 kgs/plot was recorded over the populations with the mean yield of genotypes were in the range of 4.36 kg/plot (16 g / plant) (selfed progeny) to 10.61 kg/plot (39.28 g/plant) (full sibs). The regression coefficients of six population except selfed progeny were not significant from unity (Table 98). However, the mean square deviations from regression were found significantly different in all the populations except selfed progenies.

4.9 GENOTYPE X ENVIRONMENT INTERACTION AND STABILITY ANALYSIS OVER DIFFERENT DATES OF SOWING :

The analysis of variance for stability was carried out for 7 populations of sunflower sown at 5 different dates of sowing i.e. 15th November (Environment I), 1st December (Environment II), 16th December (Environment III), 2 January (Environment IV) and 16th January (Environment V) at Agricultural Research Station, Nandyal, during *Rabi* 1999 and the results are furnished in Table 90.

Variance due to populations were significant for all the characters except head diameter, stem thickness and oil per cent when it was tested

Table 90 : Analysis of variance for 8 characters of 7 populations of sunflower over 5 dates of sowing

S. No.	Source of variation	df	Plant height	Head diameter	Stem thickness	Days to maturity	100-seed weight	Oil per cent	Oil yield	Seed yield / plot
1.	Replications within environments	20	19.61	0.42	0.01	0.65	0.01	0.02	0.01	0.03
2.	Populations	6	337.59*	17.71	0.41	13.61*	2.63*	49.13	28.98**	24.30**
3.	Environments	4	447.84**	25.15**	0.14*	1.69*	0.58*	5.96*	1.24	0.19
4.	Populations x Envts.	24	92.41	3.19	0.07	1.09*	0.22	4.87*	3.08	2.39
5.	Envt. + (popln +Envt.)	28	143.19	6.32	0.08	1.18	0.27	5.03	2.81	2.94
6.	Env. (Linear)	1	1791.36**	100.59**	0.56	6.78	2.32	23.85	4.97	24.76**
7.	Popln x Env. (Linear)	6	65.49	4.16	0.11*	2.73**	0.42*	12.46**	1.25	1.12**
8.	Pooled deviation	21	86.90**	2.45**	0.04**	0.47	0.14**	2.01**	3.16**	2.42**
Populations										
9.	Mass selection	3	109.21**	6.3**	0.12**	0.06	0.27**	4.12**	1.99**	2.42**
10.	Bulk sib	3	50.28**	3.87**	0.02**	0.16	0.07**	4.76**	0.95**	0.80**
11.	Half sib	3	270.51**	4.11**	0.08**	0.14	0.19**	0.57**	2.06**	1.51**
12.	Full sib	3	59.71**	0.38	0.02**	0.21	0.08**	0.41**	12.51**	9.23**
13.	Selfed progeny	3	16.16	0.37	0.003*	1.66*	0.18**	3.42**	2.86**	1.62**
14.	Morden	3	36.80	0.75	0.03**	0.72	0.006	0.52**	1.09**	0.67**
15.	MSFH-17	3	66.64*	1.38**	0.02**	0.35	0.14**	0.23**	0.62**	0.61**
16.	Pooled error	120	25.15	0.31	0.00	0.50	0.01	0.01	0.01	0.02
17	**Total**	**34**	**177.49**	**8.33**	**0.14**	**3.37**	**0.69**	**12.81**	**7.43**	**6.71**

*, ** Significant at 5 and 1 per cent levels when tested against pooled error

against populations x environment. However, when they were tested against pooled error it was significant for all the characters. This indicates that the average performance of the populations differed significantly in various traits over environments as well as among themselves in all the environments. However, head diameter, stem thickness and oil per cent did not vary significantly indicating the stability of these characters in all the populations over the five different dates of sowing.

The population and environment interaction was further partitioned into linear and non-linear (pooled deviation) components. The mean square due to population x environment (linear) was significant for four characters i.e. oil per cent, days to maturity, 100-seed weight and stem thickness whereas for remaining characters viz., plant height, head diameter, oil yield and seed yield indicating their stability in all environments. The individual population deviation for specific characters indicated the instability of population for most of the characters as they were significant.

The non-linear interaction between population x environment revealed that three populations viz., half sibs, mass selection and MSFH-17 exhibited significant differences over dates of sowing for plant height where as the remaining four populations were found to be stable. Similarly, full sib, selfed progenies and Morden variety expressed considerable stability over the different dates of sowing for head diameter. All the populations exhibited instability in respect of stem thickness, oil per cent and seed yield. On contrary, all the populations except Morden and selfed progenies showed considerable instability for days to maturity over different dates of sowing. The Morden population also displayed stability for 100-seed weight over the different environments (dates of sowing).

4.9.1 *Stability analysis*

The mean performance of populations over five different dates of sowing and environmental index for each of these date of sowing are presented in Tables 100 to 107. Environment V (16th January sowing) was found to be superior to other environments for head diameter, days to maturity and stem thickness followed by environment IV for seed yield, oil yield and early maturity, environment I for oil per cent and 100 - grain weight and environment III for plant height. However, some of the populations did not show any deviation in their performance for some of the characters in all the dates of sowing. The character wise mean performance of the populations over five dates of sowing based on environmental index and environmental standard deviation is presented below :

4.9.1.1 ***Plant height :*** The best environment for this character was environment II (IJ = 10.37) with a mean plant height of 90.7 cm (Table 100).

Table 99 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Plant height (cm)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	62.20	105.8	85.0	82.8	81.80	15.46	83.52	1.57*	83.85**
Bulk sib	67.00	97.80	74.6	99.8	82.40	14.31	84.32	1.61*	25.92
Half sib	64.40	74.00	69.9	99.60	97.60	16.34	81.08	1.00	246.15**
Full sib	79.40	101.20	71.0	78.20	83.00	11.14	82.56	1.13	36.35
Selfed progeny	62.40	81.40	63.2	73.00	69.00	7.85	69.00	0.91	-8.19
Morden	67.80	74.00	68.0	63.20	77.60	5.67	77.60	0.26	12.44
MSFH-17	87.80	101.20	80.2	90.80	91.00	8.05	91.00	0.48	42.28*

There was considerable reduction in plant height in all the populations in 15th November and 16th December sowings (IJ = -8.82 and IJ = -7.28). Minimum environmental deviation in plant height among five environments was recorded by Morden population (ESD = 5.67) where as the highest deviation was recorded by half sibs population (ESD = 16.34).

4.9.1.2 ***Head diameter :*** The environmental index over five dates of sowing for head diameter (Table 100) showed considerable differences among them where 16th January sowing (IJ = 3.627) was found to be superior over the other sowings followed by 16th December sowing (IJ = 1.37) contrary to this, the remaining three dates of sowing showed inferiority over the other sowings. Maximum mean head diameter of 12.57 cm was recorded by all the populations with 16th January sowing while least diameter (8.41 cm) were expressed with 2 January sowing. Among all the populations, maximum head diameter was expressed by full sibs (18.16 cm) followed by half sibs (16.60 cm) with 16 January sowing. The most stable population was found to be selfed-progenies (ESD = 1.28) where as full sib population was the most unstable (ESD = 3.61) for this character.

4.8.1.3 **Stem thickness :** The environmental index for this trait for 16th January (IJ = 0.162) and 16th December sowing (IJ = 0.113) showed superiority of these dates of sowing over the remaining sowings with their

Table 100 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Head diameter (cm)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	10.16	13.76	13.72	8.64	10.64	2.27	11.38	0.352	5.97**
Bulk sib	5.96	8.14	11.22	10.62	13.46	2.89	9.88	1.235*	3.54**
Half sib	10.06	8.86	10.36	8.86	16.60	3.23	10.94	1.432*	3.78**
Full sib	9.52	10.82	14.74	10.52	18.16	3.61	12.75	1.888**	0.05
Selfed progeny	5.94	7.16	8.80	6.16	8.40	1.28	7.29	0.620	0.04
Morden	8.42	6.82	9.44	6.98	10.72	1.65	8.47	0.778	0.41
MSFH-17	8.92	7.38	11.00	7.14	10.04	1.66	8.89	0.696	1.05**

respective stem thickness of 1.29 cm and 1.24 cms (Table 101). Maximum stem thickness of 2.18 cm and 2.10 cm was expressed by full sibs with 16 January and 16 December sowings respectively whereas least stem diameter was recorded by selfed progenies (0.74 cm) with 1st December sowing. In general, full sibs recorded maximum stem diameter (1.66 cm) while selfed progenies recorded least stem thickness (0.81 cm) overall the five dates of sowing. However, based on environmental standard deviation, selfed progenies were found to be most stable with a ESD of 0.06 whereas full sibs were the most unstable with ESD of 0.52 for this character.

4.9.1.4 ***Days to maturity :*** Based on the environmental index, the best environment for the expression of this character was 1 December sowing (IJ = -0.66) followed by 2 January sowing (IJ = -0.149) with a mean maturity duration of 80.6 days and 82.05 days (Table 102). The most stable population in respect of maturity duration was found to be mass selection (ESD = 0.22) where as selfed progenies showed considerable variation in maturity among five dates of sowing with a higher environment standard deviation (ESD=2.40).

4.9.1.5 ***100 - Seed weight :*** The highest seed weight was expressed by full sibs with 2nd January sowing (5.42 g), and 15th November sowing (5.26 g) where as the lowest 100 seed weight was recorded by mass selection

Table 101 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Stem thickness (cm)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	0.980	1.54	1.52	0.86	1.08	0.31	1.19	0.656	0.1163
Bulk sib	0.92	1.06	0.92	1.06	1.22	0.12	1.03	0.138	0.015**
Half sib	1.44	0.86	1.18	1.22	1.68	0.43	1.27	1.234	0.080**
Full sib	1.82	1.20	2.10	1.04	2.18	0.52	1.66	3.573**	0.174**
Selfed progeny	0.76	0.84	0.88	0.74	0.86	0.06	0.81	0.334	-0.002*
Morden	0.78	0.84	1.18	0.80	0.76	0.17	0.87	0.417	0.0317**
MSFH-17	1.16	0.98	0.92	0.90	1.26	0.15	1.04	0.650	0.0176**

Table 102 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Days to Maturity

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	79.6	79.2	79.8	79.4	79.4	0.22	79.48	0.16	-0.462
Bulk sib	80.8	79.0	80.2	80.8	80.16	2.31	82.16	1.32	-0.357
Half sib	82.4	80.8	82.2	83.0	81.92	0.82	81.92	1.70*	-0.38
Full sib	80.8	81.4	81.4	82.0	81.3	0.43	81.32	0.469	-0.31
Selfed progeny	79.8	77.8	78.20	83.8	79.7	2.40	79.76	4.301**	1.13*
Morden	82.2	83.0	83.80	82.6	83.1	0.63	83.12	-0.466	0.20
MSFH-17	84.2	83.6	84.20	82.8	8.36	0.49	83.68	-0.521	-0.16

(2.14 g) with 16th January sowing (Table 103). In general, full sib population registered highest mean seed weight (4.44 g) where as selfed progenies recorded the lowest mean seed weight (2.70 g) over the different dates of sowing. The environmental index values revealed that 15th November sowing was found to be best for the expression of this character (IJ = 3.70). The Morden populations exhibited more stability in its performance over the different dates of sowing (ESD = 0.07) where as full sibs found to be most unstable (ESD = 0.92) in the expression of this character.

4.9.1.6 Seed yield per plot (kg) : The January sowings were found to be the most favourable environment (IJ = 1.303 and IJ = 0.649) whereas November and December sowings were unfavourable environment for the expression of high seed yield per plot (Table 104). The highest seed yield was recorded by full sibs 12.44 kg/plot (47 g / plant) with 16 January sowing where as the lowest was registered by selfed progenies 1.50 kg / plot (7 g / plant) with 15 November sowing. In general, full sibs have performed best with a mean seed yield of 9.35 kg / plot (29.6 g / plant) whereas selfed progenies have the inferior performance with a mean yield of 3.20 kg / plot (9.5 g / plant) over all the dates of sowing. The environmental standard deviation of the populations indicated that MSFH-17 was the most stable (ESD = 0.80) where as the full sib was the most unstable population (ESD=2.70) for the expression of this character.

Table 103 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for 100 Seed weight (g)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	2.88	3.36	2.18	3.500	2.14	0.64	2.812	1.56	0.26**
Bulk sib	4.14	4.06	3.42	3.70	3.70	0.29	3.80	0.58	0.06**
Half sib	4.72	3.58	4.18	4.06	4.22	0.41	4.15	0.53	0.17**
Full sib	5.26	4.50	3.34	5.42	3.72	0.92	4.44	3.07*	0.069**
Selfed progeny	2.94	2.32	2.78	3.46	2.04	0.55	2.70	1.42	0.17**
Morden	3.08	3.12	3.00	3.04	3.18	0.07	3.08	-0.060	-0.003
MSFH-17	3.08	2.34	3.04	2.50	2.88	0.33	2.76	-0.123	0.135**

Table 104 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Seed yield per plot (kg)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	Seed yield / plant (g)	bi	S^2di
Mass selection	2.94	4.08	1.66	7.48	3.28	2.18	3.88	13.3	1.62	2.45**
Bulk sib	5.4	3.16	4	4.76	4.16	0.84	4.29	14.6	0.34	0.78**
Half sib	5.18	7.48	6.12	9.98	8.3	1.87	7.41	24.6	1.63	1.49**
Full sib	10.38	5.22	10.32	8.4	12.44	2.7	9.35	29.6	0.72	9.21**
Selfed progeny	1.5	3.12	2.26	3.82	5.32	2	3.20	9.5	1.03	1.59**
Morden	4.9	4.6	2.96	6.28	4.62	1.18	4.67	13.2	1.002	0.65**
MSFH-17	6.44	6.48	5.68	7.58	5.6	0.8	6.35	17.9	0.44	0.58**

4.9.1.7 ***Oil per cent :*** Based on environmental index, 15th November was the most favourable date of sowing (IJ = 0.734) for the expression of this character (Table 106). Whereas 1 December and 15th December sowings did not show much influence on this character. On contrary, January sowings were found to be unfavourable for the expression of this important character. Selfed progenies expressed the maximum oil per cent (42.14%) with 15th December showing while the lowest was expressed by MSFH-17 in the same sowing (27.44%). However, MSFH-17 was considered to be the most stable genotype with standard deviation of 0.50, where as maximum deviation (ESD=5.00) was observed in selfed progenies.

4.9.1.8 **Oil yield :** There was no considerable difference in the expression of oil yield among the populations in January sowings (Table 107). However, the remaining environments (November and December sowings) had affected oil IJ values and were found to be in negative direction (-0.147 to -0.273). The population x dates of sowing interactions indicated maximum oil yield was expressed by full sibs (13.06 g) with 16 January sowing where as the lowest was recorded by selfed progenies (1.68 g) with 15 November sowing. Based on the environmental standard deviation, bulk - sibs population was found to be the most stable (ESD = 0.86) where as mass selection population was the most unstable (ESD = 4.03) for the expression of this character.

