EFFECT OF POLLEN BLEND ON SEED YIELD AND QUALITY OF SUNFLOWER (*Helianthus annuus L.*)

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CERTIFICATE

Miss. SAMEENA SULTANA has satisfactorily prosecuted the course of research and that the thesis entitled **"EFFECT OF POLLEN BLEND ON SEED YIELD AND QUALITY OF 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 thereof has not been previously submitted by her for a degree of any University.

16/6/04

Date : 16/6/04
Place : Hyderabad

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Major Advisor

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF POLLEN BLEND ON SEED YIELD AND QUALITY OF SUNFLOWER (*Helianthus annuus* L.)**" submitted in partial fulfilment of the requirements for the degree of "**MASTER OF SCIENCE IN AGRICULTURE**" of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Ms. SAMEENA SULTANA** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

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

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Sameena Sultana

DATE: 16|6|04 **(SAMEENA SULTANA)**

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DECLARATION

I, Miss. **SAMEENA SULTANA** here by declare that the thesis entitled **"EFFECT OF POLLEN BLEND ON SEED YIELD AND QUALITY OF SUNFLOWER** (***Helianthus annuus*** **L.)** submitted to Acharya N.G.Ranga Agricultural University for the Degree of **MASTER OF SCIENCE IN AGRICULTURE** is a result of original research work done by me. It is further declared that the thesis or any part there of has not been published earlier in any manner.

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LIST OF ABBREVIATIONS

CD	:	critical difference
DOR	:	Directorate of Oil seeds Research
et al.	:	and others
Fig	:	figure
g	:	grams
i.e.,	:	which is to say, in other words
K/H ratio	:	Kernel to Hull ratio
m	:	milligram
m ha	:	million hectares
mm	:	millimetre
mt	:	million tonnes
No.	:	number
NS	:	non significant
Sem	:	Standard error of mean
SVI	:	Seedling vigour index
%	:	Percentage

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ABSTRACT

The present study comprising of nine sunflower genotypes (four hybrids, three inbreds and two open pollinated varieties) were sown in a randomized block design replicated thrice at College Farm, ANGRAU, Hyderabad during *rabi*, 2002 to study the effect of autogamy, gietenogamy, open pollination and pollen blend on seed yield and other component traits of sunflower.

Analysis of variance revealed that, significant variation existed for different pollination treatments, genotypes and their interactions for various characters studied. Among the treatments, pollen blend treatment was regarded as the best treatment, due to its enhanced seed setting rate and higher number of filled seeds per capitulum and recorded higher accumulation of oil due to metaxenia effect. Competition among developing achenes for nutrients lead to production of thin hulled seeds with higher kernel to hull ratio, thereby recorded high kernel proportion in achene. Higher seedling vigour index was recorded by the heterozygous and heterogenous seedlings

of pollen blend and open pollination treatments. On the other hand, pollen blend recorded reduced test weight, volume weight, hull weight and kernel weight due to competition among developing achenes. Autogamy studies revealed that hybrids recorded higher autogamy and self compatibility followed by inbreds and open pollinated varieties.

The correlation studies revealed that total number of seeds per capitulum, number of filled seeds, seed setting percent, oil content and kernel to hull ratio recorded significant positive association with seed yield. Oil content showed significant, negative correlation with test weight and hull content. From the present study it can be concluded that the need of the hour is to develop synthetics, varietal mixtures and blends, which can yield on par with hybrids.

INTRODUCTION

CHAPTER I

INTRODUCTION

India is one of the major oil producing countries in the world with an area of 26.48 million hectares and production of 18.7 million tonnes (Anonymous, 2002). The stagnated oilseed production in the country during 1985-86 (10.8 mt) raised to a rapid growth of 5.7 mt in 1999-2000. This jump in the production was popularly referred to as yellow revolution (Hedge, 2000). Among oilseed crops grown sunflower occupies about 7 to 8 per cent of total oilseeds cultivated in India. In India sunflower crop is grown in an area of 1.27 m ha with a production of 0.77 mt and productivity of 606 kg ha^{-1} compared to world's average of 1216 kg ha^{-1}.

The present day per capita availability of oil in India is 12.40 kg $year^{-1}$ as against world's average consumption of 17.80 kg $year^{-1}$ (Anonymous, 2002). Considering this, sunflower with its versatile nature is expected to play a significant role in the oilseed industry of the country by exploiting the genetic potential of crop on the farmers field, as presently less than 30-50 per cent of the proven genetic potential of the crop has been exploited (Reddy, 1995).

Sunflower was introduced in India from Russia during 1969, however, large scale cultivation started in 1972 with two Russian varieties viz., Armavirsky (EC-68413) and Peredovick (EC-68414). The introduced genotypes faced the problem of self-incompatibility there by seed setting was drastically reduced. Photo-insensitivity of the crop has given the advantage of its cultivation throughout the year. Owing to the highly cross fertilized nature and self-incompatibility encountered in sunflower, quality seed production with uniform recovery of seeds with good filling and high density becomes a problem, thus causing a steep decrease in the farm productivity. One of the means to alleviate this problem is by identifying self-fertile lines and thus increasing seed set and productivity. Further, research indicates that hybrid mixtures or blends can overcome the problem of poor seed set due to self-incompatibility. Besides, there is a need to develop appropriate synthetics and composite varieties, since they have high buffering action due to their heterozygous and heterogeneous nature (Seetharam and Virupakshappa, 1994).

Apart from this, there are evidences that oil content, test weight and hull content of the seed is considerably influenced by the pollen parent that takes part in fertilization due to metaxenia effect. In such situations the foreign pollen influence can play a significant role in breaking the barriers of self-incompatibility. But there is no concerted effort in this direction. Hence, there is a need to establish metaxenia effect in sunflower and exploit it for increasing seed and oil yields.

Keeping in view the above factors, the present investigation is undertaken with the following objectives:

1.To find out the effect of pollen blend on seed yield in inbreds, varieties and hybrids.

2.To know metaxenia effect on seed weight and oil content.

3.To estimate the seed set per cent under autogamy, geitenogamy, open pollination and pollen blend.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

A brief review of the work done earlier by different research workers on sunflower and other crops with reference to varietal / hybrid mixtures, multilines, synthetics and the immediate effect of foreign pollen on maternal tissues, xenia, metaxenia, autogamy and seed characteristics is presented briefly hereunder.

2.1 AUTOGAMY, SELF FERTILITY, TEST WEIGHT, OIL CONTENT AND HULL CONTENT

2.1.1 Autogamy and self -fertility

Autogamy means pollen grains of a flower pollinate the stigma of the same flower, without intervention of foreign pollen. The problem of poor seed set and filling in the capitulum is one of the major constraints limiting crop productivity and profitability in sunflower. It is a complex phenomenon influenced by genotypic and environmental factors. Sunflower is a cross pollinated crop with self -incompatibility and protandrous nature which requires insect vectors for effective pollination.

Khanna (1972) ascribed the problem of poor seed set in sunflower to causes like inefficient pollination vectors, insufficient nutrient supply to the developing seeds and competition among developing seeds besides self-incompatibility, which is highly prevalent in sunflower.

Asthana (1973) suggested that sunflower is marginally self-sterile, and application of foreign pollen reduces this effect while protandry, protogyny and central floret sterility affect seed setting. It is further reported that open pollination in sunflower variety VNIMK (EC-68413) resulted in 73.4 per cent seed set, while pollination with mixtures of sunflower and castor pollen resulted in 40.2 per cent and 36.8 per cent seed set which was more than the seed set in selfing.

Harinarayana *et al.* (1976) observed that seed set per cent in self - incompatible, self-compatible and hybrid types of sunflower ranged from 0 to 9 per cent with mean of 5.6 per cent, 25 to 56 per cent with mean of 46.3 per cent and 26 to 65 percent with mean of 48.2 percent respectively.

Radford and Rhodes (1978) investigated the honey bee visitations and competition between developing seed in bagged and open pollinated heads in sunflower The per cent seed set under bagged condition was observed to be 10.7 per cent, and in open pollination the mean seed set was 100 per cent even under alteration of the distance of beehives.

Fick (1978) and Leclereq (1980) reported in sunflower, that varieties with 100 per cent fertility and observed increased seed set under bagged condition i.e., bagging does not reduce seed yield.

Segala *et al.* (1980a) evaluated three varieties, 39 lines and 30 hybrids of sunflower for per cent seed set under assisted selfing, natural selfing and open pollination. Higher autogamy was recorded for hybrids followed by inbred lines and open pollinated varieties. Segala *et al.* (1980b) attributed higher seed set per cent in hybrids due to abundant pollen production than lines and high *in vitro* rate of germination in hybrid pollen.

George (1982) reported that fully self-compatible types of sunflower were stable across environments, while investigating self-compatibility and autogamy in hybrids and their parents.

Rotaru (1983) studied 20 highly autogamous inbred lines of sunflower, subjecting them to three different systems of selfing viz., natural, single artificial and multiple artificial pollination. In all the lines artificial pollination enhanced the seed set compared to natural pollination. Within artificial systems, highest achene set was recorded with single than with multiple pollination. It is further suggested that multiple pollination by artificial means damages the developing florets.

Leclereq and Mandeuf (1984) reported that the sunflower cultivar Misasol, recorded highest yield in the absence of bees due to its high geitenogamy.

Birch *et al.* (1984) evaluated the effect of self pollination in 21 cultivars of sunflower and reported that upto 83 per cent autogamy exists among the genotypes.

Low and Pistillo (1986) studied self-fertility in 23 hybrids of sunflower and reported that two of them recorded higher yield without any activity of honey bees. Out of the 23 hybrids, three of them were proved to be self fertile in terms of seed yield due to artifact effects i.e., artifact ratio of between 1.25 and 1.30. The artifact ratio exceeding 1.0 would indicate positive artifact effect. The artifact ratio was calculated for individual cultivar by dividing the per cent self-fertility in terms of seed weight or yield by per cent self-fertility in terms of seed number.

Shivaraju *et al.* (1987) analysed sunflower populations, hybrids and inbreds for autogamy. Highest mean autogamy per cent was observed for hybrids (52.4 %) followed by inbred lines (45.70 %) and open pollinated varieties (7.09 %).

Freund (1988) evaluated 5 sunflower genotypes under different pollination treatments i.e., self pollination, sib pollination and open pollination. Open pollination and sib pollination treatments recorded high seed set, seed oil content and oil yield, while self pollination produced lower seed set with greater 100-seed weight.

Chaudhary and Anand (1989) studied seasonal influence on autogamy, in sunflower. Autogamy or selfing yielded high seed set in spring followed by winter and rainy season. Under open pollination winter season was most favourable for seed set followed by spring and rainy season.

Gowda and Giriraj (1989) studied hybrids, inbreds and open pollinated varieties for self-compatibility over seasons and reported high seed set, autogamy, and self-compatability during summer as compared to monsoon. Among the cultivars, hybrids were more self-compatible than inbreds and varietal populations.

Javed and Mehdi (1992) studied sunflower cultivars for autogamy and self-incompatibility under six pollination treatments. They reported that NK-262 and NK-281 were self-compatible whereas, Sundak was self-incompatible. The reduced seed set or self-incompatibility in Sundak cultivar was attributed to inability of self pollen to reach and germinate on the stigmatic surface. Autogamy of NK-281 was higher under cross pollination. (Pollen from unrelated sunflower genotypes was collected mixed and applied on alternate days during flowering). This treatment causes the stigmatic surface to become compatible to its own pollen resulting in high seed set.

In general sunflower hybrids are highly self-compatible, followed by inbreds and open pollinated varieties (Kurnik and Zelles, 1962; Robinson, 1980; Fick, 1983; Petrov and Siskov, 1985; Burlov and Kruto, 1986; Virupakshappa *et al.*, 1992 and

Seetharam and Virupakshappa, 1994). Skaloud and Kovacik (1994) evaluated different lines of sunflower with variable degrees of self-compatibility under autogamy, geitenogamy and open pollination. Their results revealed that a hybrid produced by crossing two lines with high self-compatibility will give high achene set even under unfavourable conditions.

Narsaiah (1995) studied seventy sunflower genotypes for autogamy and revealed that hybrids recorded greater autogamy and geitenogamy per cent followed by inbreds. The data showed that hybrids exhibited greater head diameter, number of seeds, test weight, oil per cent and yield per plant compared to inbreds and open pollinated varieties.

Kamaljeet *et al.* (1986) studied fifteen lines including eleven restorers and four CMS lines and their resulting forty four crosses for autogamy. The results revealed a higher per cent of autogamy in hybrids (66.36%) than their parents (60.2 %).

Doddamani *et al.* (1997) evaluated 47 sunflower genotypes comprising of experimental hybrids, inbreds and populations for self-compatibility during *kharif* and summer seasons. The results indicated, the inbred lines to be more self-compatible than hybrids and varietal populations. Among the genotypes studied, KBSH-1 among hybrids, IV 83 (NB) among inbred lines and Morden among varietal populations were proved to be more self-compatible than others.

Rao (1999) studied 77 genetic stocks, 4 hybrids and one open pollinated variety for autogamy. Results obtained revealed a higher per cent of autogamy and geitanogamy among hybrids (61.99 %, 72.88 %) respectively followed by inbreds (60.68 %, 70.86 %) and open pollinated variety (35.95 %, 50.73 %) respectively.

Goud and Giriraj (1999) studied competitive ability of pollen parents involving ten restorers, three maintainers and thirty hybrids at gametophytic and sporophytic levels. The results indicated that identification of competitive pollen parents at the gametophytic level and its utilization in developing pollen mixture hybrids in lieu of hybrid mixtures is of practical significance in getting higher yields in sunflower.

Singh *et al.* (2001) studied the influence of honeybee visitations on various sterile male rows and connoted that, a higher total hybrid seed yield per capitulum was recorded from the sterile male rows in proximity (upto 5th rows) to the male parent. The number of unfilled seeds per capitulum produced from such rows were also higher and were inferior in pollen efficiency index, number of filled seeds and 100 seed weight significantly to that of the seeds harvested from farther rows (6th, 7th and 8th rows).

2.1.2 Test weight, oil content and hull content

Robinson (1980) recorded a higher test weight of achenes under bagged condition than in open pollination. This may be attributed to the greater transfer of nutrients to the fertilized florets since bagged condition results in less number of fertilized florets per capitulum.

Dedio (1982) analysed the hull and oil content of 35 sunflower hybrids and seven inbred lines. Hull content ranged from 21.6 to 28.2 per cent. The oil content in per cent from kernel and from whole seed varied from 59.8 to 64.6 and 42.5 to 50.3 respectively.

Mandal and Singh (1993) studied 124 accessions of sunflower consisting of cultivars and hybrids of diverse origin for oil and protein content. The oil content varied from 29.33 to 44.19 per cent and 46.19 to 57.25 per cent in whole seed and kernel respectively. The hull per cent and test weight ranged from 21.60 to 39.23 and 3.79 to 9.98 g respectively. They concluded that a sharp increase in oil content could probably be achieved through selection for thin hull types, higher seed weight and high oil per cent in kernel.

Nanja Reddy *et al.* (1996) evaluated 22 germplasm lines for kernel proportion in the hull. When two genotypes with same seed yield were analysed, the one with superior kernel to hull ratio recorded higher kernel yield.

Rao (1999) reported superiority in oil per cent ranging from open pollination, geitanogamy and autogamy. These studies are in conformity with earlier studies of Tuberosa (1983) and Narsaiah (1995).

Ganapati *et al.* (1997) evaluated the frequency of hand pollination on seed quality of KBSH-1 hybrid and its parents. the results revealed that hand pollination carried out at 3, 5, 7 and 9 days after flowering recorded higher values for kernel to husk ratio, hundred achene weight and vigour index than seeds produced via natural pollination.

2.2 XENIA, METAXENIA AND IMMEDIATE EFFECT OF POLLEN

Xenia is the immediate effect of pollen on the endosperm of the seed parent which is a resultant of double fertilization (fusion of one of the sperm with egg and another sperm with polar nuclei) (Soule, 1985). Whereas metaxenia is the direct effect of pollen on the seed and fruit other than embryo and endosperm (Winburne, 1962).

1962). The term metaxenia was coined by Swingle in 1926. Denny (1992) revealed xenia effects include quantitative changes (size) and qualitative changes (colour, shape, sugar content, oil content and time of maturity).

2.2.1 Xenia

Schreiner and Duffield (1942) observed in oaks that self pollination produced heavier seeds than others. Crane and Brown (1942) reported that in interspecific pollinations in plums, different pollinations resulted in differences in time of maturity and in the size of the fruits.

2.2.2 Metaxenia

Vagvolgyi and Gaal (1987) reported occurence of metaxenia in sunflower. They observed that when cytoplasmically male sterile line, HA 89 was subjected to pollination by 5 single cross hybrids and one varietal population. Significant differences in F_1 seed oil content and 1000-seed weight were recorded between different pollinators. Further tests are recommended to determine whether yield components of hybrids grown in proximity are influenced by xenia effects from foreign pollen.

2.2.3 Immediate effect of pollen

Seetharam *et al.* (1976) reported that in sunflower, the type of pollen involved in pollination influence the seed characters particularly the seed weight, kernel weight and oil content. They further observed that, when pollen from RHA 274 was used, depressed the hundred seed weight, as compared to that of RHA 266 pollen. Similarly crossed seed had a higher kernel and oil content than seed in the parent. When RHA

266 used as a pollen parent a slight increase in oil content was observed, owing to its high oil content of 48.55 per cent.

Burton *et al.* (1980) reported that in Pearlmillet, that pollen source affected three of the grain characteristics measured viz., thousand kernel weight, amino nitrogen/ proline ratio and dye banding.

Kini and Seetharam (1994) indicated that F_0 values can serve as a base for detection of achene character of sunflower hybrids. The F_0 (hybrid seeds) of twenty crosses were obtained involving four restorer lines with five CMS lines by controlled hand pollination. The crossed seed were observed for four-achene characters viz., 100-seed weight, oil content, seed density and volume weight. The same twenty crossed hybrids were subjected to replicated trial to study the hybrid performance for the same four-achene characters under strict but effective sib pollination. Any possible relationship existing between the F_0 and F_1 seed characters was analysed by subjecting them to inter-generation correlation. A significant positive relationship between test weight, oil content and volume weight of F_0 and F_1 values was reported, while seed density exhibited a non-significant positive correlation.

Goud *et al.* (2000) reported stimulating effect of foreign pollen on resulting seed characters at the F_0 level. The per cent increase of F_0 seed values over mean sibbed values of females ranged from 5.67 to 21.51 for 1000-seed weight, 0.79 to 9.04 for oil content, 2.72 to 20.39 for seed density, 0.18 to 13.61 for volume weight, -0.45 to 13.00 for K/H ratio and -0.99 to 7.39 for hull content respectively.

Singh *et al.* (2001) observed that proximity of pollen parent to seed parent in sunflower gave higher seed yield per capitulum, but the number of unfilled seeds harvested from such capitulum were also higher. Contrary to this, the hybrid seed harvested from farther rows though produced less number of seeds per capitulum, yet had maximum number of filled seeds besides having maximum 100-seed weight. They also reported significant improvement in quality of such seeds.

2.3 VARIETAL/ HYBRID MIXTURE, MUTILINES AND SYNTHETICS

When mixtures or multilines are grown, there is every possibility of occurrence of cross pollination to over come self sterility and self-incompatibility resulting in enhanced seed set. Superiority of mixtures or multilines or synthetics in terms of grain yield and quality characters in many crops have been reported by several research workers (Tarhuni, 1990 in Viciafaba; Makne *et al.*, 1994 in Sunflower; Vasal *et al.*, 1994 in maize and Wortmann *et al.*, 1996 in Beans). However, the literature in this direction on sunflower is limited.

2.3.1 Varietal/hybrid mixtures

Makne *et al.* (1994) defined mixtures as genetically heterozygous stands which can perform better in unfavourable environmental situations and impart higher plasticity and insurance against diseases as compared to pure stand. In case of sunflower hybrids, superiority of hybrid mixtures in terms of mean yield was reported than their component hybrids and cultivars when used as check indicating that there is ample scope for raising hybrid mixtures rather than single hybrid. The higher yield of mixtures is attributed probably to higher per cent of filled seeds as compared to single hybrid. Similar results were reported by Sindagi and Virupakshappa (1989). Javed *et al.* (1995) reported that, when sunflower inbred lines mixed in all possible combinations, produced higher yields than their component pure stand. An increase in yield ranging from 28.3 to 30.37 per cent was indicated in mixed stand over pure stand.

