CHAPTER FOUR

DISCUSSION
In crop plants, yield capacity is a quantitative character, which is the end product of several yield components each of which are greatly influenced by the environmental factors. Though it is difficult to directly select mutants for higher yield in the early generations, selections can be made on one or more visible yield components. In recent years there are a number of reports on isolation of mutants superior in yield to their respective parental cultivars. Micke (1981b) reported that by using induced mutations in crop plants, so far, 227 mutant varieties or mutant derivatives have been released from 35 different countries. This list includes 147 direct mutants and 80 are derivatives of crosses involving induced mutants as one of the parents. Out of this, 22 mutant varieties are of oil seed crops including groundnut, mustard, sunflower, linseed, castor, soyabean and one in sesame.

Gustafsson (1954) reported that positive mutations surpassing the parent cultivar in biomass as well as grain yield occur, perhaps with a frequency of 1 in 500 to 1,000 genotypical changes. Gregory (1957) working with X-rayed groundnuts reported that the frequency of mutants superior
in yield may be around 1 among 500 to 5,000 M₂ plants. Similarly, the ratio between desirable to undesirable mutants was estimated to range between 1:100 or 1:1000 depending upon crop, breeding objectives etc. (Hansel, 1966). Gustafsson (1947) reported that the highest productive types deviate from the original cultivar only in a few characters. Åastveit (1970) suggested two methods for selecting higher yielding mutants. First, the qualitative mutants are selected and evaluated for their yield. In the remaining normal appearing populations, plants are directly selected for yield as a quantitative character and evaluated further.

4.1. HIGH YIELDING MUTANTS IN SESAME

In sesame, induced mutants for higher yield have been reported (Chaudary et al., 1954; Rai et al., 1956, 1958 a; Kobayashi, 1958 c, 1975, 1977; Arzumanova et al., 1972). Most of these reports however, deal with mutants in early generations only or when yields per plant are compared. Recently 'Kalika', a mutant having dwarf, compact branched type, higher seed number per capsule and 15% higher yield, evolved from sesame cultivar 'Binayak', following 1% EMS treatment has been reported to be released from India (Micke, 1981 a). No data is available.
In the present study, mutants for higher yield were first selected on the basis of capsule number/plant and were then evaluated for yield in four crop seasons. Mutant S36-10 and S337-1 showed superior yields over the parent variety N62-32. Morphologically both of these mutants were selected on the basis of higher number of capsules/plant and were phenotypically very similar to the parent. Yield potential of these mutants in relation to the parent cultivar and the other high yielding cultures at other locations is to be tested.

4.2. VARIABILITY IN OIL CONTENT

4.2.1. Seasonal variation

Kinman et al. (1954) working on 24 varieties grown in 23 locations reported that the chemical composition of sesame seed was markedly influenced by the varieties and by the locations where they were grown. Mazzani (1959 a), in seven sesame cultivars grown over a period of three years, concluded that OP was influenced more by the environmental effects, than by the inherent differences among the cultivars. Arzumanova (1965) found that in all the cultivars of sesame from Central Asia, Afghanistan and Turkey, OP was greatly affected by the conditions of cultivation. Dhawan et al. (1979) observed
variability for OP in cultivars sown between July and August. In contrast to these reports, El-Shamma et al. (1973) found that the sowing date in three consecutive months between April to June had no significant effect on OP of four cultivars. The effect of photoperiod on OP and plant growth has been studied. Kluijver et al. (1960) applied 13 different photoperiods on a branching variety, 'Early Russian'. OP was 51.6 at photoperiods of 10 hours and less and gradually increased to 57.6 when plants were grown under 20 hours of light. They suggested that either light may directly influence lipid synthesis or the increase in OP could also be due to more vigorous plant growth. On the contrary, using three photoperiods (8, 13-14 and 24 hours) and ten genotypes, Tomar et al., (1980) observed highest OP in 8 hour photoperiods compared to 13-14 hour treatments. Capsules were not set on plants grown under 24 hours illumination. Kotecha et al. (1975) reported a day neutral type 'Aceiterna'.