Table 105 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Oil per cent

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	30.9	29.76	34.00	29.32	30.32	1.85	30.86	0.633	4.108**
Bulk sib	33.86	33.26	29.18	33.40	32.16	1.89	32.37	0.023	4.748**
Half sib	34.18	33.24	32.48	33.94	34.26	0.75	33.62	-0.402	0.557**
Full sib	35.10	35.16	34.20	33.323	33.20	0.93	34.19	0.816	0.39**
Selfed progeny	39.54	40.00	42.14	38.66	29.16	5.00	37.88	5.183**	3.40**
Morden	35.38	36.10	36.44	34.40	34.08	1.0	35.28	0.886	0.50**
MSFH-17	28.56	28.10	27.44	28.34	28.40	0.5	28.16	-0.146	0.21**

Table 106 : Mean performance and stability parameters of 7 genotypes of sunflower over five environments (dates of sowing)

for Oil yield / plant (g)

Genotype	Env. I	Env. II	Env. III	Env. IV	Env. V	ESD	General Mean	bi	S^2di
Mass selection	3.16	4.56	3.08	6.28	3.42	4.03	4.10	1.38	1.98**
Bulk sib	6.28	4.32	4.40	4.30	4.38	0.86	4.73	-0.416	0.94**
Half sib	6.44	9.28	7.16	9.18	9.28	1.36	8.26	1.333	2.04**
Full sib	11.64	6.16	12.14	7.30	13.06	3.10	10.06	1.253	12.49**
Selfed progeny	1.68	4.12	5.54	4.04	2.36	1.53	3.54	-1.091	2.85**
Morden	5.08	3.84	2.38	6.14	5.56	1.53	4.60	2.847	1.07**
MSFH-17	5.64	5.40	4.34	7.10	5.70	1.000	5.63	3.88	0.60**

4.9.2 *Stability parameters :*

The three stability parameters i.e. general mean, regression and deviation from regression in respect of eight characters were compared to findout the stability of the genotypes and are presented in Table 100 to 107. The character wise study of the stability parameters are presented below.

4.9.2.1 ***Plant height :*** The genotypes recorded a general mean height of 80.40 cm over five dates of sowing with mean individual values ranging from 69.00 (selfed progenies) to 92.20 cm (MSFH-17). The regression values ranged from 0.26 (Morden) to 1.61 (bulk sibs) and were significant for bulk sibs and mass selection (Table 99). None of these regressions were significantly deviated from unity. The squared deviation from regression (S^2_{di}) ranged from -8.19 (selfed progenies) to 246.15 (half sibs) and three genotypes viz., half sibs, mass selection and MSFH-17 showed significant squared deviations from zero.

4.9.2.2 ***Head diameter :*** The mean head diameter among the populations ranged from 7.29 cm (selfed progenies) to 11.38 cm (mass selection) with a general mean of 9.94 cm (Table 110. The regression of individual genotypes over environmental index for this trait were recorded in a range of 0.352 (mass selected progenies) to 1.888 (full sibs). The individual regressions were found significant in the progenies of full sibs, half sibs, Morden and selfed progenies where as it was no-significant in the remaining populations. On contrary, the significant deviation of regression from unity was observed in full sibs and were non-significant for the remaining genotypes. The deviations from regression ranged from 0.04 (selfed progeny) to 5.97 (mass selection) and were significant for mass selection, half sibs, bulk sibs and MSFH-17 genotypes.

4.9.2.3 Stem thickness : A mean stem thickness of 11.2 cm was observed over the populations with the individual population mean ranging from 0.81 cm (selfed progeny) to 1.66 cm (full sibs) (Table 101). The regression of stem thickness on environmental index were no significantly different from unity in all populations except full sibs and selfed progenies where their individual regressions were significantly differing from unity. The regressions of individual genotypes were ranged from 0.138 (bulk sibs) to 3.573 (full sibs) and was significant for only one genotype i.e. full sibs. All the genotypes, showed significant squared deviations from regression and were recorded in the range of -0.002 (selfed progeny) to 0.1163 (mass selection).

4.9.2.4 Days to maturity : The seven populations recorded a general mean of 81.34 days over all the dates of sowing and the individual population mean ranged from 79.76 days (selfed progeny) to 83.68 days (MSFH-17)

(Table 102). The regressions of individual genotypes on environmental index were recorded in a range of -0.521 (MSFH-17) to 4.301 (selfed progeny) and was significant for selfed progeny only but were non-significant for the rest of the genotypes. However, the deviation of regression from unity was significant for mass selected population. The squared deviations from regression were found to be negative for most of the genotypes and were recorded in a range of -0.462 (mass selection) to 1.13 (selfed progeny) which were no-significant except for selfed progenies.

4.9.2.5 ***100-Seed weight :*** The populations under the study expressed a mean grain weight in a range of 2.70 g (self progeny) to 4.44 g (full sibs) with a general mean test weight of 3.39 g over different dates of sowing (Table 103). The regression coefficients were not significantly different from unity in most of the populations except Morden and full sib the populations whose regressions were found to be significantly deviating from unity. The regression on environmental index of genotypes were ranged form -0.123 (MSFH-17) to 3.07 (full sibs) and was significant for only one population i.e. full sibs. The S^2_{di} values were ranged from -0.003 (Morden) to 0.26 (mass selection) and were significant for all the populations except Morden.

4.9.2.6 ***Seed yield / plot (kg)*** : A general mean seed yield of 5.59 kg per plot was expressed by the populations in the present study over the different dates of sowing and individually the populations recorded a range of 3.20 kg/plot (9.50 g/plant) (selfed progeny) to 9.35 kg/plot (29.6 g/plant) (full sibs) per plot. The regression co-efficients of the population were in the range of 0.34 (bulk sibs) to 1.63 (half sibs) and were found to be non-significant. Similarly, these regression co-efficients did not show significant deviations from unity in all the genotypes. However, the deviation from regression were found significantly different from zero in all the populations. These deviations ranged from 0.58 (MSFH-17) to 9.21 (full sibs).

4.9.2.7 ***Oil per cent :*** A range of 28.16 (MSFH-17) to 37.88 (selfed progenies) oil per cent was recorded by populations with an overall mean of 33.19 oil per cent over the different dates of sowing (Table 105). The regression coefficients of individual population were recorded in a range of -0.402 (half sibs) to 5.183 (selfed progenies) and was highly significant for selfed progenies only. These regressions were found significantly different from unity in three genotypes i.e. half sibs, MSFH-17 and selfed progenies where as they were non-significant in the remaining genotypic populations. The deviations from regression among the populations were ranged from 0.21 (MSFH-17) to 4.748 (bulk sibs) and were significant for all the populations.

4.9.2.8 ***Oil yield :*** The population recorded a general mean oil yield of 5.84 g and the oil yield of individual genotypes ranged from 3.54 g in selfed progenies to 10.06 g in full sibs (Table 107). The individual regressions were observed in a range of -1.091 (selfed progeny) to 3.88 (MSFH-17) and were non-significant. Similarly, the deviation of regression from unity were found to be non-significant for all the genotypes. The mean square deviations from regression were recorded in a range of 0.60 (MSFH-17) to 12.49 (full sibs) and were found significantly from zero in all the populations.

Chapter - V

Discussion

CHAPTER - V

DISCUSSION

Sunflower is one of the world's leading and fast spreading edible oil seed crop. It is a rich source of edible oil and considered as of good quality from health point of view due to high concentration of poly unsaturated fatty acids viz., linoleic acid and oleic acid which are known to reduce the risk of coronary diseases by reducing the cholesterol in blood plasma. The credit of tailoring a branching and ornamental sunflower into an oil bearing mono head type goes to the Russian breeders.

In India, sunflower is grown in an area of 2 m.ha with a production touched to 1.17 m.t (Anonymous, 2000). The major sunflower growing states are Karnataka, Andhra Pradesh, Maharastra and Tamil nadu. In recent years, it has made inroads into newer areas in the states of Bihar, Madya Pradesh, Uttar Pradesh, Haryana and Punjab. It has also proved its potential in newer agro-ecological niches and cropping systems.

The discovery of cytoplasmic male sterility by Leclercq (1966) in France and fertility restoration by Kinman (1970) in USA provided the required break through for heterosis breeding. In this direction, concerted efforts were made and released a number of hybrids. This has resulted inaccessibility of majority of poor farmers of this country for cultivation of hybrids because of its high cost. Not only that, the farmers of this country have a habit of saving the seed of the crop for future sowings. Hence, there is a need to develop number of open pollinated varieties in sunflower to meet the demands of the poor farmers since sunflower is spreading to marginal and sub marginal lands. In this direction, all the breeders working on sunflower crop made sincere efforts to develop open pollinated varieties by adopting several population improvement methods with modifications as applicable to other cross pollinated crops for increased seed and oil yield.

The relative efficiency of selection methods depends on the initial population used, the extent of genetic variability present, characters considered for improvement, the time available at the disposal of breeders and the most important one is the procedure followed. An ideal selection method should bring about not only the desirable genetic improvement but also utilise less time and resources. The most commonly applied intrapopulation improvement methods in sunflower breeding are mass selection, pustovoit method of seed reserves, S_1 selection, half sib and full sib progeny selection and recurrent selection methods. However, less work has been done to compare the relative efficiency of these selection methods in effecting the yield and yield attributes and to suggest suitable strategy for sunflower improvement.

Hence, in the present investigation, the most popular methods viz., mass selection, bulk sib selection, half sib and full sib selection and selfed progeny selection with slight modifications were employed to assess the relative efficiency of these approaches in improving yield and yield attributes in the open pollinated sunflower variety Morden.

The results obtained by imposing various selection schemes on yield and yield attributes in sunflower are attempted for discussion in understanding the most selective approach to be adopted for the development of open pollinated varieties.

5.1 MEAN, RANGE, VARIANCE AND COEFFICIENT OF VARIATION IN THE BASE POPULATION

The success of any population improvement programme mainly depends on the variability available in the base population. Morozov (1944) attributed that the failure to increase yield in sunflower was due to limited variability present in the base material. Whereas Chaudhary and Anand (1987) had noticed that the character exhibiting greater variability like seed yield would produce better genetic advance on selection.

5.1.1 *Plant height (cm)*

In the base population allotted for various selection schemes, wide range of 63.8 to 139.3 cm for plant height was recorded. The base population allotted for S_0 population recorded lowest mean of 80.1 cm and the highest mean of 95.2 cm in HS_0 population. Where as MS_0 recorded the lowest variance (36.0) and coefficient of variation 6.42. The maximum variance of 219.04 in HS_0 an 17.4 coefficient of variation in S_0 were found for plant height (Table 2). This indicated the population Morden chosen for the study had wide variability in the base population for plant height.

5.1.2 *Head diameter (cm)*

Head diameter, over all the base populations, showed wide range values from 9.34 to 25.83 cm. The MS_0 population showed low mean head diameter (13.32 cm) and BS_0 population exhibited highest mean of 17.78 cm. The lowest variance of 2.66 and coefficient of variation 9.35 were found in FS_0 population and the highest variance 10.82 and coefficient of variation 23.07 in S_0 population (Table 3). This indicated appreciable amount of variability was found in the head diameter in the base population allotted for various selection schemes.

5.1.3 *Stem thickness (cm)*

Moderate range values were found for stem thickness form 1.04 to 5.21 cm over all the base populations. However, it has not reflected in the mean and variance values. Where as the base populations of S_0 (27.06 cm) followed by MS_0 (21.80 cm) exhibited maximum co-efficient of variation (Table 4).

5.1.4 *Days to maturity*

The range values for days to maturity was found in S_0 population 78-87. However, not much differences were found in the mean values among the populations. However, FS_0 population recorded maximum variance (47.74) and coefficient of variation (8.10). The rest of the populations did not differ much in mean, variance and co-efficient of variation except FS_0 population (Table 5).

5.1.5 *100-Seed weight (g)*

Over the various base populations wide range values for 100 seed weight ranged form 2.63 to 8.13 (g). The base population of HS_0 recorded low mean of 3.55 (g) and S_0 population 6.17 (g). The variance and co-efficient of variation was maximum in BS_0 population. (Table 6)

5.1.6 *Seed yield / plant (g)*

Seed yield / plant showed maximum range values from 13.93 to 36.72 (g) over all the base population. S_0 population recorded lowest mean seed yield / plant (18.41 (g)) and the highest in HS_0 base population (24.08 (g)). Where as the variance and coefficient of variation were maximum in BS_0 population and the lowest in MS_0 population. (Table 7)

5.1.7 *Oil per cent*

Oil per cent over all the base populations also showed wider range values from 27.63 to 40.42. However, it has not reflected in the mean values. The base population BS_0 recorded high variance (16.89) and coefficient of variation (13.13) followed by HS_0 population and the lowest was in FS_0 base population. (Table 8)

5.1.8 *Oil yield / plant (g)*

Similarly, oil yield / plant over all the base populations exhibited wider range values form 4.34 to 11.23 (g). The highest mean oil yield / plant was found in HS_0 base population (7.82 (g)) followed by BS_0 population (6.93 (g)) and the same trend reflected in the variance and coefficient of variation. (Table 9)

From the fore gone discussion, it is concluded that the attributes like plant height, head diameter, 100 seed weight, oil per cent, oil yield and seed yield / plant exhibited wider variability in the form of range, mean, variance and coefficient of variation where as moderate variability for stem thickness and low for days to maturity were found. Similar results were also reported by Shivakumar, 1995. These results indicated that the population Morden selected for the study had appreciable variability for majority of the traits. Hence, selection of Morden as base population in imposing various selection schemes is justified.

5.2 EFFECT OF VARIOUS POPULATION SCHEMES ON MEAN, VARIANCE, AND COEFFICIENT OF VARIATION OF YIELD AND YIELD ATTRIBUTES

The individual effect of various population schemes on mean, variance and coefficient of variation of yield and yield attributes in different generations / seasons are presented here. The mean, variance and coefficient of variation were taken into consideration in the present discussion.

5.2.1 *Mass selection*

In the MS_1 generation, mass selection has not shown any effect in influencing the mean values of all the characters studied over the base population in the positive direction. However, in the MS_2 generation, there was an improvement in the head diameter, oil per cent, oil yield / plant and seed yield / plant during *kharif* and *rabi* seasons over base population and MS_1 generation population. Whereas increased stem thickness was found in MS_2 rabi population than the base and MS_1 generation (Table 107).

The variance and coefficient of variation values were maximum in MS_1 generation population over the base population in the characters viz., plant height, oil per cent, oil yield and seed yield / plant. Whereas head diameter, stem thickness and days to maturity, in general, showed low variance and coefficient of variation compared to that of the base population. The variance and coefficient of variation in MS_2 generation for almost all the characters were lower than that of MS_1 and also base population except for oil per cent (Table 107).

