CHAPTER VI
SUMMARY AND CONCLUSIONS

The present investigation entitled "Genetic analysis of seed yield and its components over environments in sesame (Sesamum indicum L) " was conducted to ascertain the magnitude of combining ability and gene action and the extent of heterosis and inbreeding depression for 15 different quantitative traits and how are they impacted by genotype x environment interaction. The initial experimental material consisted of nine genotypes of sesame viz., AT 164, AT 238, AT 255, AT 282, AT 345, China, Nesadi Selection, GT 1 and GT 10, which were collected from the office of the Research Scientist, Agricultural Research Station, Junagadh Agricultural University, Amreli. These genotypes were crossed in all possible combinations using diallel mating design excluding reciprocals during summer 2015. Some seeds from 36 F1s were sown in kharif 2015-16 in separate pots to get F2 seeds by selfing at Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. Set of 36 F1s, 36 F2 and 9 parents along with 1 standard check (GT 3) were evaluated in a Randomized Block Design with three replications over four environments during summer 2016 at two locations, Sagadividi Farm, Department of Seed Science and Technology, College of Agriculture, JAU, Junagadh and Krishi Vigyan Kendra, JAU, Nana Kandhasar. At each location, two environments were created by different date of sowing as E1 = February 20, 2016 and E2 = March 15, 2016 at Sagdividi Farm (L1) and E3 = February 22, 2016 and E4 = March 17, 2016 at KVK, Nana Kandhasar (L2). Each entry of the experimental material was sown in a single row plot of 3.0 m length keeping row-to-row and plant-to-plant distance of 45 cm and 15 cm, respectively. The recommended package of practices and plant protection measures were followed to raise a healthy crop of sesame. Five competitive plants per genotype in parents, F1 and standard check, and 20 competitive plants in F2, in each replication in each environment were selected randomly for recording observations on different characters viz., days to flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, height to first capsule (cm), length of capsule (cm), width of capsule (cm), number of capsules per leaf axil, number of seeds per capsule, 1000 seed weight (g), seed yield per plant (g), biological yield per plant (g), harvest index
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and oil content (%). The data were analyzed for heterosis and combining ability (Method-II, Model-I of Griffing, 1956a), while the genetic components of variation were estimated according to Hayman (1954) and G x E interactions and stability parameters were calculated following the model of Eberhart and Russell (1966). The salient findings of the present study are summarized below:

Mean squares due to genotypes, parents, F1 (hybrids) and F2 (segregating population) were significant for all the traits in all the environments, except for genotypes in oil content in all the individual environments; for parents in oil content in E1, E3 and E4; for hybrids (F1s) in days to flowering in E4, plant height in E2, and for oil content in all the four environments; and for segregating population (F2s) in days to flowering in E2, E3 and E4, and oil content in environments E3 and E4. Mean squares due to parents vs. F1s were significant for all the characters in all the individual environments, except for number of capsules per plant, 1000 seed weight and oil content in E1; for days to flowering, plant height, number of branches per plant, height to first capsule, 1000 seed weight, harvest index and oil content in E2; for days to maturity, number of capsules per plant, height to first capsule, width of capsule, 1000 seed weight and oil content in E3; and for days to flowering, days to maturity, number of branches per plant, width of capsule and oil content in E4. The results indicated that the performance of parents was different from that of hybrids, thereby suggesting the presence of mean heterosis for all these characters. Mean squares due to parents vs. F2s were significant for all the characters in all the individual environments, except for plant height, height to first capsule, length of capsule and number of seeds per capsule in E1; for height to first capsule in E2; for plant height, height to first capsule, length of capsule, number of seeds per capsule and oil content in E3; and for days to flowering, days to maturity, plant height, length of capsule and oil content in E4. These results suggested that the parental group was quite different from their F2s. Mean squares due to F1s vs. F2s were significant for all the characters in all the individual environments, suggesting presence of considerable amount of inbreeding depression in F2 generation.