Rattunde *et al.* (1988) reported that land Equivalent Ratios (LER) (yield response of a cultivar in a mixture relative to its yield in pure stand was expressed as land equivalent ratio) of cultivar mixtures in groundnut more frequently showed over compensation rather than under compensation The largest LER's recorded were 1.23, 1.29 and 1.18 for pod yield, kernel yield and haulm yield. They further indicated that greater stability was exhibited by cultivar mixtures rather than higher yield over high yielding variety.

Stutzel and Aufhammer (1990) depicted a model explaining mixing effects in cultivar blends that cannot be attributed to reduced disease levels, but are thought to result from improved compensatory reactions to environmental stress in cereal cultivar blends. It is assumed that a cultivar which yields less than expected in a particular environment does not utilise all growth factors available. The amount of growth factors not utilized is postulated to be taken up by other mixture component which then produces more than expected in pure stands. It is hypothesized that this additional compensatory yield is what is usually named the mixing effect.

2.3.2 Multilines

Groenewegen (1977) defined multilines as component mixtures of backcross derived lines from several sources of resistance. Further indicated that these lines are found to be stable in performance.

2.3.3 Synthetics

Putt (1962) observed that synthetics are better than hybrids in sunflower, where both utilize inbred lines. Even the double cross hybrids produced by natural pollination did not show any superiority over synthetics made from the same lines.

Putt (1965) analysed the seed yield and oil per cent of the highest ranking 100 synthetics composed of 10 lines, in F_6 assuming 50 and 60 per cent out crossing between F_2 and F_6. All the values exceeded the mean performance of four check samples of commercial hybrids. Many recorded higher values for oil content than the highest rank check. Synthetics were proved to be superior to present hybrids and desirable synthetics can be developed only from few lines. In sunflower synthetics composed of 3 to 4 lines are proved to be superior to their inbred parents in yield and oil content.

2.4 CORRELATION STUDIES

Correlation determines the relationship between two variables and enables for the improvement of a particular character by selecting superior lines or plants.

Fick *et al* (1974) recorded a high positive correlation of seed oil content with test weight in sunflower. However, no correlation of oil content with seed yield or seed weight was reported. This indicates the property of smaller seeds accumulating higher oil content.

Potdar *et al.* (1977) reported a positive and significant correlation of yield with filled seeds per capitulum and 1000 seed weight. Zali *et al.* (1977) reported a positive correlation of oil per cent with plant height and number of seeds but it was negatively correlated with seed yield.

Lakshmanaiah (1978) observed in sunflower that characters like test weight, number of seeds per capitulum, seed filling and oil content were positively and significantly correlated with seed yield.

Dedio (1982) reported in sunflower that test weight, kernel and whole seed oil content were significantly and negatively correlated with hull content. While test weight recorded non-significant and positive correlation with kernel and whole seed oil content.

Robinson (1980) reported a highly significant negative (-0.91) correlation between test weight and oil content in sunflower, indicating the tendency of larger seeds to accumulate low oil content.

Srinivasa (1982) reported in sunflower that yield per plant was positively and significantly correlated with 100 seed weight and oil content. Further it was observed that oil content showed a positive correlation with 100 seed weight and a negative correlation with yield per plant and hull content.

Sudhakar (1984) observed that various yield attributes viz., head diameter, seed filling per cent and test weight were positively and significantly correlated with seed yield and among themselves in sunflower.

Rao (1987) reported positive correlation of seed yield with capitulum diameter, oil content and 100 achene weight in sunflower. Shashikala (1992) reported a positive and significant correlation of seed yield per plant with head diameter, number of filled seeds per plant and test weight in sunflower. Similar results were reported by Singh *et al.* (1985), Fiazani(1988),Reddy(1989), Lakshminarayana (1991) and Manoharamba (1992). Gangappa and Virupakshappa (1994) evaluated 324 sunflower accessions and reported a positive and significant correlation of seed yield with majority of yield attributes except with days to 50 per cent flowering.

Punia and Gill (1994) evaluated 63 sunflower genotypes and revealed that seed yield per plant was significantly correlated with number of seeds per head, test weight, percentage of filled seeds and head diameter.

Suma and Virupakshappa (1994) evaluated 196 sunflower accessions and indicated a positive correlation of seed yield with number of filled seeds per head, test weight and seed filling percentage. Oil per cent recorded a negative association with seed yield at genotypic level.

Nanja Reddy *et al.* (1996) evaluated 22 germplasm lines of sunflower and indicated a positive association of kernel to hull (K/H) ratio with test weight, harvest index, seed yield and kernel yield. No association between K/H ratio and oil content was recorded. Padma (1996) reported that seed yield was significantly and positively correlated with total number of seeds per head, number of filled seeds per head, seed filling percentage, test weight, oil content, germination percentage and seedling vigour index.

Patil *et al.* (1996) indicated a significant and positive correlation between yield and other characters viz., plant height, head diameter, number of seeds per head and test weight in sunflower. Similar results were also reported by Sheriff *et al.* (1986), Sheriff *et al.* (1987), Kalaiselvan and Manoharan (1994) and Narsaiah (1995) Doddamani *et al.* (1997) evaluated 47 genotypes of sunflower and indicated that 1000 seed weight, head diameter and plant height showed a significant positive correlation with seed yield.

Several researchers have reported highly significant positive correlation of test weight with seed yield per plant (Chandra and Anand, 1977; Varshney and Singh, 1977; Anand and Chandra, 1979; Giriraj *et al.*, 1979; Lawrence, 1986; Pathak *et al.*, 1986; Vanisree, 1987; Dahipale and Kanwar, 1993). Contrary to this Akhanda *et al.* (1979) and Robinson (1980) have reported significant negative correlation of test weight with seed yield.

Diwakar (1998) reported that oil content was significantly correlated with filled seeds per head (0.9223), seed set per cent (0.9524) and test weight (0.9552) while it showed a significant negative association with total number of seeds (-0.8607) and number of unfilled seeds (-0.9267).

Mirza *et al.* (1998) reported a positive correlation of seed yield with filled seeds per head (0.764) and 1000-seed weight (0.746) but a negative correlation with days to flowering (-0.504). It is further suggested that seed yield in sunflower can be enhanced by increasing the number of filled seeds per head, 1000 seed weight, head diameter and number of leaves per plant.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experimental material used and the methodology adopted in the investigation is presented in detail in this chapter.

3.1 LOCATION

The present investigation entitled "Effect of pollen blend on seed yield and quality of sunflower (*Helianthus annuus* L.)" was conducted at College Farm, College of Agriculture, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, during late *rabi* 2002, which is situated at an altitude of 518 m above mean sea level and latitude of 17.2°N and longitude of 78.3°C.

3.2 METEOROLOGICAL OBSERVATION

The meteorological observations on the basis of mean weekly data with respect to rainfall, minimum and maximum temperature, relative humidity recorded during the experimental period and furnished in Appendix I.

3.3 EXPERIMENTAL MATERIAL

3.3.1 Material

The experimental material for the present study comprised of nine sunflower genotypes, including checks collected from Directorate of Oilseeds Research, Hyderabad. Of the nine genotypes choosen, three were inbred lines, two were open pollinated populations and remaining four were hybrids.

Hyderabad. Of the nine genotypes choosen, three were inbred lines, two were open pollinated populations and remaining four were hybrids.

3.3.2 Experimental design

The experiment was laid out in two factorial randomized block design (one factor is genotypes and second factor is type of pollination) under three replications.

3.3.3 Details of the experiment

The experiment consisted of the following four types of pollination methods.

S. No	Treatment	Particulars of the treatment
1.	Autogamy	Sunflower heads were bagged before commencement of flowering. The bagged heads were left to self-pollination without disturbance until harvest.
2.	Geitenogamy	The flower heads during flowering were hand pollinated, by gently rubbing the heads with the help of muslin cloth.
3	Open pollination	The capitulums were left for open pollination without bagging to allow self and cross-pollination.
4.	Pollen blend	During flowering, pollen collected from hybrids, populations and inbred lines was mixed and dusted on the heads of receiver lines.

3.3.4 Layout of the experiment

The experiment was sown in an area of 2250 m^2. Each genotype was sown in eight rows with a row length of 6 m spaced at 60 cm between rows and 30 cm between plant to plant. Out of the eight rows sown, two rows were allocated for each type of pollination treatment viz., autogamy, geitanogamy, open pollination and

POLLEN OF GENOTYPES MIXED IN POLLEN BLEND TREATMENT

Sl.No.	Genotype	Pollen of genotypes mixed in Pollen blend
1.	M-1008	M-1008 x (Mixture of M-1008 + M-1026 + M-269 + Morden + GAUSUF-15)
2.	M-1026	M-1026 x (Mixture of M –1026 + M-1008 + M-269 + Morden + GAUSUF-15)
3.	M-269	M-269 x (Mixture of M-269 + M-1008 + M-1026 + Morden + GAUSUF-15)
4.	MFSH-17	MFSH-17 x (Mixture of MFSH-17 + Jwalamukhi + KBSH-1 + Sungene)
5.	Jwalamukhi	Jwalamukhi x (Mixture of Jwalamukhi + KBSH-1 + MFSH-17 + Sungene)
6.	KBSH-1	KBSH-1 x (Mixture of KBSH-1 + MFSH-17 + Jwalamukhi + Sungene)
7.	Sungene	Sungene x (Mixture of Sungene + MFSH-17 + Jwalamukhi + KBSH-1)
8.	Morden	Morden x (Mixture of Morden + GAUSUF-15 + M-1008 + M-1026 + M-269)
9.	GAUSUF-15	GAUSUF-15 x (Mixture of GAUSUF-15 + Morden + M-1008 + M-1026 + M-269)

pollen blend. Atleast 40 plants were maintained in each treatment of which 10 plants were selected for analysis.

3.4 PACKAGE OF PRACTICES

The sunflower crop was grown by following the standard package of practices recommended by Acharya N.G. Ranga Agricultural University for raising a healthy crop. Plant protection measures were taken whenever required.

3.4.1 Manures and fertilizers

Sixty kilograms of nitrogen in the form of urea, 90 kg of P_2O_5 in the form of single super phosphate and 60 kg K_2O in the form of muriate of potash per hectare were applied.

3.4.2 Harvesting

The individual plants in each treatment were harvested separately, threshed and dried to safe moisture limits.

3.5 OBSERVATIONS RECORDED

3.5.1 Seed yield (g)

Seeds were threshed from the 10 capitulums selected in each treatment per replication, dried to safe moisture limits and average weight was recorded in grams on per plant basis.

Plate 1 : Sunflower crop in maturity stage - after bagging

3.5.2 Number of filled seeds per head

In each treatment ten heads selected randomly per replication, were threshed and filled seeds were counted (no./head) and average number of filled seeds per head were recorded.

3.5.3 Number of unfilled seeds per head

The number of unfilled seeds were counted and the average number of unfilled seeds per head were calculated.

3.5.4 Seed set per cent

The seed set per cent was calculated by the formula given by Roath and Miller (1982).

$$\text{Seed set \%} = \frac{\text{Number of filled seeds}}{\text{Total seeds}} \times 100$$

Autogamy and self compatibility per cent was calculated by formulae given by George *et al.* (1980).

$$\text{Autogamy\%} = \frac{\text{Per cent seed set under autogamous pollination}}{\text{Per cent seed set under open pollination}}$$

$$\text{Self compatibility\%} = \frac{\text{Per cent seed set under gietanogamy}}{\text{Per cent seed set under open pollination}}$$

3.5.5 Test weight (g)

From the filled seeds, hundred seeds were taken at random in each replication, treatment wise and average weight of hundred seeds was recorded on top pan balance.

3.5.6 Oil content (%)

Oil content was estimated by using Nuclear Magnetic Resonance Spectrometer (NMR) at Directorate of Oilseeds Research, Hyderabad.

3.5.7 Kernel weight (mg)

Hundred seeds were drawn at random, their kernels and hulls were separated. The weight of the separated hundred kernels were recorded replication wise.

3.5.8 Hull weight (mg)

Hundred seeds were drawn at random, their kernels and hulls were separated. The weight of the separated hundred hulls were recorded replication wise.

3.5.9 Hull content (%)

Hull per cent was calculated by the following formula

$$\text{Hull \%} = \frac{\text{Weight of hull}}{\text{Total weight of seeds}} \times 100$$

3.5.10 Kernel to hull (K/H) ratio

Hundred filled seeds were drawn at random, their kernels and hulls were separated. The K/H ratio was calculated by dividing the kernel weight of hundred seed by their hull weight.

3.5.11 Volume weight (g)

Hundred cubic centimetre of seed was separated by using a conical flask and weight was recorded in grams.

3.5.12 Seed length, breadth and thickness (mm)

Ten random seeds were selected from each treatment replication wise. Their lengths, breadths and thickness were recorded using seed length and breadth measuring device. Their mean, length, breadth and thickness was calculated as L_1, B_1 and T_1 respectively.

3.5.13 Kernel length, breadth and thickness (mm)

Ten random seeds were selected from each treatment, replication wise. Their kernels and hulls were separated. Their length, breadth and thickness was measured using the length and breadth measuring device and calculated L_2, B_2 and T_2 respectively.

3.5.14 Kernel proportion in achene

The kernel proportion in achene was calculated by the following formulae:

$$\text{Kernel proportion in achene (length-wise)} = \frac{L_2}{L_1} \times 100$$

L_1 = Seed length
L_2 = Kernel length

$$\text{Kernel proportion in achene (breadth-wise)} = \frac{B_2}{B_1} \times 100$$

B_1 = Seed breadth
B_2 = Kernel breadh

$$\text{Kernel proportion in achene (thickness-wise)} = \frac{T_2}{T_1} \times 100$$

T_1 = Seed thickness
T_2 = Kernel thickness

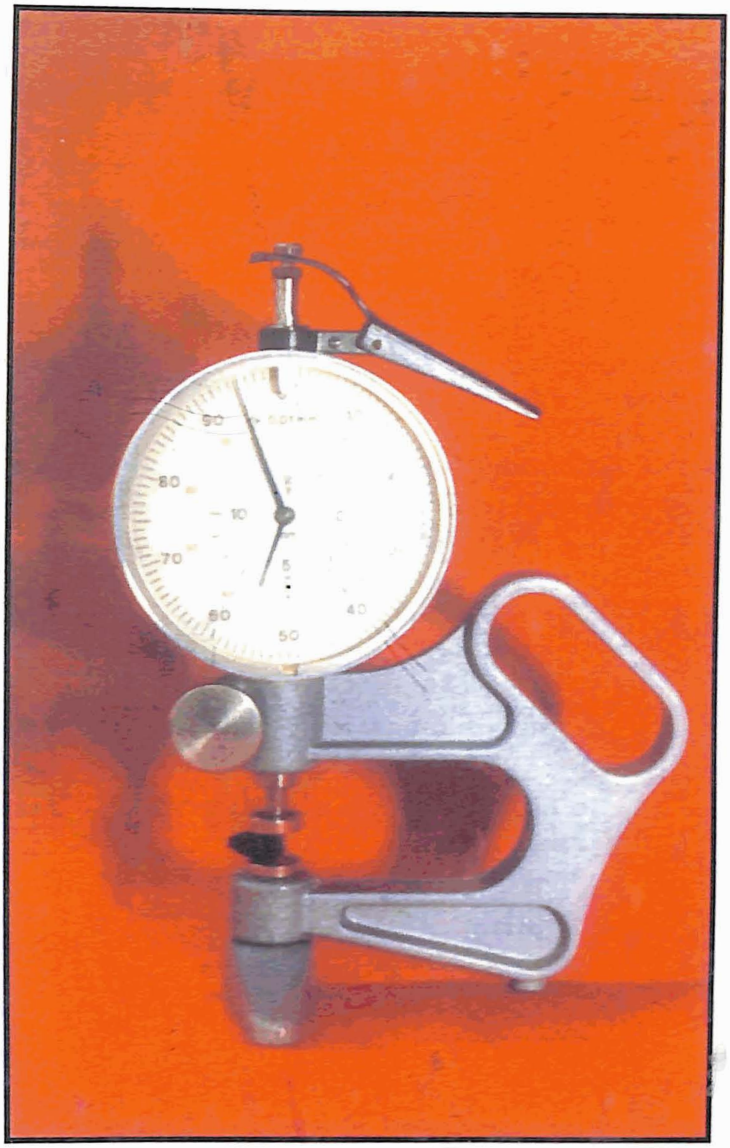

Plate 2 : Seed length and breadth measuring device

3.5.15 Germination percentage

Germination test was conducted by using a germination paper towel, and between paper method as prescribed by the International Seed Testing Association (1985). From each replication, hundred seeds were utilized for germination test. The seeds were placed on paper towels, rolled and placed in the BOD incubator at 30/20 ± 1°C day/night temperature for 8/16 hours. Germination count was taken on 10th day and based on the number of normal seedlings produced, germination percentage was worked out.

3.5.16 Seedling vigour index

Ten normal seedlings were selected at random from the germination test conducted separately. The shoot and root lengths were measured in centimetre. The seedling vigour index was calculated by multiplying mean seedling length (cm) with germination percentage as indicated by Abdul-Baki and Anderson (1973).

3.6 STATISTICAL ANALYSIS

3.6.1 Analysis of variance

Data obtained from the experiment was subjected to statical analysis following Two Factorial Randomized Block Design as given by Panse and Sukhatme (1985). Statistical significance was tested by F value at 1 and 5 per cent level of significance.

3.6.2 Correlation studies

The data on various characters recorded in this experiment is computed for phenotypic and genotypic correlation coefficients using the formula suggested by Al-Jibouri *et al.* (1979).

$$\text{Phenotypic } r(x_i.x_j) = \frac{\text{Cov. } (x_i.x_j) \text{ (phenotypic)}}{\sqrt{\text{Var}(x_i \text{ (phenotypic).var } x_j \text{ (phenotypic)}}}$$

$$\text{Genotypic } r(x_i.x_j) = \frac{\text{Cov. } (x_i.x_j) \text{ (genotypic)}}{\sqrt{\text{Var } (x_i \text{ (genotypic).var } x_j \text{ (genotypic)}}}$$

where,

$r(x_i x_j)$ = Correlation coefficient between i^{th} and j^{th} character

Cov $(x_i x_j)$ = Covariance between i^{th} and j^{th} character

Var x_i Var x_j = Variance of i^{th} and j^{th} character

The significance of correlation coefficients were compared with the 'r' table values (Fisher and Yates, 1967) at n-2 degrees of freedom at 1 per cent and 5 per cent level of significance, where 'n' denotes number of observations.

RESULTS

CHAPTER IV

RESULTS

The results of the field experiment conducted to investigate the effect of different pollination treatments on seed yield and yield attributes of sunflower genotypes are presented in this chapter under the following headings.

4.1 Effect of different pollination treatments and genotypes on various characters

4.2 Correlation studies

4.1 EFFECT OF DIFFERENT POLLINATION TREATMENTS AND GENOTYPES ON VARIOUS CHARACTERS

The analysis of variance for different characters studied in the present investigation are presented in Appendix-II. The results revealed that there was significant difference between various pollination treatments for total number of seeds per head, number of filled seeds per head, number of unfilled seeds per capitulum, seed set per cent, test weight, volume weight, kernel to hull ratio, oil content, germination percentage and seedling vigour index. There was significant difference between the genotypes for various characters studied. The interaction effect between types of pollination and genotypes was also significant.