Based on percentage increase or decrease in the mean performance of yield and yield attributes in MS_2 generation over MS_0 base population, it has been observed that there was an increase of 28.30% (*kharif*) and 32.28% (*rabi*) in the head diameter. Similarly, there was an increase of 20.85% (*kharif*) and 2.5% (*rabi*) in oil per cent, 27.06 (*kharif*) and 16.66% for oil yield and 8.52% (*kharif*) and 22.44% (*rabi*) for seed yield were found in MS_2 population over MS_0 base population. In the other characters, there was negative effect (Table 108). These results indicated mass selection will be

Table 107 : **Effect of mass selection on mean, variance, and coefficient of variation of yield and yield attributes in different generations of sunflower**

S. No.	Characters		Generations				
			MS_0	MS_1	MS_2 (S)	MS_2 (K)	MS_2 (R)
1.	Plant height (cm)	m	93.5	82.5	58.6	79.6	74.0
		v	36.00	112.36	40.96	5.76	3.61
		cv	6.42	12.84	7.9	3.1	2.40
2	Head diameter (cm)	m	13.32	12.18	7.65	17.09	17.62
		v	9.79	4.88	1.56	0.58	1.16
		cv	23.49	18.44	16.39	4.45	6.17
3.	Stem thickness (cm)	m	2.66	2.40	0.76	1.81	3.48
		v	0.34	0.16	158.26	0.05	0.02
		cv	21.80	16.67	16.56	12.38	3.97
4.	Days to maturity	m	87.52	86.41	81.23	81.41	81.20
		v	0.50	0.82	0.41	1.17	0.41
		cv	0.81	1.05	0.89	1.32	0.70
5.	100 Seed weight (g)	m	6.11	6.07	5.23	3.92	3.41
		v	0.46	0.39	0.22	0.03	0.05
		cv	11.13	10.38	9.09	4.82	6.57
6	Oil percent	m	32.85	28.31	27.41	39.70	33.68
		v	7.45	16.97	171.4	4.16	2.62
		cv	8.31	14.55	15.13	5.14	4.82
7	Oil yield / plant (g)	m	6.06	4.21	1.69	7.70	7.07
		v	1.06	1.51	0.10	0.26	0.14
		cv	16.90	29.22	19.08	6.67	5.27
8	Seed yield / plant (g)	m	18.49	15.14	6.23	20.06	22.64
		v	8.91	13.98	0.30	0.35	0.05
		cv	15.68	24.70	8.85	6.67	6.57

m = mean v = variance cv = coefficient of variation

S = *Summer*, 1998-99

K = *Kharif*, 1999

R = *Rabi*, 1999

Table 108 : Percent increase (+) or decrease (-) in the mean performance of yield and yield attributes of the selected populations

Population	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Mass Selection								
MS_1 - MS_0	-11.76	-8.56	-9.77	-1.27	-0.65	-13.82	-30.57	-18.11
MS_2 - MS_1 (S)	-28.96	-37.19	-68.33	-5.99	-13.83	-3.17	4.212	-58.85
MS_2 - MS_1 (K)	-3.52	40.31	-24.58	-5.78	-35.42	40.23	82.89	32.49
MS_2 - MS_1 (R)	-10.30	44.66	45.00	-6.03	-43.82	18.97	67.93	49.53
MS_2 - MS_0 (S)	-37.33	-42.57	-71.43	-7.18	-14.40	-16.56	-72.11	-66.52
MS_2 - MS_0 (K)	-14.86	28.30	-31.95	-6.98	-35.84	20.85	27.06	8.52
MS_2 - MS_0 (R)	-20.86	32.28	30.82	-7.22	-44.18	2.52	16.66	22.44

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999

effective in improving head diameter, oil per cent, oil yield and seed yield / plant over the generations more specifically in *kharif* and *rabi* seasons, though the mean of these attributes improved, the variances were narrowed down in second generation. This might be due to narrow down of genotypic differences among the selected plants.

Where as Shivakumar (1995) reported phenotypic co-efficient of variability was not reduced in MS_2 when compared to MS_1 population. He also reported the *per se* mean for seed yield, oil content and oil yield were lower in MS_2 than MS_1 and this might be due to seasonal differences in which these two generations were raised. In the present study also seasonal effects were observed, where in, the *summer* season mean, variance and coefficient of variation in MS_2 were lower than that of MS_1 generation for almost all yield and yield attributes. Nayak and Patnaik (1979), Nyindu (1981) and Mulamba *et al* (1983) reported adequate variability for yield and yield components of maize even after few cycles of mass selection.

5.2.2 *Bulk sib selection*

In general, in BS_1 population, the mean values for yield and yield attributes were lower than that of base population except days to maturity (87.41), 100 seed weight (5.21) and oil per cent 35.02. Similarly, the mean values of yield and yield attributes in BS_2 populations in different seasons were lower than the BS_1 and BS_0 populations except 100 seed weight and oil per cent (36.71) during *summer* season (Table 109). Similar trend was found when percentage increase or decrease in the mean performance of yield and yield attributes were studied in BS_2 generation over BS_0 base population (Table 110).

The variance and coefficient of variation were higher in BS_1 population over BS_0 population for attributes like head diameter, 100 seed weight, oil per cent, oil yield and seed yield / plant. However, the same trend was not maintained between BS_2 and BS_1 populations. In BS_2 population, the variance and coefficient of variation were low when compared to BS_0 and BS_1 populations. (Table 109)

The low mean, variance and coefficient of variation in BS_2 population when compared to BS_0 and BS_1 populations indicated that bulk sib selection is not effective in improving yield and yield attributes.

5.2.3 *Half sib selection*

Comparatively, in HS_1 population various attributes recorded low mean values than HS_0 base population except 100 seed weight. The mean values of 100 seed weight and oil per cent in HS_2 population were high during *summer*, *kharif* and *rabi* than HS_0 and HS_1 populations. Where as mean

Table 109 : Effect of bulk sib selection on mean, variance and coefficient of variation of yield and yield attributes in different generations of sunflower

S. No.	Characters		Generations				
			BS_0	BS_1	BS_2 (S)	BS_2 (K)	BS_2 (R)
1.	Plant height (cm)	m	90.20	83.00	65.7	80.6	81.30
		v	136.99	114.49	108.16	43.56	4.00
		cv	12.90	12.90	15.9	7.5	2.50
2	Head diameter (cm)	m	17.78	13.00	8.46	15.60	16.78
		v	7.89	10.11	1.02	0.31	0.30
		cv	15.80	24.46	11.99	3.61	3.33
3.	Stem thickness (cm)	m	3.54	2.67	0.83	1.79	2.60
		v	0.30	0.05	0.01	0.15	0.02
		cv	15.53	8.23	11.90	21.89	5.95
4.	Days to maturity	m	85.91	87.41	81.51	81.20	80.91
		v	2.28	2.22	0.92	0.83	0.50
		cv	1.71	1.61	1.12	1.06	0.91
5.	100 Seed weight (g)	m	5.04	5.21	5.80	3.72	3.13
		v	1.53	14.97	0.27	0.21	0.03
		cv	24.60	74.35	9.12	12.36	5.19
6	Oil percent	m	31.28	35.02	36.71	33.44	31.00
		v	16.89	52.27	16.97	0.21	111.94
		cv	13.13	20.66	11.23	3.88	1.84
7	Oil yield / plant (g)	m	6.93	3.83	3.97	5.06	5.48
		v	1.96	1.53	0.17	1.66	0.04
		cv	27.41	32.52	10.72	6.67	3.91
8	Seed yield / plant (g)	m	22.38	11.98	10.89	16.31	18.20
		v	39.94	92.16	0.44	0.09	0.45
		cv	28.23	80.09	6.13	1.91	3.70

m = mean v = variance cv = coefficient of variation

S = *Summer*, 1998-99

K = *Kharif*, 1999

R = *Rabi*, 1999

Table 110 : **Percent increase (+) or decrease (-) in the mean performance of yield and yield attributes of the bulk sib selection**

Population	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Bulk sib selection								
BS_1 - BS_0	-7.98	-26.88	-24.57	1.75	3.37	11.96	-44.73	-46.47
BS_2 - BS_1 (S)	-20.84	-34.92	-68.91	-6.75	11.32	4.83	3.66	-9.09
BS_2 - BS_1 (K)	2.89	20.00	-32.96	-7.10	-28.59	-4.51	32.11	36.14
BS_2 - BS_1 (R)	-2.05	29.07	-2.62	-7.43	-39.92	-11.48	43.08	51.91
BS_2 - BS_0 (S)	-27.16	-52.41	-76.55	-5.12	15.07	17.35	-42.71	51.34
BS_2 - BS_0 (K)	-10.64	-12.26	-49.43	-5.48	-26.19	6.91	-27.10	-27.12
BS_2 - BS_0 (R)	-98.66	17.78	-26.55	-5.82	-37.89	-0.89	-20.92	-18.67

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999

values of oil yield / plant, seed yield / plant and head diameter were higher in HS_2 *kharif* and *rabi* populations than HS_0 and HS_1 populations. The HS_0 population showed higher mean values for plant height and days to maturity than HS_1 and HS_2 populations (Table 111). These results indicated that plant height and days to maturity were not affected by half sib selection.

The variance and co-efficient of variation for plant height, head diameter, oil per cent, oil yield / plant and seed yield / plant were low in all the seasons of HS_2 when compared to HS_0 and HS_1 populations. Where as HS_2 populations in *summer* for stem thickness and oil per cent in *rabi* showed higher coefficient of variation than HS_0 and HS_1 populations.

The percentage increase in the mean values of HS_2 population over HS_0 base population was found in head diameter 7.39% (*kharif*) and 16.59% (*rabi*), 100 seed weight 44.50% (*kharif*) and 27.60% (*rabi*), oil per cent 31.73% (*kharif*) and 26.55% (*rabi*), oil yield 63.5% (*kharif*) and 67.52% (*rabi*) and seed yield 26.95% (*kharif*) and 34.72% (*rabi*) (Table 112).

The results indicated that half sib selection is effective in improving the attributes like 100 seed weight, oil per cent, oil yield, seed yield and head diameter over the generations more specifically in *kharif* and *rabi* seasons. Low variance and coefficient of variation in the HS_2 populations for many

Table 111 : Effect of half sib selection on mean, variance and coefficient of variation of yield and yield attributes in different generations of sunflower

S. No.	Characters		Generations				
			HS_0	HS_1	HS_2 (S)	HS_2 (K)	HS_2 (R)
1.	Plant height (cm)	m	95.2	85.3	60.3	88.7	86.00
		v	219.04	96.04	75.69	21.16	19.36
		cv	15.50	11.49	14.5	5.2	2.50
2	Head diameter (cm)	m	17.72	11.36	8.93	19.03	20.66
		v	8.58	1.29	1.32	0.25	0.33
		cv	16.47	10.04	12.89	2.65	3.33
3.	Stem thickness (cm)	m	3.55	2.97	0.93	2.99	4.36
		v	0.32	0.36	1.10	0.18	0.17
		cv	16.06	20.20	34.19	14.66	5.95
4.	Days to maturity	m	85.81	80.97	83.04	81.43	81.44
		v	1.27	6.45	3.09	0.55	1.08
		cv	1.32	3.14	1.75	0.91	0.99
5.	100 Seed weight (g)	m	3.55	4.40	5.40	5.13	4.53
		v	0.36	2.07	0.15	0.03	0.08
		cv	16.90	35.77	7.39	3.50	5.19
6	Oil percent	m	32.46	30.11	34.43	42.76	41.08
		v	11.16	7.78	9.36	0.96	115.56
		cv	10.28	9.29	8.91	2.31	0.58
7	Oil yield / plant (g)	m	7.82	3.84	4.53	12.79	13.10
		v	3.96	0.41	0.56	0.13	0.16
		cv	25.44	19.86	16.69	2.93	3.10
8	Seed yield / plant (g)	m	24.08	10.81	13.16	30.57	32.44
		v	27.56	3.53	3.53	0.26	0.34
		cv	21.80	17.41	14.34	1.67	0.67

m = mean v = variance cv = coefficient of variation

S = *Summer*, 1998-99

K = *Kharif*, 1999

R = *Rabi*, 1999

Table 112 : **Percent increase (+) or decrease (-) in the mean performance of yield and yield attributes of the selected populations over the base population**

Population	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Half sib selection								
HS_1 - HS_0	-10.39	-34.54	-16.33	-5.64	13.80	-7.24	-50.89	-55.10
HS_2 - HS_1 (S)	-29.30	-21.39	-68.68	2.56	24.75	14.34	17.96	21.74
HS_2 - HS_1 (K)	3.98	67.52	0.67	0.57	26.98	42.01	233.07	182.79
HS_2 - HS_1 (R)	0.82	81.86	44.78	1.23	12.13	36.43	241.14	200.09
HS_2 - HS_0 (S)	-36.65	-49.60	-73.80	-3.22	52.11	6.06	-42.07	-45.34
HS_2 - HS_0 (K)	-6.82	7.39	-15.77	-5.10	44.50	31.73	63.55	26.95
HS_2 - HS_0 (R)	-9.66	16.59	22.81	-5.09	27.60	26.55	67.52	34.72

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999

attributes is expected as selection was exercised for superior progeny lines in HS_1 generation and thus resulted in narrowing down of genotypic differences. Though the variance and coefficient of variation were low, the mean values for various attributes were high because selection was aimed at better progeny lines in HS_1 generation for high oil yield and seed yield / plant. The *kharif* and *rabi* seasons were found to be more favourable for expression of head diameter, 100 seed weight, oil per cent, oil yield and seed yield / plant.

5.2.4 *Full sib selection*

Low mean values were recorded for all the attributes studied in FS_1 population than FS_0 population except plant height. FS_2 populations in *kharif* and *rabi* showed higher mean values for all the attributes than FS_0 and FS_1 populations except days to maturity. (Table 113)

When percentage increase or decrease in the mean values were taken into account, maximum percentage increase of 203.84 (*kharif*) and 198.39 (*rabi*) for oil yield / plant and 108.25% (*kharif*) and 120.02 (*rabi*) for seed yield / plant were found in FS_2 population over FS_0 base population when compared to other attributes (Table 114). The *kharif* and *rabi* seasons were found to be more favourable for full sib selection also.