The analysis of variance pooled over environments revealed significant differences among genotypes, parents, F1s and F2s for all the characters. The comparison of parents vs. hybrids (F1) was found significant for all the
characters, except for number of branches per plant, number of seeds per capsule, 1000 seed weight and oil content, while the comparison of parents vs. F$_2$ was found significant for all the characters, except for height to first capsule, length of capsule and width of capsule, which, in general, revealed the existence of heterosis and inbreeding depression. Mean squares due to F$_1$s vs. F$_2$s were significant for all the characters, also suggesting presence of considerable amount of inbreeding depression in F$_2$ generation. The interaction of parents x environments was significant for number of branches per plant, number of capsules per plant, height to first capsule, number of capsules per leaf axil and harvest index. The mean squares due to hybrids x environments and F$_2$s x environments was significant for all the characters, except for 1000 seed weight in hybrids x environments interaction and for number of capsules per leaf axil in F$_2$s x environments interaction. Parents vs. hybrids x environments interaction was found significant for all the characters, except for days to maturity, height to first capsule and oil content, while parents vs. F$_2$s x environments interaction was found significant for all the characters, except for days to maturity, number of seeds per capsule, biological yield per plant and oil content.

On the basis of per se pooled data, none of the parent yielded comparatively higher than the standard check, while three hybrid combinations AT 238 × AT 345 (9.35 g) and AT 282 × GT 10 (9.03 g) yielded significantly higher than the standard check. These hybrids also manifested superior per se performance for yield contributing traits viz., plant height, number of branches per plant, number of capsules per plant, length of capsule and number of seeds per capsule.

No specific consistency was observed with regards to heterosis for seed yield and its components in different crosses. This may be due to interacting effects of different component traits in manifestation of heterosis for seed yield. This reflected that in different crosses, path-way for releasing heterotic effects varied from cross to cross.

With respect to heterobeltiosis recorded for different cross combinations for seed yield per plant, it was observed that AT 238 × GT 1 (90.70 %), AT 255 × Nesadi Selection (82.91 %) and AT 164 × AT 238 (76.29 %) in E$_1$; AT 238 × GT 1 (109.97 %), AT 255 × Nesadi Selection (103.94 %) and AT 164 × AT
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238 (98.34 %) in E₂; AT 255 × Nesadi Selection (57.24 %), AT 238 × GT 1 (45.27 %) and AT 164 × AT 238 (40.45 %) in E₃; AT 238 × GT 1 (70.35 %), AT 255 × Nesadi Selection (67.39 %) and AT 164 × AT 238 (65.01 %) in E₄; and AT 238 × GT 1 (94.43 %), AT 255 × Nesadi Selection (94.24 %) and AT 164 × AT 238 (83.30 %) in pooled over environments were the best three cross combinations.

First ranked with respect to per se seed yield, the cross AT 238 × AT 345 manifested highly significant and desirable heterobeltiosis for seed yield per plant along with significant and desirable heterobeltiosis for days to maturity, height to first capsule, length of capsule, width of capsule and biological yield per plant. Similarly, second ranked cross with respect to per se seed yield, AT 282 × GT 10 exhibited significant and desirable heterobeltiosis for seed yield per plant and biological yield per pant, and third ranked cross AT 238 × GT 1 exerted significant and desirable heterobeltiosis for seed yield per plant along with significant and desirable heterobeltiosis plant height, length of capsule and biological yield per plant, which indicated that in different crosses, pathways for releasing heterotic effects varied. Overall, the results of heterobeltiosis of five best crosses based on per se performance for seed yield per plant revealed significant and desirable heterobeltiosis for seed yield per plant and plant height, height to first capsule, number of branches per plant, length of capsule, width of capsule, test weight and biological yield per plant were the main contributors towards increased seed yield.