4.1.1 Number of filled seeds per capitulum

The data on number of filled seeds per capitulum is presented in Table 4.1 and Fig. 1. It was indicated from the table that there was significant difference between types of pollination and pollen blend treatment recorded the highest average number of filled seeds per capitulum (537.27), followed by open pollination (445.39) while

Table 4.1 : Effect of different pollination treatments and genotypes on number of filled seeds per capitulum

Genotype	Number of filled seeds per capitulum				Mean
	Autogamy	**Geitenogamy**	**Open Pollination**	**Pollen blend**	
M-1008	129.70	219.17	293.90	422.96	**266.43**
M-1026	152.83	196.85	256.83	276.73	**220.81**
M-269	172.23	262.74	365.73	428.70	**307.35**
MFSH-17	340.37	316.07	588.53	807.67	**513.16**
Jwalamukhi	261.90	384.00	471.37	479.57	**399.21**
KBSH-1	448.43	566.00	597.67	716.57	**582.17**
Sungene	222.67	319.77	402.93	505.07	**362.61**
Morden	147.18	366.77	473.53	592.53	**387.50**
GAUSUF-15	28.00	307.00	558.00	605.67	**374.67**
Mean	**211.48**	**326.48**	**445.39**	**537.27**	**379.32**

	Pollination treatment	**Genotype**	**Interaction**
S.Ed ±	10.7542	16.1313	32.2627
CD (0.05)	21.4439	32.1659	64.3317
C.V (%)	10.4169		

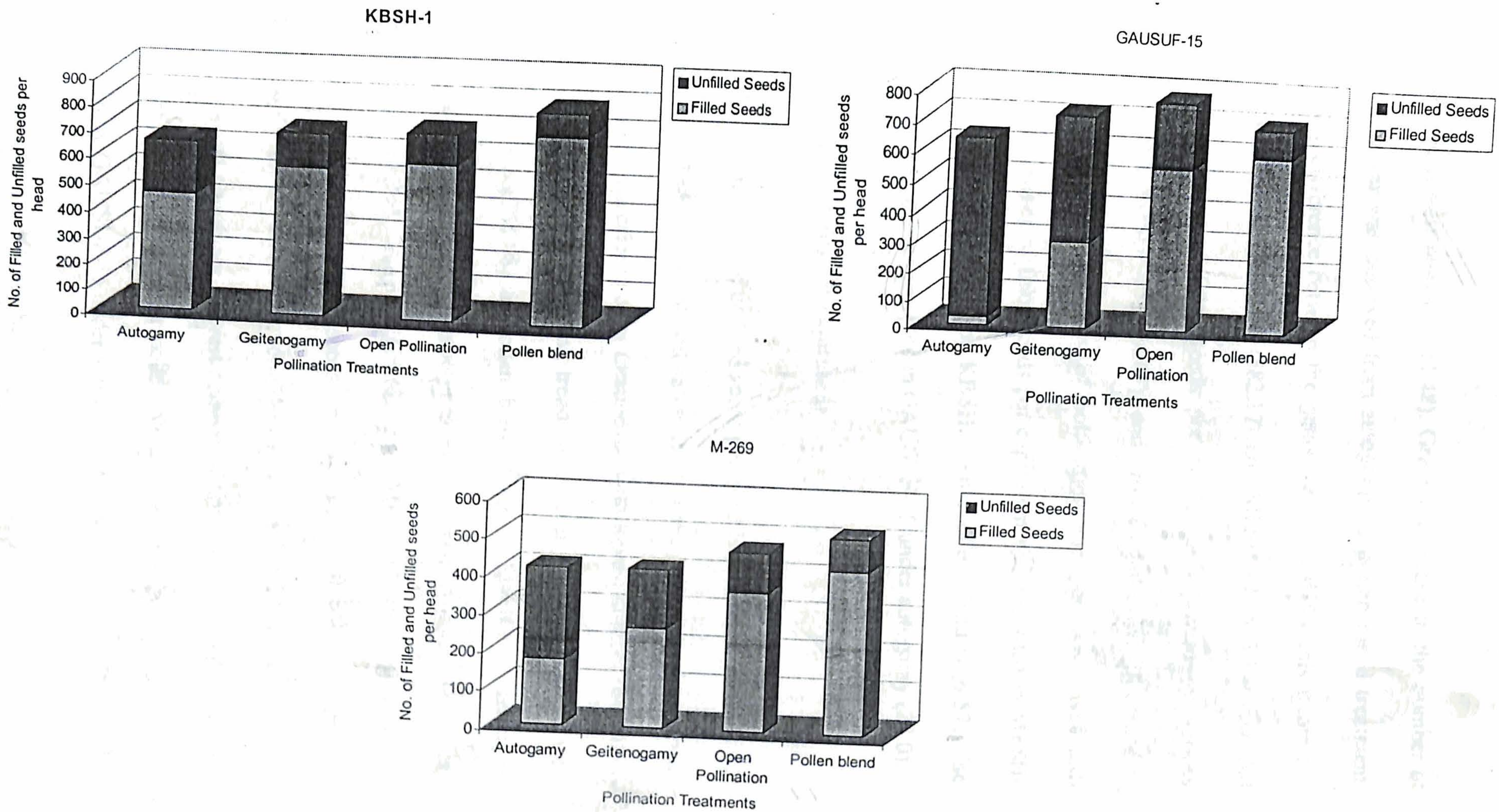

Fig. 1 Influence of Pollination treatments on number of filled and unfilled seeds per head of KBSH-1, GAUSUF-15 and M-269

autogamy recorded the lowest number (211.48). Gradual increase in the number of filled seeds per capitulum was observed from autogamy to pollen blend treatment. There was significant difference between the genotypes studied for this treatment. Among genotypes, the hybrids KBSH-1 (582.17) and MFSH-17 (513.16) recorded significantly highest number of filled seeds per capitulum followed by varities [(Morden (387.50) and GAUSUF-15 (374.67)] and lowest number was recorded in inbreds. The interaction effect of types of pollination and genotypes was also significant. Maximum number of filled seeds per capitulum was recorded in MFSH-17 with pollen blend (807.67) followed by KBSH-1 with pollen blend (716.57). The lowest number of filled seeds were recorded in GAUSUF-15 under autogamy (28.0).

4.1.2 Number of unfilled seeds per capitulum

The data on mean number of unfilled seeds per head is presented in Table 4.2 and Fig.1. Among the different types of pollination treatments, pollen blend treatment proved to be significantly superior to other treatments, with lowest number (64.64) of unfilled seeds per capitulum. A decreasing trend of number of unfilled seeds was observed from autogamy (255.98) to pollen blend (64.64). Significant genotype differences were recorded between the genotypes for this trait. Among genotypes, hybrids, Jwalamukhi (78.36), Sungene (96.62) and MFSH-17 (90.90) recorded significantly lowest number of unfilled seeds per capitulum followed by varieties (Morden, 125.71) and inbreds. The interaction effect was significant between types of pollination treatments and genotypes. Lowest number of unfilled seeds per capitulum was recorded in MFSH-17 (27.43) under pollen blend treatment. While the highest number was recorded by GAUSUF-15 under autogamy (609.43).

Table 4.2 : **Effect of different pollination treatments and genotypes on number of unfilled seeds per capitulum**

Genotype	Number of unfilled seeds per capitulum				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	291.87	139.62	68.53	47.20	**136.81**
M-1026	283.43	178.22	180.83	41.33	**170.95**
M-269	241.15	152.27	104.73	86.67	**146.21**
MFSH-17	179.27	88.83	68.07	27.43	**90.90**
Jwalamukhi	142.60	82.30	52.27	36.27	**78.36**
KBSH-1	199.50	128.47	114.53	86.63	**132.28**
Sungene	117.53	105.87	91.12	71.98	**96.62**
Morden	239.02	101.77	75.77	86.28	**125.71**
GAUSUF-15	609.43	416.33	221.53	98.00	**336.32**
Mean	**255.98**	**154.85**	**108.60**	**64.64**	**146.02**

	Pollination treatment	Genotype	Interaction
S.Ed ±	1.8549	2.7823	5.5646
CD (0.05)	3.6986	5.5479	11.0957
C.V (%)	4.6673		

4.1.3 Total number of seeds per head

The mean total number of seeds per capitulum in four different methods of pollination treatments for nine genotypes is presented in Table 4.3. It was observed from the table that, among pollination treatments pollen blend treatment recorded the highest total number of seeds per capitulum (611.48) followed by open pollination (557.36), geitenogamy (478.92) and autogamy (474.45). Among genotypes Jwalamukhi (714.45) and Morden (710.99) recorded highest number of seeds per capitulum and were on par with each other. The interaction effect of pollination treatments and genotypes was proved to be significant. The highest total number of seeds were recorded by MFSH-17 (835.10) under pollen blend treatment, while lowest was recorded by M-1026(318.07) under pollenblend.

4.1.4 Seed setting percentage

The mean seed set percent of four different pollination treatments of nine genotypes is illustrated in Table 4.4 and Fig. 2. It was evident from the Table that significant difference existed between pollination treatments i.e., the highest seed set was recorded under pollen blend treatment (88.87) followed by open pollination and lowest under autogamy (44.69). Significant differences were also observed between the genotypes also. Among genotypes, hybrids MFSH-17 (83.87) and Jwalamukhi (82.53) excelled in their performances followed by KBSH-1 and Sungene. The interaction effect between methods of pollination and genotypes was also found to be significant, wherein the highest seed set was observed in MFSH-17 (96.71) followed by Jwalamukhi (92.97) under pollen blend treatment.

Table 4.3 : **Effect of different pollination treatments and genotypes on total number of seeds per capitulum**

Genotype	Total number of seeds per capitulum				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	421.57	358.79	362.43	470.16	**403.24**
M-1026	436.27	375.07	437.67	318.07	**391.77**
M-269	413.39	415.01	470.47	515.37	**453.56**
MFSH-17	519.63	404.40	656.60	835.10	**604.06**
Jwalamukhi	647.93	691.47	712.20	803.20	**714.45**
KBSH-1	340.20	425.63	494.05	577.04	**459.23**
Sungene	386.20	438.53	549.30	678.81	**513.21**
Morden	637.43	723.33	779.53	703.67	**710.99**
GAUSUF-15	467.46	478.00	553.99	601.92	**525.34**
Mean	**474.45**	**478.92**	**557.36**	**611.48**	**530.55**

	Pollination treatment	Genotype	Interaction
S.Ed $\pm$	10.4118	16.3677	32.7355
CD (0.05)	21.7582	32.6373	65.2746
C.V (%)	7.6317		

Table 4.4 : Effect of different pollination treatments and genotypes on seed setting percentage

Genotype	Seed setting percentge				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	30.77	61.08	81.16	89.96	**65.74**
M-1026	35.05	52.46	57.32	87.00	**57.96**
M-269	41.68	63.31	77.74	83.18	**66.48**
MFSH-17	65.50	83.66	89.62	96.71	**83.87**
Jwalamukhi	64.78	82.36	90.00	92.97	**82.53**
KBSH-1	69.22	81.52	83.92	89.21	**80.97**
Sungene	65.47	75.13	81.57	87.46	**77.41**
Morden	25.37	76.80	86.22	87.29	**68.92**
GAUSUF-15	4.37	42.28	71.58	86.07	**51.08**
Mean	**44.69**	**68.73**	**79.90**	**88.87**	**70.54**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.3142	0.4714	0.9427
CD (0.05)	0.6266	0.9399	1.8798
C.V (%)	1.6366		

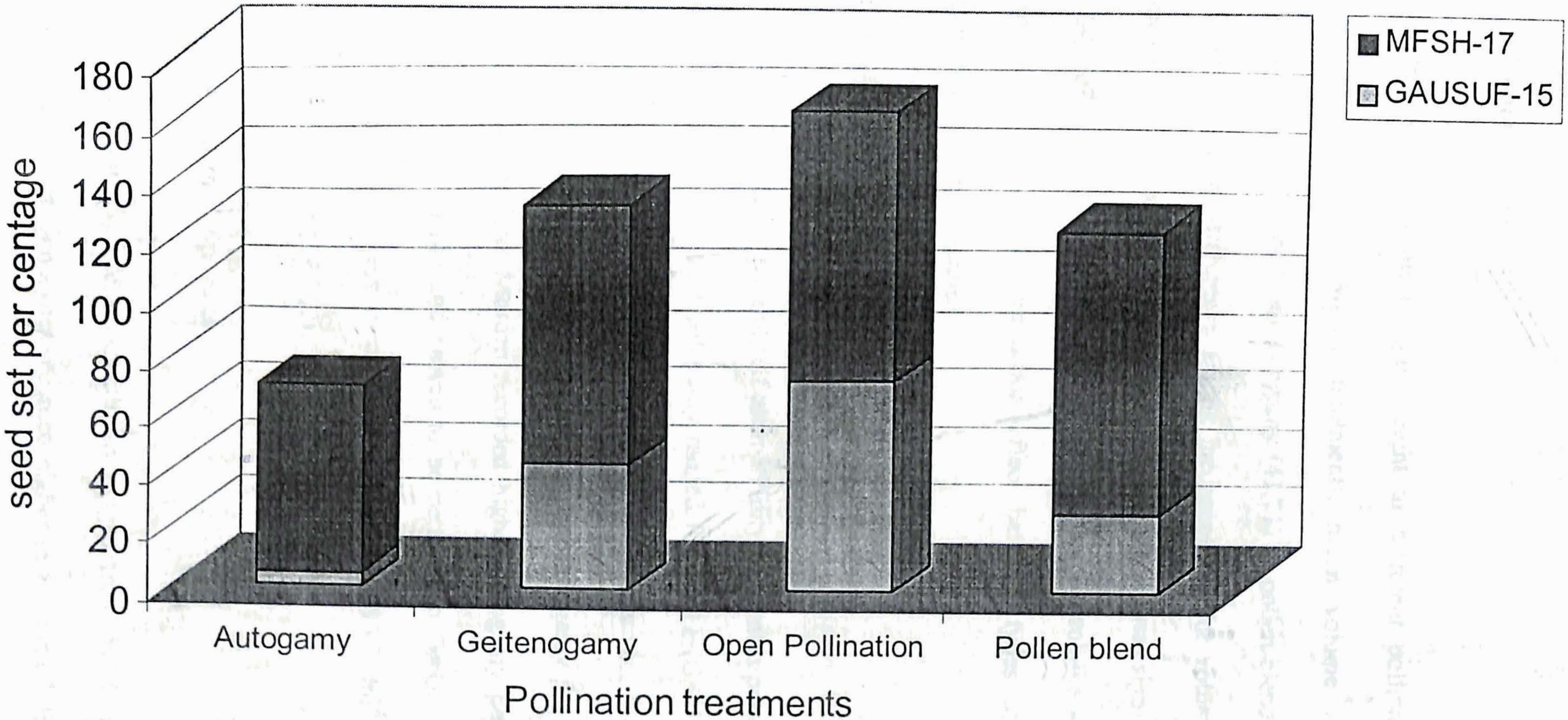

Fig. 2 Influence of Pollination treatment on seed set percentage in GAUSUF-15 and MFSH-17

4.1.5 Volume weight

The mean data on volume weight in different pollination treatments is presented in Table 4.5. Among treatments, mean volume weight recorded a decreasing trend of values from autogamy (41.71) to pollen blend treatment (38.97). There was significant difference among the genotypes for volume weight. Highest volume weight was recorded in GAUSUF-15 (46.95) and was significantly superior to other genotypes. In general populations recorded higher volume weight followed by hybrids and inbreds. The interaction effect between types of pollinations and genotypes was non-significant.

4.1.6 Autogamy per cent

The data on autogamy and self compatibility per cent is presented in Table 4.6 and Fig.3. The mean value of autogamy ranged from 6.11 (GAUSUF-15) to 82.48 (KBSH-1) with a general mean of 55.11. Five genotypes viz., M-1026, MFSH-17, Jwalamukhi, KBSH-1 and Sungene recorded higher autogamy per cent over general mean. Among populations Morden recorded higher autogamy per cent (29.43) as against GAUSUF-15 (6.11) and proved to be better than GAUSUF-15. In general high rates of autogamy was recorded by hybrids (76.951) followed by inbreds (50.891) and populations (17.767).

4.1.7 Self compatibility per cent

The mean value of self compatibility ranged from 59.06 (GAUSUF-15) to 97.14 (KBSH-1). Seven genotypes recorded higher self compatibility per cent over general mean of 82.13. It was also observed that, though Morden and GAUSUF-15

Table 4.5 : Effect of different pollination treatments and genotypes on volume weight (g)

Genotype	Volume weight (g)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	41.14	41.34	40.91	40.30	**40.92**
M-1026	40.37	39.39	38.69	37.56	**39.00**
M-269	39.15	38.05	36.92	36.17	**37.57**
MFSH-17	45.35	44.58	43.14	42.03	**43.78**
Jwalamukhi	42.79	41.76	39.06	38.20	**40.45**
KBSH-1	42.00	41.12	40.53	40.27	**40.98**
Sungene	36.12	35.43	35.11	34.77	**35.36**
Morden	38.71	37.62	36.87	36.12	**37.33**
GAUSUF-15	49.78	46.63	46.10	45.30	**46.95**
Mean	**41.71**	**40.66**	**39.70**	**38.97**	**40.26**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.4574	0.6861	1.3721
CD (0.05)	0.9120	1.3680	NS
C.V (%)	4.1740		

Table 4.6 : Effect of different pollination treatments and genotypes on Autogamy (%) and Self compatibility

Genotype	Autogamy	Self compatibility (%)	Mean
M-1008	37.91	45.27	**41.59**
M-1026	61.15	91.53	**76.34**
M-269	53.61	80.15	**66.88**
MFSH-17	73.08	93.34	**83.21**
Jwalamukhi	71.98	91.52	**81.75**
KBSH-1	82.48	97.14	**89.81**
Sungene	80.27	92.11	**86.19**
Morden	29.43	89.07	**59.25**
GAUSUF-15	6.11	59.06	**32.58**
Mean	**55.11**	**82.13**	**70.28**

