EVALUATION OF LOW CHILLING APPLES UNDER MID HILLS OF H.P. (*Malus x domestica* Borkh.)

THESIS

by

GIAN DUC CHUA

Submitted in partial fulfilment of the requirements for the degree of

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COLLEGE OF HORTICULTURE

Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan - 173 230 (H.P.) INDIA

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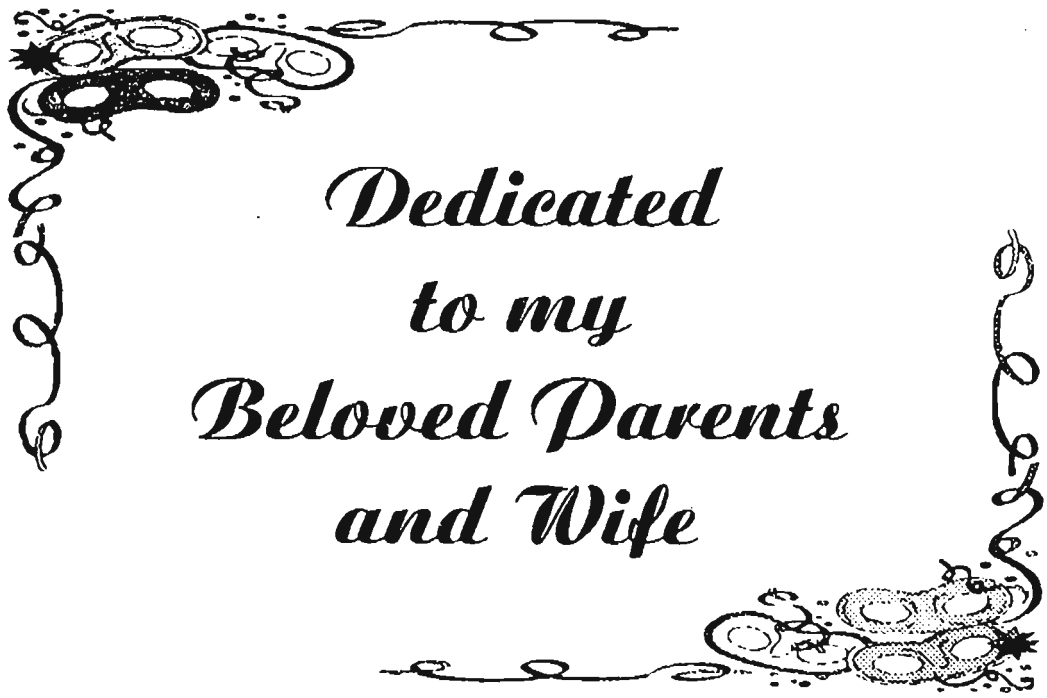
Dedicated
to my
Beloved Parents
and Wife

Dr. Girish Sharma
Asstt. Professor

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Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan – 173 230 (H.P.)

CERTIFICATE-I

This is to certify that the thesis entitled **"Evaluation of low chilling apples under mid hills of H.P. (*Malus* x *domestica* Borkh)"**, submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (FRUIT BREEDING AND GENETIC RESOURCES)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Gian Duc Chua (H-99-6-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Dated : 19th October, 2001

(Girish Sharma)
Chairman
Advisory Committee

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(Girish Sharma)
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CERTIFICATE-II

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(Girish Sharma)
Chairman
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External Examiner

13.12.2001

Professor and Head
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I solely claim all responsibilities for the shortcomings and limitations in this work.

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(GIAN DUC CHUA)

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INTRODUCTION

Apple (*Malus* x *domestica* Borkh) is an important temperate fruit crop in the world, belonging to the family Rosaceae and sub family Maloideae, formerly known as Pomoideae (Challice, 1981) and is native of South-West Asia.

Cultivation of the apple in the world seems to have been practised from a few centuries B.C. In India, first commercial cultivation of apple was done in Kullu valley of Himachal Pradesh in 1870 (Hayes, 1957). Its cultivation is mainly confined to western Himalayas comprising hilly states of Jammu and Kashmir, Himachal Pradesh, hills of Uttar Pradesh and some parts of the North Eastern States of India.

The apple production in the world was 59,963,060 metric tonnes from an area of 5,627,720 hectares and in India, it was 1,320,590 metric tonnes from an area of 227,680 hectares (FAO, 2000). Himachal Pradesh is situated in the laps of Himalayan ranges with an elevation ranging between 460 to 6400 meters (m.s.l). At present, it is the major apple growing state in the country with production of 376,736 tonnes from an area of 86,699 hectares during the year 2000-2001 with average productivity of 4.2 tonnes per hectare as compared to the national average of 5.80 tonnes per hectare and world average of 10.65 tonnes per hectare (Anonymous, 2000; FAO, 2000).

Climatic factors like temperature, rainfall affect the time of apple blooming in apple growing areas (Chaer, 1946). Apple succeeds best in the regions where the tree experiences an uninterrupted winter rest as tree requires certain minimum chilling period for growth and fruiting. Kronenberg (1979) suggested that apple requires about 1000 hours at about 7°C before flowering, however, some cultivars require just 250 hours chilling before flowering (Mita and Bose, 1991).

Apple production in recent time has seen a decline trend associated with number of factors. Despite the shortfalls, there is vast scope to augment apple production through its cultivation in non-conventional areas to meet not only demand of fresh market but also to meet the need of processing units. The temperature of the world seems to increase day after day, standard cultivars of apple in some growing areas may have to be replaced by low chilling apples because of their inability to meet the requisite chilling requirements. The present studies on evaluation of low chilling apples (about 12 in number) was undertaken in the mid hill conditions of Himachal Pradesh (Nauni) with the following objectives.

i) To evaluate various horticultural traits of low chill apple in order to provide a selection base for their cultivation in the marginal areas.

ii) To study gene action in order to know the nature of varieties and heritability of horticulturally important traits.