With respect to standard heterosis, none of the cross combination noted significant and positive standard heterosis in E₃ and E₄ environment, while AT 238 × AT 345 (15.48 %), AT 282 × GT 10 (14.83 %) and AT 238 × GT 1 (13.28 %) in E₁; and AT 238 × AT 345 (41.23 %), AT 282 × GT 10 (26.64 %), AT 238 × GT 1 (24.73%) and AT 164 × AT 238 (18.45 %) in E₂ environment. On pooled basis, AT 238 × AT 345 (11.69 %) was the best cross manifested significant and positive standard heterosis for seed yield per plant. This cross also manifested significant standard heterosis in desired direction for yield components like number of branches per plant, height to first capsule and biological yield per plant. Therefore, the cross AT 238 × AT 345 could be exploited further for yield advancement in sesame.
The variable number of crosses exhibited significant inbreeding depression for different characters. The magnitude of inbreeding depression was high for number of branches per plant, height to first capsule, number of capsules per leaf axil, seed yield per plant and harvest index; moderate for plant height, number of capsules per plant, length of capsule, width of capsule, number of seeds per capsule, 1000 seed weight and biological yield per plant; and low for days to flowering, days to maturity and oil content. However, total of 13, 1, 8, 9 and 1 cross combination noted significant and desirable inbreeding depression for height to first capsule, width of capsule, number of capsules per leaf axil, number of seeds per capsule and seed yield per plant, respectively. These crosses had possibilities of desirable segregants in F2 population.

Analysis of variance for combining ability revealed that the mean squares due to general combining ability were significant for all the characters studied in all the individual environments of both the generations, except for oil content in E4 of F1 and E3 and E4 of F2 generations. The mean squares due to specific combining ability were significant for all the characters in all the environments of both the populations, except for days to maturity in E1, E3 and E4 of F1 population and in E2 of F2 population; for plant height in E2 of F1 population; for width of capsule in E2 of F2 populations; and for oil content in all the individual environments of F1 and in E3 and E4 of F2 population. Across the environments, mean squares due to general combining ability as well as specific combining ability were significant for all the fifteen characters in both F1 and F2 populations. The significant difference of gca and sca indicated that both additive and non-additive gene effects played an important role in the genetic control of the traits under study. On pooled basis, the variance ratio of $\sigma^2_{GCA} / \sigma^2_{SCA}$ was less than unity for all the characters, except for days to maturity in both the generations; for oil content in F1 generation; and for 1000 seed weight in F2 generation indicates the preponderance of non-additive gene action for almost all the characters under investigation, which suggested that the best cross combinations might be selected on the basis of sca for further tangible advancement in sesame.

On pooled basis, parents AT 238 and AT 345 in F1s and AT 238, AT 345 and GT 10 in F2s were found good general combiners for seed yield per plant, possessed high concentration of favourable genes as indicated by significant
and positive gca effects. Besides having good general combining ability for seed yield, AT 345 was also good general combiners for some of its yield contributing characters like plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, biological yield per plant and harvest index in both the populations and 1000 seed weight in F₁ and number of capsule per leaf axil in F₂ population. The second best general combiner AT 238 was also good general combiner for height to first capsule, width of capsule, number of capsules per leaf axil, number of seeds per capsule, 1000 seed weight and harvest index in both the populations and also for days to maturity, number of branches per plant, biological yield per plant and oil content in F₁ population. GT 10 was found to be good general combiner for seed yield per plant in F₂ population, also found to be good general combiner for plant height, number of branches per plant, number of capsules per plant and biological yield per plant in both the population. Therefore, these parents may be used in combination breeding for isolating desirable types in sesame.

For earliness, Nesadi Selection, AT 238 and AT 282 in F₁ and Nesadi Selection, AT 282, GT 1 and AT 164 in F₂ segregating population expressed significant and negative (desirable) gca effects across the environments and were emerged as good general combiners for early maturity.

The present findings also revealed high degree of correspondence between per se performance of parents and their gca effect for majority of the traits studied, which indicated that per se performance can be used as a reliable criterion for selection of parents for hybridization.

The estimates of sca effects in F₁ and F₂ generation revealed that none of the hybrid was consistently superior for all the characters in both the generations. Considering the overall performance of hybrids with respect to high and significant sca effects across the environments for seed yield per plant in F₁ generation, the best ten best hybrids were AT 238 × GT 1, AT 282 × GT 10, AT 164 × AT 238, AT 238 × AT 345, AT 255 × Nesadi Selection, Nesadi Selection × GT 1, AT 345 × China, AT 255 × China, AT 238 × GT 10 and AT 255 × GT 1, while in F₂ generation, the best ten best hybrids were AT 238 × GT 1, AT 164 × AT 238, AT 255 × Nesadi Selection, AT 345 × GT 10, AT 282 × GT 10, AT 255 × China, AT 238 × AT 345, Nesadi Selection × GT 1,
China × GT 10 and AT 345 × China, manifested significant and high sca effects in that order. These best hybrids of both the generations with high sca effects for seed yield per plant also manifested the high and desirable sca effects for some of the important yield contributing characters.