Table 113 : Effect of full sib selection on mean, variance and coefficient of variation of yield and yield attributes in different generations of sunflower

S. No.	Characters		Generations				
			FS_0	FS_1	FS_2 (S)	FS_2 (K)	FS_2 (R)
1.	Plant height (cm)	m	84.1	87.5	66.4	95.8	92.80
		v	174.24	81.0	193.21	30.25	3.24
		cv	15.7	10.28	20.9	5.70	2.10
2	Head diameter (cm)	m	17.43	9.87	8.90	22.03	21.60
		v	2.66	1.44	3.72	1.37	0.18
		cv	9.35	12.17	21.71	5.33	4.27
3.	Stem thickness (cm)	m	3.24	2.00	0.86	4.39	4.64
		v	0.20	0.07	0.05	0.08	0.02
		cv	13.86	13.26	26.96	6.70	14.24
4.	Days to maturity	m	85.2	81.45	84.00	81.34	80.93
		v	47.74	3.42	2.66	0.55	1.54
		cv	8.10	2.25	1.94	0.91	1.11
5.	100 Seed weight (g)	m	5.11	3.49	6.40	6.57	6.89
		v	0.81	2.92	1.32	0.32	0.06
		cv	17.61	49.00	18.06	8.71	5.58
6	Oil percent	m	32.87	31.01	33.80	47.66	48.36
		v	5.71	6.25	7.95	0.92	0.53
		cv	7.27	8.06	8.35	2.03	1.81
7	Oil yield / plant (g)	m	6.24	3.11	2.84	18.96	18.62
		v	1.93	2.78	0.14	0.29	0.56
		cv	22.27	53.37	1.353	2.86	4.05
8	Seed yield / plant (g)	m	19.08	5.26	8.47	39.85	41.98
		v	16.16	7.89	0.59	0.30	0.01
		cv	21.06	23.42	9.19	1.39	2.13

m = mean v = variance cv = coefficient of variation

S = *Summer*, 1998-99

K = *Kharif*, 1999

R = *Rabi*, 1999

Table 114 : **Percent increase (+) or decrease (-) in the mean performance of yield and yield attributes of the selected populations over the base population**

Population	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Full sib selection								
FS_1 - FS_0	4.04	-43.37	-38.27	-4.41	-31.70	-5.66	-50.16	-72.43
FS_2 - FS_1 (S)	-24.11	-9.83	-57.00	3.13	83.38	8.99	-8.68	61.02
FS_2 - FS_1 (K)	9.48	123.20	119.50	-0.13	88.25	53.69	509.64	657.60
FS_2 - FS_1 (R)	6.05	118.84	132.00	-0.63	97.42	55.94	498.71	698.09
FS_2 - FS_0 (S)	-21.04	-48.94	-73.45	-1.42	25.24	2.82	54.48	-55.60
FS_2 - FS_0 (K)	13.91	26.39	35.49	-4.54	28.57	44.99	203.84	108.85
FS_2 - FS_0 (R)	10.34	23.92	43.20	-5.02	34.83	47.12	198.39	120.02

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999

Where as low variance and coefficient of variation in FS_2 *kharif* and *rabi* populations were observed for almost all the attributes studied. However, in *summer* season the trend was different in FS_2 population where in plant height, head diameter and oil per cent showed high variance and coefficient of variation than FS_1 and FS_0 populations. This might be due to seasonal effect. The superiority of FS_2 population over the previous generations is expected as there was controlled pollination of selected plants as compared to random pollination in mass and half sib selection. Similar type of observations were made by Shivakumar (1995).

5.2.5 *Selfed progeny selection*

S_1 progeny population showed lower mean values for all the attributes studied than the S_0 base population. Similarly, S_2 bulk population in different seasons also showed further reduction in yield and yield attributes over the S_0 and S_1 populations except oil per cent. The variance and coefficient of variation in S_2 population were lower than the S_0 base population for all the attributes. (Table 115)

The percentage increase or decrease in the mean values when taken into account, by S_2 generation, the most affected attributes are oil yield / plant and seed yield / plant. The oil yield / plant decreased by 59.51% (*summer*), 52.45 (*kharif*) and 54.26% (*rabi*). Where as seed yield / plant

Table 115 : Effect of selfed progeny on mean, variance and coefficient of variation of yield and yield attributes in different generations of sunflower

S. No.	Characters		Generations				
			S_0	S_1	S_2 (S)	S_2 (K)	S_2 (R)
1.	Plant height (cm)	m	80.1	84.5	64.2	68.1	71.3
		v	193.21	0.49	94.09	15.84	3.24
		cv	17.40	0.82	15.10	5.60	2.10
2	Head diameter (cm)	m	14.26	9.76	8.04	10.50	10.98
		v	10.82	0.92	2.46	0.16	0.18
		cv	23.07	9.88	19.52	3.88	4.27
3.	Stem thickness (cm)	m	1.96	1.89	0.77	1.40	1.60
		v	0.28	0.06	0.02	0.80	0.02
		cv	27.06	12.72	20.53	20.91	14.24
4.	Days to maturity	m	82.69	81.42	84.32	79.92	80.84
		v	4.04	3.42	0.64	2.19	1.54
		cv	2.43	2.25	0.92	1.72	1.11
5.	100 Seed weight (g)	m	6.17	5.23	4.58	2.48	3.30
		v	1.28	2.10	0.72	0.13	0.06
		cv	18.37	27.80	0.92	14.66	5.58
6	Oil percent	m	33.40	28.52	32.77	40.12	40.72
		v	6.10	23.72	5.57	0.69	0.03
		cv	7.39	17.09	7.21	2.07	1.81
7	Oil yield / plant (g)	m	6.10	3.89	2.47	2.90	2.79
		v	1.61	2.13	0.07	0.03	0.03
		cv	20.81	77.24	11.68	5.54	6.28
8	Seed yield / plant (g)	m	18.41	6.01	7.55	7.49	6.76
		v	13.39	7.56	0.21	0.11	0.25
		cv	19.88	45.70	6.02	4.41	2.13

m = mean v = variance cv = coefficient of variation

S = *Summer*, 1998-99

K = *Kharif*, 1999

R = *Rabi*, 1999

decreased by 58.98% (*summer*), 59.32% (*kharif*) and 63.28% (*rabi*). These results indicated though selection was exercised for oil yield and seed yield, there was depression on selfing except oil per cent. Hence selfing followed by selection may not be effective in improving the attributes in sunflower. It also suggested in cross pollinated crops like sunflower, vigour will be reduced upon selfing (Table 116).

5.3 COMPARATIVE EVALUATION OF POPULATION IMPROVEMENT SCHEMES IN THE SECOND GENERATION SEASONS FOR YIELD AND YIELD ATTRIBUTES

The analysis of variance for yield and yield attributes in the second generation populations in *summer*, *kharif* and *rabi* showed significant differences (Table 32 to 34). The analysis of variance indicated adequate variability among all the populations generated.

The ultimate aim of any plant breeder is the development of superior populations / varieties / hybrids with high mean yield though the variance of the base population is the pre-requisite to exercise selection. Hence, all the second generation populations were laid out in an experiment in different seasons along with the Morden as check variety to compare the efficiency of various selection schemes and seasons in improving mean yield and yield attributes.

Table 116 : **Percent increase (+) or decrease (-) in the mean performance of yield and yield attributes of the selected populations over the base population**

Population	Plant height (cm)	Head diameter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight (g)	Oil percent	Oil yield / plant (g)	Seed yield / plant (g)
Selfed generations								
S_1 - S_0	5.49	-31.55	-3.57	-1.51	-15.23	-14.61	-36.23	-67.35
S_2 - S_1 (S)	-24.02	-17.62	-59.25	3.56	-12.43	14.90	-36.50	25.62
S_2 - S_1 (K)	-19.41	7.99	-25.93	-3.35	-52.58	40.67	-25.44	24.62
S_2 - S_1 (R)	-15.62	12.09	-15.34	-2.23	-36.90	42.78	-28.27	12.48
S_2 - S_0 (S)	-19.85	-43.62	-60.71	1.97	-25.76	-1.89	-59.51	-58.98
S_2 - S_0 (K)	-14.98	-53.04	-28.57	-3.60	-59.80	20.12	-52.45	-59.32
FS_2 - FS_0 (R)	-10.98	-23.13	-18.36	1.21	-46.52	21.92	-54.26	-63.28

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999

5.3.1 *Summer, 1998*

In *summer* season, for plant height, the two populations MS_2 and HS_2 recorded significantly low mean values 58.6 and 60.3 cm when compared to the rest of the populations and also with Morden. Where as for head diameter, all the populations recorded superior mean values than the Morden variety. Not much improvement was found by the imposition of various population schemes in improving stem thickness over the Morden variety except HS_2 population showed superior mean of 0.93 cm. Though significant differences were found for days to maturity but none of the populations recorded numerical superiority over the Morden variety. All the selection schemes were effective in reducing the number of days to reach maturity. FS_2 population recorded the highest mean for 100 seed weight (6.40 (g)) and is significantly superior to the rest of the populations. Almost all the populations showed improvement in oil per cent over Morden except MS_2 population (27.41%). However, BS_2 population recorded the highest oil per cent 36.71% among all the populations studied. Similar type of results were found in oil yield / plant and seed yield / plant where in MS_2 population recorded lowest mean oil yield and seed yield / plant followed by S_2 population. However, HS_2 population recorded highest oil yield and seed yield plant 4.53 (g) and 13.16 (g) followed by BS_2 population 3.97 (g) and 10.89 (g), respectively. From the foregone discussion based on percentage increase over Morden variety, it is concluded during *summer*, half sib selection scheme is more effective in improving the attributes like seed yield, oil yield, stem thickness and head diameter and full sib selection scheme for 100 seed weight and plant height and bulk sib selection for oil per cent. When the fore most important characters like oil per cent, oil yield and seed yield / plant were taken into account, half sib selection followed by bulk sib selection were effective in improving these attributes and the least influence was found by mass selection (Table 117).

5.3.2 *Kharif*, 1999

During *kharif* season, though significant differences were found among populations for plant height and head diameter, FS_2 population recorded highest mean values for both plant height 95.8 cm and head diameter 22.02 cm followed by HS_2 population. The other populations of MS_2, BS_2 and S_2 recorded lower mean values than Morden variety for these characters except BS_2 and S_2 populations for head diameter. Only two populations of FS_2 and HS_2 showed higher mean values for stem thickness 4.39 cm and 2.99 cm respectively and the other populations showed lower mean values when compared to Morden variety (Table 118). Significant differences for days to maturity were found among the populations studied. However, none of the populations recorded more number of days to maturity than Morden variety. All the populations showed significantly superior mean values for 100 seed weight than S_2 population. Only two populations FS_2 (6.57 g) and HS_2

Table 117 : Mean values of various populations for yield and yield attributes during *summer*, 1998-99

S. No.	Character	MS_2	Percent increase over check	BS_2	Percent increase over check	HS_2	Percent increase over check	FS_2	Percent increase over check	S_2	Percent increase over check	Morden check	S.Em
1	Plant height (cm)	58.6	90.15	65.7	101.07	60.3	92.76	66.4	102.15	64.2	98.76	65.00	1.66
2	Head diameter (cm)	7.65	101.59	8.46	112.35	8.93	118.59	8.90	118.19	8.04	106.77	7.53	0.42
3	Stem thickness (cm)	0.76	89.41	0.83	97.64	0.93	109.41	0.86	101.17	0.77	90.58	0.85	0.04
4	Days to maturity	81.23	96.01	81.51	96.34	83.04	98.00	84.00	99.29	84.32	99.66	84.60	1.10
5	100 Seed weight (g)	5.23	138.35	5.80	153.43	5.40	142.85	6.40	169.31	4.58	121.16	3.78	0.09
6	Oil percent	27.41	84.33	36.71	112.95	34.43	105.93	33.80	104.00	32.77	100.83	32.50	1.57
7	Oil yield / plant (g)	1.69	65.00	3.97	152.69	4.53	174.23	2.84	109.23	2.47	95.00	2.60	0.09
8	Seed yield / plant (g)	6.23	83.62	10.89	146.17	13.16	176.64	8.47	113.69	7.55	101.34	7.45	0.48

Table 118 : Mean values of various populations for yield and yield attributes during *kharif*, 1999

S. No.	Character	MS_2	Percent increase over check	BS_2	Percent increase over check	HS_2	Percent increase over check	FS_2	Percent increase over check	S_2	Percent increase over check	Morden check	S.Em
1	Plant height (cm)	79.6	87.76	80.6	88.86	88.7	99.79	95.8	105.62	68.1	75.08	90.7	1.12
2	Head diameter (cm)	17.09	105.49	15.6	96.29	19.03	117.46	22.03	135.98	10.5	64.81	16.2	0.55
3	Stem thickness (cm)	1.81	61.56	1.79	60.88	2.99	101.70	4.39	149.31	1.4	47.61	2.94	0.07
4	Days to maturity	87.41	98.79	81.2	98.54	81.43	98.82	81.34	98.71	79.92	96.99	82.4	0.49
5	100 Seed weight (g)	3.92	108.88	3.72	103.33	5.13	142.50	6.57	182.50	2.48	68.88	3.6	0.29
6	Oil percent	39.7	108.46	33.44	91.36	42.76	116.83	47.66	130.22	40.12	109.62	36.6	0.61
7	Oil yield / plant (g)	7.7	108.75	5.06	71.46	12.79	180.64	18.96	267.79	2.9	40.96	7.08	0.32
8	Seed yield / plant (g)	20.06	89.55	16.31	72.82	30.57	136.47	39.85	177.90	7.49	33.43	22.4	0.59

(5.13 g) showed significantly superior 100 seed weight than Morden variety. For oil per cent and oil yield / plant, FS_2, HS_2 and MS_2 populations showed superior mean performance than Morden variety. The S_2 and BS_2 populations showed lower mean values than the Morden variety. Similar trend was found for seed yield/ plant except MS_2 population which recorded lower mean seed value than Morden variety. From the fore gone discussion, percentage increase over Morden variety is taken into consideration, it is concluded that full sib selection will be more effective in improving the mean values of all the attributes except days to maturity followed by half sib selection. Selfed progeny selection has not made any improvement in influencing the characters over Morden variety. Between mass selection and bulk sib selection, MS_2 population showed superiority over BS_2 population.

5.3.3 *Rabi* 1999

During *rabi* season, though significant differences were observed among populations for plant height and days to maturity, none of the populations recorded higher mean values than Morden variety except BS_2 for plant height. FS_2 and HS_2 populations recorded significantly superior mean values for head diameter, stem thickness, 100 seed height, oil per cent, oil yield and seed yield / plant with few exceptions where in MS_2 population also showed superiority over Morden for certain traits. When the percentage increase over the Morden variety is taken into account, it is concluded that full sib selection followed by half sib selection were more effective in improving the yield attributes in second generation. Mass selection will be better than bulk sib selection and both of them were superior to selfed progeny selection (Table 119).

