DISCUSSION

The present study “Cultivation of strawberry under protected conditions in sub-tropical region of Punjab” has yielded useful and horticulturally applicable results. Conspicuous features of these investigations are discussed here as under in the light of relevant available literature.

Experiment I: Planting time, protected conditions and GA₃ influencing plant and fruit characteristics of strawberry cv. Chandler.

5.1 Plant Characteristics

Plant height was significantly affected by the planting time, protected conditions and GA₃ applications. The maximum plant height was recorded in the plants which were planted on Oct 12 (T₁) and treated with GA₃ 100 ppm with the protection of poly-tunnel (100 gauge). Similar observations on enhancement plant height in strawberry were also reported by Kongsrud (1994). Tripathi (1997) also reported the effectiveness of time of planting on the height of strawberry plants. The application of gibberellic acid effectively increased the cell elongation in sub-apical meristem of strawberry shoot and promoted synthesis of auxin like substances in plant system (Guttridge and Thompson, 1959). Also, maximum number of shoots plant⁻¹ were produced from the runners planted on Oct 12 and protected under white polytunnel (100 gauge), GA₃ 100 ppm was also found to increase shoot number. According to Krishnamoorthy (1981) GA₃ caused stem elongation which in turn is due to both cell division and cell elongation. Rana (2001) registered the maximum plant height in strawberry cv. Chandler with the application of GA₃ 100 ppm. Joshi (2003) also reported incremented plant height in strawberry cv. Chandler with the use of GA₃ under temperate conditions, the results of the present experiment are in line with the findings of Dhillon (2005) who also reported increased plant height and number of shoots with GA₃ application under sub-tropical conditions. Improvement in plant height with the application of plant bio regulators may be due to enhanced rate of cell division, cell elongation and corresponding increase in epidermal and parenchymal cell length. These results are corroborated with the findings of Guttridge and Thompson (1963). The increase in cell elongation might be due to increased synthesis of auxin in the strawberry plant system (Singh and Phogat, 1983 and Dwivedi, 1987). Singh and Singh (1978), Singh and Phogat (1983) in sub-tropical and Dhillon (2005) in sub-tropical agro climatic conditions of Punjab reported an enhancement in plant height with the use of gibberellins in different strawberry cultivars.
The leaf number was affected significantly by the planting time, protected conditions and GA₃ treatments. In the combination of T₁ + P₂ + G₃ conditions, the delay in planting time resulted in decreased count of leaves. Number of leaves were counted to be maximum in the plant of Oct 12 (T₁) plantation under reed cover protection, GA₃ 100 ppm produced maximum leaves plant⁻¹. Maximum leaf area was measured under Oct 26 (T₂) planting time and under protection of white polytunnel (100 gauge), GA₃ 100 ppm also found helpful in producing maximum leaf area followed by its 50 and 25 ppm concentrations. Minimum leaves were counted under control. These observations are also in line with earlier reports of Rosati (1971), who found that number of leaves decreased as the planting was delayed. It might be possible that due to decrease in temperature range and increase in humidity causes reduction in number of leaves. Tripathi (1997) reported maximum leaf area at earlier dates of planting.

Singh and Singh (1978), Tafazoli and Shaybany (1978) and Singh and Phogat (1983) also reported an enhancement in number of leaves plant⁻¹ with the application of gibberellins in different strawberry cultivars. The leaf number was recorded to be maximum with the application of GA₃ 100 ppm. The results of the present study are in line with the findings of Joshi (2003) who reported increased leaf number with GA₃ treatments in strawberry. The maximum leaf area was recorded with the application of GA₃ 100 ppm and minimum under control conditions, it has been reported widely to increase photosynthetic activity (Satisbury and Ross, 1986) so, exogenous application of GA₃ might have increased the photosynthetic activity especially in upper plant part which is affected by CO₂:O₂ ratio (Kumar et al., 1996, Du –Yao, 2000). A study conducted by Dwivedi et al. (1999) resulted in maximum leaf area production in cvs. Senga Sengana and Missionary of strawberry with the application of GA₃ ( 0, 50 and 45 ppm) per plant. The increase in leaf area under polytunnels are in accordance with the findings of John and Dana (1966 ) in strawberry cv. Senga Sengana.