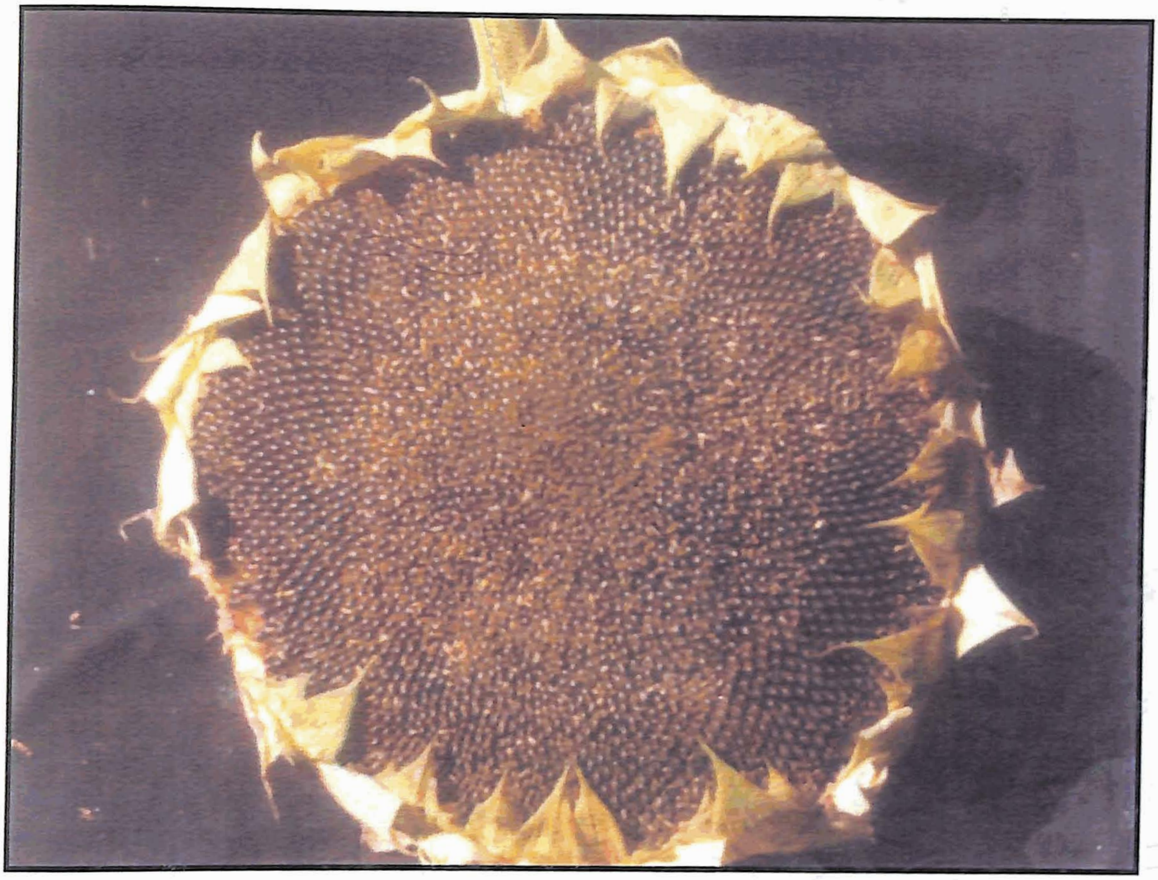

Plate 3 : Pollen blend capitulum of GAUSUF-15

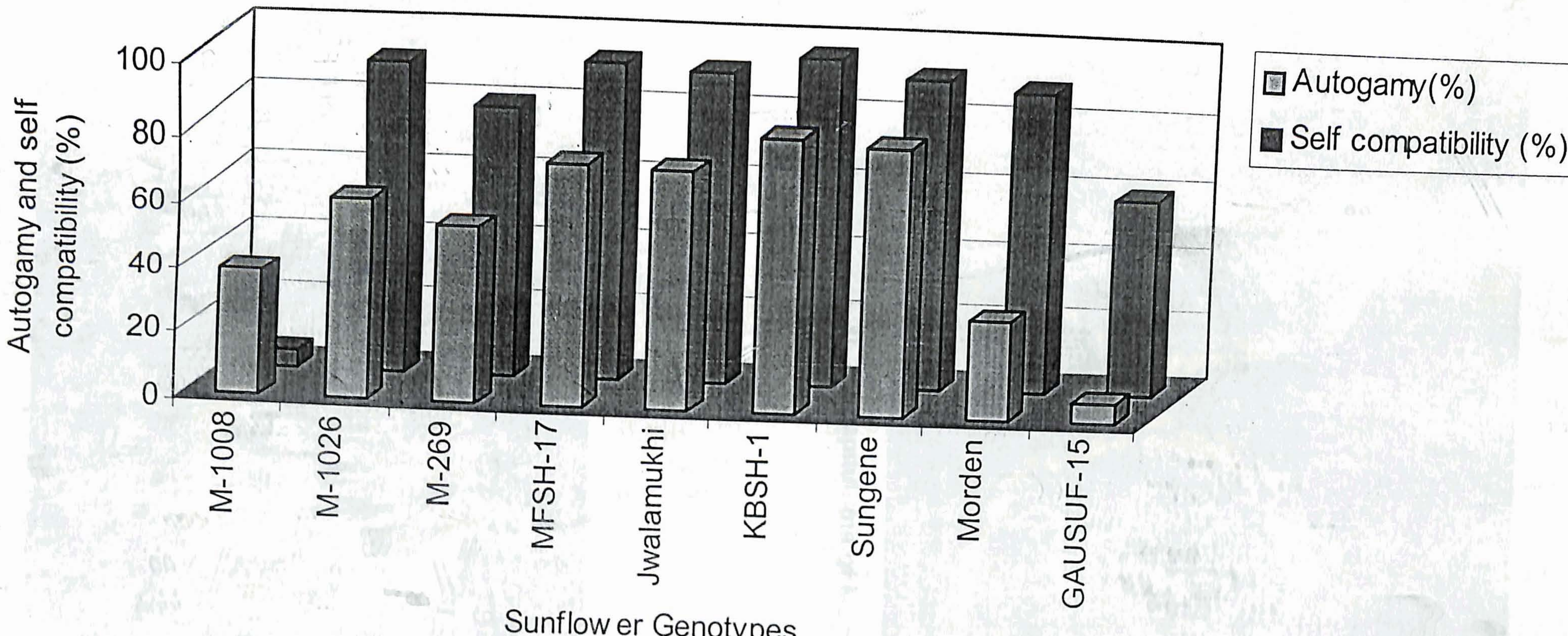

Fig.3 Autogamy and self compatibility percentage in nine sunflower genotypes

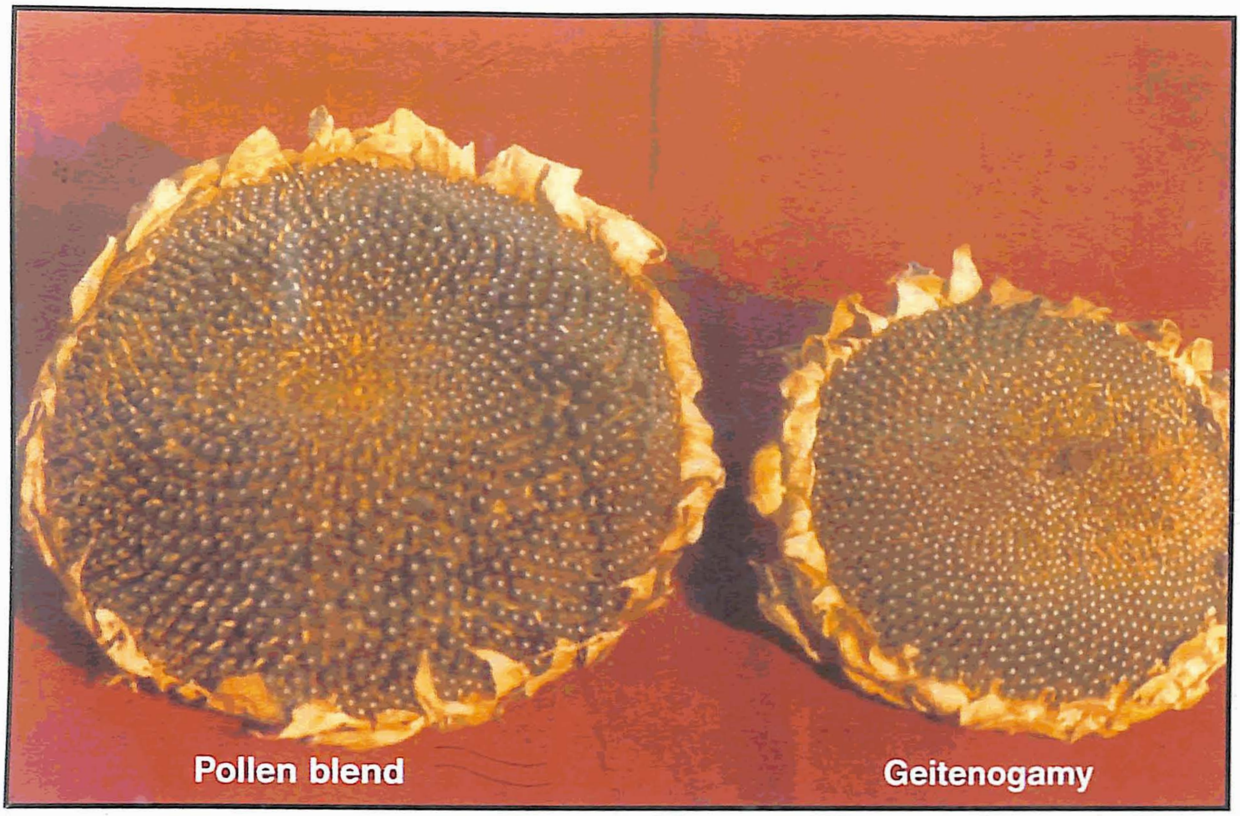

Plate 4 : Pollen blend and geitenogamy capitulums of Morden

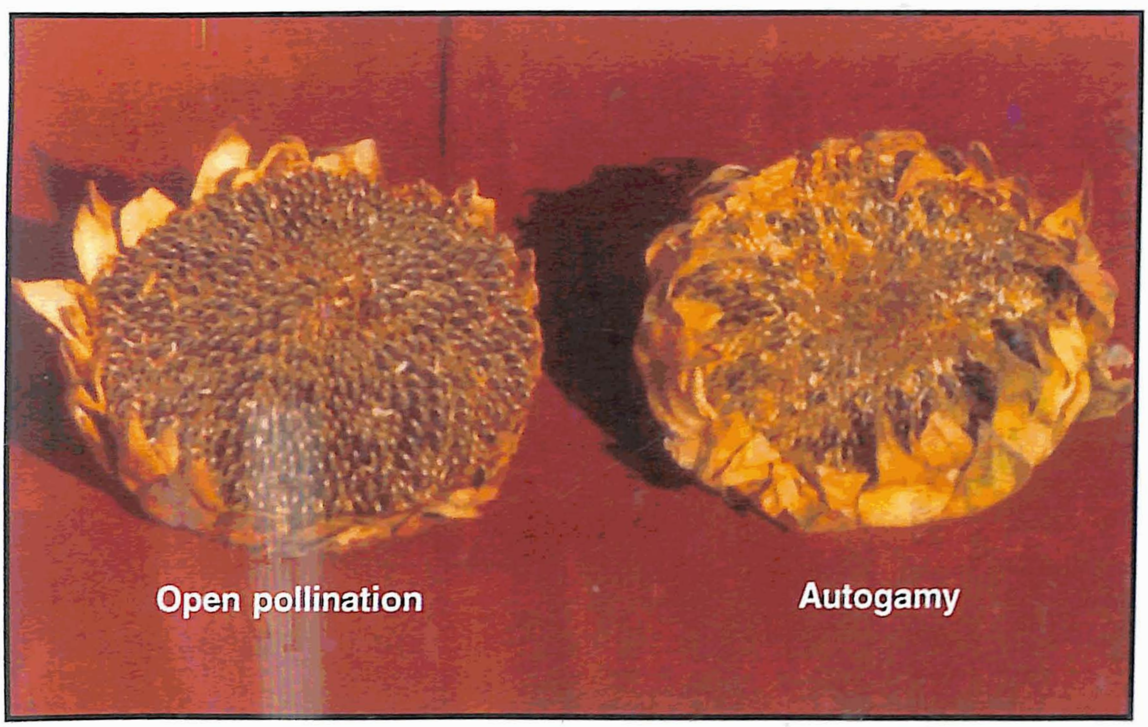

Plate 5 : Open pollinated and autogamy capitulums of M-1008

recorded low autogamy per cent (29.43 and 6.11 respectively). Their self-compatibility per cent (89.07 and 59.06 respectively) was better. Among inbreds M-1026 recorded high self-compatibility per cent (91.53) than others. In general highest self-compatibility per cent was recorded by hybrids (93.52) followed by inbreds (82.31) and populations (74.65).

4.1.8 Test weight

The data pertaining to nine genotypes under four different pollination treatments is given in Table 4.7. Significant differences were observed between types of pollination treatments and also between genotypes. Test weight recorded a decreasing trend of values from geitenogamy (4.87) to pollen blend (4.75). Autogomy treatment proved to be significantly superior to the other treatments with a treatmental mean of (4.97). Among genotypes MFSH-17 (5.49) recorded highest test weight followed by Jwalamukhi (5.29). Hybrids proved superior followed by inbreds [M-1008 (5.28) and M-1026 (5.15)] and varieties.

4.1.9 Weight of kernel

The mean kernel weight of nine genotypes in four different pollination treatments is given in Table 4.8. It is evident from the Table that significant difference was observed between methods of pollination and between genotypes. Kernel weight registered a decreasing trend from autogamy (390.26) to pollen blend (365.78). Autogamy recorded highest kernel weight (390.26) followed by geitenogamy

Table 4.7 : Effect of different pollination treatments and genotypes on test weight (g)

Genotype	Test weight (g)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	5.58	5.55	5.01	4.99	**5.28**
M-1026	5.08	4.96	4.83	5.72	**5.15**
M-269	4.61	4.54	4.40	4.35	**4.48**
MFSH-17	5.65	5.51	5.45	5.33	**5.49**
walamukhi	5.42	5.35	5.23	5.17	**5.29**
KBSH-1	4.39	4.36	4.32	4.31	**4.35**
ungene	4.48	4.43	4.25	4.12	**4.32**
Morden	3.86	3.82	3.79	3.75	**3.80**
AUSUF-15	5.62	5.30	5.16	5.02	**5.28**
Mean	**4.97**	**4.87**	**4.72**	**4.75**	**4.83**

	Pollination treatment	Genotype	Interaction
S.Ed $\pm$	0.0800	0.1199	0.2399
CD (0.05)	0.1594	0.2392	NS
C.V (%)	6.0916		

Table 4.8 : Effect of different pollination treatments and genotypes on kernel weight (mg)

Genotype	Kernel weight (mg)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	430.75	423.77	394.11	388.34	**409.24**
M-1026	383.61	372.72	366.46	360.78	**370.89**
M-269	359.22	349.58	337.65	331.19	**344.41**
MFSH-17	414.75	404.95	396.26	389.52	**401.37**
Jwalamukhi	443.09	437.93	427.89	415.42	**431.08**
KBSH-1	372.30	369.56	360.28	354.27	**364.10**
Sungene	341.72	333.28	326.47	318.23	**329.92**
Morden	319.74	317.38	307.37	307.98	**313.12**
GAUSUF-15	447.20	443.38	436.19	426.27	**438.26**
Mean	**390.26**	**383.62**	**372.52**	**365.78**	**378.05**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.5598	0.8397	1.67.93
CD (0.05)	1.1162	1.6743	3.3485
C.V (%)	0.5440		

Table 4.8 : Effect of different pollination treatments and genotypes on kernel weight (mg)

Genotype	Kernel weight (mg)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	430.75	423.77	394.11	388.34	**409.24**
M-1026	383.61	372.72	366.46	360.78	**370.89**
M-269	359.22	349.58	337.65	331.19	**344.41**
MFSH-17	414.75	404.95	396.26	389.52	**401.37**
Jwalamukhi	443.09	437.93	427.89	415.42	**431.08**
KBSH-1	372.30	369.56	360.28	354.27	**364.10**
Sungene	341.72	333.28	326.47	318.23	**329.92**
Morden	319.74	317.38	307.37	307.98	**313.12**
GAUSUF-15	447.20	443.38	436.19	426.27	**438.26**
Mean	**390.26**	**383.62**	**372.52**	**365.78**	**378.05**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.5598	0.8397	1.67.93
CD (0.05)	1.1162	1.6743	3.3485
C.V (%)	0.5440		

(383.62) and least kernel weight was recorded in pollen blend. Genotype GAUSUF-15 (438.26) has recorded significantly highest kernel weight and lowest was recorded by Morden (313.12). The interaction effect between methods of pollination and genotypes was significant. Maximum values of kernel weight was recorded by GAUSUF-15 (447.20) under autogamy, while lowest was recorded by Morden (307.37) under open pollination treatment.

4.1.10 Weight of hull

The data pertaining to hull weight under differential pollination treatments of nine genotypes is presented in Table 4.9. It is evident from the table that there was a significant difference between types of pollination treatments and pollen blend treatment recorded the lowest hull weight (110.12) followed by open pollination (115.32), while maximum hull weight was recorded under autogamy (128.26). A steady decrease in hull weight was observed from autogamy to pollen blend. There were significant differences between the genotypes for this character. Among genotypes Sungene recorded significantly lowest hull weight (97.91), while M-1008 recorded highest hull weight with a genotypic mean of 149.87. The interaction effect of types of pollination treatments and genotypes was also significant. Lowest hull weight was recorded by Sungene (90.14) with pollen blend treatment followed by Morden (94.54) under pollen blend while highest was recorded by M-1008 (165.17) under autogamy.

4.1.11 Hull content

The data on mean hull content of nine genotypes in four different pollination treatments is presented in Table 4.10. It is evident from the table that significant

Table 4.9 : Effect of different pollination treatments and genotypes on hull weight (mg)

Genotype	Hull weight (mg)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	165.17	157.52	140.49	136.28	**149.87**
M-1026	143.76	138.11	130.95	124.16	**134.24**
M-269	113.48	107.37	101.71	100.00	**105.64**
MFSH-17	121.67	115.44	112.20	109.50	**114.70**
Jwalamukhi	134.95	129.40	121.35	116.97	**125.67**
KBSH-1	117.15	112.75	105.94	102.29	**109.53**
Sungene	105.30	99.95	96.23	90.14	**97.91**
Morden	107.58	104.30	99.91	94.54	**101.58**
GAUSUF-15	145.32	138.33	129.08	117.15	**132.47**
Mean	**128.26**	**122.57**	**115.32**	**110.12**	**119.07**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.3221	0.4832	0.9664
CD (0.05)	0.6423	0.9635	1.9269
C.V (%)	0.9940		

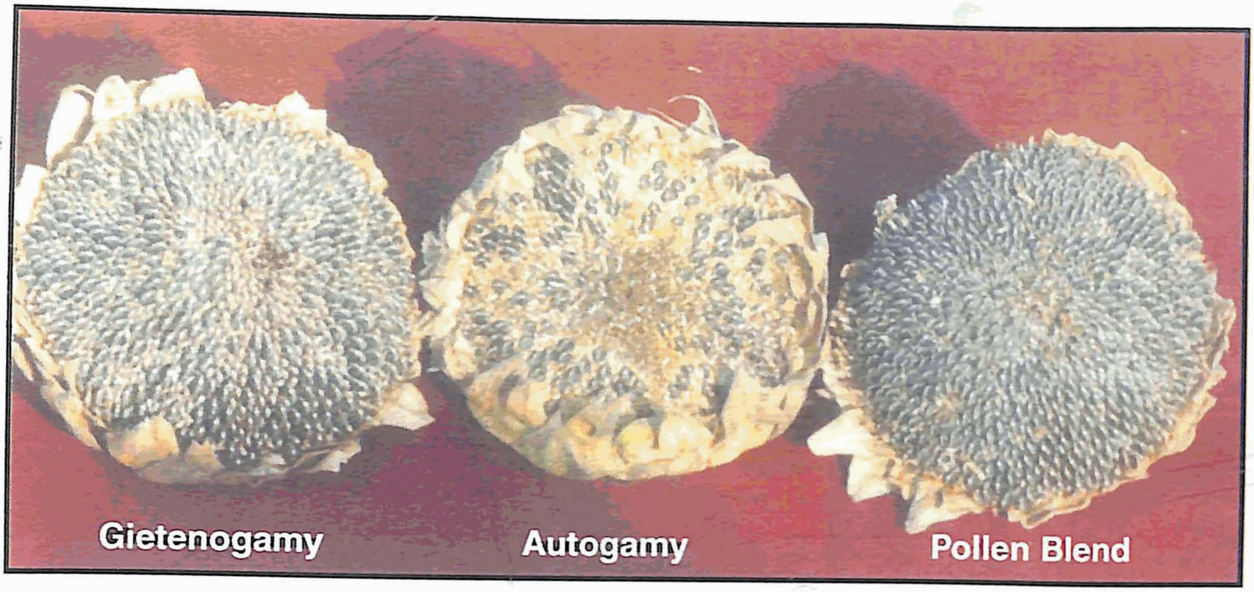

Plate 6 : Gietenogamy, autogamy and Pollen blend capitulums of M-1008

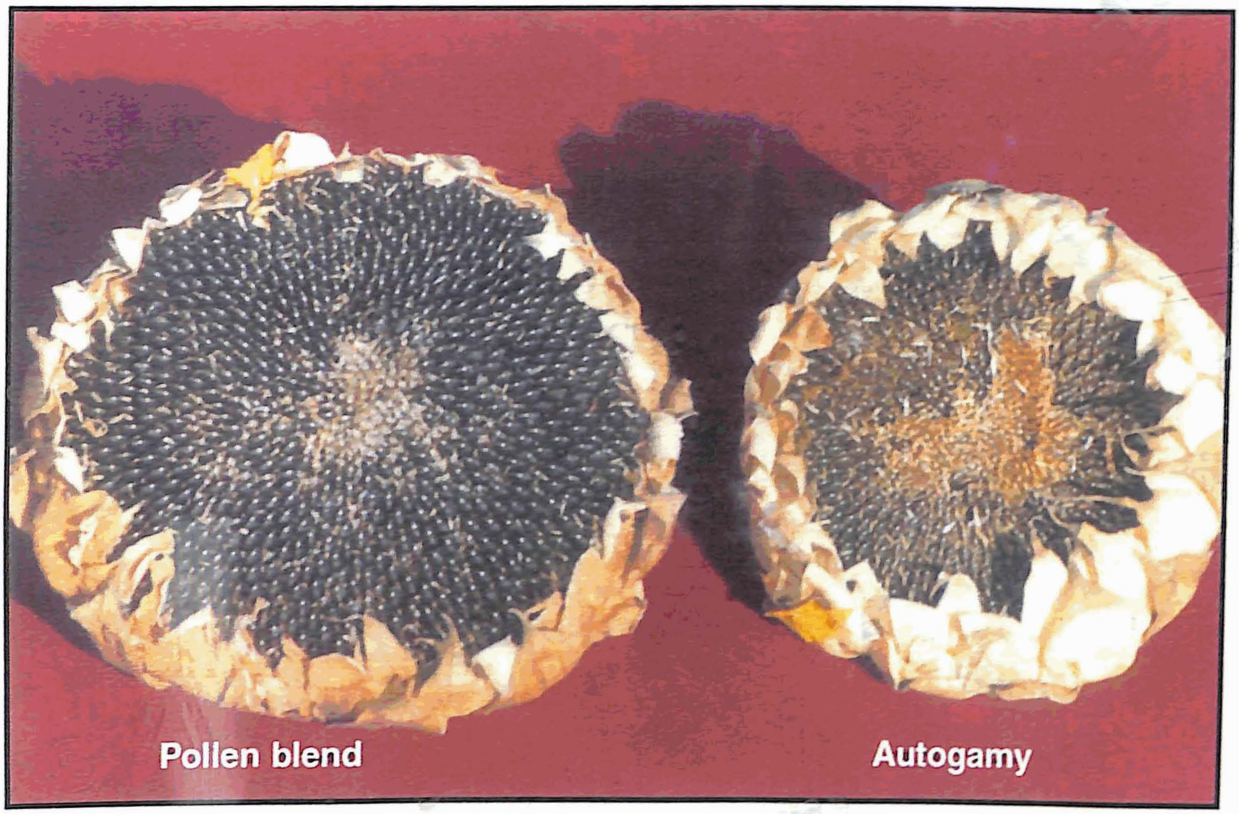

Plate 7 : Pollen blend and autogamy capitulums of KBSH-1

differences existed between types of pollination treatments and also between genotypes. Pollen blend treatment proved to be significantly superior by recording low hull content (23.13) followed by open pollination (23.69). While autogamy proved to be inferior to all the treatments with highest (24.63) hull content. Among genotypes, lowest hull content was recorded by MFSH-17 (22.22) under hybrids, while highest was recorded by M-1008 (26.71) under inbreds. The interaction effect of methods of pollination and genotypes was also significant. Highest values of hull content were recorded by M-1008 (27.51) under autogamy followed by M-1026 (27.26) under autogamy, while lowest was recorded in GAUSUF-15 (21.55) under pollen blend.