In general full sib and half sib selection schemes were effective in improving the yield and yield attributes over all the seasons tested than mass selection, bulk sib selection and selfed progeny selection and even over Morden variety. The superior performance of full sib and half sib selection schemes is expected because progeny testing is involved in these schemes where as no progeny test for selection is mass and bulk sib selection schemes. Between full sib and half sibs, full sib selection scheme is more effective because of controlled pollination than half sib selection schemes. Shivakumar (1995) also reported similar results. Funduianu (1977) revealed that half sib family selection was superior to mass and S_1 selections. On the contrary Mukherjee *et al.* (1980) noticed among the progenies of S_1, half sib, and full sib selections, S_1 progenies yielded 94 per cent higher seed yield compared to the source population, where as half sib progenies yielded no gain but, two of the four full sib progenies yielded 5 per cent improvement. Between MS_2 and BS_2, response for BS_2 was good in *summer* season than MS_2, where as in *kharif* and *rabi*, MS_2 showed better performance. Normally it is expected that BS_2 should perform better than MS_2 because of controlled

Table 119 : Mean values of various populations for yield and yield attributes during *rabi*, 1999

S. No.	Character	MS_2	Percent increase over check	BS_2	Percent increase over check	HS_2	Percent increase over check	FS_2	Percent increase over check	S_2	Percent increase over check	Morden check	S.Em
1	Plant height (cm)	74.06	92.50	81.3	101.62	86	107.50	92.8	116.00	71.3	89.12	80	1.33
2	Head diameter (cm)	17.62	111.66	16.78	106.34	20.66	130.92	21.6	136.88	10.98	69.58	15.78	1.06
3	Stem thickness (cm)	3.48	122.53	2.6	91.54	4.36	153.52	4.64	163.38	1.6	56.33	2.84	0.14
4	Days to maturity	81.2	97.59	80.91	97.24	81.44	97.88	80.93	97.27	80.84	97.16	83.2	0.53
5	100 Seed weight (g)	3.41	86.11	3.13	79.04	4.53	114.39	6.89	173.98	3.3	83.33	3.96	0.06
6	Oil percent	33.68	92.02	31	84.69	41.08	112.24	48.36	132.13	40.72	111.25	36.6	1.03
7	Oil yield / plant (g)	7.07	102.46	5.48	79.42	13.1	189.85	18.62	269.85	2.79	40.13	6.9	0.26
8	Seed yield / plant (g)	22.64	103.85	18.2	83.48	32.44	148.80	41.98	192.56	6.76	31.00	21.8	0.43

pollination. But the present results showed in *kharif* and *rabi*, MS_2 performance is better than BS_2 and BS_2 performance better in *summer* season. So it is inferred that the populations of MS_2 and BS_2 were affected by the seasonal conditions. Shivakumar (1995) reported better performance of BS_2 over MS_2 might be due to controlled pollination.

Empig *et al.* (1971) compared the efficiency of various methods of intra and inter population improvement schemes. Differences in the base populations, testers, plant population and differences in selection intensities besides the differences in efficiency of different experimental designs used to reduce the environmental variation and genotype environmental interaction have made comparison of different methods of selection difficult. Sprague and Eberhart (1977) concluded from the results obtained from different intrapopulation improvement methods that although differences in base population (parental material), environments and selection intensities made direct comparison of the relative efficiency difficult but there appeared to be no striking or consistent difference among these different methods.

5.4 GENETIC PARAMETERS

5.4.1 *Genetic parameters in HS_1, FS_1 and S_1 progenies*

The first generation progenies HS_1, FS_1 and S_1 were laid out in separate experiments and analysis of variance was worked out separately. The analysis of variance revealed significant differences for all attributes studied in all the populations of HS_1, FS_1 and S_1 (Table 26 to 28).

Genetic parameters for yield and yield attributes in different populations of HS_1, FS_1 and S_1 were worked out to illicit information on the effectiveness of these schemes (Table 29 to 31).

In HS_1 populations, low GCV and PCV values were observed for plant height, days to maturity and oil per cent, low and medium GCV and PCV values in head diameter, stem thickness, high and high GCV and PCV values for 100 seed weight, oil yield and seed yield / plant, high heritability and moderate genetic advance in plant height, head diameter and oil per cent, high heritability and low genetic advance in days to maturity. From these results it is inferred that the attributes viz., 100-seed weight, oil yield and seed yield/ plant which have shown high heritability and genetic advance can be improved by simple selection as they are largely influenced by additive gene effects.

The FS_1 population also showed high GCV, PCV, heritability and genetic advance for the characters viz., 100 seed weight, oil yield and seed yield / plant thereby indicated additive gene effects and simple selection will improve these characters. The same trend was observed in S_1 populations also. However oil per cent showed high heritability and moderate genetic advance in HS_1 and FS_1 populations. However, in S_1 population high genetic advance was observed.

High heritability estimates in half sib selection were reported for days to maturity, oil content seed yield / plant and head diameter and full sib selection, the high estimates were found in seed yield, oil yield, 100 seed weight, head diameter and oil per cent (Shivakumar 1995). Higher heritability for seed yield was also reported by Srivastava and Mishra (1976), Furedi and Frank (1981), Shinde *et al* (1983), Sen *et al.* (1985), Alam *et al* (1987), Singh *et al* (1989) and Tariq *et al* (1992). On the contrary, Volf and Kasyanenko (1972) and Sivaram (1982) observed for heritability, while Pathak (1975) reported moderate heritability for seed yield. For days to flowering or maturity, higher heritability was reported by Oka and Campos (1974), and Sen *et al* (1985). Shinde *et al* (1983) found that head diameter had high heritability but Oka and Campos (1974) and Venkateswarlu *et al.* (1980) reported low heritability. Studies of Piquemal (1968), Volf and Dumacheva (1973), Srivastava and Mishra (1976) and Singh *et al* (1977) indicated that 100 seed weight was highly heritable. However, Volf and Kasyanenko (1972) reported low heritability for the trait.

Shivakumar (1995) reported that predicted genetic advance expressed as per cent of mean was higher with respect to seed yield, oil yield and 100 seed weight in full sib progenies compared to half sib progenies. However, for oil per cent, plant height, head diameter and days to maturity, the expected gain from half sib progenies was greater than full sib progenies. In the present investigation, it was found that both selection schemes were almost on par with each other with a slight edge of full sib progenies over half sib progenies. When different selection procedures were evaluated in maize with respect to expected genetic advance for seed yield, Sarma and Satyanarayana (1993) found that full sib selection was more effective compared to mass selection, where as Funduianu and Moga (1980) and Khehra *et al* (1985) reported full sib selection to be better than both half sib and mass selection methods. But for oil yield improvement half sib and full sib selections were equally effective (Funduianu and Moga, 1980).

5.4.2 *Genetic parameters over all second generation populations in different seasons*

In order to test significant differences among the various second generation populations viz., MS_2, BS_2, HS_2, FS_2, S_2 and Morden, separate experiments were laid out in *summer*, *kharif* and *rabi* seasons. The data obtained on various yield and yield attributes were subjected to analysis of variance. From the variance values, genetic parameters were worked out and discussed (Table 38). The results indicated that not much differences existed between GCV and PCV values in all yield and yield attributes and also in seasons. This has resulted in getting high heritability estimates for all attributes and also in different seasons except in *rabi* season for days to maturity. Though high heritability estimates were found in all the attributes in all the seasons, the expected genetic advances were low in head diameter, stem thickness, days to maturity and 100 seed weight in all the seasons. This might be due to predominance of epistasis and dominance component. Where as plant height and oil yield / plant in *kharif* and *rabi* showed high heritability and medium genetic advance there by indicating the gene actions will be influenced by environment. High heritability and genetic advance was found in plant height (*summer*) and seed yield (*rabi*) and simple selection will yield good response.

From the fore gone discussion it is concluded that the nature of gene action will be influenced by the type of selection scheme, generation and the environment in which it is grown.

5.5 CHARACTER ASSOCIATION

Correlation coefficients were worked out in different generation populations of various selection schemes in order to study the effect of various populations in different generations on various yield and yield attributes. In the present discussion importance was given to illicit information mainly on the association of yield attributes on seed yield and oil yield / plant rather than among yield attributes association.

5.5.1 *Plant height (cm)*

Plant height did not show any significant positive association with oil yield and seed yield either in the base population nor in different generation populations of various selection schemes / seasons. These results indicated that plant height was not effected by selection schemes / generations / seasons in influencing oil yield and seed yield / plant. Hence, selection based on plant height in improving oil and seed yield may not be worthwhile in sunflower breeding. Shivakumar (1995) reported not-significant association of plant height with seed yield and oil yield in BP_2, MS_2, BS_2 and FS_2 populations except in HS_2 population. Similar type of results were also reported by Caylak and Emiroglu (1984), Chaudhary and Anand (1985), Abdel *et al* (1987), Vanisree *et al* (1988), Cecconi *et al* (1989), Singh and Labana (1990), Khan and Islam (1991), Chaudhary and Anand (1993), Patil (1993) and Gangappa and Virupakshappa (1994). It was also observed the association of plant height with other yield attributes was not consistent either in the population schemes / generations and seasons (Table 120).

Table 120 : Correlations which showed significant positive or negative relationships of plant height with yield and other yield attributes

Generations		Character							
		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0			+	+					
BS_0									
HS_0							+		
FS_0									
S_0									
MS_1									
BS_1									
HS_1					—				
FS_1		+	+			+		+	
S_1									
MS_2	S		+	+					
	K			+	+	+	+		—
	R		+		—				—
BS_2	S								
	K								
	R								
HS_2	S		+						
	K		+						
	R			—	—	+			
FS_2	S		+			+		+	
	K		+						
	R								
S_2	S								
	K		+		—				
	R			+	+				

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999
+ = Significant positive association
– = Significant negative association

5.5.2 *Head diameter (cm)*

The head diameter showed positive significant association with oil yield and seed yield / plant in the base populations allotted of various selection schemes except in MS_0 population. Similar trend was found in the first generation populations of various selection schemes except in S_1 population (Table 121). However in the second generation populations / seasons, the head diameter did not show significant positive association with oil yield and seed yield / plant except MS_2 population in *kharif* with oil yield and FS_2 population in *summer* with oil yield. The weakening of significant positive association of head diameter with oil yield and seed yield / plant in most of the populations of second generation might have resulted due to weakening of strong significant association of head diameter with stem thickness as is evident from the second generation populations of various selection schemes. Burns (1970) reported high correlation between head diameter and seed yield and opined that yield estimations based on head diameter would be reliable compared to direct seed yield measurements especially when there was severe bird damage in the plot. Similar reports of significant positive association between seed yield and head diameter were made by several researchers (Singh and Labana, 1990 ; Khan and Islam, 1991; Chaudhary and Anand, 1993 ; Mogali, 1993 ; Patil, 1993 ; and Gangappa and Virupakshappa, 1994). However Natali and Shaik (1970) reported that the association between seed yield and head diameter was significantly negative.

Table 121 : Correlations which showed significant positive or negative relationships of head diameter with yield and other yield attributes

Generations		Character							
		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0		+		+					
BS_0				+		+	+	+	+
HS_0				+		+		+	+
FS_0				+				+	+
S_0				+				+	+
MS_1				+			+	+	+
BS_1				+				+	+
HS_1				+				+	+
FS_1		+		+		+		+	+
S_1				+					
MS_2	S	+		+					
	K							+	
	R	+							-
BS_2	S			+					
	K								
	R						+		
HS_2	S	+		+					
	K	+							
	R								
FS_2	S			+	+			+	
	K	+		+		+			
	R								
S_2	S			+					
	K	+				+	+		
	R					+			

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999
+ = Significant positive association
- = Significant negative association

5.3.3 *Stem thickness (cm)*

Significant and positive correlation was found between stem thickness and oil yield / seed yield / plant in the base populations and also in the first generation populations derived by various selection schemes (Table 122). In the second generation populations in different seasons such strong relationship disappeared. The conclusions drawn for head diameter are more pertinent here. The significant positive relationship of stem thickness with other attributes in second generation populations of MS_2, BS_2, HS_2, FS_2, and S_2 were not consistent in all the seasons. This indicated that not only population schemes adopted but also seasons will influence the character association. The positive association of stem thickness with oil yield / seed yield / plant was also reported by Pathak and Dixit (1990) and Gangappa and Virupakshappa (1994). Where as Shivakumar (1995) reported negative association.

5.5.4 *Days to maturity*

Very weak association was recorded between days to maturity and oil yield / seed yield / plant either in the base populations nor in different seasons / generation populations of mass selection, bulk sib selection, half sib selection, full sib selection and selfed progeny selection. These results indicated that days to maturity cannot be taken as a criterion of selection for the improvement of oil yield / seed yield / plant (Table 123). Similar observations were made by Shivakumar (1995). Where as significant positive

Table 122 : Correlations which showed significant positive or negative relationships of stem thickness with yield and other yield attributes

Generations		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
		Character							
MS_0		+	+						
BS_0			+			+	+	+	+
HS_0			+			+		+	+
FS_0			+					+	+
S_0			+		+			+	
MS_1			+				+	+	+
BS_1			+		—			+	+
HS_1			+					+	+
FS_1		+	+						
S_1			+						
MS_2	S	+	+						
	K	+			+	+	+	+	
	R								
BS_2	S	+							
	K							+	
	R						+		
HS_2	S	+							
	K								
	R	—			+	—			
FS_2	S	+	+		+		+	+	
	K		+			+			
	R								
S_2	S		+						
	K								+
	R	+							

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999
+ = Significant positive association
- = Significant negative association

Table 123 : Correlations which showed significant positive or negative relationships of days to maturity with yield and other yield attributes

Generations		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0							—		
BS_0									
HS_0									
FS_0									
S_0				+					
MS_1									—
BS_1				—					
HS_1		—							
FS_1									
S_1							+		
MS_2	S								
	K			+					
	R	—							
BS_2	S								+
	K								
	R								
HS_2	S								
	K								
	R	—							
FS_2	S		+	+				+	
	K						+		
	R								
S_2	S					—			
	K	—							
	R	+							

S = *Summer* 1998-99
K = *Kharif* 1999
R = *Rabi* 1999
+ = Significant positive association
- = Significant negative association

association of days to maturity with seed yield / plant was reported by Singh and Labana (1990).

5.5.5 *100 Seed weight (g)*

In the base populations allotted for various selection schemes, it was found that 100 seed weight did not show significant positive association with oil yield / seed yield / plant. However, in BS_1, FS_1 and FS_2 *rabi* populations, 100 seed weight showed significant positive association with oil yield / seed yield / plant (Table 124). Shivakumar (1995) reported significant positive association between 100 seed weight and oil yield / seed yield / plant in MS_2, BS_2 and HS_2 population. The negative association of 100 seed weight with oil yield / seed yield / plant was reported by Tariq *et al* (1992). These results also indicated inconsistancy in the association of 100 seed weight with other attributes in the various populations described by various selection schemes and also in different generations. This might be due to breakage of linkages in the generations or seasonal differences.