REVIEW OF LITERATURE

Chapter-2

REVIEW OF LITERATURE

Apple is an important fruit crop of the temperate regions of the world. Apple trees require cool climate for their proper growth and development, they require certain minimum chilling periods for their satisfactory growth and fruiting. Buds of apple trees may not open or blossoming may be uneven if their chilling requirements are not met. This chilling process takes place at temperature below 7°C (45°F). Most apple varieties need to experience such temperature for about 1200 hours in order to achieve complete and adequate rest. These temperatures are prevalent in the temperate regions but some varieties can manage with as little as 250 hours of chilling, these varieties can be grown successfully in tropical and subtropical zones on high mountains where the altitude provides the necessary cold climate (Kanwar, 1987). The work done on "Evaluation of low chilling apples under mid hills of Himachal Pradesh (*Malus x domestica* Borkh)" has been reviewed under following subheads:

- Evaluation of low chill apples
- Heritability studies

2.1 EVALUATION OF LOW CHILL APPLES

Saure (1973) reported that Rome Beauty apple was grown very successfully in Batu tropical region of Indonesia at relatively low altitude of 800 to 1200 meters where temperature seldom fell below 16°C.

According to Jules Janick (1974), 'Rome Beauty', a low chilling apple also called 'Ohio Beauty' in Brazil was very suited to tropical condition of Java, Indonesia, highland areas from 700 to 1200 meters altitude, with annual rainfall around 2000 millimeters per year. 'Rome Beauty' gave two crops per year with the help of technique such as leaf

stripping performed one month after harvest. It gave good yield of about 50 kilograms per plant for two harvests. At maturity, the fruit was almost completely red and there were some redder sports on the surface on fruit compared to the village clone 'Kampung'. Apparently, the 'Rome Beauty' may be self compatible under these conditions for solid blocks set well and bagged flowers also reportedly set. The flower petals attached to the young fruits suggested parthenocarpic set. Rowland (1978) while working on low chilling apples reported that cultivars Tropical Beauty, Anna and Dorsett Golden were suited for growing in the subtropical regions of Florida, USA at an elevation of 61 meters above sea level.

Vered, an early maturing apple, small to medium sized fruits, used fresh or cooked, yellow green with a red brush and the creamy-white flesh with a pleasant flavour, was suitable for growing in the foothills as it has low chilling requirement around 250 hours at or below 7°C. It produced a worthwhile crop in the third year. The fruit was ready for harvest by the first week of June (Dadlani *et al.*, 1980).

According to Huang and Powell (1982), cultivars Bevery Hills and Ein Shemer with low chilling requirements were sensitive to heat treatment for two hours at 39°C after cold storage at 4°C. The growth of terminal and lateral buds was promoted whereas in cultivars Marin Onfroy, Delicious, Northern Spy and Cross Bios with high chilling requirements were not stimulated into growth by heat treatment. In India, Seth (1983) developed four low chill hybrids, hybrid (11-1/12) from the cross between Red Delicious and Winter Banana was observed to have low chilling requirement of about 700 hours. Among the thirty two apple cultivars evaluated at Gainesville and Monticello, Florida, USA receiving 350-550 chilling hours, cultivars Anna, Dorsett Golden, Michai, Elah, Maayan and Schlomit were found to be adapted and had acceptable fruit quality (Miller and Baker, 1983).

Aguila (1986) reported seven apple mutants with low chilling requirements. Two of them from Starking Delicious, two each from Golden Delicious, Red Delicious and one from Peron. The mutants had better characters than parents such as larger fruit,

earlier flowering (11-20 days earlier), higher percentage of vegetative bud break, high soluble solids content in fruit.

Bist and Sharma (1986) investigated the flowering behaviour of ten low chilling apple cultivars under Nauni (Solan) conditions and observed that the flowering duration varied from ten days each in Tamma and Golden Delicious to 17 days each in Sharp's Early and Parlin's Beauty.

Gautam and Chauhan (1986) in varietal variation study with respect to growth, yield and quality characters of some low chilling apple cultivars found that cultivar Tropical Beauty gave maximum trunk girth (32.6 cm). Tropical Beauty also gave maximum average cumulative yield (69.09 kg/plant) during 1980-1983, whereas Early Shanburry, Sharp's Early and Tamma were poor in yield performance.

Denardi and Hough (1987) accounted the apple breeding programme of the Institute Agronomica de Campinas, Sao Paulo, Brazil since 1940's especially on low chill apples. The Institute released 'Rainh', 'Delicia', 'Bonita', 'Dulcina', 'Paulista' and 'Culinaria'. The selection 'BR_1' and 'BR_2' with 500-600 hours chill requirement were of interest.

According to Kanwar (1987), 'Red June' an early variety which ripens near the end of June or beginning of July, advocated its testing in low hills.

Hermano *et al.* (1987) reported that six low chill apple cultivars planted in the dry season, February 1984 at Baguio, Philippines, at an elevation of 1500 meters. Three to five long shoots grew vigorously from the maiden stem. After five months, while still growing strongly, these were topped, defoliated and tied horizontally. Lateral buds burst and formed spurs with terminal buds. These were defoliated again after five months. Some flowers emerged and few fruit set took place. Anna and Dorsett Golden responded well to defoliation. Beverly Hills and Gordon burst poorly. Gordon produced long shoots rather than spurs. The Indonesian practice of bi-annual defoliation and tying down of

long shoots was being continued successfully. Timing of treatments in relation to leaf maturity was critical. For chemical defoliation, 4-6 per cent $CuSO_4$ was most promising, to break bud dormancy, 2 per cent Thiourea was effective.

In the valley of the Ang-Khang Rang, Northern Thailand at 1400 meters above sea level and 18°N latitude where lowest temperature of -5°C (was in the cold season) persisted from November to January, a place with the shortest frost free period in the country, forty five varieties of apple were introduced and overall growth was observed for five growing seasons. Low chilling varieties such as Anna, Ein Shemer and Dorsett Golden grew well under Ang-Khang conditions. These varieties seemed to have no problem in floral bud differentiation. They flowered readily and the fruit set was satisfactory. However, fruit set of Anna was much better if cross pollinated with Ein Shermer and yield was 8 kg per plant for each Anna and Ein Shermer, whereas in high chilling varieties such as Golden Delicious, McIntosh, Fuji and Granny Smith, failure of lateral buds to grow was the most important problem (Subhadrabandhu and Punsri, 1987).