The best three hybrids, on the basis of the significant positive effects pooled over environments for seed yield per plant were AT 238 × GT 1 (2.76), AT 282 × GT 10 (2.61) and AT 164 × AT 238 (2.57) in F₁ generation. Out of these hybrids, AT 238 × GT 1 exhibited significant and desired sca effect for plant height, number of branches per plant, number of capsules per plant, number of capsules per leaf axil, biological yield per plant and harvest index; AT 282 × GT 10 for number of branches per plant, number of capsules per plant, length of capsule, number of capsules per leaf axil, biological yield per plant and harvest index; and AT 164 × AT 238 for plant height, number of branches per plant, number of capsules per plant, length of capsule, width of capsule, number of seeds per capsule, 1000 seed weight, biological yield per plant and harvest index. Of these three hybrids, two hybrids AT 238 × GT 1 (1.84) and AT 164 × AT 238 (1.79) were also amongst the best three hybrids on the basis of the significant and desirable sca effects pooled over environments for seed yield per plant in F₂ population. AT 255 × Nesadi Selection (1.78) was the third best hybrid based on sca effects for seed yield per plant in F₂ population, which was the fifth best hybrid based on sca effects for seed yield per plant in F₁ generation. Out of these crosses, AT 238 × GT 1 exhibited significant and desirable sca effects for number of branches per plant, biological yield per plant and harvest index; AT 164 × AT 238 for days to maturity, plant height, length of capsule, width of capsule, number of seeds per capsule, biological yield and harvest index; and AT 255 × Nesadi Selection for height to first capsule, biological yield per plant and harvest index in F₂ generation. The crosses showing significant sca effects are expected through-off transgressive segregants in segregating generation and thus, such crosses could be exploited for the improvement of yield and specific yield contributing characters.

AT 238 x AT 345 was the top ranked hybrid with respect to per se for seed yield per plant across the environments, ranked fourth with respect to sca effects for seed yield per plant in F₁ generation and seventh in F₂ generation.
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This hybrid also manifested significant and desirable SCA effects for number of capsules per plant, width of capsule, 1000 seed weight, biological yield per plant, harvest index and oil content in F₁ population (Table 5.4.2.2), and for plant height, length of capsule, number of capsules per leaf axil and biological yield per plant in F₂ population.

Three best specific crosses with respect to seed yield per plant, AT 238 × GT 1, AT 282 × GT 10 and AT 164 × AT 238 involved good x poor, average x average and average x good general combiners in F₁ and AT 238 × GT 1, AT 164 × AT 238, AT 255 × Nesadi Selection involved good x average, poor x good and average x poor general combiners in F₂. The high SCA effects for seed yield per plant and important yield components were also accompanied with high heterosis as well as high \textit{per se} performance. Thus, on the basis of these results, it is expected that these crosses could be exploited through heterosis breeding and may also give desirable segregants in subsequent generations and hence, it would be worthwhile to use them for improvement in seed yield \textit{per se} in sesame.

The additive as well as dominant components were significant for seed yield per plant and its component traits with few exceptions in different environments, revealing equal importance of both additive as well as non-additive genetic effects for the traits studied. However, in most of the traits including seed yield per plant, the relative magnitude of dominance components were found to be higher than additive components in all four environments, indicates that studied characters were mostly under the control of dominance variance.

The average degree of dominance \((H_1/D)^{1/2}\) indicated over dominance type of gene action in all four environments for all the traits studied except for days to flowering in environment E₂ and E₄ of F₂ generation; for plant height E₂ in F₁ generation; for number of branches per plant in all four environments of F₂ and E₁, E₃ and E₄ of F₁ generation; for length of capsule E₁ and E₂ of F₂ generation; for width of capsule E₁ of F₂ generation; and for oil content E₂ of F₁ generation. Thus, on the basis of present study, it is evident that characters studied are under the control of non-additive gene action.

The distribution of genes with positive and negative effects \((H_2/4H_1)\) in the parents was observed nearly symmetrical in both F₁s and F₂s in all the
environments for seed yield per plant and all the characters studied, indicating considerable degree of gene symmetry over all the loci for the studied traits.