5.5.6 *Oil per cent*

Strong significant positive correlation was recorded between oil per cent and oil yield in the base population, and first and second generation populations of various selection schemes and also in different seasons except in S_1 population, BS_2, HS_2 and FS_2 populations in *rabi* season. Whereas in

Table 124 : Correlations which showed significant positive or negative relationships of 100 seed weight with yield and other yield attributes

Generations		Character							
		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0									
BS_0			+	+					
HS_0			+	+					
FS_0									
S_0									
MS_1									
BS_1								+	+
HS_1							+		
FS_1		+						+	+
S_1									
MS_2	S								+
	K	+		+			+	+	
	R							+	
BS_2	S								
	K								
	R							—	
HS_2	S						+		
	K								
	R	+		—					
FS_2	S	+							
	K		+	+			—		
	R							+	+
S_2	S				—				
	K		+				+		
	R		+					+	

S = *Summer* 1998-99

K = *Kharif* 1999

R = *Rabi* 1999

+ = Significant positive association

- = Significant negative association

kharif season in S_2 population, significant negative relationship was recorded. Strong significant positive relationship between oil per cent and seed yield / plant was not observed either in the base population nor in the various generation populations / seasons except in BS_0, BS_1 and S_2 in summer season. These results indicated oil per cent was increased although selection was not practiced for oil per cent *per se*. In consistency of oil per cent with other characters in different populations / generations / seasons indicated that selection based on oil per cent can not be relied on improving plant height, head diameter, stem thickness, days to maturity, 100 seed weight and to some extent seed yield / plant also. (Table 125)

5.5.7 *Oil yield / plant*

Oil yield / plant showed significant positive association with oil per cent and seed yield / plant in all generation populations / seasons except in S_2 in *kharif* and *rabi*, BS_2 in *rabi*, HS_2 in *kharif* and FS_2 in *summer* and *kharif*. Oil yield / plant also showed significant positive association with head diameter and stem thickness in the base populations allotted for various selection schemes except MS_0 population. In MS_1, BS_1, HS_1, MS_2 (*kharif*) and FS_2 (summer), oil yield / plant also showed significant association with head diameter and stem thickness. In the rest of the combinations consistency in the association was not observed. The results indicated that selection in all the populations was mainly based on seed yield and oil yield / plant and

Table 125 : Correlations which showed significant positive or negative relationships of oil percent with yield and other yield attributes

Generations		Character							
		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0					---			+	
BS_0			+	+				+	+
HS_0								+	
FS_0								+	
S_0								+	
MS_1			+	+				+	
BS_1								+	+
HS_1						+		+	
FS_1								+	
S_1					+				
MS_2	S							+	
	K	+		+		+		+	
	R							+	
BS_2	S							+	
	K							+	
	R		+						
HS_2	S					+		+	
	K							+	
	R								
FS_2	S			+				+	
	K				+	—		+	
	R								
S_2	S							+	+
	K		+			+		—	--
	R							+	

S = *Summer* 1998-99

K = *Kharif* 1999

R = *Rabi* 1999

+ = Significant positive association

- = Significant negative association

hence resulted strong association between oil yield and seed yield / plant in the first and second generation populations and also in seasons (Table 126).

5.5.8 *Seed yield / plant (g)*

Seed yield / plant showed strong significant positive association with oil yield / plant in the base populations of various selection schemes and in the first and second generation population and seasons except with few exceptions like MS_2 *kharif* and *rabi*, BS_2 *summer*, HS_2 *kharif* and FS_2 in *summer* and *kharif*. Hence selection for any one trait will improve the other trait. Head diameter and stem thickness also showed significant association with seed yield / plant in all the populations in the initial generations but later associations were weakened (Table 127). This might be due to selection mainly based on yield and seed yield / plant in each generation.

From the foregone discussion it is observed that neither the populations nor generations / seasons have effected plant height, days to maturity and 100 seed weight to influence seed yield and oil yield / plant in positive direction. The head diameter and stem thickness in the initial generations of various populations showed strong association with oil yield and seed yield / plant. Later generations such association weakened because selection in each population / generation was mainly based on oil yield and seed yield / plant without looking for other attributes.

Table 126 : Correlations which showed significant positive or negative relationships of oil yield with yield and other yield attributes

Generations		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
		Character							
MS_0							+		+
BS_0			+	+			+		+
HS_0			+	+			+		+
FS_0			+	+			+		+
S_0			+	+			+		+
MS_1			+	+			+		+
BS_1			+	+		+	+		+
HS_1			+	+			+		+
FS_1		+				+	+		+
S_1									+
MS_2	S						+		+
	K		+	+		+	+		
	R					+	+		
BS_2	S						+		
	K			+			+		+
	R					+			+
HS_2	S						+		+
	K						+		
	R								+
FS_2	S	+	+	+	+		+		
	K						+		
	R					+			+
S_2	S						+		+
	K						—		+
	R						+		+

S = *Summer* 1998-99

K = *Kharif* 1999

R = *Rabi* 1999

\+ = Significant positive association

\- = Significant negative association

Table 127 : Correlations which showed significant positive or negative relationships of seed yield with yield and other yield attributes

Generations		Character							
		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0								+	
BS_0			+	+			+	+	
HS_0			+	+				+	
FS_0			+	+				+	
S_0			+	+				+	
MS_1			+		--			+	
BS_1			+	+		+	+	+	
HS_1			+	+		+		+	
FS_1		+				+		+	
S_1								+	
MS_2	S					—		+	
	K	—							
	R	--	—						
BS_2	S								
	K						+	+	
	R							+	
HS_2	S							+	
	K								
	R							+	
FS_2	S								
	K								
	R						+	+	
S_2	S							+	
	K			+			+	+	
	R						+	+	

S = *Summer* 1998-99

K = *Kharif* 1999

R = *Rabi* 1999

+ = Significant positive association

- = Significant negative association

5.6 PATH ANALYSIS

The direct and indirect effects were estimated in order to find out the effect of various population schemes in influencing yield and yield attributes in different generations and also in season. Much importance was given to discuss direct effects only rather than discussing indirect effects. (Table 128). In the present investigation, it was found that in all the base populations allotted for various selection schemes, oil yield / plant showed very high direct effect on seed yield / plant. However, oil per cent in MS_0 and HS_0 populations showed negative effect on seed yield / plant. Where as other attributes showed negligible direct effects on seed yield / plant. Where as in BS_1 and HS_1 populations very high and in MS_1, FS_1 and S_1 populations high direct effects of oil seed / plant on seed yield / plant were observed. Oil per cent in BS_1 populations showed very high direct effect on seed yield but in MS_1 and HS_1 populations the effects were high and negative.

In the second generation populations, during *summer*, oil yield / plant showed very high direct effect on seed yield / plant in MS_2, BS_2, HS_2 and S_2 and high in FS_2 population. Where as in *kharif* season, high direct effects were recorded in MS_2, HS_2, and S_2 populations and in *rabi* season in BS_2, HS_2 and S_2 populations. These results indicated direct selection of oil yield / plant in *summer* will improve seed yield / plant. However in *kharif* and *rabi* seasons, the effects were weakened. The oil per cent showed very high

Table 128 : Direct effects of yield attributes on seed yield / plant

Generations		Character							
		Plant height (cm)	Head dia-meter (cm)	Stem thickness (cm)	Days to maturity	100 seed weight	Oil per-cent	Oil yield / plant (g)	Seed yield / plant (g)
MS_0		N	N	N	N	N	H—	VH	
BS_0		N	N	L	N	N	H—	VH	
HS_0		N	N	N	N	N	H—	VH	
FS_0		N	L	M	N	N	M	H	
S_0		N	N	N	N	N	M—	VH	
MS_1		N	N	N	N	L	H—	VH	
BS_1		N	L	N	N	N	H—	VH	
HS_1		N	N	N	N	N	H—	VH	
FS_1		N	N	N	N	N	L	VH	
S_1		N	L	N	L	L	N	H	
MS_2	S	N	L	L	N	L	VH—	VH	
	K	M	N	N	L	H—	H	H	
	R	H—	M	N	N	N	L	N	
BS_2	S	N	N	L	N	N	VH—	VH	
	K	N	N	H- -	L	L	H	L	
	R	M	M	H	L	L	L	H	
HS_2	S	N	N	N	N	N	H—	VH	
	K	N	N	H	H--	L	H—	H	
	R	H	M	H--	L	L	L	H	
FS_2	S	L	H	L	H--	N	H	H	
	K	H	H—	M	L	H	H	L	
	R	N	N	N	L	L	N	M	
S_2	S	N	H	H--	L	L	VH—	VH	
	K	L	M	L	N	H—	L	H	
	R	L	L	L	N	H	N	H	

N = Negligible
L = Low
M = Medium
H = High
VH = Very high

negative direct effect on seed yield / plant in MS_2, BS_2 and S_2 populations during *summer* and high positive direct effect during *kharif* in MS_2, BS_2 and FS_2 populations. Whereas in *rabi* season, low or negligible effects were observed. The other attributes like plant height, head diameter, stem thickness, days to maturity and 100 seed weight showed variable direct effects on seed yield / in different populations / generations. From this, it is inferred inconsistency of these attributes in influencing seed yield / plant.

From the foregone discussion, it is concluded that direct selection for oil yield will improve seed yield / plant irrespective of seasons / populations/ generations. The rest of the attributes showed inconsistency in effecting seed yield / plant directly in various populations / generations / seasons.

5.7 GENOTYPE X ENVIRONMENT INTERACTION AND STABILITY ANALYSIS

Genotype x environment interaction continues to be a challenging issue among plant breeders, geneticists and production agronomists who are involved in crop performance trials across diverse environments. Stability of performance is considered as an important aspect of yield trials. Plant breeders have recognised variability among crop varieties and populations across a range of environments. Development of populations with stable performance over a range of environmental conditions would allow a population to be useful and productive in a larger region. Population improvement methods applicable to sunflower includes mass selection, S_1 selection, half sib progeny selection, full sib progeny selection and bulk selections etc. Mass selection was widely used to improve yield and adaptability in the early stages of sunflower breeding. Similarly the two methods viz., selfed progeny selection and half-sib family selections are of particular interest to breeders, since these allows evaluation of the combining ability of individuals in the population. However, the studies on maize crop indicated the superiority of selfed progenies over the other progenies derived through different selection schemes in improvement of yields of populations (Virupakshappa, 1994).

All the improved populations which were derived through various selection schemes are adapted to a different range of environment. In the past the term "stable genotype" often has been used to mean a variety / genotype / hybrid / population that does relatively better over a wide range of environments. In a homeostatic genotype, the component characters shift in a compensating manner in the changing environments in order to give consistent performance of end character. The phenomenon of component compensation in imparting homeostasis to complex character has also been stressed by Griffing (1956).

against pooled error which revealed differential behaviour of populations to varying environments for seed yield and its components except for stem thickness. The populations also differed significantly for their linear response to environmental effects and also for the deviations from the linearity which suggested that both the linear regressions and the deviations from the linearity were the major components for differences in stability for seed yield and its components in these populations.

A comparison of the effect of five locations on performance of populations (Table 91 to 98) indicated that Sirivella centre was superior to Nandyal and Badvel locations for oil yield, oil per cent and early maturity while Nandyal location favoured for 100-grain weight and plant height. On contrary, Badvel centre was found to be superior for seed yield and for late maturity. However, the remaining centres viz., Penukonda and Mundlamothukapalli locations were favoured for head diameter and stem thickness. This indicate that the differences among five locations were not from the cultural operations but from unpredictable sources.

Linear regression represents definite and measurable response to environments (Breeze, 1969). However, the variance due to deviations from linear function which is primarily due to unpredictable causes depends on the environments sampled for testing the material. The influence of unpredictable

A high degree of environmental variability involving growing season of a year or different years or over the different locations influences the performance of populations. To assess the specific combination of these and other environmental effects would require precise field experimental techniques and control (Johnson *et al.* 1968). In the present study environment was treated only in terms of its total effect over different locations in the same year or season and over different dates of sowing in the same location. The progenies derived through different selections i.e. mass selection, bulk selection, half-sib, full-sib, selfed progenies as well as morden variety and MSFH-17 hybrids were enhanced over the five locations as well as over five different dates of sowing representative of late *Rabi* and early *summer* environments.

ANOVA for stability among populations of sunflower over five locations (Table 89) revealed that mean squares due to populations were highly significant for all the characters except for oil yield indicating that each population differed significantly from one another for yield and most of its components thus giving scope for selection. In respect of environments, significant differences were observed for two traits viz., head diameter and 100-seed weight where as for all the remaining characters it was non-significant indicating stability of all the characters across environments. The population x environment interaction was also highly significant when tested irregularities for a particular population may be less in one sample of environment and reverse may the case in another sample of environments. This may be one of the reasons which no definite trend for deviation mean squares could be observed in any population over the environments. On the basis of these results all the three stability parameters seem to be equally important.

The populations which showed stability for different characters were half-sibs, MSFH-17, selfed progenies and Morden for plant height, Morden, half-sibs and full-sibs for days to maturity, full-sibs and selfed progenies for head diameter, bulk sibs and half-sibs for stem thickness, mass selection for 100-seed weight and selfed progenies for seed yield (Table 91 to 98).

The average performance of the populations over five locations revealed that maximum yielding populations i.e. fullsibs and half-sibs for seed yield were least stable. The same populations also revealed superiority for head diameter, stem thickness, and oil yield, however, they were found to be least stable. Characters like head diameter, stem thickness, 100-grain weight and oil yield appear to be greatly affected due to environments, whereas plant height, maturity, seed yield and oil per cent appear to be least affected.

A perusal of performance of genotypes (populations) based on the relative ranking indicated large differences between the populations for mean performance ranging from 77.0 to 82.0 days for maturity and 4.36 kg / plot (16 g / plant) to 10.61 kg / plot (39.2 g / plant) for seed yield per plot. No population appeared to possess the same rank for all the said characters. It is to note that full sibs population expressed the superiority for seed yield, oil yield, stem thickness, head diameter and seed weight but it had late maturity and low oil per cent. On contrary, selfed progenies were dwarf in height, earliest in maturity and ranked first in oil per cent but it had undesirable features with regard to the other characters under consideration. The populations like full sibs, half-sibs and bulk sibs in general, seem to be high performing for most of the yield attributes.

The results of pooled deviation of regression from zero indicated that almost all the population recorded significant deviation from zero for characters except selfed progenies for seed yield, bulk sibs and half sibs for stem thickness, full sibs and selfed progenies for head diameter, half sibs, full sibs, and Morden for maturity, mass selection for 100-seed weight and half sibs, selfed progenies, Morden and MSFH-17 for plant height. Where the later characters showed non-significant deviation from zero for the respective characters.

Eberhart and Russell model (1966) was tried to classify the populations based on stability parameters for low, medium and high yielding environments based on the mean seed yield. The results indicated that half-sibs was found to be suitable for high yielding environment as it had high mean and regression value more than one. On contrary, full sibs and MSFH-17 were found to be suitable for low yielding and stress environments as they have higher mean and regression values were negative or approaching zero. However, in all the above populations the yield is unpredictable owing to their significant deviation form zero (S^2_{di}).

The populations exhibited considerable differences among them for all the characters under the study. The populations, Morden and the hybrid MSFH-17 for plant height, full sibs for head diameter, half sibs and Morden for stem thickness, full sibs for late maturity, selfed progenies for seed yield, bulk sibs, full sibs and self progenies for oil yield showed significant deviation of regression from unity (bi=1). On contrary, none of the populations expressed significant deviation of regression from unity for 100-seed weight indicating the stability of this trait in all the populations.