In the present studies, considerable variation in OP was observed between kharif and rabi season crops. In general, higher OP was observed in kharif season than in rabi. In this season crop duration is about 130 days and higher phytomass, seed yield and oil yield were recorded. In rabi, the crop duration is about 90 days and seed yield as well as OP are lower. Richharia (1957) reported that sesame varieties in the collection
of erstwhile Central Provinces of India, were classified into two broad groups, *kharif* and *rabi* types. The *rabi* cultivars were characterised by early flowering and shorter crop duration. When the *rabi* cultivars were grown in *kharif* season, they produced lot of vegetative growth but poor bearing (Richharia, 1957). The two types differ in their photoperiodic response. The *rabi* types behave as short day plants while the *kharif* ones are day neutral (Joshi, 1961). Matsuoka et al. (1960 c) made two intersecting varietal groups among their germplasm collection, depending upon their adaptation for temperate vs. tropical climate or dry vs. rainy season. The variety N62-32 used in this study is a *kharif* cultivar. At Trombay, during *kharif* season, with an average rain fall of about 2,000 mm, it produces large vegetative growth, higher seed yield and OP as compared to the *rabi* season.

4.2.2. Oil percentage in individual vs. bulk harvests

It is seen from the present results that greater variability for OP was observed in individual plant harvests than in the bulk samples. These results indicated that selection for higher OP should be made on the basis of mean OP values in the established mutant lines than on single M2 plants. This procedure was followed in selecting mutants for higher OP.
4.2.3. Variability within a plant

4.2.3.1. Variation at different nodes

Hiltebrandt (1932) reported that the average seed weight in sesame plant varied rather widely according to the capsule position on the stem. Capsules at lower nodes produced seeds with higher seed weights than the terminal ones. A similar trend was observed in the present sampling of the main, primary and secondary branches.

Williams (1962) in safflower reported that the OP varies with the position of heads. Gangrade et al. (1973) recorded OP ranging from 52.6 to 57.1 in sesame seeds from the capsules borne on different nodes of the main stem. In sesame, flowers are borne in acropetal succession (Joshi, 1961) and the plants continue to produce flowers even when the lower nodes bear ripe, shattering capsules (Khidir et al., 1972; Gangrade et al., 1973). In the present studies, variations in HSW, OP and OPS noticed are possibly due to the differences in maturity period.

4.2.3.2. Variation in the bulk samples of main, primary and secondary branches

Williams (1962) reported that OP in safflower averaged 25.7, 28.6 and 32.3 in seeds produced from
primary, secondary and late-flowering heads respectively. In the present study on sesame, highest H8W and OPS were observed in the main shoot followed by primary and secondary branches (Fig. 13). The OP values were also significantly higher in the main and secondary branches, compared to the primary branches. The variation in these three parameters is possibly due to the differences in maturity as discussed in the previous paragraph (4.2.3.1). Sampling for oil percentage on bulked produce of a single plant and then testing its bulked progeny in the next generation was found to give reliable results.

4.3.1. Mutants with higher oil content

In the present study, 10 selections, made in the M4 generation for higher oil content, maintained their relative superiority over the parent cultivar, upto the M7 generation. Mutants with higher OP have been reported earlier in sesame. Rai et al. (1956, 1958 b) isolated two mutants, 'white flowered' and 'small seeded' with 44.1 and 52.1 OP against 41.5% in the parent T16. Similarly, Nayyar (Nair, 1961) observed SSM-2 mutant with 55.5 OP compared to 47.8% in the parent cultivar T10. Kobayashi (1975, 1977) evolved mutants with OP ranging between 53 to 55 compared to 50% in the original parents. The range of OP, in 721 introductions of world sesame collections
was between 40.4 to 59.8 with a mean of 53.5% (Yermanos et al., 1972). In another report OP in the local Sudanese and exotic varieties was within this range (El Tinsy et al., 1976). Values higher than 60% have also been reported in sesame (Arzumanova, 1963). In the All India Co-ordinated Research Project on Oilseeds (AICORPO) trials, conducted during 1977 kharif season, OP in the cultivars varied at different centres. Among the various trials, the lowest OP recorded was 41.8 (in JT.66-135) and the highest was 55.7 in JT.67-52, while the OP in the national check variety 'TC-25' ranged between 50.0 to 55.0%. In the national evaluation trial 1980 kharif conducted at Mahatma Phule Agriculture University, Jalgoan (Maharashtra State), the cultivars showed OP around 50.0% compared to 49.8 in the local check variety, 'Phule Til No. 1'.