Powell and MayBee (1987) studied changes in abscisis acid (ABA) in bud of *Malus x domestica* Borkh during winter and found that ABA declined during the dormancy period. This decline occurred principally in meristematic tissues of the bud, but not in the bud scales and that the decline was more rapid in low chilling cultivars than in those with higher chilling requirements.

Armas Reyes *et al.* (1987) studied the performance of ten year old 'Anna' apples on different rootstocks for their adaptability to Mexico and found that trees on M26 were smaller than on M7 and MM111. Yields were low on all rootstocks. Fruit size was largest on M7 and MM111 while fruit firmness was similar on all rootstocks. Fruit acidity was high and sugar content low at harvest and fruits had a short storage life, reaching the climacteric after eight day's storage at room temperature.

Williams and Menegazzo (1988) while studying the apple culture in the highlands of Guatemala, USA, reported that low chill apples such as Anna, Maayan, Dorsett

Golden grew well at lower elevations above 1400 meters and below 2000 meters and bloom in January and February having a harvest in April and May. Anna did not produce well at higher elevations because of the frosts.

Llanes *et al.* (1988) reported that Beverly Hill, low chilling apple which failed to burst buds in low land sites of Cuyapo, Newtown, Silang of Philippines had carried 143 partly grown fruits twelve months after planting with help of spraying H_2CN_2 (2% a.i.) to force buds which failed to burst following defoliation and Mg $(ClO_3)_2$(Mag40) at 0.76 per cent of active ingradient to cause partial defoliation.

Bernardi (1988) studied the behaviour of some apple cultivars in the subtropical region of Brazil and found that under condition with chilling below 7°C is 538 hours at an altitude of 960 meters from the sea level, the cultivars studied presented several problems such as retarded and deficient foliation, low productivity, small fruit size and flattened fruit shape. The use of chemicals to break bud dormancy in spring could partially supply the chilling requirement, allowing some cultivars to grow quite well. Some of the low chilling cultivars were very susceptible to apple scab (*Venturia inaequalis*) mainly due to the high humidity and low temperature that occurred at the beginning of the growing season, at the end of winter and early spring. Some cultivars with very low chilling requirements such as Anna, Ein shemer and Vered did not crop due to spring frost. Those with low chilling requirements such as Gala, Willie Shape and Mollie's Delicious as well as those with intermediate chilling requirements such as Belle de Boskoop and Granny Smith cropped quite well with the chemical treatment for breaking bud dormancy. Monteverde (1989) in Venezuela found that low chilling cultivars including Anna, VC-I and Dorsett Golden performed well and were recommended for growing at intermediate altitudes (500 m a.s.l.).

In Dhamas province of Yemen Arab Republic at an elevation of 2350 meters having about 700 hours of chilling, Anna plants had dwarfing habits and early bearing on MM 106 rootstock. The fruit set was very high with three or four fruits in each cluster. but the size of the fruits was not large due to few seeds The trees of Dorsett Golden had

a vigorous habit in first two years on MM 106. The majority of fruits were from the terminal buds of the water sprouts. The plant growth was limited due to increase in number of fruits that used up the food reserves. The trees of Ein Shermer had a moderate growth habit either on MM 106 or on MM 111 rootstocks. The fruits were from the terminal buds of shoots and from the spurs. The fruits were very small due to the poor foliage production and few seed in fruits (Finetto and Hussein, 1990).

In Cameron Highlands of Malaysia, apple cultivation under mild climatic regions, at an elevation of 900 to 1550 meters above mean sea level, where the temperature remains more or less constant throughout the years varying only from 14°C night time to 22°C day time and rainfall of about 2474 millimeters per year, 'Granny Smith' and 'Rome Beauty' were found suitable for these conditions. Performance of three low chilling cultivars Anna, Ein Shermer and Orleans, bud grafted on to M7 and MM106 rootstocks in these conditions was evaluated. The cultivar Orleans remained dormant, there was no further growth for yield evaluation. 'Ein Shermer' had a significantly lower flower and fruit set than that of 'Anna'. The cultivar Anna was vigorous in growth on both M7 and MM106 rootstocks and gave satisfactory yields. However, the yield of 'Anna' on M7 rootstock was not as high as on MM106 rootstock. The performance of all the three low chilling apples was below expectation although the vegetative growth of 'Ein Shermer' was moderately vigorous, the fruit yield was low, russetting and cracking also occurred on the fruits (Ko, 1990).

Ramizer and Saavedra (1990) identified Agua Naeva II, a mutant derived from Golden Delicious. The mutant required only 500 chilling hours to obtain early blooming. It also produced profuse flowering on one year woods and these characters were related to indigenous hormone balance in the bud tissues where a tendency for concentration of cytokinins was higher than that of giberellins and auxins at the time of fruit initiation.

Subhadrabandhu and Watanawongvijit (1990) studied flower forcing in Anna apple at Ang-Khang station, Thailand. Three kinds of shoots of similar length with same age were selected: one year old shoot with terminal bud attached; one year old shoot with

only lateral buds; shoot with spurs. These shoots were kept for 30 days under 5°C and 10°C as a substitution to winter temperature. After the completion of the treatment, the chilled shoots were grafted on to the apple rootstock. The result showed that the buds from one year old shoots kept at 10°C had a better flower development than those kept at 5°C. The buds from spurred shoot developed flowers faster if kept at 5°C compared to those kept at 10°C. The number of flowers developed from the shoots kept at 5°C and 10°C were not significantly different from similar shoots cut from the trees and immediately regrafted on to the stock without low temperature treatment, while the buds from those similar shoots kept on the tree did not develop flowers.

Verheij (1990) reported that in the tropical conditions of Netherlands, apple reverts to a shrub when unattained. The reason being that as the distance between apex and root system increased, the feed back control between shoot and root faded out, thereafter vigorous new ground shoots took over. This growth habit was typical feature of shrub. Both shrub habit and cleistogamy were more pronounced for high chilling cultivars. Interestingly, low chilling cultivars which were better adapted to tropical conditions, grew and fruited more in accordance with the pattern at high latitudes. The low chilling apple cultivar Anna for instance, did not bear satisfactory in the tropics without cross pollination, nor was it inclined to produce parthenocarpic fruits. It branched more freely and leaves on side shoots helped to maintain the sapstream in the branch.