4.1.12 Kernel to hull ratio

The data on mean kernel to hull ratio of nine genotypes in four different pollination treatments is presented in Table 4.11. It is evident from the table that there was significant difference between types of pollination treatments and pollen blend treatment recorded highest kernel to hull ratio (3.34), while lowest kernel to hull ratio was recorded under autogamy (3.07). Gradual increase of K/H ratio was observed from autogamy to pollen blend. There was significant difference between the genotypes studied. Among genotypes the hybrids [MFSH-17 (3.49) and Jwalamukhi (3.43)] recorded significantly highest K/H ratio followed by populations [GAUSUF-15 (3.32)] and inbreds [M-269 (3.27)]. Significant interaction effect was observed between types of pollination and genotypes. Highest kernel to hull ratio was recorded by GAUSUF-15 (3.64) under pollen blend, while the lowest was recorded by M-1008 (2.63) under autogamy.

Table 4.10 : **Effect of different pollination treatments and genotypes on hull content (%)**

Genotype	Hull content (%)				Mean
	Autogamy	**Geitenogamy**	**Open Pollination**	**Pollen blend**	
M-1008	27.51	27.09	26.28	25.97	**26.71**
M-1026	27.26	27.03	26.82	25.60	**26.68**
M-269	23.68	23.49	23.16	23.19	**23.38**
MFSH-17	22.68	22.16	22.06	21.97	**22.22**
Jwalamukhi	23.34	22.80	22.12	21.96	**22.56**
KBSH-1	23.93	23.37	22.72	22.40	**23.11**
Sungene	23.55	23.07	22.72	22.07	**22.85**
Morden	25.17	24.73	24.53	23.48	**24.48**
GAUSUF-15	24.52	23.77	22.83	21.55	**23.17**
Mean	**24.63**	**24.17**	**23.69**	**23.13**	**23.90**

	Pollination treatment	**Genotype**	**Interaction**
S.Ed ±	0.0423	0.0635	0.1270
CD (0.05)	0.0844	0.1266	0.2532
C.V (%)	0.6510		

Table 4.11 : Effect of different pollination treatments and genotypes on kernel to hull ratio

Genotype	Kernel to hull ratio				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	2.63	2.69	2.80	2.85	**2.74**
M-1026	2.67	2.69	2.79	2.90	**2.76**
M-269	3.22	3.25	3.31	3.31	**3.27**
MFSH-17	3.41	3.50	3.53	3.53	**3.49**
Jwalamukhi	3.28	3.38	3.52	3.55	**3.43**
KBSH-1	3.17	3.28	3.40	3.46	**3.33**
Sungene	3.24	3.33	3.40	3.53	**3.38**
Morden	2.97	3.04	3.07	3.25	**3.08**
GAUSUF-15	3.07	3.20	3.38	3.64	**3.32**
Mean	**3.07**	**3.15**	**3.24**	**3.34**	**3.20**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.0075	0.0112	0.0224
CD (0.05)	0.0149	0.0223	0.0446
C.V (%)	0.8561		

4.1.13 Seed thickness

The data on seed thickness is presented in Table 4.12. It is evident from the table that there was significant difference between types of pollinations and autogamy recorded the highest seed thickness (3.92). A decreasing trend of values of seed thickness was recorded from autogamy to pollen blend. There was significant difference between the genotypes for this treatment. Among genotypes Morden recorded significantly highest seed thickness (4.02), while lowest was recorded by M-269 (3.11). In general, among hybrids MFSH-17 (3.51), M-1008 (4.30) among inbreds and Morden (4.02) among population produced thicker seeds compared to others. Significant interaction effect was observed between methods of pollinations and genotypes.Thickest seed was produced by M-1008 (4.87) under gietenogamy while the thinnest seed was produced by M-269 under pollen blend (2.92) and is on par with KBSH-1 (2.93).

4.1.14 Kernel thickness

The data on kernel thickness is presented in Table 4.13. It was indicated from the table that significant difference existed between types of pollinations, genotypes and their interactions. Autogamy treatment recorded highest kernel thickness (2.15) followed by geitenogamy. In general a decreasing trend was observed for kernel thickness from autogamy (2.15) to pollen blend (1.98). Maximum kernel thickness was recorded by GAUSUF-15 (2.38) followed by KBSH-1 (2.19). Maximum kernel thickness was recorded by GAUSUF-15 under autogamy (2.44) followed by KBSH-1 (2.36), lowest was recorded by Morden under pollen blend treatment (1.70) Among genotypes Morden recorded lowest kernel thickness (1.80) followed by M-1008 (1.95).

Table 4.12 : Effect of different pollination treatments and genotypes on seed thickness (mm)

Genotype	Seed thickness (mm)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	4.02	4.87	4.72	3.58	**4.30**
M-1026	3.47	3.22	3.14	3.00	**3.21**
M-269	3.37	3.14	3.00	2.92	**3.11**
MFSH-17	3.95	3.63	3.33	3.11	**3.51**
Jwalamukhi	3.90	3.54	3.20	3.06	**3.43**
KBSH-1	3.98	3.51	3.27	2.93	**3.42**
Sungene	3.73	3.63	3.25	3.13	**3.44**
Morden	4.51	4.22	3.95	3.38	**4.02**
GAUSUF-15	4.38	4.05	3.78	3.56	**3.94**
Mean	**3.92**	**3.76**	**3.52**	**3.18**	**3.59**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.0135	0.0203	0.0406
CD (0.05)	0.0270	0.0404	0.0809
C.V (%)	1.4023		

Table 4.13 : Effect of different pollination treatments and genotypes on kernel thickness (mm)

Genotype	Kernel thickness (mm)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	2.01	1.95	1.93	1.91	**1.95**
M-1026	2.07	2.07	2.02	1.96	**2.03**
M-269	2.09	2.05	2.00	1.95	**2.02**
MFSH-17	2.10	2.09	2.02	1.98	**2.05**
Jwalamukhi	2.24	2.16	1.99	1.96	**2.09**
KBSH-1	2.36	2.19	2.11	2.11	**2.19**
Sungene	2.10	2.07	1.97	1.97	**2.03**
Morden	1.89	1.81	1.80	1.70	**1.80**
GAUSUF-15	2.44	2.40	2.36	2.32	**2.38**
Mean	**2.15**	**2.09**	**2.02**	**1.98**	**2.06**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.0085	0.0128	0.0255
CD (0.05)	0.0170	0.0254	0.0509
C.V (%)	1.5161		

4.1.15 Seed breadth

Seed breadth of nine genotypes in different pollination treatments is presented in Table 4.14. Highest seed breadth was recorded under autogamy (5.69) and lowest under pollen blend (4.96). In general a gradual decrease in the values of seed breadth. was recorded form autogamy to pollen blend. Among genotypes, the inbred M-1008 (6.17) recorded highest seed breadth and was on par with GAUSUF-15 (6.04) under populations. Lowest seed breadth was recorded in hybrids [KBSH-1 (4.91), Sungene (4.92)]. Among the interactions highest seed breadth was recorded by GAUSUF-15 (6.93) under autogamy.

4.1.16 Kernel breadth

The data on kernel breadth of nine genotypes under four different pollination treatments is presented in Table 4.15. In general a decreasing trend for kernel breadth was observed from autogamy (4.28) to pollen blend (4.14). Highest kernel breadth was observed in autogamy (4.28) followed by gietenogamy (4.22) while lowest kernel breadth was recorded in pollen blend (4.14). Among genotypes, inbred M-1008 (4.86) recorded highest kernel breadth followed by populations [GAUSUF-15 (4.50)] and hybrids. The interaction effect between types of pollination and genotypes was also significant. The inbredline M-1008 recorded highest kernel breadth (4.91) under autogamy whereas lowest kernel breadth was recorded by KBSH-1 (3.79) under pollen blend.

4.1.17 Seed length

The data on seed length of nine genotypes under four different pollination treatments is presented in Table 4.16. Significant differences were observed between

Table 4.14 : Effect of different pollination treatments and genotypes on seed breadth (mm)

Genotype	Seed breadth (mm)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	6.42	6.17	6.10	5.97	**6.17**
M-1026	5.36	5.26	5.16	5.00	**5.19**
M-269	5.16	5.06	4.88	4.68	**4.94**
MFSH-17	5.49	5.32	3.56	4.84	**4.80**
Jwalamukhi	5.60	5.24	5.11	4.87	**5.21**
KBSH-1	5.28	5.03	4.84	4.49	**4.91**
Sungene	5.32	5.01	4.77	4.59	**4.92**
Morden	5.65	5.51	5.28	4.89	**5.33**
GAUSUF-15	6.93	6.08	5.82	5.33	**6.04**
Mean	**5.69**	**5.41**	**5.06**	**4.96**	**5.28**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.1240	0.1860	0.3719
CD (0.05)	0.2472	0.3708	NS
C.V (%)	8.6271		

Table 4.15 : Effect of different pollination treatments and genotypes on kernel breadth (mm)

Genotype	Kernel breadth (mm)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	4.91	4.84	4.86	4.84	**4.86**
M-1026	4.17	4.11	4.06	4.03	**4.09**
M-269	4.20	4.14	4.11	4.08	**4.13**
MFSH-17	4.38	4.33	4.29	4.25	**4.31**
Jwalamukhi	4.28	4.22	4.16	4.08	**4.18**
KBSH-1	3.95	3.91	3.90	3.79	**3.89**
Sungene	3.97	3.95	3.95	3.90	**3.94**
Morden	3.99	3.96	3.95	3.92	**3.95**
GAUSUF-15	4.67	4.50	4.42	4.39	**4.50**
Mean	**4.28**	**4.22**	**4.19**	**4.14**	**4.21**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.0049	0.0074	0.0148
CD (0.05)	0.0098	0.0148	0.0295
C.V (%)	0.4312		

types of pollination treatments and between genotypes. It is evident that autogamy recorded highest seed length (12.34) followed by gietenogamy (12.01). While pollen blend recorded lowest seed length (11.40). In general a decreasing trend in seed length was observed from autogamy to pollen blend. Among genotypes, inbreds [M-1008 (13.49), M-269 (12.31)] produced lengthier seeds followed by hybrids [Sungene (12.43), MFSH-17 (11.85)] and populations [GAUSUF-15 (11.36)]. The interaction effect between types of pollinations and genotypes was non-significant.

4.1.18 Kernel length

The data pertaining to kernel length of nine genotypes under four different pollination treatments is given in Table 4.17. A steady decrease of kernel length was observed from autogamy to pollen blend. Autogamy produced lengthier kernels (9.80) followed by geitenogamy (9.71) and shortest kernels by pollen blend (9.47). There was significant difference between the genotypes for kernel length. Among genotypes, inbreds [M-1008 (11.17), M-1026 (10.12), M-269 (10.14)] produced lengthier kernels followed by hybrids [MFSH-17 (9.79), Jwalamukhi (9.64)] and populations [Morden (7.98)]. The interaction effect of types of pollinations and genotypes was also significant. Highest kernel length was recorded by M-1008 (11.28) under geitenogamy and lowest by Morden (7.88) under pollen blend.

4.1.19 Kernel proportion in achene (%)

Kernel proportion in achene in terms of length, breadth and thickness is presented in Table 4.18a, 4.18b, 4.18c. It is revealed from the data that a steady increase in kernal proportion in achene was noticed from autogamy (79.24, 75.01, 55.07) to pollen blend (83.04, 83.28, 62.35). Kernel proportion in achene in terms of

Table 4.16 : Effect of different pollination treatments and genotypes on seed length (mm)

Genotype	Seed length (mm)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	13.78	13.60	13.46	13.13	**13.49**
M-1026	12.60	12.27	11.94	11.73	**12.14**
M-269	12.61	12.41	12.26	11.98	**12.31**
MFSH-17	12.28	12.07	11.68	11.37	**11.85**
Jwalamukhi	11.93	11.60	11.59	11.36	**11.62**
KBSH-1	11.77	11.33	10.91	10.60	**11.15**
Sungene	12.81	12.54	12.39	11.96	**12.43**
Morden	11.50	10.81	10.27	9.73	**10.58**
GAUSUF-15	11.81	11.50	11.37	10.78	**11.36**
Mean	**12.34**	**12.01**	**11.76**	**11.40**	**11.88**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.0632	0.0948	0.1897
CD (0.05)	0.1261	0.1891	NS
C.V (%)	1.9550		

Table 4.17 : Effect of different pollination treatments and genotypes on kernal length (mm)

Genotype	Kernal length (mm)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	11.03	11.28	11.24	11.14	**11.17**
M-1026	10.53	10.15	9.95	9.84	**10.12**
M-269	10.26	10.21	10.17	9.93	**10.14**
MFSH-17	10.04	9.85	9.76	9.51	**9.79**
Jwalamukhi	9.70	9.65	9.64	9.57	**9.64**
KBSH-1	9.36	9.17	8.97	8.91	**9.10**
Sungene	9.72	9.61	9.42	9.25	**9.50**
Morden	8.06	8.00	7.96	7.88	**7.98**
GAUSUF-15	9.53	9.44	9.22	9.20	**9.35**
Mean	**9.80**	**9.71**	**9.59**	**9.47**	**9.64**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.0136	0.0204	0.0409
CD (0.05)	0.0272	0.0408	0.0815
C.V (%)	0.5193		

Table 4.18a : Effect of different pollination treatments and genotypes on kernel proportion in achene (length wise) %

Genotype	Kernel proportion in achene (length wise) %				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	80.04	82.91	83.51	84.89	**82.84**
M-1026	83.52	82.72	83.30	83.94	**83.37**
M-269	81.33	82.32	82.97	82.90	**82.38**
MFSH-17	81.79	81.61	83.53	83.63	**82.64**
Jwalamukhi	81.35	83.21	83.14	84.53	**83.06**
KBSH-1	78.47	80.88	82.22	83.94	**81.38**
Sungene	75.88	76.61	75.98	77.33	**76.45**
Morden	70.09	74.05	77.50	80.88	**75.63**
GAUSUF-15	80.71	82.15	81.08	85.34	**82.32**
Mean	**79.24**	**80.72**	**81.47**	**83.04**	**81.12**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.1128	0.1692	0.3385
CD (0.05)	0.2250	0.3374	0.6749
C.V (%)	0.5110		

length was maximum in M-1026 (83.37), while Morden recorded lowest kernel proportion in achene (75.63) followed by Sungene (76.45). Kernel proportion in achene in terms of breadth was maximum in M-269 (83.68). It recorded highest values in all the treatments barring pollen blend. While lowest kernel proportion in achene was recorded in Morden in all the treatment with an overall mean of 73.36. Kernel proportion in achene in terms of thickness was highest in M-269 (65.23) followed by KBSH-1 (63.79) while lowest was recorded in Morden in all the treatments with a general mean of 45.14.

4.1.20 Oil content

The data on mean oil content is furnished in Table 4.19 and illustrated in Fig.4. It is evident from the table that among the pollination treatments, oil content recorded an increasing trend of values from autogamy (35.58) to pollen blend (39.92). Among genotypes highest oil content was recorded in MFSH-17 (44.67) followed by Jwalamukhi (42.51) and Sungene, whereas M-269 recorded a lowest oil content of 31.23. Five genotypes (GAUSUF-15, Sungene, Jwalamukhi, KBSH-1, MFSH—17) exceeded in their performance in their mean oil content over general mean (37.61). The interaction effect between type of pollinations and genotypes was non-significant.

4.1.21 Seed yield per plant

The data on mean seed yield per plant recorded for nine genotypes under four different pollination treatments is furnished in Table 4.20 and depicted in Fig.5. It was observed from the table that there was significant difference between types of pollination and pollen blend treatment recorded highest seed yield per plant (25.00) followed by open pollination (21.00) and lowest in autogamy (10.37). In general a

Table 4.18b : Effect of different pollination treatments and genotypes on kernel proportion in achene (breadth wise) %

Genotype	Kernel proportion in achene (breadth wise) %				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	76.48	78.38	79.67	80.83	**78.84**
M-1026	77.78	78.17	78.74	80.52	**78.80**
M-269	81.39	81.94	84.22	87.17	**83.68**
MFSH-17	76.40	80.41	81.29	84.25	**80.59**
Jwalamukhi	79.67	81.50	84.21	87.87	**83.31**
KBSH-1	74.75	77.72	80.45	84.48	**79.35**
Sungene	74.51	78.90	82.80	84.97	**80.30**
Morden	66.66	71.93	74.70	80.17	**73.36**
GAUSUF-15	67.43	73.97	75.82	79.28	**74.13**
Mean	**75.01**	**78.10**	**80.21**	**83.28**	79.15

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.5005	0.7508	1.5016
CD (0.05)	0.9981	1.4971	2.9942
C.V (%)	2.3235		

Table 4.18c : Effect of different pollination treatments and genotypes on kernel proportion in achene (thickness wise) %

Genotype	Kernel proportion in achene (thickness wise) %				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	49.95	50.42	51.83	53.39	**51.40**
M-1026	59.80	62.38	64.22	65.37	**62.94**
M-269	61.92	65.25	66.77	66.97	**65.23**
MFSH-17	53.29	53.39	57.57	60.70	**56.24**
Jwalamukhi	57.47	61.05	62.02	64.23	**61.19**
KBSH-1	59.24	62.35	64.53	69.02	**63.79**
Sungene	56.25	56.88	60.78	63.00	**59.23**
Morden	41.93	42.93	45.48	50.20	**45.14**
GAUSUF-15	55.78	59.39	62.43	68.26	**61.46**
Mean	**55.07**	**57.12**	**59.52**	**62.35**	**58.51**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.1124	0.1686	0.3373
CD (0.05)	0.2242	0.3363	0.6725
C.V (%)	0.7060		

Table 4.19 : Effect of different pollination treatments and genotypes on oil content (%)

Genotype	Oil content (%)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	30.57	31.83	33.57	35.80	**32.94**
M-1026	30.33	31.93	32.87	33.90	**32.26**
M-269	28.82	30.90	31.72	33.47	**31.23**
MFSH-17	42.10	44.23	45.43	46.93	**44.67**
Jwalamukhi	40.63	41.47	43.47	44.47	**42.51**
KBSH-1	39.53	40.13	40.97	42.47	**40.78**
Sungene	39.40	41.13	41.33	43.27	**41.28**
Morden	32.63	34.23	34.53	36.73	**34.53**
GAUSUF-15	36.17	36.63	38.20	42.27	**38.32**
Mean	**35.58**	**36.94**	**38.01**	**39.92**	**37.61**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.4745	0.7118	1.4236
CD (0.05)	0.9462	1.4193	NS
C.V (%)	4.6254		