Maximum runner production plant⁻¹ was registered in plantation time of Oct (T₁) and protected condition polytunnel (100 gauge), GA₃ 50 ppm resulted in maximum number of runners plant⁻¹ followed by GA₃ 100 ppm and 25 ppm. Danek (1984) and Chandler et al. (1991) also reported that early planting in the month of August had the maximum effect on the number of runners produced. Maximum number of runners plant⁻¹ were observed when these were treated with GA₃ 50 ppm but Joshi (2003) reported the maximum runner production with GA₃ 100 ppm Gibberellic acid application increased the cell elongation which might have accelerated
the development of auxiliary buds that resulted in more runner production in strawberry cv. Chandler (Phogat and Singh 1982, Dwivedi 1987, Anwar et al., 1990 and Turemis and Kaska, 1997). They further stated that exogenous gibberellins application might have increased the levels of endogenous gibberellins, which in turn increased auxiliary bud formation and promoted crown production in strawberry. Enhancement of runner production with GA$_3$ in strawberry has been advocated by several research workers (Pipattanawong et al., 1996; Sangwook et al., 1996; Turemis and Kaska, 1997; Proussi et al., 2002 and Khokhar et al., 2004). The planting of saplings late in the season resulted in reduced runner production which may be attributed to the prevailing environmental conditions of the place. The white polytunnel (100 gauze) was observed to be the best selection for runner production. The findings of the present study are corroborated with the findings of the Lisiecka and Pudelski, (1997) which confirms the findings of the present studies.

Minimum number of days taken for flower initiation were counted in the plantation of Oct 12 ($T_1$) and Polytunnel (100 gauze) protected conditions, application of GA$_3$ had positive and significant effect on number of flowers and setting of fruits during both the seasons of study. The findings of the present studies have been sustained by the work of Dhaliwal and Singh (1983), Joolka and Badiyala (1983), Awasthi and Patiala (1984) and Kidmose et al. (1996) in strawberry. It has been observed that days taken to produce first flower depended upon early establishment of plants which entails vegetative growth before flowers are initiated.

This could be due to the fact that these growth regulators accelerated the development of differentiated inflorescence in strawberry as reported by Mikhteleva and Petrovskya (1974), Kalie et al. (1980) and Ozdemir and Kaska (1997). Pathak and Singh (1971) also reported an increase in total number of flowers in Pusa Early Dwarf and Katrain Sweet cvs. of strawberry with GA$_3$ 75 ppm. Maximum duration of flowering was observed when plants were treated with GA$_3$ 100 ppm protected under white poly tunnel (100 gauze) and planted on Oct 12 ($T_1$) during both the years of study. GA$_3$ inhibited the vegetative growth and promoted flowering and fruiting. These results are in accordance with the findings of Kalie et al., (1980) and Joshi (2003) in strawberry cv. Chandler respectively but Moroto et al., (1983) and Tehranifer et al., (1997) demonstrated the similar type of results with GA$_3$ 50 ppm in cv. Chandler. The plants under white poly tunnel was found to be helpful in inducing early flowering than in the plants under control because of its reducing effect of lowering the temperature during the night time than in
the day. The findings of John and Dana (1966) and Soczek (1966) advocated the findings of the present study.

Maximum number of flowers plant\(^{-1}\) were counted in the plantation of Oct 12 (T\(_1\)) and under white polytunnel 100 gauze protected conditions. GA\(_3\) 100 ppm treatment produced maximum number of flowers plant\(^{-1}\) followed by 50 and 25 ppm during both the seasons of study. The findings have been substantiated by the reporting of Fiedler and Weier (1983) that later plantings reduced the number of flower plant\(^{-1}\). Findings of Tripathi (1997) also confirms the results of the present studies.

Likewise, maximum fruit number plant\(^{-1}\) was counted in Oct 12 plantation and P\(_1\) protected condition and GA\(_3\) 100 ppm concentration treatments, these treatments also resulted in highest fruit set percentage during both the cropping seasons. The present studies indicate that number of fruit set was influenced by date of planting Caruso and D’Anna (1995) observed that as the planting was delayed, the fruit number was reduced considerably. Tripathi (1997) also reported decrease in number of fruits plant\(^{-1}\) with the delay in planting time of strawberries. Maximum per cent of fruit set was registered in the plants grown under white poly tunnels and treated with GA\(_3\)100 ppm through out the course of study during both the cropping seasons. It is in conformation with the research work of Dhillon (2005) also reported enhanced fruit set with GA\(_3\) treatments. Tehranifer et al. (1997) reported maximum berry setting with GA\(_3\) 50 ppm in strawberry cv. Chandler. The results under poly tunnels are in accordance with the work done by John and Dana (1966) and Soczek (1966) in cv. Senga Sengana.