Hauagge and Cummins (1991) studied genetics of length of dormancy period in vegetative buds of Malus and found that more than 50 per cent of Anna descendants had low chilling requirements, many of the seedlings were of the extreme low chilling requirements. The low chilling requirement present in 'Anna' was controlled by at least one major dominant gene and that minor genes interact to modulate its effects.

Hauagge and Cummins (1991) while working on phenotypic variation of length of bud dormancy in apple cultivars and related Malus species, reported that the mean number of chilling units required to break bud dormancy of field overwintered shoots varied between 218±113 hours for Anna variety. He also indicated that in addition to

chilling unit accumulation, there were interaction among the cultivars and the environment factors that were responsible for terminating bud dormancy in several cultivars. The species *Malus brevipes, M. rockii, M. spectabilis, M. turissii* were more tolerant than *M. baccta* and its hybrids which were recognized for their adaptation to sub tropical environment.

Primicia and Princesa, the new low chill apples for Santa Catarina, Brazil have winter temperature/chilling at or below 7.2°C of about 600 hours. Primicia was derived from a cross between two USA selections immune to *Venturia inaequalis*,viz D1R103T245 x D1R101T117. Princesa was derived from a cross between the USA selection NJ-56 and the Israeli cultivar Anna. Both new cultivars can be grown successfully without need for dormancy breaking treatment, both gave high production, bearing medium sized red fruits of good flavour with maximum storability of two and two and half months Primicia and Princesa, respectively (Denardi *et al.*, 1992)

In Marondera, Zimbabwe at an altitude 1630 meters, lalitude 18° 11°S, having only 417 hours per year at less than or equal to 7.2°C. The low chilling requirement cultivars Anna, Maayan, Michal and Elah on MM106 rootstock were precocious and cropped heavily. They flowered profusely early in spring, there was obviously no need for use of dormancy breaking sprays. 'Anna' flowered earliest in all five seasons, followed by Maayan, Elah and Michal flowering later. Accumulated yield over the four cropping seasons was highest in Elah and Maayan, than were in Anna and Michal (174 kg and 171 kg comparable to 156 kg and 122 kg, respectively) (Bepete and Jackson, 1995). Two apple cultivars Stark Adina and Orleans with low-medium chilling requirements resulted in fruits of better quality than the widely grown commercial cultivar 'Anna' in the subtropical climate of Egypt (Shaltout, 1995).

Study on floral bud differentiation and activity of Anna apple trees on different rootstocks revealed that the process of flower bud initiation and differentiation of Anna apple was divided into nine successive stages from June 13th 1990 till March 6th 1991 (Fouad *et al.*, 1995). There were slight differences in dates of floral differentiation due to

the studied rootstocks of MM111, MM106 and EM.IX. Dome like shape was recorded up to June 13th. The bud apex became flat in shape on July 16th, and on August 16th sepal primordia were first recorded. Stigma primordia occurred on September 17th and differentiation of anthers was observed on 15th November. The appearance of petal and pistil primordia was noticed on 21st November, style and anther with pollen mother cells were observed on January 3rd. Formation of tetra microspores could be seen on Feb. 10th. Bud burst activity was started from 2nd February and ended by 15th March, and the determination coefficient between dates and bud burst activity for different rootstocks was highly significant in respect to different bud location. Duration of blooming on MM106 was the longest, followed by MM111 while EM.IX was the shortest.

In the subtropical area of Sindh province, Pakistan receiving 100-550 chill units and 3700-4500 heat units, Anna and Dorsett Golden were found disappointing. 'Anna' flowered every year, two weeks before Dorsett Golden. Dorsett Golden produced some fruits in the same period but the fruit number and size were small. Dormex application did not help in synchronising the flowering of these two varieties (Panhwar, 1995).

Sherman and Lyrene (1996) reported that 'Tropic Sweet' apple, originated from a poly cross of selection from NJ.38 and Anna, was not self fertile but was cross fertile with Anna and Dorsett Golden. Fruits were of medium size and sweet tasting. 'Tropic Sweet' had low chilling requirement and was recommended for trial where Anna was adapted.

Finetto (1997) investigated the chilling requirement of some mid chill apple cultivars in the PO valley, Italy. During the winter season for four years, 30 one-year old twigs and 30 shoots with spurs were taken from the trees every week and kept with their bases in water in a growth chamber for 20 days at 21°C. Apical and lateral buds were both counted and evaluated as to percentage of the total that grew and as to bud development stage. The temperatures during the winters were recorded and both the Richardson and Crossa-Raynaud formulae were tested and growing degree hours (GDH) were calculated. The onset of bud break and the end of rest in the one year old shoots and

in the spurs were assessed by means of the ratio between the chilling units (CU), the chilling hours (CH) and GDH and by the above mentioned indexes. Although significant regression were observed between the indexes and CU, CH, and GDH throughout the years, the prediction of end of the rest was generally best when the time was considered rather than the quantity of chilling. The two different buds varied in length of dormancy within cultivars, this could modify the value of their chilling requirements.

As a result of trials over ten years, the Chinese varieties Liaofu, Fushurai, Hangfu and Hangcuei were recommended for cultivation in Zhejiang, Hubei and Jiangxi province of China which had high temperature, little rain in July-August, warm temperature and heavy precipitation during the remaining months. Foreign varieties Geneva Early, Vesta Bella and Jerseymac performed well. *M. hupehensis* was recommended as a rootstock for these varieties and M26 as an interstock (ChenQifeng and HuXiao Bao, 1997). EPAGRI 408-Condessa, derived from a controlled cross between Gala (female) and M41 (male), was a new Brazilian semi-spur type cultivar characterized by a low chilling requirement of about 400 hours with good resistance to scab (*Venturia inaequalis*). The fruits of this cultivar matured 20-25 days before those of Gala (Denardi and Camilo, 1998).

