The cracking in lime and pomegranate fruits is characterised by some similarities, as well as, dissimilarities. The two fruits, on account of different periods of maturity are subjected to different sets of atmospheric conditions. The period of fruit cracking, however, differs and overlaps each other in both the fruits under study. In lime, the fruit cracking mostly starts at the close of dry season and with the advent of rains and continues till fruits are near maturity, i.e., by the end of rainy season. In pomegranate, fruit cracking begins in the dry season and continues only upto July in the rainy season. As the fruits mature in August, i.e., earlier than those in lime, the cracking stops after July. The investigation shows that cracking was most common in fruits located on the top branches rather than on the middle and lower branches. The cracking in fruits located on the top branches was as high as 57.44 and 47.87 per cent in lime (variety Kagzi Kalan) and pomegranate (variety Desi), respectively. It was, further, noted that fruit cracking under shade was far less than that in case of exposed ones. Highest percentage of the cracked fruits (82.97 and 80.00 per cent in lime and

CHAPTER V

DISCUSSION

The cracking in lime and pomegranate fruits is characterised by some similarities, as well as, dissimilarities. The two fruits, on account of different periods of maturity are subjected to different sets of atmospheric conditions. The period of fruit cracking, however, differs and overlaps each other in both the fruits under study. In lime, the fruit cracking mostly starts at the close of dry season and with the advent of rains and continues till fruits are near maturity, i.e., by the end of rainy season. In pomegranate, fruit cracking begins in the dry season and continues only upto July in the rainy season. As the fruits mature in August, i.e., earlier than those in lime, the cracking stops after July. The investigation shows that cracking was most common in fruits located on the top branches rather than on the middle and lower branches. The cracking in fruits located on the top branches was as high as 57.44 and 47.87 per cent in lime (variety Kagzi Kalan) and pomegranate (variety Desi), respectively. It was, further, noted that fruit cracking under shade was far less than that in case of exposed ones. Highest percentage of the cracked fruits (82.97 and 80.00 per cent in lime and
pomegranate, respectively) was observed under exposed condition. The explanation for this can be sought to expound the fact that fruits located on top branches were the most exposed to weather conditions like direct sunlight, dry hot wind, air movement and rain etc. This has also implied to the unshaded fruits. The nature of cracks showed that radial type of fruit cracking was maximum (i.e., 54.25 and 61.70% in lime and pomegranate, respectively) in both the fruits. The results are in confirmation with those of Frazier (1934) and Reynard (1951) in tomato, who found high percentage of radial cracking. The studies further revealed that cracking in lime fruits was mostly observed during the rainy season, whereas in pomegranate, dry period was most conducive to fruit cracking. The variation in cracking of lime and pomegranate were due to the developmental differences in the two fruits. It, thus, shows that irrespective of weather the cracking is maximum 2 to 2½ months before maturity of fruits. In lime, the increase in water supply to the fruit tissues, low transpirational water loss under conditions of rain and humidity are the factors which favour high turgor pressure within the fruit and induce cracking. When growth proceeds at a moderate rate the fruit seldom cracks. It is only when fruit enlargement
is abnormally rapid and exceeds the limit of extensibility, higher cracking occurs. The effect of rains on fruit cracking in pomegranate is indirect and to a limited extent. The largest percentage of the crop is affected if soil moisture fluctuates on account of rains during dry period, especially when it accompanies high temperature. The above findings are in line with those reported by Taylor et al. (1958) in Navel orange, Meynhardt (1957) in grapes, Verner (1938) in cherries and Cheema et al. (1954) in pomegranate.

Fruits from early set of flowering though better developed were more susceptible to cracking. This is due to the fact that maximum growth period coincides with the conditions conducive to cracking, both in lime and pomegranate.