Maximum fruit yield, marketable yield were recorded with Oct 12 (T\(_1\)) planting time and white polytunnel 100 gauze (P\(_1\)) protected condition, the application of GA\(_3\) showed a prominent effect on the yield of strawberry crop and remarkably increased the yield of strawberries in both the cropping seasons of study. Yield was influenced significantly by time of planting. Wienberd and Seidl (1972) and Tripati (1997) also reported that yield from the earlier plantings was higher as compared to late plantings. This may be due to the formation of more metabolites and large number of leaves resulting in more flowering and achene setting. The application of GA\(_3\) 100 ppm recorded maximum yield, it was closely followed by GA\(_3\) 50 ppm. These results are in confirmation with the findings of Zakhorova,1979; Singh and Phogat,1983 who reported similar type of information. GA\(_3\) 100 ppm has a pronounced effect on the yield of strawberry crop and remarkably increased the yield. The increase in fruit yield possibly be due to the increased
percentage of achene formation, setting higher number of fruits per plant, berry size and weight. The results of the present studies have been corroborated by the findings of Kalie et al. (1980) and Rana (2001) who confirms the findings of present study. Increase in yield due to the effect of poly tunnels has also been reported by Kongsrud (1994), Kaska et al. (1997) Cu-Xiao (2000) and Lieten (2001) in different cultivars of strawberry which advocated the findings of the present study.

The marketable yield has been observed to decrease than that of the total yield of the strawberry fruits during both the cropping seasons of study. Maximum marketable yield has been reported in the plants treated with GA$_3$ 100 ppm and protected under P$_1$ conditions and planted on Oct 12 (T$_1$). The findings of the present study are corroborated by the findings of Probasco (1994) who reported that the time of planting was effected by the marketable yield due to the increase in the temperature. The reduction of the marketable yield than the original yield was observed, may be due to the reason of its perishable nature of the fruit.

5.2 Fruit Characteristics

Planting time, protected conditions and GA$_3$ treatments significantly influenced the size (length and breadth) and weight of strawberry fruits, Oct 12 (T$_1$) plantation, P$_1$ protected condition and GA$_3$ increased the length of fruits during both the cropping seasons. The increase in fruit size in earlier plantings of the present study has been confirmed the findings of Rosati (1971), Human (1993) and Tripathi (1997) who reported that fruit size decreased with the later plantings.

The fruit size in terms of length and breadth was markedly affected by GA$_3$ application. The increment in fruit size was due to enlargement f cells with gibberellins in the different strawberry cultivars have also been reported by Singh and Phogat (1983), Techawengstein (1989) and Camargo et al. (1995). The increase in fruit length, breadth and volume may be due to the better supply of assimilates and occurrence photosynthesis which in turn help achene development with the application of growth regulators. Maximum fruit length was recorded with GA$_3$100 ppm and fruit breadth with GA$_3$ 50 ppm during both the years of study. The findings of the present study are in line with the findings of Rana (2001) who reported increased strawberry size with the application of GA$_3$. The findings of Miranda et al. (1990) also reported increased berry size in strawberry with the application of GA$_3$ which confirms the findings of the present study. The increase in fruit size under poly tunnels is also advocated by Kongsrud (1994).
The maximum fruit weight was registered in the planting of Oct 12 (T₁) under protected conditions P₁ and treated with GA₃ 100 ppm. As the average fruit weight was significantly influenced by the dates of plantings, Tripathi (1997) also reported increased fruit weight of strawberries in earlier plantings.

The results of the present study are in accordance with the research work of Camargo et al. (1995) who reported increase in fruit weight with GA₃. Montero et al. (1998) reported that GA₃ 100 ppm improved fruit weight in strawberry cv. Chandler which confirms the findings of the present study during both the cropping seasons of study. The effect of GA₃ on berry weight may be due to additional supply of photosynthates which otherwise would have been used for vegetative growth as in case of growth promoters. Maximum fruit weight was recorded under poly tunnel (100 gauze) during both the years of research. Such results have also been obtained by Funaro (2000) in strawberry cvs. Tudla and Camarosa when planted in open field and also in protected poly tunnel conditions.