2.2 HERITABILITY STUDIES

Falconer (1981) while studying the quantitative genetics reported that heritability estimates express the proportion of the variation of a character/trait that has genetic origin, which in turn also acts as a basis of selection. The most significant function of heritability is its predictive role, expressing the reliability of the phenotypic value as a guide to breeding value. In the morphological, taxonomical, genetical studies on species and species hybrid of the genus Malus, Henning (1947) observed that fruit shape, fruit colour, relative length of stalk and the calyx behaviour were inherited in comparatively simple manner whereas characters like fruit size, other fruit traits, fruit skin colour had a polygenic basis of inheritance.

Phenological, morphological and genetical studies on the progenics of apple varieties revealed that onset of flowering, flowering duration, start of maturity, fruit

shape, size, weight, colour and keeping quality, all were governed by polygenes (Schmidt, 1947). The finding of Sedov (1970) in Russia also showed that inheritance of economically useful characters like large fruit size, high yields and plant growth habit had low heritability, their inheritance being polygenically controlled. Zhmurko (1973) in hybrid seedlings of apple studied the inheritance of fruit characters. Cross combination of Autumn Striped x Titovka, Autumn Striped x Papirovka and Skryzhaped x Simirenko's Reinette all yielded largest fruit(250-260 gram). The study further showed that round fruit shape was dominant over elongate shape.

From inheritance studies of fruit characters like fruit size uniformity, colour, aroma, flavour and ripening date in 26 inter-varietal crosses of apple, Likhonos and Seregina (1978) found that progenies with fruit of above average size were more often obtained when one parent had large fruit or was a complex hybrid. Hybrids with late ripening were obtained from crosses involving winter varieties. Blazek and Vondracek (1979) from the progenies of twelve controlled crosses in apple found that the average mean fruit weight of the progeny was lower than that of the lower parent.

According to Schmidt (1982) fruit size in apple was polygenically controlled and the mean values generally fell between parental values. In the progeny of Gloster, 27 per cent had fruits larger than 70 millimeters. Likewise the corresponding figures for Alkemene, Golden Delicious, Astramel 65319 (Jork) were 18, 23 and 50 per cent respectively. Sedov and Serova (1984) derived high yielding hybrids with regular bearing from crosses, Pepinka Litovskaya x Skryzhaped and Nesravennoe x Purple Anise. Fruit weight was found to be polygenically controlled.

Qian *et al.* (1983) found fruit weight in F_1s derived from crosses between different varieties of apple and crab apple was closer to that of the parent with the smaller fruit. Average fruit weight was 12.25 grams higher in the F_2's studied than F_1's. In both generations, large fruited progenies were derived from large fruited parents. The character fruit shape was found to be a quantitative character.

Precocity and some patterns of its inheritance were studied by Shidakov *et al.* (1985) which involved precocious, non precocious and moderately precocious varieties. The highest percentage of moderately precocious hybrids came from Golden Delicious x Wagner (23.6%). The percentage of precocious seedling resulting from crosses between precocious and non-precocious was 25.6. The cultivars considered as most useful donors of precocity were McIntosh, Melba, Golden Delicious, Papirovka and Jonared.

Fruit ripening date in hybrids of apple and pear indicated that ripening date of progenies were close to that of the parents (Vinovets, 1987). Inheritance of commercial characters in crosses of apple varieties was carried out by Wang *et al.* (1989). They reported that the progenies of Quinguan, Golden Delicious and Rainier which were themselves early fruiting, fruited earlier. Cultivar Starkrimson Delicious seemed to have genes for early fruiting, while the progenies of Rainier were likely to have large fruit. According to Zelenskii (1988), hybrids of apple consistently inherited traits like ripening date, mean fruit weight and fruit shape from the material parent and other characters like colour of fruit, flesh colour and fruit flavour from the pollen parent.

Hauagge and Cummins (1991) while working out the genetics of length of dormancy period in Malus vegetative buds indicated that cultivars with very low chilling requirements had shallow bud dormancy. According to the authors broad sense heritability for the length of vegetative bud dormancy in 43 cultivars ranged between 0.76 $\pm$0.04 in 1986 and 0.81 $\pm$ 0.04 in 1987. Narrow sense heritability estimates were 0.66 $\pm$0.13 in 1986 and 0.69 $\pm$ 0.13 in 1987. Further in 'Anna', low chilling requirement was controlled by at least one major dominant gene and minor genes interact to change its effects.

The inheritance of growth in apple especially compact growth and spurriness in apple in detail has been studied. According to Lapins and Looney (1974), the progenies of apple cross between Golden Delicious x McIntosh Wijcik segregated into distinct types i.e. spur and non spur type, the growth type was found to be controlled by single dominant gene. Further the cultivars transmitting high spur tendency to their progeny

were Melba, Julyred, whereas Jonathan, Galli Beauty and Northern Spy were rated as poor in transferance of spurriness. Lapines (1976) studied the inheritance of compact growth. Test crosses within the progeny of 'Golden Delicious' x 'McIntosh Wijcik confirmed the hypothesis that the typical compact growth habit of 'McIntosh Wijcik' was under a single dominant gene CO. A small and regular variation in the compact class indicated the presence of modifier gene or genes. Blazek (1982) studied inheritance and genetic variation of spurred growth habit in apples and recorded highest proportion (67%) of spur type growth from the cross between Golden Delicious x Starkrimson. Crosses involving cultivar Bancroft, Idared and Hajkova resulted in seedlings with spur type and spreading tree habit.

In France, Lespinasse *et al.* (1985) confirmed that compact growth habit was polygenically controlled, after they analysed the segregation data from crossing standard and compact forms of Granny Smith with a common female parent. Blazek (1992) evaluated segregating 28,000 apple seedlings for spur or compact growth habit. Spur type growth was characterized by the upright and thick growth, short internodes, sparse branching and abundance spur formation. Compact growth was characterized by upright growth, short internodes, frequent branching and less spurring and sometimes with more bare wood. Columnar habit was similar to spur type but with restricted branching and very short internodes, nearly all axillary buds growing into spurs and tree growing into a sturdy cordon. Crosses of two spur types resulted in 30-50 per cent spur type seedlings; likewise compact type yielded 20-30 per cent compact seedlings. In case both parents were columnar, 44 per cent seedlings were of the same type. Sedov and Serova (1984) found a dominant gene for dwarf habit CO. The said gene was found in cultivars McIntosh Vazhek and McIntosh Bendik which ensured 50 per cent of seedlings with compact habit, with spur type in the progeny. Recently, Meulenbroek *et al.* (1999) with columnar apple tree studied their inheritance and reported that this type of growth was controlled by one dominant gene, besides some modifying gene or genes were involved. Further columnar trees in no way were precocious compared to the normal type trees.