Culp (1959) investigated the inheritance of both oil and protein contents. OP as well as PP were polygenically controlled and there was no evidence of dominance. Most of the variation was additive and environmental. Murty et al. (1973) reported, dominant gene action for both OP and PP. In contrast, Selim et al. (1976) inferred that OP was controlled by a pair of major genes with modifiers. The heritability for oil content observed in these studies were 50 (Culp, 1959), 23 (Murty et al., 1973) and 48 percent (Selim et al., 1976).
In the mutant selections included in the present study, correlation between OP or PP with (i) SY and (ii) HSW were not significant (Table 11). Negative significant correlation was obtained between OP and PP. Relations between the chemical composition of sesame seed with some agronomical characters have been reported. Mazzani (1959 b) found that, OP was positively correlated with profuse branching and (to a lesser extent) with small seed size. No correlations were found between OP and plant height, height of first fruit or seed yield. Yeranos et al. (1972) observed that short plants had clear oil while tall plants had light green oil. Early plants had higher OP than medium and late plants. Earliness, yellow seeds and large seeds were correlated with lower iodine values. Similarly, earliness and yellow seeds were correlated with higher oleic and low linoleic acids. There are conflicting reports on the relationship between seed coat colour and seed composition. Hiltebrandt (1932) and Singh (1952) reported that lighter the seed coat colour, higher is the OP. In contrast, Parthasarathy et al. (1949) and Baradi (1973) observed higher OP in black and brown seeds. Singh (1952), Krishnamurty (1959) and Krishnamurty et al. (1960) reported that PP was highest in black seed types followed by brown and white types. However, El Tinay et al. (1976) did not find any relationship between seed coat colour and OP or PP.
Among the ten selections in the present study, which have maintained their superiority in OP for three generations, eight had lower HSW (Table 10) while in one (S22-2), it was significantly higher, compared to the parent in this experiment. HSW in another selection (S40) was the same as the parent N62-32. Other induced higher OP mutants reported by Rai et al. (1956, 1958 b) and Nayar (Nair, 1961) also had lower HSW. In this context, selections S22-2 and S40 are of interest. These, however, need to be evaluated for their yield.

4.3.2. Protein percentage in high oil selections

In dry seeds of sesame PP was reported to range between 26.2 to 29.0% and in defatted seed meal it was between 45.0 to 60.0% (Kinman et al., 1954; El Tinay et al., 1976). Kinman et al. (1954) were of the view that protein synthesis in sesame was favoured at the expense of oil synthesis, depending upon the genetic constitution of the variety or when the growing conditions resulted in an increased nitrogen supply. Higher OP of sesame seed may result when nitrogen supply becomes a limiting factor for protein synthesis, particularly late in the season. A negative correlation between OP and PP was reported. They also worked out that with an increase of 1 percent point in PP, there may be a corresponding 0.85 percent point reduction.
in OP. Similarly, a 1% increase in OP results only 0.18% decrease in PP. In fact, they even suggested to breed sesame for protein than for oil. Heritability values for PP in sesame were reported to be 60% (Culp, 1959) and 30% (Murty, 1973).

In the present study, PP in the seed as well as defatted meal in eight of the high oil selections were within the range of earlier reports. These selections showed lesser PP compared to the parent N62-32. On dry weight basis, when OP and PP (defatted meal) were compared with N62-32, the selection S22-2 appears to be of interest with increased OP as well as PP compared to other selections (Table 10). However, these results need further confirmation. This was the first attempt to investigate PP in induced mutants of sesame.

4.4. INCREASE IN DRY MATTER AND OIL CONTENT IN THE DEVELOPING SEEDS

In sesame, oil, protein and dry matter accumulation in developing seeds were studied by Khidir et al. (1972). They reported that OP was low at 10 DAF and the 'critical period' for oil accumulation was between 10 to 32 DAF. In the present study the parent and the two mutants with higher OP were compared. There were no major differences in dry matter, OP and OPS increase
during seed development. All the three parameters studied showed a slight reduction after reaching the peak levels. Khidir et al. (1972) observed such a reduction of OP in one out of three sesame varieties.