Attractive bright red coloured glamorous fruits were produced in the plantation of Oct 12 T₁ and under white polytunnel 100 gauze (P₁) during both the cropping seasons GA₃ 100 ppm and 50 ppm treatment were also progressively produced impressive red coloured fruits during both the cropping seasons of research. The during both the cropping seasons of research. The organoleptic scoring of fruits was of like that of the colouration, highest organoleptic rating was awarded to the strawberry fruits of T₁ planting and under P₁ protected conditions. The fruits under GA₃ 100 and 50 ppm treatment scored good gradation of palatability. From the present study it was evolved that fruit colour in strawberry is a highly variable character. The red colour is strawberry fruit is derived from the orange brown anthocyanin pigment (Bakker et al., 1994). The fruits with good colour development almost scored higher points for their palatability from the panel of five judges.

Total soluble solids, in general increased significantly with the planting time of Oct 12 (T₁), P₁ protected conditions and GA₃ treatments during both the cropping seasons. Planting of T₁ time resulted in maximum total soluble content of strawberry fruits. Maximum TSS of strawberry fruits of earlier planting has also been reported by Tripathi (1997) which confirms the findings of the present study. Maximum TSS was obtained in the strawberry fruits which were treated with GA₃100 ppm and planted under poly tunnel (100 gauze) conditions. The increase in TSS may be due to conversion of starch and other polysaccharides. These results show
conformity with the findings of Bhautkar (1994) and Rana (2001) who also reported the maximum TSS with GA$_3$ 100 ppm in cv. Chandler which is in line with the present findings. The enhancement of total soluble solids with GA$_3$ may be due to the fact that it checks the vegetative growth and in turn make available more carbohydrates to developing achenes which ultimately affected the quality of the achenes by improving TSS content, the results of the present study are supported by Ozdemir and Kaska (1997) who recorded enhancement in strawberry cvs. Aliso, Pochantas and Tioga, the planting time did not affect the total soluble solids of the achenes, may be due to there genetic characters.

Higher total sugars were detected in the fruits from Oct 12 (T$_1$) planting, P$_1$ protected conditions. Maximum sugars were observed under reed cover (P$_3$) protected conditions. Total sugars were significantly increased by GA$_3$ treatments. The maximum total sugar was analysed in the fruits treated with GA$_3$ 100 ppm during both the years of study. The enhancement in sugars of strawberry plants with growth regulator may be due to the fact that it checks vegetative growth, which in turn readily makes available more carbohydrates to the developing berries and ultimately improved their sugar content. Evidently, the increase in sugars might be due to conversion of starch and other polysaccharides into soluble sugars. These results are in line with the findings of Rana (2001) in strawberry cv. Chandler under sub-tropical conditions of Punjab but total sugars were found to be also higher when the plants were treated with GA$_3$ 50 and 75 ppm (Singh and Phogat, 1983). The Poly tunnels 100 gauze also resulted in maximum sugars but Antuono et al. (2000) reported that the fruits of strawberry under protected conditions although looked good but these were low in their sugar contents.

Inconsistent trend of per cent acidity was noted during both the cropping seasons of study, however, the maximum titratable acidity was recorded in the strawberries harvested from the experimental plots under control than the plants under polytunnels in cropping seasons of research. Similar trend of acidity has been reported by Tripathi (1997). The strawberries grown under polytunnels (P$_1$) registered reduced acidity percentage of fruits, the results of the present studies coincide with the results of Antuono et al. (2000) and Dhillon (2005) in various cultivars but in contrast to the present study Singh and Phogat (1983) reported increased fruit acidity with GA$_3$ 50 ppm.