The heritability studies are very important as it pertains to the quantum of variation of a character having genetic origin, which subsequently provides an

appropriate platform for selection, Boicheva (1976) in reciprocal crosses in apple cultivars Golden Delicious and Jonathan and between Red Delicious and Jonathan found low heritability (H_2=0.17-0.32) for fruit size, but in Jonathan x Red Delicious, it was intermediate (H_2=0.50). Inheritance of characters and properties in the F_1 generation pertaining to fruit shape and size especially fruit shape had comparatively high heritability (H_2= 0.44-0.60), and were found dominant in nature. The overall variation in these characters were greater in the hybrid than in the parents. To develop new selection principles, Serova (1989) while breeding apples for large fruit obtained fairly high coefficients of heritability for fruit weight (H_2= 0.68) and indicated the possibility of selecting parents by phenotypes in apple.

Dathe (1978) on the basis of quantitative genetical investigations worked out the broad and narrow sense heritability estimates for juvenile characteristics of apple seedlings and observed that the wide range of estimated heritability values indicated that an environmental factors strongly influence the expression of the traits. The characters like average internode length, crown volume and time of onset and end of vegetative growth were regarded promising for further improvement on the basis of high heritability associated with these characters. High heritability for leaf length, leaf shape index, fruit length, diameter and fruit shape index in apple were observed by Shin *et al.* (1986). Durel *et al.* (1998) obtained higher values of heritability for vigour assessed by circumference of the trunk (0.57).

Using statistical methods for analysis of heritability, Blinova *et al.* (1979) reported the ineffectiveness of selection of varieties for hybridization by phenotypes for those characters which showed low coefficient of heritability. Phenotypic and genetic analaysis of variation of 17 characters of five apple varieties were studied by Bukarchuk (1979). A fairly high coefficient of heritability for frost resistance (H^2=0.4768) was found in the top crosses with Bel'fler-Kitaika but low coefficient of heritability (H^2=0.1372) in the top crosses with Bogatur (Savel'ev, 1979). The genotypic variation determined by analysis of variance without progeny tests were close to the coefficient of heritability. The genotypic variation for fruit weight was recorded to be 4.2 per cent in

cultivars Kalter Bohmer, Simirenko's Reinette, Champagne Reinette and Snow Calville, whereas H_2 for this character was 10.1 per cent. Boicheva (1980) in apple hybrids found that flowering and ripening dates were controlled by additive genes with partial dominance of the late flowering and late ripening parent. The maternal parent had a greater effect on flowering date than the pollen parent, but both parents had an equal effect on ripening date. Low values were found for the coefficients of heritability for flowering and ripening date, indicating low genetic variation and poor results from selection.

Gelvonauskis and Gelvonauskiene (1992) observed additive genes to be predominant in the control of the date of bud break in apple varieties Prima and Idared. Sestras *et al.* (1995) on the basis of vigour of growth reported tree height as an indicator of tree vigour and the trait was additively inherited in apple. Tancred *et al.* (1995) reported harvest date to be highly heritable and additive genetic components of variance were responsible for the variation. According to the authors, the best strategy for a breeder to predict the harvest date of progeny was to calculate the mean harvest date of parents. Durel *et al.*(1998) found heritability values around 0.35-0.40 for apple fruit characteristics like size, texture, flavour, juice content, attractiveness and russeting.

MATERIALS AND METHODS

Chapter-3

MATERIALS AND METHODS

The present investigation was carried out in the Department of Fruit Breeding and Genetic Resources, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan 173 230 INDIA (HP) during the year 1999-2000 and 2000-2001. The experimental site was located at around 1250 meters above mean sea level and situated at 31°N latitude and 77°E longitude with an average annual rainfall of about 1200 millimetres.

3.1 PLANT MATERIAL

The material consisted of twelve low chilling apple genotypes with the same age (15 years old) and propagated by grafting method, namely Anna, Aziza, Chahla, Early McIntosh, Maayan, Michal, Parlin's Beauty, Red Baron, Red June, Schlomit, Tamma, and Tropical Beauty. Five uniform trees in each cultivar were taken for recording the observations.

3.2 GROWTH CHARACTERS

The time of measurement of growth characters was before prunning.

3.2.1 Plant height

The height of the tree was measured with the help of measuring pole from the base to the tip of the tallest branch of the tree and it was expressed in metres.

3.2.2 Tree spread

Tree spread was measured with the help of measuring pole in two directions (South-North and East-West) and mean was worked out.

3.2.3 Trunk girth

The trunk girth was measured at a height of fifteen centimeters from graft union with the help of measuring tape and was expressed in centimetres.

3.2.4 Tree volume

The tree volume was calculated as per the methodology suggested by Westwood (1978).

For the trees which were having height more than mean spread:

$$\text{Tree volume} = 4/3\ \pi\ a^2b$$

For the trees which were having height less than mean spread:

$$\text{Tree volume} = 4/3\ \pi\ ab^2$$

where:

a = 1/2 of the mean spread

b = 1/2 of the height

3.2.5 Shoot length

The shoot length was recorded from four uniform branches in four directions with the help of measuring tape and it was expressed in centimetres. Twenty shoots of each tree were measured before flowering.

3.2.6 Leaf area

Leaf area was measured by taking four uniform shoots in four directions. The unit shoot length was taken as thirty centimetres. Matured leaves present on the

shoots were collected separately and the leaf area was measured with the help of leaf area meter.

The leaves present on each shoot were separately measured and the mean of leaf area was worked out.

$$\text{Leaf area} = \frac{\text{Total leaf area of four shoots}}{\text{Number of leaves}}$$

The time of measurement of leaf area was in September to October.

3.3 FLORAL CHARACTERS

The full trees were taken as unit for taking observation on the time and duration of flowering. Data were recorded on the dates of bud break, first flower opening, full bloom and date of petal fall. Days between each stage were worked out.