It is interesting to compare the period when the peak levels of HSW, OP and OPS were reached in the parent and two mutants (Table 21). In selection S22-2, HSW, OPS and OP reached the peaks at 35 DAF. This selection appears to be slightly earlier in maturity. In the parent and S34-3 peak HSW reached at 40 DAF while OPS peaks were at 35 and 40 DAF respectively. This indicates that in both of them dry matter accumulated till 40 DAF. In N62-32 increase in dry matter was mainly due to 'non-oil' components as is evident by OPS peak at 35 DAF. In S34-3 both oil and 'non-oil' components contributed towards increase in dry matter. The results indicate that these two mutants with increased OP show a slightly different pattern of oil and dry matter increase during the period of seed growth. This, however, needs further confirmation in different season and location.

To the best of author's knowledge, such studies on induced mutants with higher oil content have not been carried out in sesame.
TABLE 21. DAYS AFTER FLOWERING WHEN PEAKS WERE NOTED IN M62-32, S22-2 AND S34-3

<table>
<thead>
<tr>
<th></th>
<th>DAF for peak values of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HSW</td>
</tr>
<tr>
<td>M62-32</td>
<td>40</td>
</tr>
<tr>
<td>S22-2</td>
<td>35</td>
</tr>
<tr>
<td>S34-3</td>
<td>40</td>
</tr>
</tbody>
</table>
4.5. HETEROESIS IN INTER-MUTANT HYBRIDS

Pal (1945) was the first to report heterosis in the inter-cultivaral hybrids of sesame. Heterotic effects have been reported for yield and other agronomic characters like percentage of seed germination, length of radicle and plumule, plant height, number of branches/plant, number of leaves/plant, leaf area, early flowering, late maturity, number of capsules/plant, capsule length and breadth, height of first capsule, 1000-seed weight etc. (Riccelli et al., 1964; Srivastava et al., 1968; Sarathe et al., 1969; Murty, 1975; Salzar et al., 1975; Dixit, 1976; Srivastava et al., 1977; Murty et al., 1977; Amirshahi et al., 1979; Kotecha et al., 1979; Khodabandah et al., 1979; Sarafi, 1979; Ujo, 1979; Yermanos et al., 1979). Although the need for the development and production of hybrids in sesame has been felt (Rajan, 1967), yet hybrid vigour has not been commercially exploited in this crop.

In general, heterosis has frequently been related to the degree of genetic diversity of the parents involved in the cross (Paterniani et al., 1963). In sesame, Riccelli et al. (1964) observed that heterosis was more conspicuous in the hybrids between cultivars from distant localities. Murty (1975) reported higher heterotic effect in Indian X exotic than in exotic X exotic and Indian X Indian inter-cultivaral hybrids. Heterosis in a cross
between wild species of *Sesamum (S. radiatum Schum & Thonn.)* and a local cultivar, 'Meghna' was reported by Srivastava et al. (1968).

In the present studies, since the $F_1$ hybrids between the mutants obtained from the same cultivar were superior in yield not only to the mutant parents, but also to the original cultivar N62-32 (Table 12), the observed heterotic effects are of considerable interest. SY of $F_1$ hybrids in replicated experiment were significantly higher than the parent N62-32 and also to the respective better mutant parent, except in cross no. 3 (Table 13), which was at par compared to the better parent. This appears to be the first report of heterosis in inter-mutant hybrids in sesame.

Heterosis in the hybrids has been explained on genetic, cytoplasmic, physiological and biochemical bases (Sinha et al., 1975; Rai, 1979). Whitehouse et al. (1955) suggested that yield was the end product of multiplicative interactions between the yield components. In the present study, the heterotic effects to some extent were observed in almost all the yield components and the increased seed yield of the $F_1$ hybrids can be attributed as the net result of the combined increase in various yield components.
Such heterotic effects in induced mutant X mutant or mutant X parent crosses have been reported in other self-pollinated crops like groundnut (Gregory, 1956, 1957; Carlson et al., 1975), tomato (Yakovleva et al., 1969), sweet clover (Miche, 1976) and peas (Gottschalk, 1976). Reports on the combined use of induced mutations and heterosis in the other crops have been reviewed by Stoilov et al. (1975). In pearl millet, Burton et al. (1980) studied forage yields of F1 hybrids between inbreds and mutants isolated from them. They concluded that simply inherited mutants capable of giving heterotic forage yields in pearl millet occur at low frequency but intermating unrelated inbreds was a more efficient method of producing high yielding hybrids.