Maximum ascorbic acid content was registered in fruits of Oct 12 (T$_1$) planting, protection reed cover. The planting time of Oct 26 (T$_2$) and reed cover protected conditions
registered maximum level of titratable acidity of strawberry cv. Chandler fruits, GA$_3$ 100 ppm concentration produced fruits with minimum its contents. The findings of Tripathi (1997) confirms the findings of the present studies. In the present studies GA$_3$ had shown its effect by significantly improving ascorbic acid content of strawberry fruits as compared to those fruits which are under control, it 50 ppm concentration registered maximum contents. Maximum ascorbic acid content was registered in the plants of strawberry cv. Chandler which were treated with GA$_3$ 50 ppm. Galactose is a precursor for ascorbic acid, it may be assumed that the increase in its level may be because of the conversion of the sugars. Increase in ascorbic acid content in strawberry by the application of various growth regulators has also been reported by Mikhteleva and Petrovskya (1974), Singh and Phogat (1983) and Dhillon (2005) in strawberry cv. Chandler.
Experiment II: Performance of strawberry cultivars under field conditions

5.3 Plant Characteristics

In second experiment strawberry cultivars Chandler, Tioga, Fern, Selva and Blackmore were tried for studying the plant and physico-chemical fruit characteristics under field conditions of Amritsar area.

Some variations in the survival of plants of different strawberry cultivars were observed under the similar agro-climatic field growing conditions. Plant establishment was significantly affected by the planting time. Planting time of T₁ (mid Oct) resulted in maximum establishment of plants followed by T₂ (end Oct) and T₃ (mid Nov) plantation. Tripathi (1997) reported good plant survival during earlier planting times. The strawberry cvs. Chandler registered maximum per cent plants survival followed by cvs. Blackmore, Tioga and Selva while the cv. Fern trailed behind during both the cropping seasons of study. This variation may be attributed to their higher and low chilling requirements by the cultivars for its growth and development which were not met in the plains of Amritsar (Pb) area. All the cultivars of strawberry registered a higher magnitude of success besides cvs. Fern and Selva in terms of plant survival under the agro-climatic conditions of Amritsar area of Punjab. The results of the present studies are in line with that of Athwal (1976) and Singh (1982) who tried cvs. Climax, Blackmore, Jucanda, Senga Sengana, Senga Gigana, Sweet Katrain and Howard under field conditions of Ludhiana area (Pb.). Janick and Hayden (1973) carried out studies on strawberry cultivars and reported that the cvs. Apollo, Atlas and Red Chief survived the best under sub-tropical conditions.

The cultivars of strawberry showed significant difference with respect to plant height during the different planting times maximum plant height of strawberry plants was recorded in T₁ planting time followed by T₂ and T₃ times. Amongst the cultivars under trial, maximum height was attained by cv. Blackmore during both the cropping seasons of study, it was followed by cvs. Tioga. In the first cropping seasons it was followed by cultivar Fern while in the consecutive season it was followed by cvs. Chandler and Selva and cv. Fern remained at last position. Reduced plant height was observed when saplings were planted late in mid of Nov. (T₃) confirms the fact that planting time affected the plant height to some extent. The lowest plant height among the cultivars may be attributed either to its genetic make up or the sub-tropical agro-climatic conditions of Punjab state which adversely affected the development of plants properly. However, the late planting induced early flowering which suppressed the height and
other vegetative characteristics. Varietal differences reported by John and Dana (1966), Athwal (1976), Singh (1979), Singh (1982). Strawberry plant reacts strongly, both vegetatively and reproductively to the environmental parameters viz., temperature, photoperiod and light intensities. Here, in the present study marked variation was noticed among different cultivars. The findings of the study are in agreement with the studies conducted by Gupta (1998) and Suman (2000) who also noted variation in plant height and spread. Grewal et al. (1988) observed significant differences in spread of strawberry plants of cv. Tioga. Since the plant size is influenced by different environmental factors, which are responsible for variation in plant height and spread in some of the cultivars. Beniwal et al. (1989) proposed the reason for the variation could be the genes responsible for the above aspect did not express them fully with the same degree as it does at other places because of different agroclimatic conditions of the area where these are grown.

Results of shoot number plant\(^{-1}\) showed highly significant differences between the cultivars and the planting time. Firstly an ascending trend in the number of shoot was observed with the advancement of time of plantation then it shows descending trends during both the cropping seasons of study. Maximum shoot number was counted in cv. Chandler followed by cv. Tioga while the lowest was in cv. Selva during both the cropping seasons. The varying shoot number may be due to the temperature variation, changing weather conditions which affects growth of plants. The variation in shoot number in different varieties may be due to the particular varietal character and their growth habits.

