5. SUMMARY AND CONCLUSIONS

The present investigation entitled “Generation mean analysis for pod yield and horticultural traits in garden pea (Pisum sativum L.)” was carried out to detect the nature and magnitude of gene effects in garden pea. The experimental material comprised of twelve generations namely, two parents (P₁ and P₂), F₁, F₂, B₁, B₂, B₁₁, B₁₂, B₂₁ and B₂₂ of three different intervarietal crosses namely, ‘Palam Sumool × Punjab-89’, ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’. The parents involved in these crosses were diverse e.g. ‘Palam Sumool’ has very long pods with resistance to powdery mildew disease, while ‘Punjab-89’ has long and well filled slender pods. Similarly, ‘Azad P-1’ is a highly adapted variety but highly susceptible to powdery mildew disease, whereas ‘Palam Priya’ bears two pods at each node. Twelve generations of each cross were raised in Randomized Complete Block Design, replicated thrice during winter season of 2014-15 at the Experimental Farm, Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The material was also raised during summer 2014 at Highland Agricultural Research and Extension Centre, Kukumseri to assess severity of powdery mildew disease along with isolation of desirable progenies with resistance to powdery mildew disease.

The observations were recorded on ten randomly selected competitive plants of each parents and F₁’s, 20 plants in each backcross generations (B₁, B₂, B₁₁, B₁₂, B₂₁ and B₂₂) and 30 plants in each F₂’s, B₁S and B₂S over the replications at Palampur with respect to yield and yield attributing trait. The data collected were subjected to statistical analysis using statistical software SPAR-1. The mean and variances were calculated as suggested by Hayman (1958). The presence of epistasis was detected by using ‘A’, ‘B’, ‘C’ and ‘D’ scales for digenic non-allelic interactions (Mather 1949) and ‘X’ and ‘Y’ scales for trigenic interactions (Vander Veen 1959). To test the adequacy of additive-dominance model, the individual scaling tests given by Mather (1949) as well as joint scaling tests by Cavalli (1952) were applied using three, six and ten-prameter model.
Majority of the crosses exhibited non-allelic interactions for different traits as evident from the inadequacy of additive-dominance and digenic model which was depicted from the significance of ‘A’, ‘B’, ‘C’ or ’D’ scaling tests. In such cases, populations have to be advanced to next generations in order to arrive at the best fit model e.g. days to first picking and shelling percentage in all three crosses, pod length in ‘Palam Sumool × Palam Priya’, seeds per pod and protein content in ‘Palam Sumool × Punjab-89’, plant height in ‘Palam Sumool × Punjab-89’ and Palam Sumool × Palam Priya’, pod yield per plant in ‘Palam Sumool × Palam Priya’ and ascorbic acid content in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Azad P-1’. However, non-significance of simple scaling tests showed the adequacy of additive-dominance model and thereby, indicated the absence of non-allelic interactions for days to flowering in all the three crosses, pod length in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Azad P-1’, seeds per pod in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’ and total soluble solids in ‘Palam Sumool × Azad P-1’. The significance of ‘X’ or ‘Y’ scales revealed the presence of trigenic or higher order interactions for days to first picking, pods per plant, pod yield per plant, protein content and total sugars in all the three crosses, plant height in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’, ascorbic acid content in ‘Palam Sumool × Palam Priya’ and powdery mildew disease severity in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Palam Priya’.

Genic effects revealed the presence of additive gene action in the desirable direction in crosses ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’ for days to flowering, ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Palam Priya’ for pod length, and ‘Palam Sumool × Azad P-1’ for total soluble solids suggesting selection of desirable plants for these traits in the early generations. Positive additive (d) gene effect along with negative additive × dominance (j) and positive additive × dominance × dominance (y) genic interactions in ‘Palam Sumool × Azad P-1’ and that of positive sign of additive × dominance × dominance (y) along with negative sign of dominance × dominance × dominance (z) in cross ‘Palam Sumool × Palam Priya’ for days to first picking, suggested to delay the selection to obtain desirable early or medium maturing transgressive segregants. The negative additive (d) genic effect in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam
Priya’ for seeds per pod and pods per plant while that of positive and significant dominance (h) genic effect in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Azad P-1’ for shelling percentage and positive dominance effect for pods per plant and pod yield per plant in ‘Palam Sumool × Punjab-89’, directed to delay the selections in the later generations.