Miche (1976) used the term 'monogenic heterosis' for the heterosis observed in the hybrids of parent X mutant where the mutant differs from the parent in one trait (mostly inherited as monogenic recessive). Similarly, heterosis observed in the hybrids of two different mutants isolated from a common parent, was designated as 'digenic heterosis'. Miche (1976) also pointed out that most of the induced mutants, besides the most obvious trait, may also carry a number of other mutations that are phenotypically less obvious, but may influence
the vigour of the mutant and its hybrids. In peas, the fasciated mutants when crossed with non-fasciated ones, showed high heterosis (Gottschalk, 1976). These fasciated mutant phenotypes resulted from mutations at, at least, 10 different loci randomly distributed over the seven chromosomes. Three of them are reported to be responsible for stem fasciation.

The $F_1$ hybrids of two multilocular mutants S1 and S2 when crossed with the other mutants affecting capsule characters, S8 (multicapsule) and S13 (bold capsule) which were all isolated from N62-32 gave superior yields. Different degrees of fasciation was observed in stem, leaves, corolla, stamens, gynoeicum and fruits of the mutants S1 and S2. Such an association of fasciation with multilocular capsule character was reported earlier by Demir (1965) and Khidir (1973). Stem fasciation in sesame is a recessive character controlled by one or two genes (Nohara, 1933). The multilocular mutants are also reported to be monogenic recessives (Nohara, 1933; Langham, 1945 a; Demir, 1965; Khidir, 1973) to the normal four loculed condition. In sesame, as in peas (Gottschalk, 1976) the induced fasciated mutants seem to show significant heterosis. However, the genetic basis of the observed heterosis in inter-mutant hybrids in sesame needs further investigation.
4.6. INHERITANCE STUDIES

4.6.1. Inheritance of small capsule mutant

Small capsule mutants were induced in earlier studies with sesame (Chavan et al., 1979; Zia-Ul-Hasan, 1980). However, their inheritance pattern has not been reported. The segregation pattern in the $F_2$ and $F_3$ generations of the cross between the parent and small capsule mutant, S17, indicated that the mutant phenotype was inherited as a monogenic recessive. The symbol $sc$ is proposed for genes governing the mutant character.

4.6.2. Inheritance of seed coat colour

On the basis of visual observations, seed coat colour in sesame has been broadly classified as black, dark brown, grey, light brown, dirty white and white. There is a strong consumer preference for white seed coat colour, for confectionary. Coloured seeds tend to be larger than white seeds (Khidir et al., 1970). Opinions differ on the genic control of seed coat colour in sesame. Pal (1934) reported a single gene difference between white and dark seed coat colour. Mohara (1933), Patel (1936) and Sikka et al. (1947) observed two gene differences between white and black seed coat colours, while Teshima (1931) reported a three gene difference.
Sikka et al. (1947), reported a monohybrid segregation between dark brown and dirty white, former being dominant. Khidir et al. (1971), studied the problem in detail with three different crosses. In a cross between white X brown, the phenotypic segregations in the F2 generation were 9 (brown): 3 (light brown): 3 (grey): 1 (white). On the basis of their F2 results the following genotypes were designated, black (AABB), brown (AAbb) and white (aabb).

One of the mutants (88) selected for capsule character in the present study, had light brown seeds compared to the white seed coat colour of the parent N62-32. Another mutant (S22) had cream white seed coat. In the F2 of a cross between 88 X S22 and their reciprocal, a dominant monogenic inheritance was observed for the light brown seed coat colour.

4.6.3. Inheritance of split corolla mutant

The induced mutant S64 with split corolla, has a close phenotypic resemblance with the photograph of 'split flower' published by Langham (1947 b), which was reported to be fertile. In the S64 mutant, though the pollen was fertile it did not set any seed. This may be due to the impaired functioning of gynoecium.