Strawberry cultivar showed significant differences with regard to leaf area and leaf number plant\(^{-1}\). Leaf number count plant\(^{-1}\) showed a decreasing trend with the delay in time of planting during both the cropping seasons of study. Tripathi (1997) also reported minimum leaf area with the delay in planting in strawberry which advocated the findings of the present studies. Maximum number of leaves were counted in cv. Chandler followed by cvs. Tioga, Blackmore and Selva while cv. Fern trailed behind during both the cropping seasons of study. These results are in line with the findings of Singh (1982) and Dhillon (2005) who reported similar type of observation while working on strawberry under open cultivation maximum leaf area was obtained in cv. Blackmore which was followed by cv. Chandler and Fern during both the cropping seasons of study while cv. Selva registered minimum leaf area. Variation in leaf area among different strawberry cultivars could be attributed to the fact that different progenies may
have reacted differently to photoperiod, light, temperature and status of media (Darrow, 1966 and Tanaka and Mizuta, 1974). Hence, it seems that a negative correlation between these two character variable between these two variables coexists. Apparently, plant condition or environment or both affect these two variables differentially or independently.

The data indicate that all the parameters regarding time of runner formation, runners plant$^{-1}$ and runner length showed significantly variable results for their planting times. The cv. Chandler was found to be the earliest to develop runners after planting and it was followed by cvs. Blackmore, Fern and Selva. Strawberry cv. Tioga took maximum days for commencement of runner development during both the cropping seasons of study. The saplings planted in the month of Oct (T$_1$) started forming runners earlier than the late planted saplings of T$_2$ and T$_3$. However, maximum number of runners plant$^{-1}$ was obtained in cv. Chandler which tended to decrease with the advancement in planting time. The cv. Tioga produced the minimum number of runners plant$^{-1}$ which was almost negligible in the late planted saplings. Significant differences were observed with regard to the runner length. Runner length was measured maximum in cvs. Chandler, it was followed in line by cvs. Blackmore, Fern and Selva while cv. Tioga recorded minimum runner length during both the years of study. In the present studies, marked variation in runner formation ability was recorded among different strawberry genotypes. The mother plant initiated to runner formation when flowering was about to cease. Similar observations were also recorded by Athwal (1976) and Singh (1979). The vast differences in the time of runner formation, runners plant$^{-1}$ and runner length in the various cultivars may be ascribed either a varietal character or genetic make up of the plants or both which affect the plants to react differently under the same agro-climatic conditions. The temperature of the site also affected the runner formation. The rise in temperature led to the decreased runner formation and the runner length because a complete death of the tissues was observed by the rising temperature during the months of April and May. It may be noted that the cultivars which started producing runners very late or produced very few runners i.e. less than three runners per plant could not be considered suitable for cultivation as they are not economical from plant multiplication view point and the saplings planted late are not suitable for runner production under prevailing climatic conditions of Punjab. Similar results have been reported by Athwal (1976), Singh (1979) and Singh (1982) under Punjab conditions which further confirms the results of the present study.
All the cultivars of strawberry planted in the first week of Oct started development of their flowers in the third week of Jan except Fern and Selva, which showed their development in the second week of Jan. Maximum duration of flowering was observed in Selva. The difference in the time of flower-bud development in different cultivars of strawberry seems to be controlled by their chilling requirements. Saplings planted on mid of Oct 12 (T1) resulted in early flower-bud development but due to increase in temperature the flower-bud development and duration of flowering was reduced in the saplings planted in the mid Nov. It shows that in Punjab's agroclimatic conditions early planting in the months of Oct will be considered more beneficial than late plantation in the month of Nov. The results of the present study are collaborated by the findings of Dhiman (2003) who reported maximum flowering duration by cv. Selva but cv. Blackmore took minimum flowering duration in the hilly climate of Himachal Pradesh, early blooming cultivars had more prolonged flowering seasons in comparison to the late blooming cultivars which had short duration of flowering. The difference of results might be due to the climatic variations of Punjab and Himachal Pradesh. However, Dhalliwal and Singh (1983) while working on strawberry in Ludhiana conditions, Beniwal et al. (1989) and Kidmos et al. (1996) in Denmark conditions recorded similar type of observations which confirms the findings of present study.