The physico-chemical characteristics of fruits showed that peel thickness varied in different parts of a fruit and so was the firmness. The peel at stem end was thicker than the middle portion and the stylar end. In lime, peel thickness was observed to have substantially increased at the stylar end, leaving only, the portion lying between the stem and stylar ends which was thin and less firm. Fruit peel thickness in pomegranate decreased gradually from the stem end to the stylar end. In both the fruits peel thickness was least
in the portion adjoining the stylar end. This part of the fruit is most susceptible to fruit cracking. The study of different varieties revealed that fruits with thick and firm peel (pomegranate variety Sour) or with thin peel but more elastic in nature (Sweet lime) were resistant to fruit cracking than the fruits with thin, less firm and non-elastic peels. The results of the present investigations are similar to those of Reynard (1951) in tomato, who found a correlation between crack resistance and skin toughness.

Susceptibility of fruits to cracking indicates lack of strength and elasticity on the part of the fruit skin to withstand pressure imposed on it by internal growth during the period of quick development. It was recorded that resistant or less susceptible varieties of both the fruits contained high percentages of pectin and protepectin in the peel which imparted more strength to the fruit skin. Among different fruit parts, the stem end was superior in these characters and was more firm in comparison to middle and stylar end portions. Thus, the fruit peel in case of former two, was less firm which explains the initiation of cracks from these fruit parts in most of the cases. Similar results were reported by Frazier (1934) in tomato. Less pectin content in cracked fruits suggests that it is likely
that the pectin in the peel has been subjected to simple decomposition thereby changing it into soluble form and reducing the firmness.

In fruit juice, the resistant varieties of lime, lemon and pomegranate were marked with low total soluble solids, sugars and osmotic pressure except Sweet lime, which has probably resisted cracking on account of firm and elastic nature of the peel. Similar trend was observed in case of uncracked fruits. The susceptible varieties, as well as, the splitted fruits showed these characteristics opposite to those recorded in resistant varieties and the normal fruits both in citrus and pomegranate.

Since, stylar end of the fruit is highly affected by splitting, the present studies also show that among different fruit parts, total soluble solids, sugars and osmotic pressure were high in the stylar end than in the stem end. This has also been reported by Haas and Klotz (1935) in citrus. Singh (1964) has attributed radial cracking in tomato fruits to increase in soluble solids from stem end to blossom end. It was further recorded that fruits with high total soluble solids and sugars had high osmotic pressure. The results, thus show tendencies of such fruits to attract more water on account of high osmotic
pressure of juice and are liable to crack. Verner and Blodgett (1931) and Savada (1934) have also found similar findings who have reported that cherry fruits with high total soluble solids tend to crack rapidly than those with lower soluble solids.

It has also been observed in lime that permeability of fruit skin differed among the fruits and within the fruit as well. The result show that stylar half of fruit was more permeable to water than the stem half. Similar results have been reported by Klotz and Haas (1933) in citrus. The stem half, therefore, is most liable to crack on account of higher intake of water through that part of the fruit during rains.

The probable course of water intake by the fruits using coloured solution was also observed which indicated that the water moved into the fruits through stem and surface of the fruit as well. In lime, movement of water was extended along the pith from the stylar half towards the stem half. It is, thus, evident that stylar half is liable to absorb maximum atmospheric moisture viz, rain, and may induce cracking due to abnormal enlargement of fruits. On the contrary, in pomegranate, the coloured solution never penetrated deep in the peel. The water intake is probably hampered by the thick peel
and thus, it may be due to this fact that little fruit cracking was observed during rains in comparison to period proceeded earlier.

Experiment conducted to induce fruit cracking under laboratory conditions show that in lime hot air treatment followed by water immersion of fruits affected 66.66 per cent cracking at a medium temperature (40°C) rather than at a high temperature (45°C). The results are in conformity with Levin et al. (1969), who reported increased cracking in cherries at a medium temperature. Similarly, fruits when subjected to mist treatment showed a high cracking percentage. It is likely that high temperature and excessive transpiration during May - June adversely affected the fruit development and reduced the percentage of cracking but with the advent of rains, abnormal high rate of fruit development and increased turgidity of the fruits brought about conditions conducive to fruit cracking.