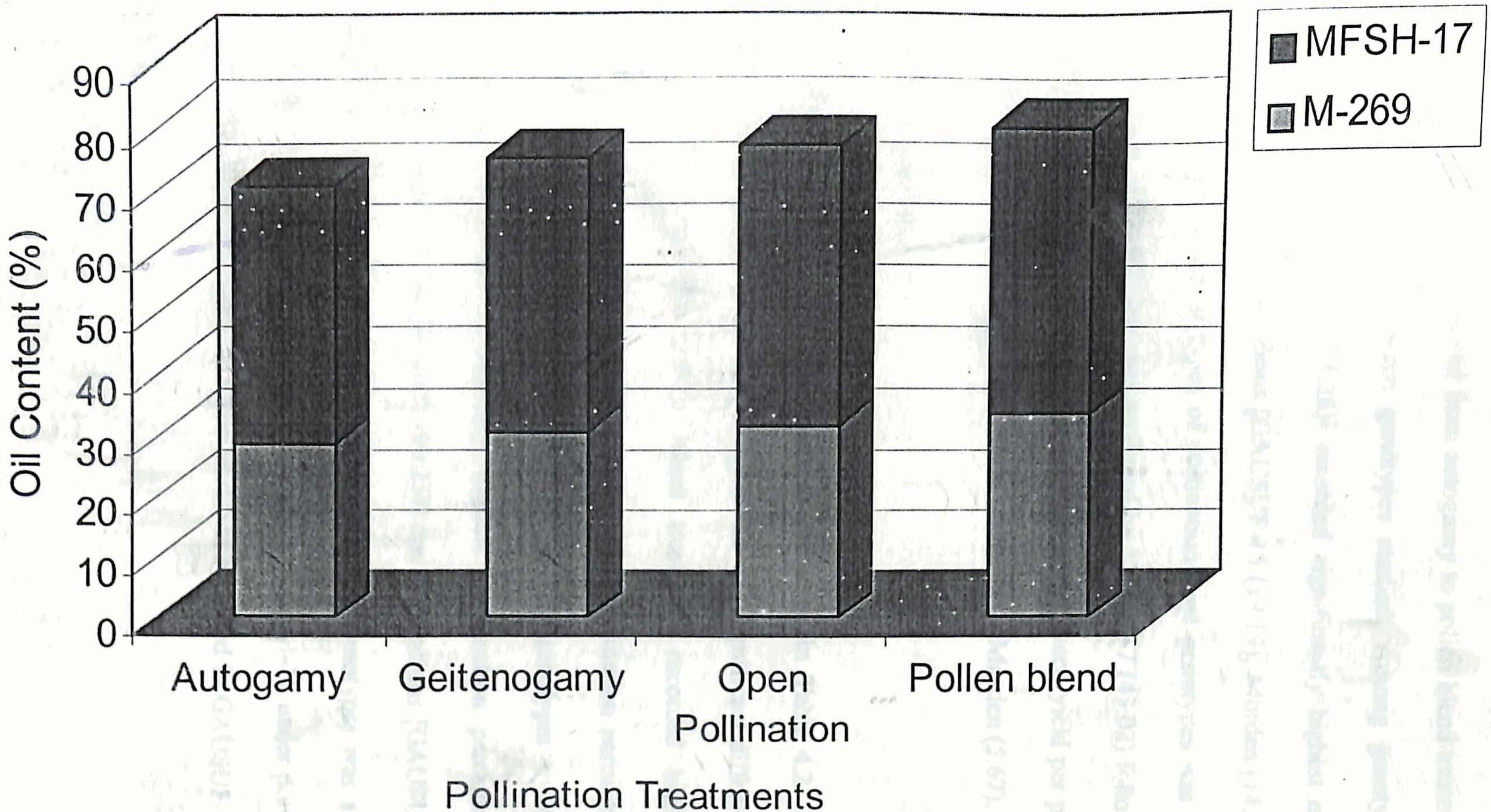

Fig. 4 Influence of Pollination treatments on oil content (%) of M-269 and MFSH-17

steady increase in seed yield was observed from autogamy to pollen blend treatment. There was significant difference between genotypes studied. Among genotypes, hybrids [MFSH-17 (29.85), KBSH-1 (25.28)] recorded significantly highest mean seed yield per plant followed by populations [GAUSUF-15 (19.19), Morden (14.68)] and inbreds. The interaction effect of types of pollinations and genotypes was also significant. Highest seed yield per plant was produced by MFSH-17 (43.02) followed by same genotype (32.09) under open pollination. While lowest seed yield per plant was recorded by GAUSUF-15 (1.58) under autogamy followed by Morden (5.67).

4.1.22 Germination percentage

The mean data on germination percentage is presented in Table 4.21 and illustrated in Fig.6. It is indicated from the table that there was significant difference between types of pollination. The pollen blend treatment recorded highest germination (92.48). Among treatments steady increase in germination percentage was observed from autogamy to pollen blend treatment. Among genotypes, hybrids [MFSH-17 (94.25), KBSH-1 (95.75)] recorded highest germination percentage followed by inbreds [M-1026 (91.50), M-1008 (90.25)] and populations [GAUSUF-15 (85.50)]. The interaction effect of types of pollinations and genotypes was also significant. Highest germination percentage was recorded by MFSH-17 under pollen blend (98.67) followed by KBSH-1 (96.33), while least was recorded in GAUSUF-15 (81.33) under autogamy.

4.1.23 Seedling vigour index

The data pertaining to seedling vigour index of nine genotypes subjected to four different pollination treatments is shown in Table 4.22. It is evident from the

Table 4.20 : Effect of different pollination treatments and genotypes on seed yield per plant (g)

Genotype	Seed yield per plant (g)				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	7.24	12.16	14.71	21.12	**13.81**
M-1026	7.77	9.77	12.40	13.07	**10.75**
M-269	7.94	11.94	15.50	18.82	**13.55**
MFSH-17	19.24	25.04	32.09	43.02	**29.85**
Jwalamukhi	14.20	20.54	24.64	24.79	**21.04**
KBSH-1	19.71	24.68	25.84	30.91	**25.28**
Sungene	9.98	13.81	17.12	20.81	**15.43**
Morden	5.67	12.88	17.93	22.22	**14.67**
GAUSUF-15	1.58	16.15	28.81	30.24	**19.19**
Mean	**10.37**	**16.33**	**21.00**	**25.00**	**18.18**

	Pollination treatment	Genotype	Interaction
S.Ed ±	0.1124	0.1686	0.3372
CD (0.05)	0.2241	0.3362	0.6724
C.V (%)	2.2724		

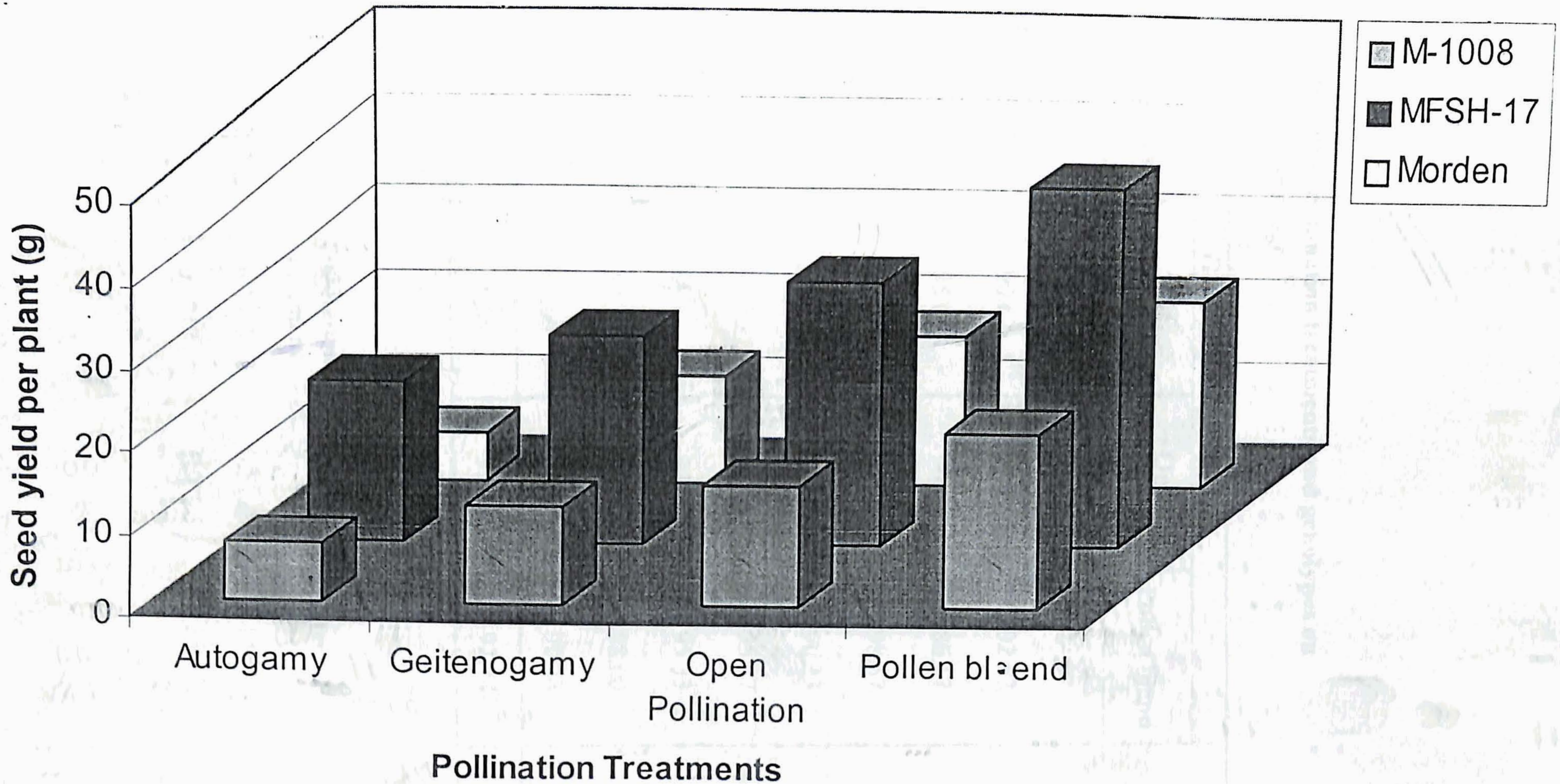

Fig 5. Influence of pollination treatments on seed yield per plant (g) of M-1008, MFSH-17 and Morden

Table 4.21 : Effect of different pollination treatments and genotypes on germination percentage

Genotype	Germination percentage				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	87.33	89.33	91.67	92.67	**90.25**
M-1026	90.33	90.67	92.33	92.67	**91.50**
M-269	84.33	85.00	90.67	86.67	**86.67**
MFSH-17	90.33	92.33	95.67	98.67	**94.25**
Jwalamukhi	87.67	86.33	88.00	90.33	**88.08**
KBSH-1	95.00	96.33	96.00	95.67	**95.75**
Sungene	92.00	91.67	93.67	95.33	**93.17**
Morden	81.67	84.33	86.00	88.00	**85.00**
GAUSUF-15	81.33	84.00	86.33	90.33	**85.50**
Mean	**87.78**	**88.89**	**91.15**	**92.48**	**90.07**

	Pollination treatment	**Genotype**	**Interaction**
S.Ed ±	0.3419	0.5128	1.0256
CD (0.05)	0.6817	1.0226	2.0451
C.V (%)	1.3946		

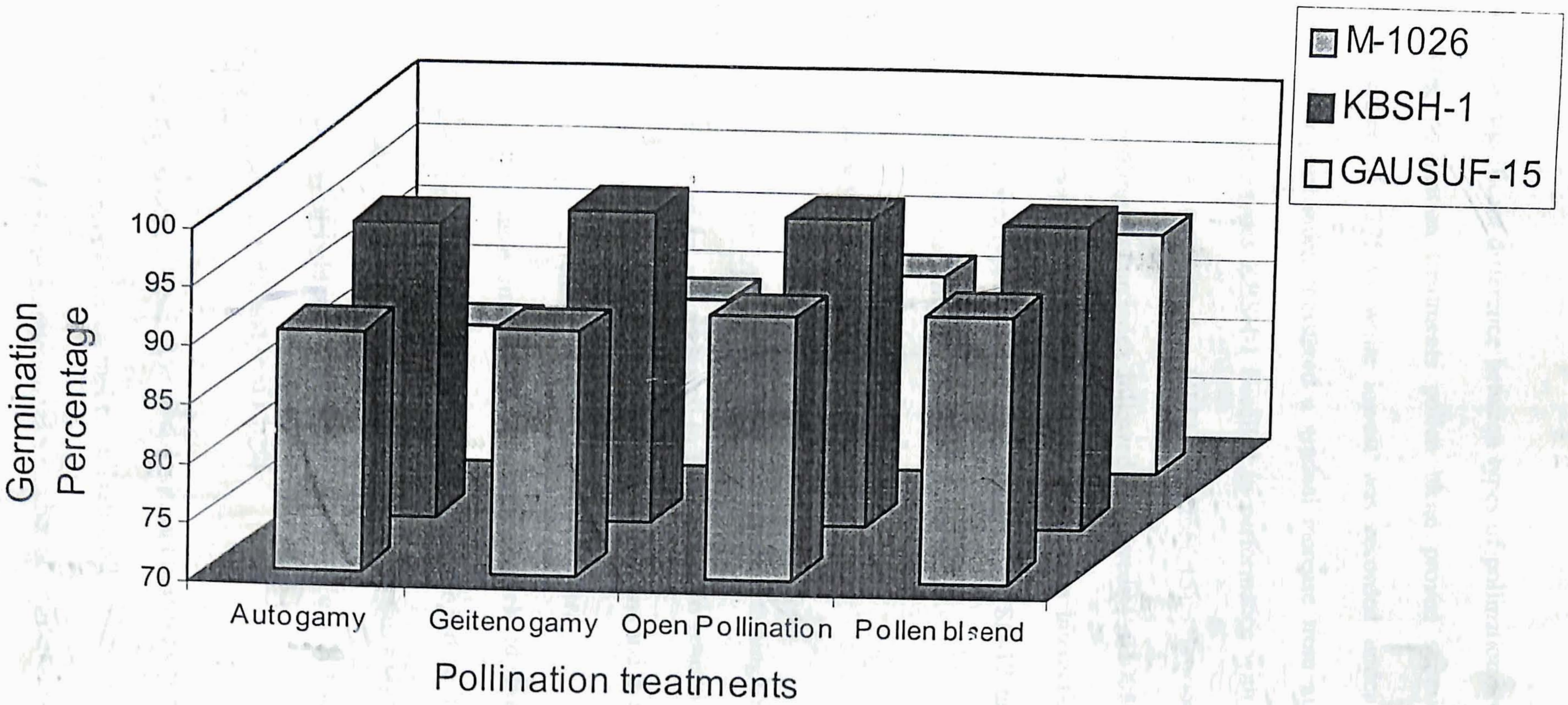

Fig. 6 Influence of pollination treatments on germination percentage of M-1026, KBSH-1 and GAUSUF-15

table that there was significant difference between types of pollination and between genotypes. Among pollination treatments pollen blend proved superior with a seedling vigour index of 2275.33 while lowest was recorded under autogamy (1788.46). Seedling vigour index registered a gradual increase from autogamy to pollen blend. Among genotypes KBSH-1 excelled in performance with a seedling vigour index of 2667.16 followed by MFSH-17 (2556.15). Hybrids recorded significantly higher seedling vigour index followed by inbreds [M-1008 (1625.48), M-1026 (1605.62)] and populations [Morden (1622.01)]. The interaction between types of pollinations and genotypoes was also significant. MFSH-17 under pollen blend treatment (2898.81) recorded highest seedling vigour index.

4.2 CORRELATION STUDIES

The phenotypic and genotypic correlation coefficients pertaining to different characters studied are worked out and presented in Table. 4.23. In general genotypic correlations were higher in magnitude than phenotypic correlations and in similar directions. Hence phenotypic correlations are discussed hereunder.

Seed yield per plant was positively and significantly correlated with filled seeds, total seeds, seed set percent, kernel to hull ratio, kernel proportion in achene (length, breadth and thickness-wise) and oil content. Contrary to this a significant negative correlation with seed yield was recorded for number of unfilled seeds, hull content, seed thickness, seed breadth and seed length.

Number of filled seeds per head showed a significant positive correlation with total number of seeds, seed set percent, kernel to hull ratio, oil content and seed yield. While it had a significant negative correlation with number of unfilled seeds per head, hull weight, hull content, seed thickness, seed breadth and seed length.

Table 4.22 : Effect of different pollination treatments and genotypes on seedling vigour index

Genotype	Seedling vigour index				Mean
	Autogamy	Geitenogamy	Open Pollination	Pollen blend	
M-1008	1491.68	1572.90	1629.95	1807.37	**1625.48**
M-1026	1430.59	1508.63	1565.07	1918.18	**1605.62**
M-269	1407.09	1483.25	1513.22	1720.19	**1530.94**
MFSH-17	2250.13	2416.93	2658.75	2898.81	**2556.15**
Jwalamukhi	2017.21	2209.47	2511.59	2762.03	**2375.08**
KBSH-1	2525.93	2589.36	2696.41	2856.96	**2667.17**
Sungene	2105.24	2277.85	2495.28	2714.17	**2398.14**
Morden	1409.09	1521.68	1659.96	1897.29	**1622.01**
GAUSUF-15	1459.19	1472.47	1520.20	1902.95	**1588.70**
Mean	**1788.46**	**1894.73**	**2027.83**	**2275.33**	**1996.59**

	Pollination treatment	Genotype	Interaction
S.Ed ±	3.1090	4.6635	9.3270
CD (0.05)	6.1993	9.2990	18.5980
C.V (%)	0.5721		

Table 4.23: Phenotypic and Genotypic correlation coefficients for various characters in sunflower (*Helianthus annuus L.*)

		No. of unfilled Seeds per head	Total No. of seeds	Seed set (%)	Test weight	Volume weight	Kernel weight	Hull weight
No. of filled seeds per head	P	-0.5761**	0.7686**	0.7808**	-0.2088	-0.0455	-0.1217	-0.5089**
	G	-0.5916**	0.7561**	0.8014**	-0.2369	-0.0529	-0.1265	-0.5235**
No. of unfilled seeds per head	P		0.080	-0.9025**	0.2169	0.5237**	0.3598*	0.4859**
	G		0.0805	-0.9030**	0.2423	0.5858**	0.3605*	0.4885**
Total No. of seeds per head	P			0.2459	-0.0849	0.3543*	0.1331	-0.2404
	G			0.2578	-0.0962	0.4102*	0.1363	-0.2506
Seed set (%)	P				-0.1646	-0.3212	-0.2253	-0.5239**
	G				-0.1823	-0.3606*	-0.2262	-0.5260**
Test weight	P					0.4604**	0.8043**	0.6842**
	G					0.7802**	0.9057**	0.7615**
Volume weight	P						0.7593**	0.5241**
	G						0.8443**	0.5885**
Kernel weight	P							0.7512**
	G							0.7538**
Hull weight	P							
	G							
Hull content	P							
	G							
K/H Ratio	P							
	G							
Seed thickness	P							
	G							
Kernel thickness	P							
	G							
Seed breadth	P							
	G							
Kernel breadth	P							
	G							
Seed length	P							
	G							
Kernel length	P							
	G							
Kernel proportion in achene (length)	P							
	G							
Kernel proportion in achene (breadth)	P							
	G							
Kernel proportion in achene (thickness)	P							
	G							
Oil content	P							
	G							
Seed yield	P							
	G							

Table Contd.

		Hull content	K/H Ratio	Seed thickness	Kernel Thickness	Seed breadth	Kernel breadth	Seed Length
No. of filled seeds per head	P	-0.6360**	0.6452**	-0.4510**	-0.0897	-0.5064**	-0.3358*	-0.5782**
	G	-0.6543**	0.6636**	-0.4654**	-0.0920	-0.6653**	-0.3455*	-0.6138**
No. of unfilled seeds per head	P	0.3213	-0.3352*	0.5634**	0.5769**	0.5421**	0.3347*	0.1468
	G	0.3239	-0.3377*	0.5678**	0.5894**	0.7085**	0.3379*	0.1509
Total No. of seeds per head	P	-0.5242**	0.5246**	-0.1090	0.3422*	-0.1933	-0.1476	-0.5903**
	G	-0.5460**	0.5462**	-0.1144	0.3648*	-0.2473	-0.1528	-0.6363**
Seed set (%)	P	-0.5319**	0.5419**	-0.5779**	-0.3541*	-0.5382**	-0.3170	-0.3387**
	G	-0.5354**	0.5454**	-0.5625**	-0.3621*	-0.7028**	-0.3199	-0.3499**
Test weight	P	0.1205	-0.0968	0.0486	0.3818*	0.2657	0.6225**	0.3758*
	G	0.1163	-0.0931	0.0592	0.4352**	0.3864**	0.6991**	0.4307*
Volume weight	P	-0.0580	0.0632	0.4242**	0.6718**	0.3842*	0.5285**	-0.0138
	G	-0.0546	0.0606	0.4724**	0.7577**	0.5589**	0.5957**	-0.0114
Kernel weight	P	0.0030	0.0198	0.2481	0.6145**	0.4041*	0.6813**	0.2371
	G	0.0042	0.0190	0.2452	0.6255**	0.5287**	0.6860**	0.2457
Hull weight	P	0.6574**	-0.6376***	0.3715*	0.3243	0.6080**	0.7930**	0.5291**
	G	0.6573**	-0.6375**	0.3753*	0.3301*	0.7941**	0.7997**	0.5503**
Hull content	P		-0.9978**	0.3066	-0.2050	0.4640**	0.4060*	0.4930**
	G		-0.9982**	0.3103	-0.2100	0.6088**	0.4110*	0.5142**
K/H Ratio	P			-0.3247	0.2015	-0.4697**	-0.3891*	0.4794**
	G			-0.3290	0.2064	-0.6173**	-0.3943*	0.5005**
Seed thickness	P				0.2450	0.6047**	0.3765*	0.0895
	G				0.2519	0.7966**	0.3798*	0.0915
Kernel thickness	P					0.2604	0.1871	0.0300
	G					0.3327*	0.1891	0.0325
Seed breadth	P						0.5950**	0.3248
	G						0.7723**	0.4222*
Kernel breadth	P							0.5769**
	G							0.6034**
Seed length	P							
	G							
Kernel length	P							
	G							
Kernel proportion in achene (length)	P							
	G							
Kernel proportion in achene (breadth)	P							
	G							
Kernel proportion in achene (thickness)	P							
	G							
Oil content	P							
	G							
Seed yield	P							
	G							

Table Contd..