It has been observed from the data that different cultivars significantly influenced the fruit set. Maximum fruit set was observed in cvs. Blackmore, Tioga and Fern in line while cv. Selva stood at last during both the cropping seasons of study. In the first week of Oct (T1) planting maximum fruit set was recorded as compared to the later planting, where it was reduced with the advancement in planting time. It was noted that the fruit set per cent was reduced with the planting time as the early planted saplings received the favourable climatic conditions but the saplings planted in the mid Nov faced the low chilling temperature rising temperature at the fruit set time which resulted in the complete necrosis of the developed fruit or the flower. Per cent fruit set of strawberry depends upon the agro-climatic field conditions of the place of there cultivation. Different research workers reported variability in the per cent fruit set of various varieties depending upon agro-climatic conditions of the area of cultivation. Singh (1982) reported maximum per cent fruit set of Pusa Early Dwarf followed by cv. Tioga under Ludhiana agro climatic conditions of Punjab. The variability in the per cent fruit set under Amritsar’s prevailing agro-climatic conditions may be due to the effect of temperature and humidity of the
The maximum number of fruits plant$^{-1}$ were obtained in cv. Chandler whereas, fruits harvested from it were lesser in the saplings planted in the early Oct. The saplings which were planted late in the middle of Nov, the fruit number and harvested fruit number were decreased. This is perhaps due to change in environmental conditions from cool to warm temperature and rise in temperature caused fruits to rotting. Singh (1982) also reported similar type of observation while working on the various strawberry cultivars.

Maximum fruit yield plant$^{-1}$ and marketable yield were obtained in plants of T$_1$ plantation followed by T$_2$ and T$_3$ plantations during both the season of research. The fruit yield aspect decreased with the delay in planting time of strawberry cv. The maximum yield plant$^{-1}$ was obtained in cv. Chandler and the minimum was obtained in cv. Selva. Sharma and Yamdagni (2000) also reported cv. Chandler as high yielding cultivar amongst other cultivars and mentioned variability in the yield and marketable yield of strawberry fruits of different cultivars. The yield plant$^{-1}$ also decreased with the planting time. Similar observations on yield plant$^{-1}$ have been reported in different cvs. of strawberry by Singh (1982) and Sharma and Badiyala (1980). These results are in accordance with the findings of several research workers (Bedarad et al., 1971; Lal and Seth, 1980; Hancock et al., 1983. They found a strong correlation with fruit number per plant and weight with total fruit yield but in contrast Dhaliwal and Singh (1983) reported that higher yield of strawberry cultivars was due to number of fruits per plant which may be smaller and lighter in size.

### 5.4 Fruit Characters

The fruit weight showed significant variations between different cvs. of strawberry. Maximum fruit weight was measured in cv. Chandler, it was followed by cvs. Fern and Tioga in line while the cv. Selva produced light weighed fruits during both the years of study. The fruit weight was reduced with the delayed planting time. Saplings of strawberry has shown its effect on the weight of produced fruits. Fruit weight tends to reduce with the advancement of plantation during first and also in the second year of study.

Earlier planting resulted in better coloured fruits with good organoleptic scoring, the colouration standard as well as organoleptic scores awarded to fruits by a panel of judges showes a descending trend with the delay in the time of planting. It has been observed that the fruits
which were good coloured, were also superior in quality and received better acceptance due to attractive colour and taste. While going through the tables, it was noted that strawberry fruits of cv. Chandler produced attractive, glamorous red fruits, however, cv. Blackmore also developed good greyed red colour shades and also awarded good organoleptic scoring. The strawberry fruits of cvs. Chandler and Blackmore observed to be at correct stage of maturation, the reason being, it got good scoring and acceptability. The fruits of cvs. Tioga, Fern and Selva although developed red colour, but not so attractive up to the mark and consumer’s acceptability, might be due to the non-acceptability of the cultivars to the agro-climatic conditions of the state. The colour development in strawberry fruits has also been reported by Dhiman (2003) during her work on strawberry fruits in Solan area of H.P. Anon (2008) also described colouration development in strawberry fruits in Shimla hills of H.P.