The analysis of *per se* performance of individual population for all the characters revealed that full sibs recorded the highest mean performance (desirable) for seed yield, oil yield, head diameter, stem thickness and 100-

grain weight and had undesirable trait performance for maturity, oil per cent and plant height. However, its regression co-efficients were negatively lesser than one for seed yield, oil per cent, oil yield and maturity, and were positively more than one for 100-seed weight, head diameter, stem thickness indicating its undesirability from the point of cultivation in large areas part of which could be low or undesirable environments.

The second ranking population half sibs for seed yield had above average performance for head diameter, stem thickness, 100-seed weight, and oil yield but this population suffers from undesirability for plant height, oil per cent and maturity as well as due to its regression above unit value. On contrary, the hybrid MSFH-17 had high mean yield, regression value not exceeding one indicating its desirability for low yielding environments. However, its yield response is of greatly unpredictable in nature due to its significant deviation of regression from zero. However, it had desirable performance per plant height, and maturity. The other genotypes which occupied the bottom rank for seed yield are desirable only for specific characters and in general were least performing for the characters under study.

Estimates of stability parameters for plant height revealed that selfed progenies, and mass selection population were dwarf and selfed progenies were highly negative to favourable environmental changes (bi > 1) whereas mass selection and Morden populations were responsive to unfavourable environments. Populations also exhibited non-significant selfed progenies and Morden mean share deviations thus indicated their good stability under respective environments. Similarly for head diameter and full sibs progenies were suitable for favourable environment and response is predictable in nature. Whereas halfsibs population expressed suitability for favourable environment but response was unpredictable in nature. Similar kind of unpredictable response and adaptation to poor environment. In general all the population was expressed by MSFH-17 hybrid population for head diameter.

Stability of population for stem thickness indicated that half sibs, an bulk sibs were found to be highly adaptable to favourable and poor environments, respectively and were stable whereas full sib population had adaptation to average environment but with unpredictable response as it had significant mean square deviation from zero. The remaining populations though exhibited general adaptation but all of them had reduced stem thickness resulting in weakened progenies. Among all the populations, selfed progenies were earliest in maturity and had adaptation to unfavourable environment with greater stability. Similarly, mass selection population was also early in maturity but it showed highly responsiveness to favourable environment with greater deviations in response to environmental changes.

Contrary to this, MSFH-17 hybrid was latest in maturity and exhibited highly unpredictable response to poor environment. In general, all the populations expressed earliness in maturity when compared to MSFH-17 hybrid population and most of the genotypes had general adaptation to poorer environment with greater stability.

For 100-seed weight full sibs and half sibs showed unstable performance under favourable environment. Whereas mass selected population had stable performance under unfavourable environment. All the remaining genotypic populations had lesser seed weight but with stability for poor environment except MSFH-17 which showed unstable performance and adaptation to favourable environment.

The genotypes exhibited high range of variability in respect of oil per cent being it was highest in selfed progenies followed by morden and full sibs with unstable performance having general adaptation to poor environment. Similar kind of adaptation of genotypes to unfavourable environment with stable performance was expressed with bulk sib population for oil per cent. Hence bulk-sibs could be of greater value in improvement of sunflower genotypes for high oil content.

None of the genotypes expressed stable performance for oil yield. However, only two populations viz., full sibs and half sibs had high oil yield but with unstable performance. Among these, full sibs was highly adapted poor environment whereas half sib population had general adaptation to average environment for this important trait. All the remaining genotypes were found to be oil yields with unstable performance having specific adaptation to either poor or average or favourable environments.

From the foregoing discussion, it is clear that none of the populations were found to be constant in ranking for all the characters under study except full sibs and half sibs which were found to be relatively most desirable for all the characters except maturity and oil per cent. In the present study, it is to conclude that the characters in the populations were highly unstable over environments and recorded a decrease in their performance under different locations. However, certain populations viz., full sibs, half sibs, selfed progenies and bulk sibs expressed stability for specific characters like, head diameter, stem thickness, maturity and plant height and showed increase in the performance of respective characters. Chaudhary (1978) also observed considerable stable performance of characters viz., head diameter, seed yield and 100-seed weight in sunflower genotypes over different environments Similar kind of general adaptation and stability of sunflower varieties was also revealed by Sharma and Chopde (1979), and

Kandalkar (1997). Though similar kind of results have been observed in the present investigation with different populations, it is suggested that selection strategies may be formulated in order to capitalize maximum exploitation of the available variability as well as to generate new variability in the stable populations identified for specific characters viz., full sibs populations for head diameter, mass selection for seed weight, bulk-sibs for oil per cent and stem thickness.

Further multi-location testing of these populations over a range of diverse agro-climatic regions is warranted in order to gather more information on the stability and adaptation of these genotypes.

5.8 STABILITY ANALYSIS OF POPULATIONS OVER DATES OF SOWING

The analysis of variance for stability of populations over different dates of sowing (Table 99-106) revealed that variance due to population x environment (linear) interaction were significant for four characters viz., oil per cent, days to maturity, 100-seed weight and stem thickness when tested against pooled deviation and also were significant for all the remaining characters when tested against pooled error suggesting that all the characters showed differential responses under different dates of sowing. (*Rabi* to early *summer* sowings). The variance due to environments (linear) was highly significant for plant height, head diameter and seed yield. The mean squares for pooled deviation were also found to be significant for all the characters except days to maturity indicating the differences in general adaptation and stability of the characters over the environments. Significant variances due to both genotype x environment (linear) interaction and pooled deviation indicated that both predictable and unpredictable components of genotype (G) x environments (E) interactions were important in the expression of oil per cent, maturity, 100-seed weight and stem thickness while the unpredictable component was found to be predominant for the remaining characters including seed yield. Similar kind of findings were reported in sunflower by Singh and Yadav (1982) and Shinde *et al.* (1992) under different dates of sowing during winter season.

The individual deviation of all the populations were found to be significant for all the characters indicating their unpredictable responses to the changing dates of sowing. However, certain populations showed stability for certain characters. In the present study, all the genotypes except selfed progenies expressed high stability for maturity. Similarly, four populations viz., bulksibs, full sibs, Morden and selfed progenies responses exhibited least changes in dates of sowing for plant height. On contrary, full sibs, selfed progenies and Morden expressed greater stability for head diameter. Morden was also found to be most stable population for 100-seed weight besides head diameter. Thus, prediction of stability and performance of individual genotypes should be made on stability parameters.

The expression of different characters in different environments (dates of sowing) revealed that 2nd January sowing was favourable for seed yield and oil yield but unfavourable for all the remaining characters. However, 16th January sowing was superior for the component characters such as head diameter, maturity and stem thickness but it greatly reduced oil per cent trait in the populations. On contrary, late *Rabi* sowings highly favoured the development traits viz., dwarf height, high seed weight as well as oil per cent with 15th November sowing and tall height with 1 December sowing. It is interesting to note that early *summer* season ie., 2nd and 16th January sowings were highly conducive for high seed yield as well as oil yield than late winter sowings (November and December sowings). Another interesting feature that emerged out from this study is that perfect magnitude and correlation in the trend between mean and environmental index in the expression of the characters.

The mean performance of the populations in each of the environments indicated that full sibs exhibited the highest seed yield, oil yield and head diameter in environment V (16 January sowing) and superiority for stem thickness with 1 December sowing. On contrary, selfed progenies expressed early maturity with 1 December sowing and highest oil per cent with 15 December sowing. Mass selection progenies were the dwarfest in height with 15 November sowing. Whereas full sibs and MSFH-17 expressed maximum height with 1 December sowing. In general, it was found that early *summer* was favourable for seed yield and oil yield whereas late *winter* sowings favoured component characters of yield including developmental traits such as height and maturity. Contrary to these Telli *et al.* (1996) reported the superiority of spring sowings over *summer* sowings for the expression of characters in sunflower.

It is to note that none of the populations expressed superiority for all the characters over different dates of sowing. Full sibs had highest seed yield, seed weight, head diameter as well as oil yield but it had delayed maturity. Similarly, the second ranking high yielding population i.e., half sibs had desirable traits such as oil yield, 100-seed weight, stem thickness, shorter height and head diameter but it was late in maturity and possess low oil per cent. On contrary, selfed progenies ranked first for high oil per cent and shortest height but it was lowest yielder with undesirable performance for all the remaining characters. These progenies could be utilized for the isolation of dwarf genotypes with high oil per cent and further recurrent selection schemes may be advocated for improvement of these genotypes for oil per cent. All the populations also recorded significant deviation from zero in respect of seed yield, oil per cent, oil yield and 100-seed weight and stem thickness, indicating the greater influence of unpredictable component in these characters. On contrary, they exhibited least response due to environments for days to maturity. Similarly instability was expressed for plant height and head diameter by three populations and four populations, respectively. The populations which showed significant deviation from unity regression were, full sibs for head diameter, stem thickness and 100-seed weight; selfed progenies for stem thickness and oil per cent ; mass selection for maturity, half sibs and MSFH-17 for oil per cent and Morden for 100-seed weight suggesting their unstable performance under average environment.

The results discussed sofar clearly indicated that the response of the populations varied in different dates of sowing as evidenced by their environmental standard deviations. Therefore, considering this fact, a stable population is defined as one with a regression co-efficient near 1.0 and deviations from regression approaching zero.

All the genotypes were evaluated based on the above three criteria and full sibs and half sibs populations were found promising for seed yield and oil yield with specific adaptation and for average favourable environments, respectively, but however their responses to dates of sowing are highly unpredictable in nature. Mass selected progenies were found promising for early maturity with stable performance and exhibited specific adaptation to poor environments. On contrary, MSFH-17 hybrid and Morden were found promising stable populations for tall height with least changes over the environments. In respect of head diameter, full sibs, mass selection and half sibs recorded greater head diameter than general mean but only full sibs were found to be stable. Where as mass selection and half sibs were having unstable performance. Among these three populations, full sibs and half sibs exhibited adaptation to favourable environment while mass selection was suitable for poor environment.

For 100 seed weight, full sibs, half sibs and bulk sibs were found as promising populations but all of them had highly unpredictable behaviour over the environments. However, full sibs showed suitability for favourable environment whereas half sibs and bulk sibs were suitable for poor environment. Though selfed progenies had highest oil per cent but it expressed highly unpredictable behaviour and suitability for favourable environment. On contrary, Morden and full sibs also recorded high oil per cent but with unpredictable response and adaptation to average environment.

In general, MSFH-17 hybrid was the tallest and late maturity genotype than rest of the populations and showed slightly unpredictable response and specific adaptations to poor environment. Similarly, selfed progenies and

Morden were the dwarfer and late maturing genotypes, with stable performance and adaptation to poor environments. The results of the present study indicated that most of the populations expressed stability and predictable behaviour in respect of days to maturity and plant height character whereas greater instability and highly unpredictable behaviour for the remaining characters.

The above discussion based on three parameters obviously indicated that the populations were highly responsive to changes in different dates of sowing (late *winter* to early *summer* sowing dates). None of these population was stable for all the characters under study except for developmental traits such as plant height and maturity. Further, most of the populations which were identified as more responsive to each of the individual environment were found unpredictable in their performance across the environments. Similar kind of findings were reported in sunflower varieties by Kandalkar (1997). Hence, different recurrent selection schemes may be practiced and continued in the present material for further one or two generations in order to generate and develop the stable populations for seed yield, oil yield and its components in sunflower. The studies on development and continuous evaluation of different sunflower populations derived through different selection schemes may be advocated over several locations since the present study has been confined to only one location i.e. Nandyal with regarding to dates of sowing. This also enables to obtain additional information on response and stability of populations and could be further utilized for sunflower crop improvement programme. The best populations identified in the present study for specific characters forms valuable source populations for isolation of inbred lines in sunflower or may be utilised in future breeding programme.

Chapter - VI

Summary

CHAPTER - VI

SUMMARY

The present investigation was undertaken at Regional Agricultural Research Station, Nandyal to study the effectiveness of various population improvement schemes in improving yield and yield attributes and also stability of populations / characters over different locations and dates of sowing. The various population improvement schemes applied on Morden open pollinated variety were mass selection, bulk sib selection, half sib, full sib and selfed progeny selection.

The Morden base population alloted for various selection schemes revealed that the attributes like plant height, head diameter, 100-seed weight, oil percent, oil yield and seed yield exhibited wider variability in the form of range, mean, variance and co-efficient of variation where as moderate variability for stem thickness and low for days to maturity.

When individual schemes effects were considered based on percentage increase or decrease in the mean performance of yield and yield attributes, it was observed in MS_2 generation over that of MS_0 generation as in case of head diameter in *kharif* and *rabi*. Similarly in oil percent and seed yield / plant in both *kharif* and *rabi* seasons. In the other characters, there was negative variation decreased as the generations advanced in MS_2 generation.

In BS_1 generation populations, the mean values for yield and yield attributes were lower than that of BS_0 population except days to maturity, 100-seed weight and oil percent. Similarly the mean values of BS_2 population in different seasons were lower than BS_1 and BS_0 populations except 100-seed weight and oil percent during *summer*. The variance and co-efficient of variation narrowed down when it comes to BS_2 generation.

Half sib selection scheme has shown an effect in improving the attributes like head diameter, 100-seed weight, oil percent, oil yield and seed yield in both *kharif* and *rabi* by HS_2 selection, oil yield / plant and seed yield / plant were improved by FS_2 generation. The variances in both half sib and full sib families were reduced as the generations advanced.

In selfed progeny selection, the most affected yield attributes by S_2 generation were oil yield and seed yield / plant. The extent of reduction was ranged form 52.45% (*kharif*) to 59.5% (*summer*) for oil yield / plant where as for seed yield it was 59.98% (*summer*) to 63.28% (*rabi*).

The comparative evaluation of various selection methods were taken into account, the full sib and half sib selection methods were the most effective methods in improving yield and yield attributes over all the seasons when compared to mass selection, bulk sib selection and selfed progeny selection.

All the populations expressed greater unpredictable behaviour and instability for all the characters across the different locations. However, the stability of characters observed in the populations were, selfed progenies for seed yield, head diameter and plant height, bulksibs and halfsibs for oil per cent, stem thickness and maturity, full sibs for head diameter and maturity and mass selection for 100-seed weight. In contrast to these, oil yield, oil per cent, 100-seed weight and seed yield were greatly affected by changes in locations.

Full sibs for poor environment, half sibs and MSFH-17 for average environment and selfed progenies for favourable environment were found suitable. None of these populations were stable in performance for all the characters.

Similarly the genotype and environments (dates of sowing) revealed both predictable and unpredictable components of populations x dates of sowing interaction were important in the expression of oil per cent, maturity, 100-seed weight and stem thickness while the unpredictable component was predominant for all the remaining characters.