This mutant, when crossed as a male parent to N62-32, the segregations for normal tubular corolla and S64 phenotypes showed a good fit to the 15:1 ratio in
the F2 and to the expected 15:1 and 3:1 ratios in the F3 generation. However, in the F3 generation, the expected genotypic segregation of 7:8 ratio between the segregating and non-segregating progenies was not observed. This could be due to less number of F2 progenies studied. In the M6 generation, a large number of segregating progenies were studied and they showed good fit to the 7:8 ratio.

Based on the F2 data, Langham (1947 b) reported that his 'split flower' mutant could be controlled by duplicate recessive genes. The F2, F3 and M5 segregations of the mutant obtained in this study also suggest a similar genetic control for the split corolla character. It was not possible to obtain the 'split flower' mutant of Langham (1947 b) to check the allelic relationship of the two mutants.
4.7. SUMMARY OF RESULTS

The overall objective of the present study was to explore the possibilities of further improvement in sesame cultivar N62-32, using mutation approach. The two major objectives were to isolate and evaluate mutants for (a) higher seed yield and (b) higher oil content.

A large number of variants affecting the morphological and physiological characters were selected in the M2 generation derived from the treatments of gamma rays and EMS. Breeding behaviour of the variants was studied in the M3 and subsequent generations. Further selections were made, in 25 true breeding mutants and the following aspects were investigated upto the M8 generation:

1. Seed yield and yield components were studied for identifying high yielding types. Eleven promising selections from M4 generation were further evaluated for yield in six replicated trials spread over a period of four crop seasons. Two mutant selections, S36-10 and S337-1 gave significant increase in seed yields over the parent N62-32. The average yield of N62-32 in four crop seasons was 500 kg/ha. The mutants S36-10 and S337-1 gave yields of 758 and 708 kg/ha respectively.
2. In the $N_4$ generation, initially 48 selections were screened for oil content. Oil percentage was followed in 10 desirable selections for another three crop seasons (upto the $N_7$ generation). Ten selections were superior in oil content over the parent N62-32. The highest mean oil percentage for the last two seasons in replicated experiments was 51.8% compared to 48.1% of N62-32.

Thus, the two major objectives of the study were achieved.

3. Environmental variability for oil content in N62-32, between seasons, plants, within a plant was investigated to arrive at appropriate methods of sampling for oil content. Sampling for oil percentage on bulked produce of a single plant and then testing its bulked progeny in the next generation was found to give reliable results.

4. Dry matter and oil accumulation in developing seeds of N62-32 and two mutants with higher oil percentage S22-2 and S34-3 were compared in a replicated experiment. There were no major differences for the increase in dry
matter, oil percentage and oil per seed between the two mutants and parent cultivar.

5. The F1 hybrids in the inter-mutant crosses showed significant increase in seed yields over the respective mutant parents and also over the parent N62-32. In a replicated trial, seed yields (g/m$^2$) were in the range of 75 to 108 in comparison to 27 of cultivar N62-32.

6. In the inheritance studies, small capsule and drooping mutants were found to be monogenic recessives. A dominant inheritance was observed for light brown seed coat colour of S8 mutant. In the fourth, the split corolla phenotype was controlled by recessive duplicate genes. Gene symbols for small capsule (sc) and drooping (dr) mutants have been suggested.

On the basis of this study, it is concluded that the induced mutation approach provides an additional tool for further improvement of sesame cultivars with respect to their seed and oil yield potential.
4.8. SUGGESTIONS FOR FUTURE WORK

The investigations reported in this dissertation have led to isolation of two mutants that were superior in seed yield at Trombay for four seasons. These mutants need further evaluation for their yield potential at other locations in comparison to the parent cultivar N62-32 and other high yielding cultivars at different levels of fertilizer application.

The mutants with higher oil percentage are of great interest both from the genetics and breeding point of view. In further investigations, it may be pertinent to ask the question whether the different mutants with increased OP are allelic or are the result of mutations at different loci. Information on the segregations for OP in the inter-mutant crosses, and further selections for still higher OP will be of interest. In the long range one could even ask the question, 'Is it possible to increase oil content in sesame beyond the range reported in the natural germplasm?', at acceptable yield levels.

Heterosis observed in the inter-mutant crosses could be of great significance in enhancing the yield potential of this crop. Experiments should be initiated to evaluate the $F_1$ seed in multilocalational trials and explore its utilization on commercial scale.