The strawberry cultivars and their plantations at different times showed significance differences with regard to the fruit size (length x breadth). The earlier planted saplings produced large sized fruits than the late planted saplings. The planting of T1 resulted in fruits with maximum length followed by the fruits produced in T2 and T3 plantation during the first cropping season, same trend of increase in fruit length of strawberries has been noted during the second cropping season of study. Also, the time of planting showed significant effect on the breadth of strawberry fruits. Strawberries with maximum diameter were found during the T1 planting time, in the next planting times i.e. T2 and T3 fruit diameter decreased drastically during the first and consecutive cropping seasons of study. During the first cropping season cv. Chandler produced fruits with maximum breadth followed by cvs. Tioga, Blackmore, Selva and Fern whereas in the conjunctive cropping season the fruits of cvs. Chandler and Tioga were almost of the same breadth, followed by cv. Blackmore and the fruits of cvs. Fern and Selva registered the same breadth size. The length of fruits were found maximum in cv. Chandler, it was followed in line by cvs. Blackmore, Tioga and Fern while cv. Selva secured at last position during both the cropping seasons of study, in the first cropping seasons cv. Fern remained at last but not like the former year cv. Fern remained at par with cv. Selva. Morrow et al. (1958), Dhariwal and Singh(1983), Sharma et al.(1984) and Hancock and Bringhurst (1988) and Dhiman (2003) recorded sufficient variation in fruit size in different strawberry cultivars. Recupero et al. (1989) also reported large sized fruits in cv. Chandler, Pajaro and Selva. According to Janick and Eggert (1968) and Morrow et al.,(1970) these differences in fruit size were primarily due to plant
vigour, competition among fruit in the inflorescence, number and size of developed achenes, differences in activity among the achenes in the production of growth material, agroclimatic conditions, irrigation and plant nutrient etc. Difference in fruit size of different of strawberry has been reported while studying the performance of different strawberries in wet-temperate zone of Himachal Pradesh (Anon, 2008).

5.5 Biochemical changes

The total soluble solids of strawberry fruits exhibited a significant variation due to plantation time and different cultivars. Total soluble solids showed its descending trend in fruits of strawberries with the advancement of plantation time but with statistically significant differences. The trend for TSS in different strawberry cvs. appeared quite inconsistent and haphazard. In the first year of study maximum total soluble solids were detected in cv. Chandler which was followed by cv. As it is to be noted that major constituent of all soft fruits is water, it is of utmost importance to determine the TSS contents of the strawberry fruits. The results of the present study are in conformity with the findings of Veazie (1995) who reported that TSS content vary from 4.0 to 11.0 Brix in strawberry. The findings of Dhiman (2003) also advocated the findings of the present study. Furthermore the TSS content in strawberry are influenced by environmental conditions rather than genetic inheritance during production (Shaw, 1990).

The highest content of total sugars per cent was registered in cv. Chandler in the early planted saplings. The lowest total sugars were recorded in Blackmore, However, there was a slight variation in the sugars due to the planting time. This may be due to the change in the environmental conditions as well as due to the genetical constitution of the different strawberry cultivars. The level of sugar content observed in the present study are in accordance with that of Dhaliwal and Singh (1983), Kader(1991) and Dhiman (2003) which confirms the findings of the present study. The reason for deviation in fruit sugar may be due to differences in growing conditions, climatic variation and cultivar involved as reported by Polovyanov (1985), Wrolsted and Shallenberger (1981), Kader (1991) and Dhiman (2003).

The titratable acidity content of strawberry fruits was found to be inconsistent, in the first year it ranged from 0.41 to 0.88 per cent while in the second year it was from 0.25 to 0.89 per cent. During both the years acidity level of fruits showed declining trend with the advancement of planting time. The results of the present study have been supported by Veazie (1995) who reported acidity in ripe strawberries varies from 0.45 to 1.81 per cent depending upon cultivar
and environment. Such differences could be due to the fact that varieties grown under sunny days and cool nights have better TSS and acid contents than those under cloudy, humid and warm nights (Avidov, 1986 and Kidmos et al., 1996). Dhiman (2003) also confirms the result of the present study with regard to acidity level of strawberry fruits. According to Shaw (1990) titratable acidity is a heritable traits and is less influenced by environment than TSS contents.

The highest ascorbic acid content was obtained in fruits of cv. Chandler followed by Tioga and Selva with minimum in Blackmore. There was a slight variation in ascorbic acid content with the planting time. According to Wang and Camp (2000) high temperature during and night lead to synthesis of less ascorbic acid content in the strawberry. It can be said that the cultivar which had higher sugars also synthesized higher quantity of ascorbic acid contents in the fruits.