		Kernel Length	Kernel proportion in achene (length)	(breadth)	(thickness)	Oil content	Seed Yield
No. of filled seeds per head	P	-0.3906*	0.2529	0.4713**	0.3315*	0.6301**	0.9268**
	G	-0.4013*	0.2627	0.5143**	0.3399*	0.6844**	0.9508**
No. of unfilled seeds per head	P	0.0635	-0.1394	-0.6801**	-0.1375	-0.3618*	-0.5605**
	G	0.0639	-0.1417	-0.6770**	-0.1377	-0.3823*	-0.5621**
Total No. of seeds per head	P	-0.4266**	0.1994	0.0817	0.2966	0.4852**	0.6916*
	G	-0.4442**	0.2098	0.0863	0.3085	0.5357**	0.7193**
Seed set (%)	P	-0.1686	0.2753	0.6463	0.2750	0.5536**	0.7672**
	G	-0.1692	0.2783	0.7010**	0.2754	0.5862**	0.7685**
Test weight	P	0.5733**	0.5424**	0.0486	0.1368	0.1347	0.0453
	G	0.6444**	0.6158**	0.0517	0.1537	0.1477	0.0504
Volume weight	P	0.1409	0.3194*	-0.3442*	-0.0108	0.1671	0.1382
	G	0.1579	0.3579*	-0.4097*	-0.0128	0.2034	0.1522
Kernel weight	P	0.4467**	0.5234**	-0.0629	0.1263	0.2055	0.1144
	G	0.4482**	0.5289**	-0.0687	0.1264	0.2179	0.1142
Hull weight	P	0.6431**	0.3716*	-0.2821	-0.1557	-0.3399*	-0.3551*
	G	0.6445**	0.3738*	-0.3031	-0.1563	-0.3611*	-0.3560*
Hull content	P	0.4307**	0.0360	-0.3879*	-0.3934*	-0.7494**	-0.6686**
	G	0.4334**	-0.0379	-0.4187*	-0.3953*	-0.8000**	-0.6720**
K/H Ratio	P	-0.4073*	0.0629	0.4118*	0.4076**	0.7622**	0.6856**
	G	-0.4098*	0.0649	0.4440**	-0.4099**	0.8147**	0.6893**
Seed thickness	P	-0.1602	-0.5326**	-0.845**	-0.7621**	-0.1909	-0.4262**
	G	-0.1595	-0.5413**	-0.9169**	-0.7674**	-0.1714	-0.4289**
Kernel thickness	P	0.1088	0.1871	-0.2542	0.3999*	0.1922	0.0150
	G	0.1111	0.1912	-0.2781	0.4016*	0.2008	0.0160
Seed breadth	P	0.2525	-0.0788	-0.5119**	-0.3818*	-0.3390**	-0.4554**
	G	0.3210	-0.1013	-0.7065**	-0.4943**	-0.4872**	-0.5900**
Kernel breadth	P	0.6770**	0.3373*	-0.1645	-0.2662	-0.2188	-0.1595
	G	0.6830**	0.3628	-0.1787	-0.2687	-0.2309	-0.1607
Seed length	P	0.8665**	0.0642	0.0126	-0.0835	-0.3501*	-0.4634**
	G	0.8977**	0.0671	0.0245	-0.0856	-0.3839*	-0.4776**
Kernel length	P		0.5173**	0.2540	0.1836	-0.2749	-0.2309
	G		0.5182**	0.2746	0.1845	-0.2990	-0.2316
Kernel proportion in achene (length)	P			0.5323**	0.5811**	0.0834	0.3819*
	G			0.5792**	0.5877**	0.0919	0.3836*
Kernel proportion in achene (breadth)	P				0.6012**	0.2996	0.4910**
	G				0.6501**	0.3296	0.5312**
Kernel proportion in achene (thickness)	P					0.2063	0.3401*
	G					0.2177	0.3411*
Oil content	P						0.7286**
	G						0.7716**
Seed yield	P						
	G						

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

The association of number of unfilled seeds per head was significant and positive with volume weight, hull weight, seed and kernel thickness and seed breadth. In contrast it recorded a significant negative correlation with seedset percent, kernel to hull ratio, seed yield and oil content.

Total number of seeds recorded a significant positive association with number of filled seeds per head, kernel to hull ratio, oil content and seed yield. In contrast volume weight, seed length and kernel length recorded a significant negative correlation with number of filled seeds.

Seed set percent showed a significant positive correlation with kernel to hull ratio, oil content and seed yield. While hull weight, hull content, seed thickness, seed breadth and seed length showed a negative significant correlation with seed set percent.

Test weight recorded significant positive association with volume weight, kernel weight, hull weight, kernel thickness, kernel length and kernel breadth.

Volume weight showed a significant positive correlation with kernel weight, hull weight, seed thickness, kernel thickness, seed breadth and kernel breadth. Kernel weight recorded a significant positive correlation with hull weight, kernel thickness, kernel breadth and kernel length. Hull content showed a significant, negative correlation with K/H ratio, oil content and seed yield.

Hull weight showed a significant negative correlation with kernel to hull ratio, oil content and seed yield.

DISCUSSION

CHAPTER V

DISCUSSION

The results presented in the preceding chapter on the effect of different pollination treatments on seed characters and seed yield of nine sunflower genotypes are discussed in this chapter in the light of relevant literature under the following headings:

5.1 Effect of different pollination treatments and genotypes on various Characteristics

5.2 Correlation studies

Sunflower is a major oilseed crop in the world after soybean and groundnut. The significant developments that took place in varietal front and its ability to adjust and grow in different agroclimatic situations, expanded sunflower cultivation to all the conditions, consequently the sunflower area had crossed 21 mha, producing around 1.5 mt of seed annually. Though the progress achieved is satisfactory in terms of area and production, India's productivity of 500-600 kg ha^{-1} is still lowest in the world. So there is a necessity to ascertain and identify the reasons for low productivity and initiate remedial measures to sustain sunflower cultivation.

One of the important constraints limiting productivity in sunflower is the high percentage of empty and partially filled seeds. Seed set in sunflower is a complex phenomenon and several workers ascribe it to nutrition, self or cross compatibility, pollination, competition among developing seeds, temperature, relative humidity, location and seasonal influence (Ranganatha, 1998; Chaudhary and Anand, 1989;

Seetharam and Suryanarayana, 1983; Vranceanu *et al*., 1978; Khanna, 1972). Seed filling problem often assumes serious dimensions in monsoon season when the peak flowering phase coincides with heavy rains, resulting in pollen wash and/or low pollinator activity resulting in low pollination. Hence, under such situations the self fertile populations/ hybrids/ mixtures assume great importance.

The present study aims to evaluate nine sunflower genotypes which include hybrids, inbreds and varietal populations for self fertility and autogamy and to understand the effect of pollen blend on seed yield and quality in sunflower.

5.1 EFFECT OF DIFFERENT POLLINATION TREATMENTS AND GENOTYPES ON VARIOUS CHARACTERS

Present study consisted of four pollination treatments viz., autogamy, gietenogamy, open pollination and pollen blend. The first two treatments are intended to evaluate genotypes for self compatibility and autogamy, and the remaining two treatments to evaluate the problem of self-incompatibility in sunflower. Among the different characters studied, number of filled seeds, seed set per cent, seed yield, oil content, kernel to hull ratio, kernel proportion in achene, germination per cent and seedling vigour index recorded a steady increase from autogamy to pollen blend. While number of unfilled seeds per capitulum, test weight, volume weight, weight of hull, weight of kernel, seed and kernel length, breadth and thickness registered a gradual decrease from autogamy to pollen blend.

Total number of seeds per capitulum were maximum under pollen blend followed by open pollination, geitenogamy and autogamy. Irrespective of treatments, hybrids exhibited maximum number of seeds per head followed by population and inbreds. These results are in conformity with the findings of Swamy Gowda and

Giriraj (1989), Narsaiah (1995) and Rao (1999). They attributed the reason for higher total number of seeds in pollen blend due to large head diameter.

Number of filled seeds per capitulum is an important seed character, which is directly related to seed yield. Pollen blend pollination treatment recorded maximum number of filled seeds followed by open pollination, gietenogamy and autogamy. The superiority of pollen blend and open pollination over other treatments can be attributed to the effective transfer of foreign pollen to the receptive stigma, thereby reducing the self-incompatibility nature. It was also noticed that there was a steep increase in the number of filled seeds from autogamy to geitenogamy in GAUSUF-15 indicating that they are highly self-incompatible, however, cross compatible within the capitulum. In general hybrids recorded higher mean number of filled seeds followed by populations and inbreds.

In case of the number of unfilled seeds per head, the reverse was true where in unfilled seeds were highest in autogamy followed by gietenogamy, open pollination and pollen blend. The hybrids recorded the lowest number of unfilled seeds per capitulum followed by inbreds and populations. GAUSUF-15 recorded the highest percentage of unfilled seeds (95.6%) under autogamy indicating self-incompatibility. However, in gietenogamy it recorded only 57.55 per cent unfilled seeds, indicating that they are cross-compatible within the capitulum. While, in pollen blends, the per cent of unfilled seeds were only 13.92 percent mainly due to the operation of differential pollination treatments for effective seed set.

Seed set per cent is the important parameter which determines the total number of seeds per capitulum and ultimately the seed yield per plant. In the present study, pollen blend treatment had recorded the highest seed set percentage irrespective of genotypes, followed by open pollination, gietenogamy and autogomy. The cause for the higher seed set in pollen blend and open pollination was due to the self incompatibility mechanism in sunflower which makes the ovule parent accept foreign pollen in preference to its own pollen, thus encouraging cross pollination. This phenomenon was observed in all genotypes of present investigation, irrespective of variety or hybrid. Similar effect of foreign pollen to over come self-incompatibility in sunflower has been reported by Roath and Miller (1982), Shivaraju *et al.* (1987), Swamy Gowda and Giriraj (1989) and Javed and Mehdi (1992). However, the poor seed set was due to self-incompatibility nature, lack of pollen movement and also high relative humidity within the bagged capitulum.

Hybrids recorded higher seed set in autogamy followed by inbreds and open pollinated varieties, indicating high self fertility nature of hybrids than inbreds and populations. Similar results were obtaiined by Ranganatha (1998), Doddamani *et al.* (1997), Kamaljeet *et al.* (1986), Narsaiah (1995), Virupakshappa *et al.* (1992), Swamy Gowda and Giriraj (1989), Burlov and Krutko (1986), Petrov and Siskov (1985), Fick (1983), Robinson (1980) and Kurnik and Zelles (1962). It was also noticed that the inbreds out yielded in seed set per cent over populations the probable reason may be ascribed that the inbreds used in the study are recently developed ones having high self fertility rate as compared to populations. Morden and GAUSUF-15, where the self fertility was meagre. It is worth noting that the genotypes with low seed set under autogamy recorded higher seed set in gietenogamy, which may be ascribable to the reason that the self incompatible varieties like GAUSUF-15 under supplemental pollination could exhibit higher seed set due to their cross compatible nature. Similar type of results were obtained by George *et al.* (1980).

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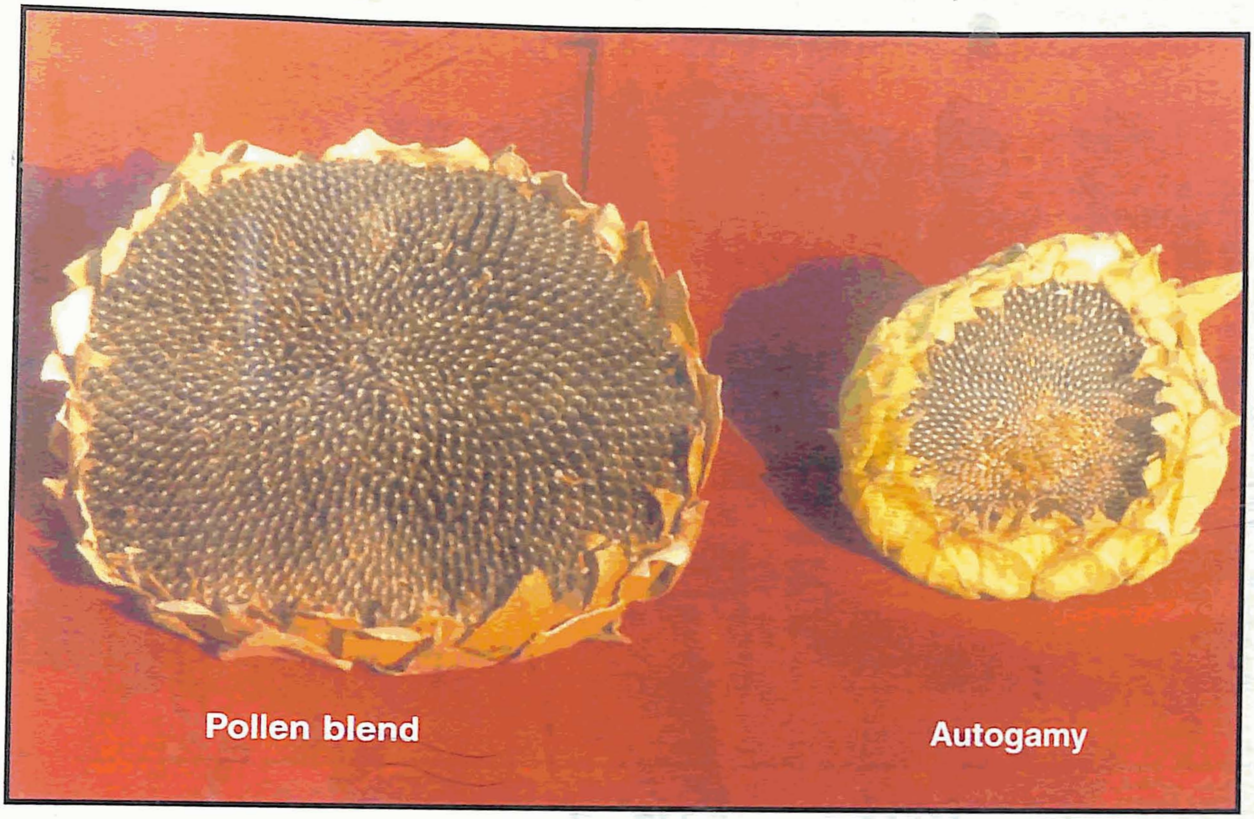

Plate 8 : Pollen blend and autogamy capitulums of MFSH-17

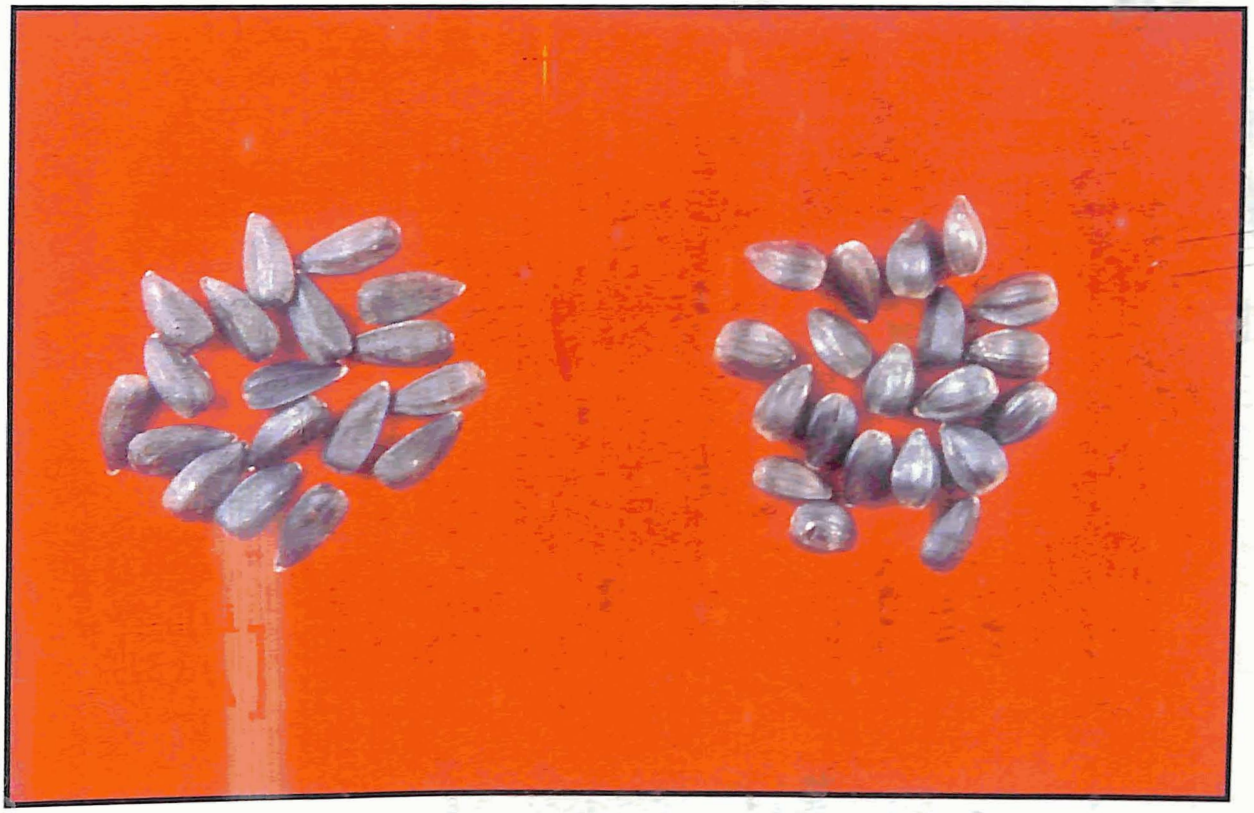

Plate 9 : Pollen blend Seed of Morden showing variation in seed size

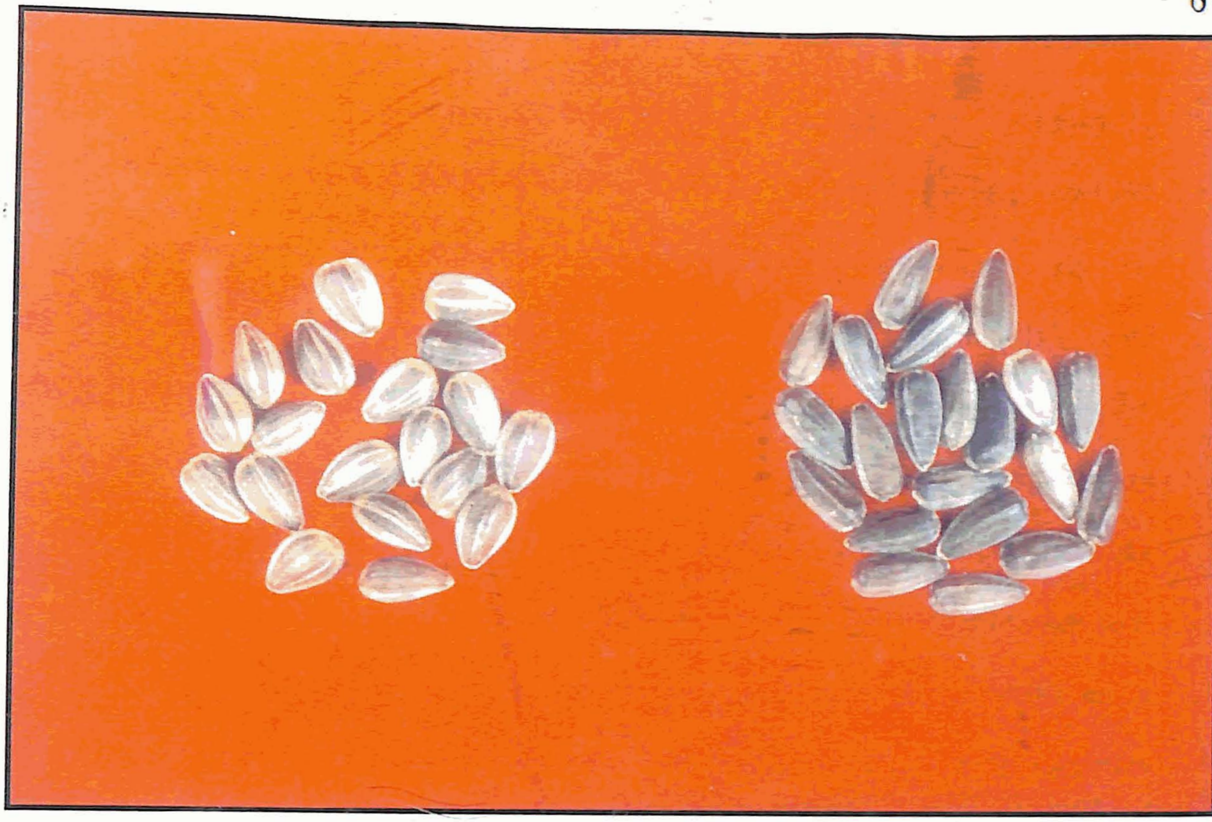

Plate 10 : Pollen blend Seed of M-1008
Showing variation in seed coat colour and seed size

Plate 11 : Pollen blend Seed of MFSH-17
showing variation in seed coat colour

Autogamy and self-compatibility studies also confirm the superiority of hybrids over inbreds and populations for self-fertility. A genotype is considered self fertile if the maximum seed set takes place under bagged condition. George *et al.* (1980) pointed out that bagging does not ensure potential self pollination in some genotypes, which, however, can be achieved by manual self pollination. Similar results were ensured in the present investigation where self incompatible variety GAUSUF-15 which recorded low autogamy per cent recorded good self compatibility per cent conforming the above findings. Hybrids recorded higher autogamy and self-compatibility per cent followed by inbreds and populations. These results are in confirmity with the findings of Doddamani *et al.* (1997), Narsaiah (1995), Seetharam and Virupakshappa (1994), Swamy Gowda and Giriraj (1989).