The populations were highly responsive to changes in different dates of sowing. None of the populations were stable across the seasons for the characters under study. However, the populations expressed stability for certain characters over different dates of sowings, (late *winter* to early summer) were, selfed progenies for early maturity, and head diameter, The genetic parameters for yield and yield attributes were worked out in HS_1, FS_1 and S_1 generation progenies. These results indicated that in HS_1 generation, the attributes like 100-seed weight, oil yield and seed yield / plant have shown high heritability and genetic advance. So ample scope for further improvement for these characters by simple selection. Similar observations were made in FS_1 and S_1 generation populations also.

The genetic parameters were also worked out in the second generation over all populations of various selection schemes. The results indicated not much of the differences existed between GCV and PCV values of all yield and yield attributes in all the seasons and hence resulted in recording high heritability estimates. However, the expected genetic advance values were low in head diameter, stem thickness, days to maturity and 100-seed weight in all the seasons. High heritability and genetic advance were found in plant height and seed yield and hence simple selection may improve the characters.

The character association studies revealed that neither various population improvement schemes nor generations of the schemes have any effect of plant height, days to maturity and 100-seed weight to influence seed yield and oil yield / plant. The head diameter and stem thickness in the initial generations of various selection schemes showed strong association with oil yield and seed yield / plant. However, later such associations were weakened.

The oil yield / plant showed strong positive significant association with seed yield / plant in almost all the generation populations.

The results of path analysis revealed that oil yield / plant showed maximum direct effect in seed yield / plant irrespective of seasons / populations / generations. The rest of the attributes showed inconsistancy in effecting seed yield / plant directly in various populations / generations / seasons.

The study on genotype and environmental (locations) revealed significant differences among the populations for all the traits except for oil yield. The linear component of G x E was predominant for oil percent whereas non-linear component was predominant for all the remaining characters.

Penukonda and Badvel locations were found to be superior environments for seed yield, head diameter and stem thickness. Similarly, Sirivella location was found to be superior for early maturity, high oil yield and oil per cent whereas Nandyal location was favourable for plant height and 100-seed weight.

Morden for maturity, plant height, 100-seed weight and head diameter, bulk sibs and full sibs for plant height and head diameter.

Early *summer* season (2 and 16 January) sowings were highly favourable for seed yield, and oil yield characters, whereas late *winter* season (November and December) sowings were favourable for dwarf height, 100-seed weight and oil per cent as well as for other components of seed yield.

Full sibs population expressed superiority for seed yield, 100-seed weight, head diameter and oil yield where as selfed progenies were superior for highest oil per cent and shortest plant height across different dates of sowing.

Full sibs and half sibs were found promising for seed yield and oil yield for cultivation under average environment. Whereas mass selected progenies for maturity and selfed progenies for oil per cent were promising under poor environment.

The testing of the present populations in multi-environments over locations and seasons in a bigway is suggested in order to assess the stability and behaviour of populations.

Plate:1 Base Population allotted for mass selection (MS_0)

Plate:2 MS_1 Generation

Plate : 3 MS_2 Generation

Plate : 4 Base population allotted for bulksib selection (BS_0)

Plate : 5 BS_1 Generation

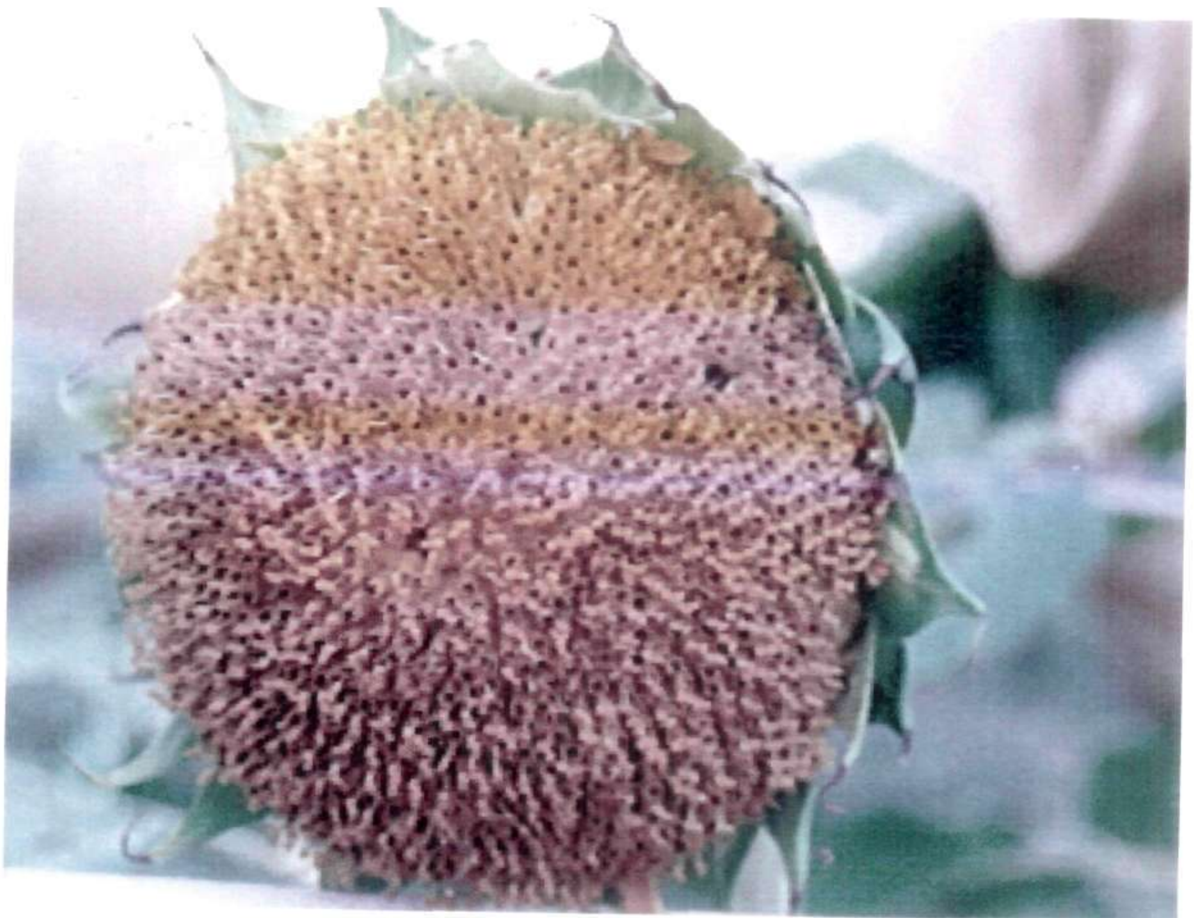


Plate : 6 BS_2 Generation

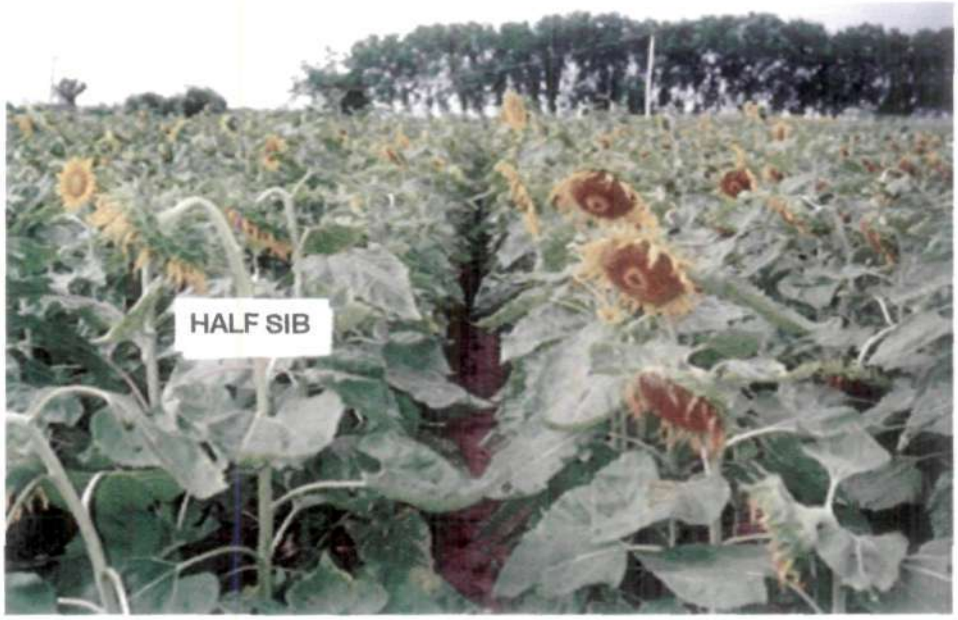


Plate : 7 Base Population allotted for half Sib selection

Plate : 8 HS_1 Generation

Plate : 9 HS_2 Generation

Plate : 10 Base Population allotted for full sib selection (FS_0)

Plate : 11 FS_1 Generation

Plate : 12 FS_2 Generation

Plate : 13 Base Population alloted for selfed progeny (S_0)

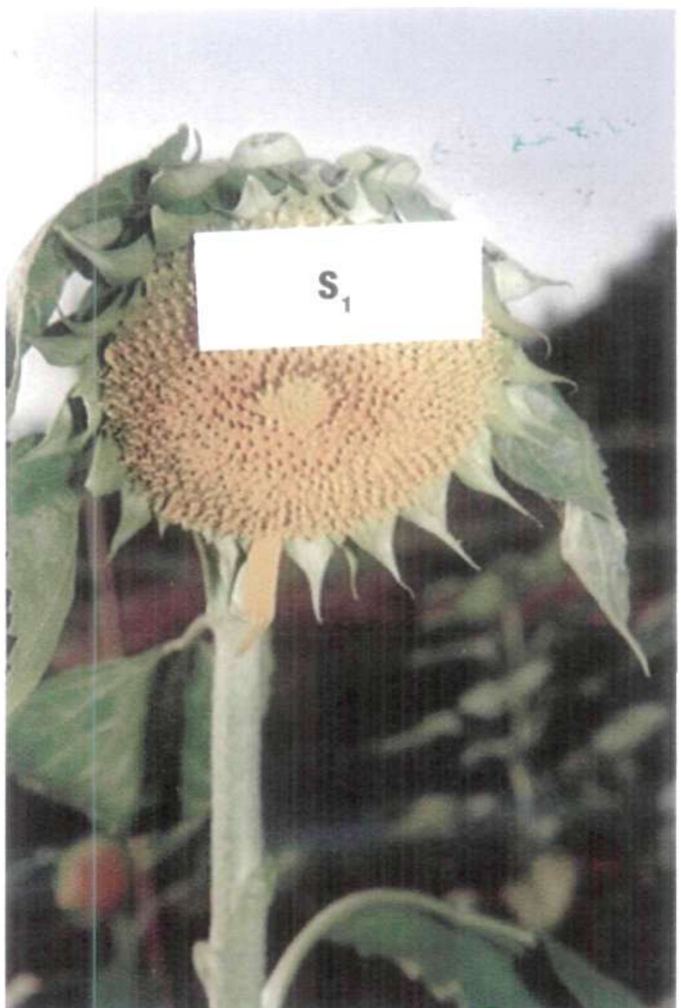


Plate : 14 S_1 Generation

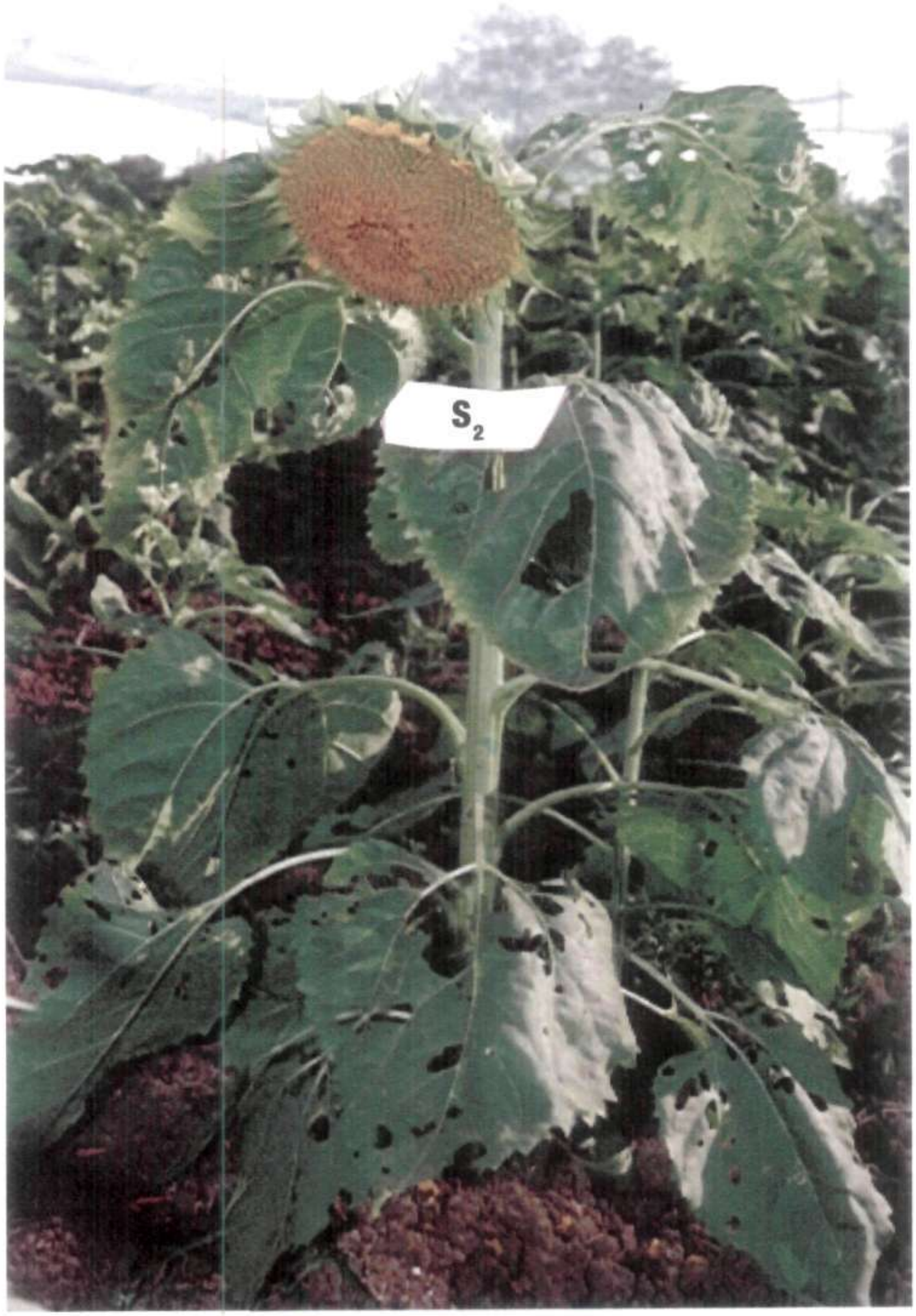


Plate : 15 S_2 generation

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