For calculating number of flowers per unit shoot length, twenty uniform shoots on each tree were randomly marked with tags and the number of flowers were counted on the shoots. The mean was worked out and taken as the number of flowers per unit shoot length. Unit shoot length was taken as sixty five centimetres.

3.4 NUMBER OF FRUITS SET PER UNIT SHOOT LENGTH

Twenty uniform shoots on each tree were marked with tags in four different directions and the number of fruits were counted on shoots after twenty days of full bloom. The mean was worked out and taken as the number of fruit set per unit shoot length (65 cm).

3.5 NUMBER OF FRUITS PER PLANT

Total number of fruits per plant was counted at the time of fruit harvesting.

3.6 YIELD IN KILOGRAM PER PLANT

The crop load of apples harvested from each plant was recorded and the results were expressed in yield per plant in kilograms.

3.7 MEAN FRUIT WEIGHT (g)

Twenty fruits were taken randomly from each tree and weighed on a single pan kitchen balance and expressed in gram (g). From this, the mean fruit weight was calculated by using the following formula:

$$\text{Mean fruit weight} = \frac{\text{Total fruit weight (g)}}{\text{Number of fruits weighed}}$$

3.8 FRUIT SIZE

It was measured in terms of length and diameter. Same fruits which were taken to estimate mean fruit weight were taken. Length was measured from calyx end to style end and breadth was recorded by measuring the distance between cheeks of the fruit with the help of Digital Calliper and mean was worked out and expressed in millimetres (mm).

3.9 TOTAL SOLUBLE SOLIDS (TSS)

TSS of five uniform ripen fruits of each tree was determined with the help of hand refractometer (0-32°B) after calibration with distilled water.

3.10 TITRATABLE ACIDITY

The same fruit samples were used for estimation of titratable acidity. Twenty five grams of fruit was crushed and the volume made up to 250 ml in a volumetric flask by adding distilled water. Out of it, 50 ml extract (solution) was taken for the estimation of acidity and the rest was used for determining total and

reducing sugars. Ten ml of this juice extract was titrated against N/10 NaOH using phenolphthalein as an indicator, change of the solution colour to light pink indicated the end point. The total titratable acidity was then calculated in terms of malic acid in percentage.

3.11 TOTAL SUGARS

The remaining 200 ml extract was taken in a 250 ml volumetric flask and neutralized with 1 N NaOH, indicator is phenolphthalein and then the volume was again made to 250 ml. To this 250 ml solution, 2 ml of 45 per cent lead acetate was added. After 5-10 minutes, 2 ml of 42 per cent potassium oxalate was added to precipitate the excess of lead acetate and filtered. Fifty ml of filtrate was taken and hydrolyzed by adding 10 ml of hydrochloric acid (1:1) and allowed it to stand overnight for complete reaction. The excess of HCl was neutralized with saturated NaOH solution the next day.

The hydrolyzed aliquot was then taken in a burette and titrated against boiling solution containing 5 ml each of Fehling A and Fehling B using methylen blue as an indicator (A.O.A.C., 1980). The end point was indicated by the appearance of brick red colour. The total sugars were worked out as per cent of fresh weight of the fruit pulp.

3.12 REDUCING SUGARS

The boiling mixture of solution containing 5 ml of Fehling A and Fehling B was titrated against remaining diluted solution using methylene blue as an indicator.

3.13 NON-REDUCING SUGARS

The amount of non-reducing sugars was worked out by subtracting reducing sugars from total sugars and multiplying the result with a factor of 0.95.

3.14 STATISTICAL ANALYSIS

3.14.1 Randomized block design

Randomized block design was used for testing the significant difference between different varieties with respect to various characters.

The statistical analysis for each character was carried out on mean values. The data were subjected to the analysis of variance as described by Panse and Sukhatme (1961). The following procedures were adopted for estimation of different statistical parameters.

Analysis of variance (yearly)

Source of variation	d.f.	SS	MSS	Ratio
Genotypes (g)	g-1	Sg	Mg=Sg/(g-1)	Mg/Me
Replication (r)	r-1	Sr	Mr=Sr/(r-1)	Mr/Me
Error (e)	(r-1)(g-1)	Se	Me=Se/(r-1)(g-1)	
Total	(rg-1)			

Where:

d.f. = Degree of freedom
SS = Sum of squares
MSS = Mean sum of squares
Sr = Sum of squares due to replications
Sg = Sum of squares due to genotypes
Se = Sum of squares due to error
Mg = Mean sum of squares due to genotypes
Mr = Mean sum of squares due to replications
Me = Mean sum of squares due to error
r = Number of replications
g = Number of genotypes

Analysis of variance (pooled)

Source of variation	d.f.	SS	MSS	F ratio
Genotype (g)	g-1	Sg	Mg=Sg/(g-1)	Mg/Me
Year (y)	y-1	Sy	My=Sy/(y-1)	My/Me
Replication (r)	r-1	Sr	Mr=Sr/(r-1)	Mr/Me
Genotype x Year	(g-1)(y-1)	Si	Mi=Si/(g-1)(y-1)	Mi/Me
Pooled error (e)	(r-1)(gy-1)	Se	Me=Se/(r-1)(gy-1)	
Total	rgy-1			

Where:

g = Genotype
y = Year
r = Replication
Si = Sum of square due to interaction of genotypes and years
Mi = Mean sum of squares due to interaction of genotypes and years

All the characters showed significant differences among genotypes and were further subjected to the analysis for the following parameters:

i) Variability (phenotypic and genotypic)
ii) Heritability in broad sense (H%)
iii) Genetic advance (GA)
iv) Genetic gain (GG)

Coefficient of variability

These were calculated at phenotypic, genotypic and environmental levels, the formula suggested by Burton and De Vane (1953).