The estimates of KD/KR ratio was more than unity indicated the excess of dominant alleles in parents for all the characters studied in all the environments of both the generations, except for days to flowering, days to maturity and 1000 seed weight in all environments of F\textsubscript{2}; for plant height in E\textsubscript{3} of F\textsubscript{2}; number of branches per plant in E\textsubscript{1}, E\textsubscript{3} and E\textsubscript{4} of F\textsubscript{2}; and for number of seeds per capsule in E\textsubscript{1}, E\textsubscript{3} and E\textsubscript{4} of both the populations; which indicated more number of dominant genes than recessive genes in the parents.

The ratio of h\textsuperscript{2}/H\textsubscript{2}, estimating the number of gene groups indicated that there was one group of genes responsible for days to flowering in all the environments of F\textsubscript{2} and E\textsubscript{1}, E\textsubscript{3} and E\textsubscript{4} of F\textsubscript{1}; for days to maturity in E\textsubscript{2}, E\textsubscript{3} and E\textsubscript{4} of F\textsubscript{1} and E\textsubscript{1}, E\textsubscript{2} and E\textsubscript{3} of F\textsubscript{2}; for plant height in E\textsubscript{1}, E\textsubscript{3} and E\textsubscript{4} of F\textsubscript{1}; and E\textsubscript{2} of F\textsubscript{2}; for number of branches per plant in E\textsubscript{3} of F\textsubscript{2}; for number of capsules per plant in E\textsubscript{2} of F\textsubscript{2}; for length of capsule in E\textsubscript{1} and E\textsubscript{2} of F\textsubscript{1}; for width of capsule in E\textsubscript{1} and E\textsubscript{2} of both the populations; for number of seeds per capsule in E\textsubscript{1}, E\textsubscript{2} and E\textsubscript{4} of F\textsubscript{1}; for 1000 seed weight in E\textsubscript{1} of F\textsubscript{2}; for seed yield per plant in E\textsubscript{1} and E\textsubscript{4} of F\textsubscript{1}; for biological yield per plant in E\textsubscript{1}, E\textsubscript{2} and E\textsubscript{4} of F\textsubscript{1} and in E\textsubscript{3} of F\textsubscript{2}; for harvest index in E\textsubscript{3} of F\textsubscript{2}; and for oil content in E\textsubscript{2} of F\textsubscript{1} population. For all the remaining environments of respective generations, more than one gene group controlled the particular trait.

High estimates of narrow sense heritability were depicted for days to flowering in E\textsubscript{1} of F\textsubscript{1}; and for width of capsule in all the environment of F\textsubscript{1}; while medium estimates of heritability were noted for width of capsule in E\textsubscript{1} and E\textsubscript{2} of F\textsubscript{2}; and for number of capsules per leaf axil E\textsubscript{1} and E\textsubscript{2} of F\textsubscript{1} and E\textsubscript{1}, E\textsubscript{3} and E\textsubscript{4} of F\textsubscript{3}. Low estimates of heritability were observed in all the remaining environments of respective generations for the studied traits. In general, narrow sense heritability was found for all the traits, indicating comparatively more role of dominance gene effects in the expression of seed yield and its attributes.

Mean squares due to G x E interactions were found highly significant for number of capsules per plant and height to first capsule when tested against pooled deviation, suggested that genotypes interacted significantly in different environments for these traits. The mean sum of squares due to environments
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(lin\(\text{e}\)) was also noted highly significant difference for all the characters studied except number of capsules per leaf axil when tested against pooled error, suggesting that differences between environments were considerable for all these traits and these traits were influenced greatly by environment indicating thereby that large differences between environments along with the greater part of genotypic response was a linear function of environment. This also indicated that environments created by sowing dates and location was justified and had linear effects.

The coincidence of genotypic performance with environmental values was observed for days to flowering, plant height, number of branches per plant, number of capsules per plant, height to first capsule, length of capsule, width of capsule, number of capsules per leaf axil, number of seeds per capsule, seed yield per plant, biological yield per plant and harvest index (%), as evident by significant G x E (linear) mean squares when tested against pooled deviation, indicating that performance of genotypes over environments could be predicted reasonably for these traits. Mean squares due to pooled deviation were significant for number of branches per plant, number of capsules per plant, height to first capsule and harvest index, which suggested that prediction of performance of genotypes over environments based on regression analysis for these traits, might not be very reliable.