Test weight is one of the important yield component characters. In the present study test weight was directly influenced by number of filled seeds per capitulum. Autogamy recorded high test weight due to poor seed set while supplemental pollination methods recorded lower test weight due to high rate of seed setting. Increase in the number of filled seeds per capitulum, lead to decrease in the test weight. The physiological reason being competition among developing seeds for limited source of nutrients thus affecting test weight. Similar results were obtained by Robinson (1980) and Akhanda *et al.* (1979). The reason for increased test weight under bagging was due to greater nutrient supply per fertile achene. While, contradictory results were reported by Rao (1999) and Narsaiah (1995) from different types of materials used in the study.

Hull and kernel weight were in higher magnitude in autogamy, followed by gietenogamy, open pollination and pollen blend. The higher weights of kernels and hulls in autogamy was due to the greater nutrient supply per fertile achene since bagging of the capitulum resulted in meagre seed set (i.e., fewer fertile achenes per head) resulting in less competition among the developing achenes for nutrients in the head leading to higher test weight compared to other pollination treatments. It can be noticed from the results that kernel weight did not increase in proportionate to hull weight, wherein M-1008 recorded highest hull weight in all the treatments, but could not put forth highest kernel weight in any of the treatments. However, genotypes GAUSUF-15 and Sungene recorded proportionate increases in kernel and hull weights.

There was a steady decrease in hull content of the achene from autogamy to pollen blend. Higher hull content in autogamy was in coordination with the increase in the size of the achene thereby proportionate increase in hull content. Higher hull content, in autogamy lead to decrease in kernel content, thereby reducing the oil content since kernel is the major oil producing portion in the achene. Similar results were obtained by Dedio (1982). The reason being, the higher hull content resulted in higher test weight and lower oil content, however, contrasting results were obtained by Shanker Goud *et al.* (2000), wherein increase in hull content resulted in increase in test weight, and higher oil content. The reason being that the foreign pollen had in general stimulating effect on the seed characters of the female parent.

Kernel to hull (K/H) ratio was highest in pollen blend treatment followed by open pollination, gietenogamy and autogamy. Ratio of kernel to hull was proved to be directly proportional to oil content of achene. Higher kernel to hull ratio resulted in high kernel weight, thereby resulted in higher oil content, as kernel is the oil accumulation portion in the achene. Similar findings were obtained by Nanja Reddy *et al.* (1996). They reported that superior K/H ratio lead to higher oil accumulation in the achene. Influence of foreign pollen on the seed parent in general influence the seed characters like volume weight, K/H ratio and oil content as reported by Shankar Goud *et al.* (2000).

Volume weight showed a steady decline of values from autogamy to pollen blend treatment. Similar types of results were obtained for test weight and hull content. The reason for decreased volume weight in pollen blend treatment in attributed to the low test weight, low seed and kernel length, breadth and thickness.

Seed and kernel thickness, length and breadth recorded highest values in autogamy followed by gietenogamy, open pollination and pollen blend. It can be noted that in autogamy, higher supply of nutrients to the fertile achenes lead to increased seed size leading to increase in test weight. However, oil accumulation was low, due to higher hull content, thereby reduced kernel to hull ratio.

Kernel proportion in achene registered a steady increase from autogamy to pollen blend. There was a direct influence of proportion of kernel in achene on oil content. Increase in seed size decreased the oil content. In the present study, high per cent of seed set per head lead to the development of smaller seed, due to competition among the developing achenes. However, smaller achene-size, did not have any negative impact on oil content. Immediate effect of foreign pollen, metaxenia, low hull content, high K/H ratio may be the reasons for smaller achene size and high oil content.

Accumulation of oil content in the achenes is the ultimate factor, which is valued for. In the present study, pollen blend treatment proved superior, in which the seeds produced, could able to accumulate higher oil content followed by open pollination, gietenogamy and autogamy. These results are in conformity with the findings of Robinson (1980), Tuberosa (1983), Narsaiah (1995) and Rao (1999). The foreign pollen in general influence the seed characters such as test weight, hull content, volume weight and oil content. The scope of influence depends on the type of pollen involved in fertilization. Similar effect of foreign pollen on seed characters was reported in sunflower by Shankar Goud *et al.* (2000), Seetharam *et al.* (1976) and Vagvolgyi and Gaal (1987), in Oliferous Brassica by Singh (1957) and Asthana and Singh (1973), in pearl millet by Burton (1952) and Burton *et al.* (1980), in maize by Pinter *et al.* (1987) and in rape seed by Downey and Harvey (1963).

It can also be noted that the treatment which proved inferior in test weight, proved to be superior in its oil accumulation capacity and vice versa. The reason being, the exploitation of metaxenia effect by the immediate effect of foreign pollen on the stigma of the pollen blend treatment. The other reason being tendency of smaller seeds to accumulate more oil. The results are in agreement with the findings of Fick *et al.* (1974) and Robinson (1980). They reported that large achenes cannot act as powerful sink as compared to smaller achenes. Hybrids proved superior in accumulating more oil content in achenes followed by populations and inbreds. As inbreds are nearly homozygous (less variability), therefore even supplementary pollination cannot improve the oil accumulation capacity.

Seed yield per plant is a result of several yield attributes viz. total number of seeds per head, seed set per cent, number of filled seeds per head and test weight. In the present study, the highest seed yield was recorded under pollen blend followed by open pollination, gietenogamy and autogamy. Hybrids were better seed yielders compared to inbreds and populations. Similar results were obtained by Doddamani *et al.* (1997), Seetharam and Virupakshappa (1994), Virupakshappa *et al.* (1992), Swamy Gowda and Giriraj (1989), Shivaraju *et al.* (1987), Burlov and Krutko (1986), Petrov and Siskov (1985), Fick (1983) and Kurnik and Zelles (1962). Higher seed yield per plant in pollen blend treatment is mainly due to higher seed set thereby increase in number of filled seeds, compared to other treatments. Inspite of decrease in test weight from autogamy to pollen blend, it did not have a negative effect on seed yield, as it lead to increase in number of filled seeds per head and higher oil accumulation per achene. The interaction effect between types of pollination treatments and genotypes was proved to be significant for this trait. Hybrids in the pollen blend treatment out-yielded inbreds populations. The one reason being the self-fertile nature of hybrids and the other reason being the superiority of pollen blend treatment in enhancing the seed set per cent, number of filled seeds and ultimately the seed yield per plant.

Seeds produced from different pollination treatments were subjected to germination studies. It was noticed that pollen blend treatment recorded high germination per cent followed by open pollination, gietenogamy and autogomy. There was a marked difference in the per cent germination among pollination treatments.

It is worth noting that seedling vigour index showed varied differences among different pollination treatments. The seedlings from pollen blend and open pollination treatments proved highly heterotic due to their heterogygous and heterogeneous nature interms of seedling vigour index compared to gietenogamy and autogamy. Hybrids proved superior compared to populations and inbreds.

5.2 CORRELATION STUDIES

Phenotypic and genotypic correlation were studied to evaluate the relationship among various yield and its components. However the genotypic correlations were recorded to have higher magnitude. Similar observations were also recorded by Rajputh *et al.* (1996) in sunflower.

Seed yield is a complex character governed by several contributing characters. In the present investigation, total number of seeds, number of filled seeds per capitulum and seed set percent showed significant positive association with seed yield. These results are in agreement with the findings of Potdar *et al.* (1977); Lakshmanaiah (1978); Sudhakar (1984); Singh *et al.* (1985); Fiazane (1988); Niranjana Murthy and Shambulingappa (1989); Lakshminarayana (1991); Manoharamba (1992); Punia and Gill (1994); Suma and Virupakshappa (1994); Narasaiah (1995); Patil *et al.* (1996), Poddamani *et al.* (1997) and Mirza et al. (1998).

Seed yield recorded a significant positive association with oil content. These results are in conformity with the findings of Lakshmaniah (1978); Rao (1987); Sharma *et al.* (1987) and Padma (1996). However contradictory results were reported by Srinivasa (1982) and Rao (1999).

Number of filled seeds per head recorded significant positive association with total number of seeds, seed set percent and oil content. Similar results were obtained by Zali *et al.*, (1977) Padma (1996) and Diwakar (1998). While number of unfilled seeds recorded negative association with number of filled seeds. Similar results were obtained by Shashikala (1992), Rukmini Devi (1994) and Rao (1999).

Test weight recorded a significant negative association with total number of seeds, number of filled seeds, seed set percent oil content, kernel to hull ratio, however a significant positive association was recorded with number of unfilled seeds weight of hull, weight of kernel, hull content and volume weight. The association, between test weight and seed yield was non significant. These results are in conformity with the findings of Akhanda *et al.* (1979) and Robinson (1980). While contradictory results were reported by Varshney and Singh (1977); Anand and Chandra (1979); Giriraj *et al.* (1979); Srinivasa (1982); Lawrence (1986) Sheriff *et al.* (1986) and 1987) Reddy (1989); Shashikala (1992); Kalaiselvan and Manoharan (1994) Narasaiah (1995); Doddamani *et al.* (1997) and Mirza *et al.* (1998). Hull content, Kernel and hull weight, number of unfilled seeds per head recorded significant negative correlation with seed yield similar results were obtained by Dedio (1982).

Oil content showed significant positive correlation with total number of seeds, number of filled seeds and seed set percent. These results are in conformity with the findings of Zali *et al.* (1977) and Diwakar (1998). Test weight recorded significant negative association with oil content. Similar results were obtained by Robinson (1980). However contradictory results were obtained by Fick et. al. (1974); Srinivasa (1982) and Diwakar (1998).

Hull content recorded significant negative association with oil content, total number of seeds, number of filled seeds, seed set percent and K/H ratio, similar association of hull content with oil content was reported by Dedio (1982) and Srinivasa (1982).

CONCLUSION

The present investigation has been conducted for single season and needs further conformity. However based on the results it can be concluded that the pollen blend treatment was superior to other pollination treatments leading to high seed yield and higher accumulation of oil content. Higher seed yield was achieved due to high seed set per cent, number of filled seeds per head, high kernel to hull ratio and higher kernel proportion in achene. Further, high seed yield is also attributed to increased oil accumulation due to metaxenia. It was also noticed that seedlings obtained from pollen blend treatment recorded higher seedling vigour index due to their heterozygous and heterogenous nature. Pollen blend treatment has following advantages over componental hybrids/varieties.

1. Mixtures or blends can perform well under varied climatic conditions and impart more plasticity against pests and diseases.
2. Blends/Mixtures maintain high amounts of heterozygousity and variability and stable in performance due to broad genetic base.
3. Blends/hybrid mixtures/varietal blends act as an alternative to hybrids without compromising for yields.

SUMMARY

&

CONCLUSION

CHAPTER VI

SUMMARY

In the present study, nine sunflower genotypes were evaluated to study the effect of pollen blend on seed yield and its component traits at College Farm, College of Agriculture, Rajendranagar during *rabi* (2002). The experiment was conducted in factorial randomized block design with two factors i.e. pollination treatments and genotypes. Data was recorded on seed yield, and other yield components viz., number of filled seeds, unfilled seeds, total number of seed in four different pollination treatments viz. autogamy gietenogamy, open pollination and pollen blend. The salient findings of the present investigation are given below.

- Significant differences were noticed between types of pollination treatments for number of filled seeds, number of unfilled seeds, seed set percent, total number of seeds, volume weight, test weight, kernel weight, hull weight, hull content, kernel to hull ratio, seed thickness, kernel thickness, seed breadth, kernel breadth, seed length, kernel length, and seedling vigour index.
- There were significant differences between the genotypes studied for all the above characters.
- The interaction effect of types of pollination and genotypes was significant for all the characters studied except volume weight, test weight, seed breadth, seed length and oil content.
- Significant variation was recorded for number of filled seeds and total number of seeds under different pollination treatment. Autogamy recorded lowest number of filled and total seeds while pollen blend recorded the highest number. Hybrids proved superior followed by varieties and inbreds.

- Significant variation was recorded for seed set under different pollination treatments. Autogamy recorded poor seed set, while pollen blend showed highest seed set. Hybrids proved superior followed by inbreds.
- Test weight was directly influenced by number of filled seeds per capitulum. Similar effect was recorded in characters such as hull weight, kernal weight and volume weight. Autogamy recorded highest values of test weight hull weight, kernel weight and volume weight while pollen blend recorded the lowest values.
- Autogamy studies revealed that hybrids recorded high rate of autogamy (76.95%) and self compatibility (93.52%) followed by inbred (50.89%, 82.31%) and open pollinated varieties (17.77, 74.65 %).
- Oil accumulation capacity in achenes was indirectly proportion to the seed size. Smaller achenes could accumulate more oil compared to larger ones. Autogamy recorded lowest oil content due to large achenes produced under poor seed set, thus reducing competition among the achenes for nutrients.
- Substantial increase in seed yield was observed in pollen blend treatment mainly due to higher seed set by supplemental pollination methods. Hybrids were superior in yield followed by populations and inbreds.
- Pollen blend treatment recorded low hull content followed by open pollination, gietenogamy and autogamy. Competition among developing seeds led to thin hulled achenes with good oil accumulation.
- A steady increase in values from autogamy to pollen blend was recorded by kernel to hull ratio. High K/H ratio determines higher kernel content thereby good oil accumulation.

- Different pollination treatments showed marked difference for germination percent and significant variation for seedling vigour index.
- Seed and Kernel length, thickness and breadth indicate that these parameters recorded a steady decrease of values from autogamy to pollen blend. Greater competition among developing achenes lead to smaller seed in pollen blend treatment.
- Kernel proportion in achene was maximum in pollen blend followed by open pollination, gietenogamy and autogamy.
- Correlation studies revealed that total number of seeds, number of filled seeds per capitulum, seed set percent, oil content, kernel to hull ratio recorded significant positive association with seed yield per plant while test weight and hull content recorded significant negative association with seed yield and oil content.

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* Originals not seen

APPENDIX

APPENDIX - I

Mean Weekly meterological data during crop growth period

Date and month	Temperature (^oC)		Mean Relative Humidity (%)	Rainfall (mm)	Rainy days	Mean temperature (^oC)
	Maximum	Minimum				
29-04 Feb	29.5	16.3	59.0	0.0	0	22.9
05-11	30.0	17.2	60.5	3.7	1	23.6
12-18	32.5	16.2	54	0.0	0	24.3
19-25	34.1	14.9	44	0.0	0	24.5
26-04 March	35.7	16.1	43	0.0	0	25.9
05-11	35.7	19.6	59.5	25.7	1	27.7
12-18	35.4	18.7	44.5	0.0	0	27.0
19-25	36.9	18.8	33.0	0.0	0	27.8
26-01 April	38.1	21.4	40.0	11.8	1	29.7
02-08	37.8	22.2	60.5	0.0	0	30.0
09-15	37.8	21.8	56.0	0.0	0	29.8
16-22	39.9	23.7	40.5	0.0	0	31.8
23-29	40.1	25.5	40.5	0.0	0	32.8
30-06 May	40.7	25.0	36.5	0.0	0	32.8
07-13	40.5	21.6	40.5	0.0	0	34.1
14-20	37.8	24.9	56.5	26.9	2	31.3
21-27	39.0	26.0	44.0	18.1	1	32.5
28-03 June	38.1	25.0	51.0	18.4	2	31.6

Source: Agricultural Research Institute, ANGRAU, Rajendranagar, Hyderabad.

APPENDIX-II

Analysis of variance for seed yield and yield attributes in Sunflower

S. No.	Character	Mean sum of squares				
		Replication	Pollination treatments	Genotypes	Pollination treatments x Genotypes	Error
	Degrees of freedom	2	3	8	24	70
1	Number of filled seeds	1303.833	545759.687**	154306.625**	17697.537**	1561.319
2	Number of unfilled seeds	51.2	181723.171**	71370.242**	11801.935**	46.446
3	Total number of seeds	955	110483.1875**	181694.750**	16350.712**	1607.417
4	Seed Setting percent	3.163	9856.899**	1584.867**	329.618**	1.333
5	Test weight	0.08821	0.34830**	4.26768**	0.10782 NS	0.08631
6	Volume weight	2.2589	3858.7409**	149.3593**	1.3048 NS	2.8241
7	Kernel weight	8.61111	3253.7409**	23797.541**	66.0048**	4.23
8	Hull weight	1.6805	1719.1944**	3668.2812**	31.114**	1.4808
9	Hull content	0.0069	11.3348**	33.6686**	0.32706**	0.02418
10	Kernel to hull ratio	0.00026	0.35036**	0.93042**	0.011923**	0.000751
11	Seed thickness	0.0017	2.73504**	1.16846**	0.04346**	0.00246
12	Kernel thickness	0.00083	0.13519**	0.30694**	0.00451**	0.00097
13	Seed breadth	0.1762	3.0121**	2.9752**	0.2707 NS	0.20746
14	Kernel breadth	0.00065	0.08745**	1.16766**	0.00393**	0.000329
15	Seed length	0.12283	4.2738**	8.5659**	0.08114 NS	0.05395
16	Kernel length	0.000597	0.5637**	9.0299**	0.03993**	0.0025
17	Kernel proporiton in achene (length-wise)	0.20486	67.4637**	103.6276**	6.3760**	0.1718
18	Kernel proportion in achene (breadth-wise)	2.8402	328.0231**	150.3125**	7.6637**	3.3822
19	Kernel proportion in achene (thickness-wise)	0.1736	265.5887**	515.3932**	5.5253**	0.1706
20	Oil content	3.5486	90.7669**	297.8463**	1.0655 NS	3.0398
21	Seed yield	0.41536	1070.0076**	467.1233**	39.4031**	0.17058
22	Germination percentage	3.10763	122.6273**	180.5546**	6.1854**	1.5778
23	Seedling vigour index	24.88889	1191216.1250**	2822.04**	19913.978**	230.48889

NS = Non-significant
** Significant at 1 percent level
* Singinificant at 5 per cent level