The duplicate type of epistasis as revealed from the opposite signs of ‘h’ and ‘l’ non-allelic interactions was observed for plant height and protein content in all the three crosses, seeds per pod and total soluble solids in cross ‘Palam Sumool × Punjab-89’, pod yield per plant in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’, ascorbic acid content and powdery mildew disease severity in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Palam Priya’ and total sugars in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Azad P-1’. In some of these crosses for certain traits, the direction of ‘l’ changed to the desirable direction (+ or -) in the higher order non-allelic interaction (z), indicating a shift from duplicate to complementary type of epistasis in higher order trigenic interaction model e.g. ‘Palam Sumool × Azad P-1’ for plant height, pod yield per plant, protein content and total sugars, ‘Palam Sumool × Punjab-89’ for protein content, total sugars and powdery mildew disease severity and ‘Palam Sumool × Palam Priya’ for powdery mildew disease severity. The duplicate type of epistasis generally hinders the improvement through selection as it decrease the variation in F2 and subsequent generations.

The significance of chi-square suggesting the inadequacy of digenic or trignic interaction model was also observed for majority of the traits in one or the other or all the three crosses. This might be due to presence of linkage among interacting genes or higher order interactions at four or more loci in respective crosses suggesting that inheritance of these traits is not simple for traits like shelling percentage, pods per plant, ascorbic acid content and total sugars in all the three crosses, pod length in ‘Palam Sumool × Palam Priya’, seeds per pod in ‘Palam Sumool × Punjab-89’, plant height and pod yield per plant in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Azad P-1’, protein content in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’ and powdery mildew disease severity in ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Palam Priya’.
Economic heterosis was observed for pods per plant and pod yield per plant in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’ along with appreciable economic residual heterosis except pods per plant in ‘Palam Sumool × Azad P-1’. Besides, ‘Palam Sumool × Punjab-89’ and ‘Palam Sumool × Azad P-1’ also showed economic heterosis for powdery mildew disease severity and pod length along with residual heterosis, respectively. In addition, ‘Palam Sumool × Punjab-89’ revealed appreciable residual heterosis over standard check (‘Punjab-89’) pods per plant, pod yield per plant, protein content and total sugars.

The presence of non-allelic interactions for majority of traits in all the three cross combinations signify the adoption of generation mean analysis. The type of gene actions observed in the present study suggested to adopt a breeding methodology which can capitalized fixable and non-fixable genic effects. Moreover, presence of duplicate type of epistasis in one or the other cross combinations for different traits directed to have mild selection intensity in the early generations followed by intense in later. The failure of trigenic model revealed the complexity of the character in question and indicated the presence of linkage among interacting genes or minor/modifier genes or prevalence of still higher order non-allelic interactions at several loci for the character(s) in question Therefore, under such complex type of gene effects and non-allelic interactions for majority of the traits in all the three crosses, population improvement methods may be useful for breaking undesirable linkages through recombinations. The other alternative can be to defer selection in later generations by advancing segregating material through bulk pedigree or single seed descent methods with one or two inter-mating like recurrent selection. Keeping in view the desirable pod characteristics, pod yield and resistance to powdery mildew disease, ‘203’ individual plants over the generations in all the three crosses were isolated. Besides, bulk seeds following single seed descent and bulk methods were harvested to isolate the desirable transgressive segregants.

**Conclusions**

- Majority of the crosses exhibited non-allelic interactions for majority of the traits and also showed the presence of trigenic or higher order interactions.
• Genic effects revealed the presence of additive (d) gene effect in the desirable direction for days to flowering, pod length and total soluble solids in one or the other crosses indicated the effectiveness of selection in the early generations (Sharma et al. 2013).

• Negative additive effect for seeds per pod and pods per plant and that of positive dominance effect for shelling percentage, pods per plant and pod yield per plant in either of the other crosses, directed to delay selection in the later generations.

• The presence of duplicate type of epistasis in majority of cross combinations for different traits suggested to have mild selection intensity in the early generations followed by intense in the later (Sharma and Sain 2002).

• The significance of chi-square indicated the inadequacy of the digenic/trigenic interaction model in some of the crosses for most of the traits, showed the presence of linkage among interacting genes or minor/ modifier genes (Mather and Jinks 1971).

• Economic heterosis was observed for pods per plant and pod yield per plant in ‘Palam Sumool × Azad P-1’ and ‘Palam Sumool × Palam Priya’ along with appreciable economic residual.

• The type of gene effects along with presence of non-allelic interactions for majority of the traits in three crosses suggested the adoption of population improvement methods to break undesirable linkages through recombination (Singh et al. 2008). The other alternative can be to defer selection in the later generations by advancing segregating populations through bulk pedigree or SSD methods with one or two inter-matings like recurrent selection (Sharma et al. 2013).

• Keeping in view the desirable pod characteristics, pod yield and powdery mildew disease severity, 203 individual plant progenies were isolated from different generations of the three crosses along with bulk seed following SSD and bulk method to isolate transgressive segregants in the later generations.