A single parent AT 345 and 11 hybrids (AT 238 x AT 345, AT 282 x GT 10, AT 164 x AT 238, AT 345 x China, AT 255 x Nesadi Selection, AT 345 x GT 10, China x GT 10, Nesadi Selection x GT 1, AT 255 x GT 10, AT 255 x GT 1 and AT 282 x AT 345) expressed their stability across the environments for seed yield per plant due to their high seed yield per plant, non-significant regression coefficient (\(b_i\)) and deviation from linear regression \((S^2_{d_i})\).

The hybrids, AT 238 x GT 1, AT 238 x GT 10, AT 255 x China, AT 255 x AT 345 and China x GT 1 were having more seed yield per plant and had the least deviation from linear regression, but significant regression coefficient (\(b_i > 1\)) and thus, found to be highly responsive to better environments. The hybrid China x Nesadi Selection having more seed yield per plant and had the least deviation from linear regression, but significant regression coefficient (\(b_i < 1\)) and thus, was found to be highly responsive to poor environments.
The highest yielding stable parent, AT 345 (7.07 g), which was found to be stable for seed yield per plant, was also showed stability for plant height, number of branches per plant and harvest index. AT 345 was one of the parents of the four stable hybrids (AT 238 x AT 345, AT 345 x China, AT 345 x GT 10 and AT 282 x AT 345) for seed yield per plant. Its utilization in hybrid breeding would be useful in boosting the yield of sesame.

The best three stable hybrids for seed yield per plant were AT 238 x AT 345 (9.35 g), AT 282 x GT 10 (9.03 g) and AT 164 x AT 238 (8.41 g). Among these, first ranked stable hybrid, AT 238 x AT 345 was also found to be stable for days to flowering, days to maturity, number of capsules per plant, length of capsule, number of seeds per capsule and test weight. It also showed stability under favourable condition for width of capsule and under unfavourable condition for height to first capsule and oil content. This hybrid ranked first with respect to seed yield per plant and had significant heterosis over better parent as well as standard check GT 3, also possessed significant and positive sca effects in both F₁ and F₂ generation. The second best stable hybrid AT 282 x GT 10 was found to be stable for plant height, number of branches per plant, biological yield and harvest index. It also showed stability under favourable environment for length of capsule. This hybrid ranked second in per se performance and had high and significant positive sca effect as well as significant heterosis over better parent and desirable but non-significant standard heterosis. The third ranked stable hybrid, AT 164 x AT 238 was found to be stable for days to flowering, days to maturity and number of seeds per capsule. It was also highly responsive to favourable environments for length of capsule, 1000 seed weight and biological yield per plant and to unfavourable environments for oil content. This hybrid ranked fourth in per se performance and had high and significant positive sca effect as well as significant heterosis over better parent and desirable but non-significant standard heterosis.

CONCLUSION

1. The present investigation indicated that both additive and non-additive types of gene actions were important in governing all the traits with preponderance of non-additive gene action for seed yield and its components and inbreeding depression could be utilized advantageously for improving yield through
heterosis breeding. As sesame is self-pollinated crop, the genetic variability resulting from additive effects can be effectively utilized through selection followed by hybridization in segregating generations. It is, therefore, suggested that biparental mating, intermatting of elite segregants and selection at later generations should be followed which meets the requirement of utilizing both types of gene actions.

2. On the basis of high per se performance, high heterosis, desirable sca effects in F\(_1\) and F\(_2\) generations along with stability across the environments with respect to seed yield per plant, cross combination AT 238 x AT 345 (9.35 g) could be exploited for improvement in seed yield of sesame, as this cross combination also showed stability for days to flowering, days to maturity, number of capsules per plant, length of capsule, number of seeds per capsule and test weight. This hybrid ranked first with respect to seed yield per plant and had significant heterosis over better parent as well as standard check GT 3, also possessed significant and positive sca effects in both F\(_1\) and F\(_2\) generation.