It has been observed that fruits differed in susceptibility to cracking on account of dissimilar rate of water absorption (because of variation in permeability of the fruit skin). Cracking in such cases may be caused due to unequal
capacities for expansion of the peripheral tissues to accommodate the increased volume resulted by water absorption. It is presumed that fruits with rapid rate of absorption and small capacity for expansion in rind cracked, while those having a slow rate of absorption and higher capacity for expansion escaped cracking.

Histological studies of fruit rind of various citrus and pomegranate varieties do not reveal any marked differences in cellular structure of epidermis and sub epidermal zone in crack resistant and susceptible varieties. The noticeable differences are of cell size, cutinization and thickening of cell walls only. In citrus, varieties susceptible to fruit cracking viz, Kagzi Kalan and Assam lemon, cells of epidermis close to crack are often found in separate groups but epidermis appears continuous due to excessive development of cutin between the radial walls. This cutinization results from premature cessation of cell division and growth in epidermis.

Besides epidermis, hypodermis and three to six layers of cells below it also show deficient growth rate in susceptible varieties. The cells are much reduced in size having thick
walls in comparison to other parts of mesocarp. In resistant varieties like Sweet lime and Eureka lemon, the cells are isodiametric, round, bigger in size with thin walls and the hypodermal part not too distinct with the remaining part of the mesocarp. This, therefore, clearly shows that the cells of hypoderm in resistant varieties due to continuous growth and capability of cells to stretch are able to keep pace with the enlargement of fruit.

In susceptible varieties of pomegranate, adverse weather and environmental conditions resulted in thickening of cells of epidermis and cortical tissues. Exposure of fruits to strong sunlight and dry hot winds in summer affects the outer surface of their peel due to desiccation which checks further cellular growth and causes thickening of cell walls and reduces elasticity. Palladin (1973) has also stated that severe water deficit promotes thickening of cell walls in the affected region.

In susceptible varieties of both citrus and pomegranate the sub epidermal cells stop growing and are less flexible due to thickening of walls. Thus, under conditions of high humidity and low transpirational water loss,
tissue hydration is increased and the rate of fruit enlargement is abnormally rapid. The limit of extensibility of sub hypodermal tissue is when exceeded, cracking occurs. In pomegranate, splitting always initiates from the epidermis. It is thus, quite obvious that the phenomena of fruit cracking can not be attributed exclusively to the exceptionally rapid rate of swelling in the cortex of cracking specimens but must also be regarded as a result of non-elastic nature and inadequate growth of their peripheral tissues. Tetley (1930) in Cox Orange Pippen apples also believed that the epidermis is unable to resist the swelling of the cells and so consequently, it cracks. Verner (1938) in various varieties of apple has also found that fruit cracking is primarily due to the tendency of the fruit tissues towards marked restriction of growth in the hypodermal layer with the progress of growing season, while the fleshy portions of the fruit may be enlarging at abnormal or an excessive rate.

A critical review of cellular changes in different sized fruits and the stage of fruit most susceptible to cracking shows that cracking generally takes place between 4 to 6 cm. diameter stage. At this stage, cells of epidermis, hypodermis, as well as, mesocarp stop elongating radially. Whatever stretching takes place it
occurs only tangentially and when the internal pressure of developing fruits increases beyond the capacity of tangential stretching these cells separate from one another radially.

In pomegranate, epidermal cells generally stop elongation radially at 4 to 6 cm. size, whereas in cortical cells radial elongation stop at 6 cm. stage and so cracking is also seen at 4 to 6 cm. stage.

In Kagzi Kalan, the origin of cracking is also found from the diseased portion or at the place of damaged rind. Similar findings have been reported by Skene (1966) in apple, who believed that cracking and russetting is associated with the presence of dead cells in the epidermis and of fine cracks in the cuticle. In peel affected with disease or bruising there is a considerable extension of cork tissues as observed in lime. It has been pointed out by Eames and MacDaniels (1947) that in most plants, the cork tissues are both inextensible and inelastic. Thus, in an epidermis under greater strain because of disproportionate growth of epidermal and cortical tissues, such localized areas of inextensible cork would mark points at which tissues might first be pulled apart.
Investigations on the control of fruit cracking revealed that the interactions of irrigations and chemical sprays resulted in effective checking of fruit cracking in lime and pomegranate. Irrigation level $I_1$ (irrometer reading 10) was found more effective in lime and the mean percentage of fruit cracking ranged from 4.46 to 4.47 per cent as compared to 16.77 to 16.85 per cent in $I_3$ (irrometer reading 40). However, irrigation level $I_2$ (irrometer reading 20) gave better results in pomegranate and only 0.51 to 1.56 per cent of fruit cracking was found, while in $I_1$ and $I_2$, 4.94 to 5.15 per cent and 5.66 to 7.01 per cent cracking was recorded.

The influence of irrigation was more pronounced in $I_1$ and $I_2$, where interactions of irrigations and sprays effectively checked or reduced fruit cracking in most of the cases. In lime, the superiority of irrigation level $I_1$ over $I_2$ and $I_3$ was mainly due to the fact that fruit growth is enhanced by the rains in July and irrigation level $I_1$ reduced the sudden impact of rains on fruit growth and thus checked cracking, while the effectiveness of irrigation level $I_2$ over $I_1$ and $I_3$ in pomegranate fruits points out a relationship between the frequency of irrigation and the rate of fruit development, having a great bearing over
cracking. Both, slow and quick development (in I_3 and I_1, respectively) of fruits being abnormal, results in cracked fruits, whereas normal development of fruits in irrigation I_2 controlled cracking. This may also be due to specific period of fruit development which lies mainly in dry months and any extreme in moisture supply results in abnormal development thereby causing cracking. An increase in moisture supply (I_1) results in increased pressure exerted by the expanding pulp on fruit skin through quick development of fruits. On the contrary, reduced soil moisture supply (I_0) results in slow fruit growth, cutinization of cells of epidermal tissues, thereby reducing their elasticity and affects cracking.

Both, borax and copper sulphate in lower and medium concentrations have reduced cracking to minimum. The results of present investigations are in conformity with those of Powers and Bollen (1947), who successfully used copper sulphate and borax for the control of fruit cracking in cherries. The physico-chemical studies of the treated fruits showed that borax and copper sulphate sprays promoted thickness, increased firmness, pectin and protopectin in fruit peel and decreased total soluble solids, sugars and osmotic pressure in fruit juice.
It is assumed that borax and copper sulphate checked cracking by increasing the elasticity of cell membranes, strengthening the cell walls and reducing the fruit peel permeability to water.

Muslin covers proved most effective in controlling cracking in pomegranate fruits. In lime, the lowest percentage of cracked fruits was under gunny bags next was under muslin. However, the fruits under gunny showed desiccation and their appearance was poor because of high temperature inside the covers. Polythene covers though superior to control, did not prove as effective as muslin or gunny bags. Results obtained by Singh (1964) also show that polythene covers failed to check fruit cracking in tomato. The fruits under polythene covers were severely desiccated due to high temperature and humidity inside the bags. The superiority of muslin bags was mainly due to their effectiveness in checking the adverse effects of atmospheric conditions on the developing fruits without an increase in temperature and humidity around the fruits. Control fruits showed maximum cracking due to their direct exposure to the atmospheric conditions conducive to cracking.

The present studies lead to further
exploration of the problem of the causes and control of this malady among other fruits. It is suggested that further experiments on artificial induction of cracking be conducted in order to have a better analysis of this malady and control be devised with an emphasis on cultural control. Other chemicals with different concentrations should also be tried to check this disorder in different fruits. New varieties which are better in fruit quality, yield and at the same time resistant to fruit cracking should replace the old ones.