3.14.2 Phenotypic coefficient of variability (PCV)

$$PCV = \frac{\sqrt{\text{Phenotypic variance (Vp)}}}{\text{General mean of population } (\bar{X})} \times 100$$

3.14.3 Genotypic coefficient of variability (GCV)

$$GCV = \frac{\sqrt{\text{Genotypic variance (Vg)}}}{\text{General mean of population } (\bar{X})} \times 100$$

3.14.4 Environmental coefficient of variability (ECV)

$$ECV = \frac{\sqrt{\text{Environmental variance (Ve)}}}{\text{General mean of population } (\bar{X})} \times 100$$

3.14.5 Heritability (broad sense)

Heritability in broad sense was calculated as per formula given by Johnson *et al.* (1955).

$$H\ (\%) = \frac{Vg}{Vp} \times 100$$

Where;

H = Heritability (broad sense)
Vg = Genotypic variance
Vp = Phenotypic Variance
Vg = (Mg - Me)/r
Vp = Vg + Ve; (Ve = Me)

3.14.6 Genetic advance

The expected genetic advance resulting from selection of five per cent superior individuals was calculated by the formula suggested by Johnson *et al.* (1955).

$$GA = K.\sigma p.\ H$$

Where:

GA = Genetic advance
K = 2.06 (Selection differential at 5% selection index)
σp = Phenotypic standard deviation
H = Heritability (in broad sense)

3.14.7 Genetic gain

Genetic advance expressed as per cent of population mean was calculated by the method given by Johnson *et al.* (1955) as follows:

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance (GA)}}{\text{Population mean } (\bar{X})} \times 100$$

EXPERIMENTAL RESULTS

Chapter-4

EXPERIMENTAL RESULTS

The results obtained on different aspects to understand the nature of variation of various horticultural traits and heritability of low chilling apples are presented in the following pages.

4.1 VARIABILITY STUDIES

4.1.1 Analysis of variance

Analysis of variance for the experimental design (Table 1) revealed that the mean sum of square due to genotype were significant for all the traits studied namely trunk girth, plant height, mean tree spread, tree volume, shoot length, leaf area, days from bud burst to first flower, days from first flower to full bloom, days from full bloom to petal fall, number of flowers per unit shoot length, number of fruits set per unit shoot length, number of fruits per plant, fruit weight, fruit length, fruit breadth, fruit yield, total soluble solids, titratable acidity, reducing sugar, total sugar and non-reducing sugar. The interaction between genotypes and years (GY) were found to be non-significant at 5 per cent level for the characters namely plant height, plant spread, trunk girth, tree volume, shoot length, leaf area, days from full bloom to petal fall, fruit weight, TSS, titratable acidity and reducing sugar in pooled analysis. However, the significance of interaction (GY) was found for characters viz. days from bud burst to first flower open, days from first flower to full bloom, number of flowers per unit shoot length, number of fruits set per unit shoot length, number of fruits per plant, fruit length, fruit breadth, fruit yield, total sugar and non-reducing sugar. The corresponding ANOVA for significant interaction are given in appendix - I which indicated that there are real differential effects of genotypes with the variation in the years. It is to be mentioned that conclusions are drawn on the basis of pooling of two years data only.

4.1.2 Evaluation of genotypes

4.1.2.1 Growth characters

The data in Tables 2 and 3 revealed the following trends pertaining to growth characters.

i) Plant height

The plant height ranged between 3.76 metres (Anna) and 6.58 (Tropical Beauty) during first year and between 3.76 metres (Anna) and 6.62 metres (Tropical Beauty) during the second year of investigation. The mean plant height of Tropical Beauty (6.60 m) was superior to others. The genotypes Schlomit (5.85 m); Red Baron (5.36 m); Maayan (5.38 m) were statistically at par with each other. The genotype Anna depicted the lowest plant height (3.76 m).

ii) Mean plant spread

The maximum plant spread was recorded in Tropical Beauty having 5.65 metres and 5.69 metres (plant spread) during the first and second year, respectively. Plant spread was minimum in Early McIntosh (2.85 and 2.89 m) during both the years of investigation. Tropical Beauty showed the highest value of mean plant spread (5.67 m), followed by Parlin's Beauty (5.29 m). 'Schlomit' (4.94 m) and 'Red June' (4.81 m) were statistically at par with each other. The minimum value was shown by 'Early McIntosh' (2.87 m).

iii) Trunk girth

In both the years, the smallest and highest values of trunk girth were observed in genotypes Early McIntosh and Tropical Beauty, respectively. The trunk girth varied from 32.2 centimetres to 64.0 centimetres and from 32.6 centimetres to 65.0 centimetres during the first and second year of investigation, respectively.

Table 1. Analysis of variance with respect to growth, flowering, fruiting and yield characters in low chilling apples

Sr. No.	Character	Mean sum of squares			
		Replication (4 df)	Genotype (11 df)	Genotype x Year (11 df)	Error (92 df)
1.	Plant height (m)	0.42	6.95*	0.003	0.19
2.	Plant spread (m)	0.11	7.56*	0.02	0.20
3.	Trunk girth (cm)	17.30	1027.00*	0.70	46.70
4.	Tree volume (m^3)	146.70	7206.10*	3.20	101.82
5.	Shoot length (cm)	13.36	422.30*	0.80	8.28
6.	Leaf area (cm^2)	0.72	668.86*	0.03	0.60
7.	Days from bud burst to first flower open	0.48	60.71*	1.71*	0.43
8.	Days from first flower to full bloom	0.55	62.93*	1.99*	0.31
9.	Days from full bloom to petal fall	0.32	22.10*	0.97	0.38
10.	Number of flowers per unit shoot length (65 cm)	62.98	1188.50*	598.70*	52.77
11.	Number of fruits set per unit shoot length (65 cm)	0.61	101.80*	36.80*	2.61
12.	Number of fruits per plant	33.18	14293.00*	1472.00*	81.30
13.	Fruit weight (g)	141.80	7580.80*	60.66	95.45
14.	Fruit length (mm)	7.01	617.20*	24.65*	3.37
15.	Fruit breadth (mm)	3.53	604.55*	23.61*	4.08
16.	Fruit yield (kg/plant)	0.58	195.67*	10.99*	0.68
17.	TSS (°Brix)	1.58	22.33*	1.27	1.31
18.	Titratable acidity (%)	0.0011	0.35*	0.0009	0.00038
19.	Total sugar (%)	0.09	17.52*	0.23*	0.05
20.	Reducing sugar (%)	0.05	9.37*	0.04	0.02
21.	Non-reducing sugar (%)	0.06	2.16*	0.22*	0.05

Table 2. Performance of different genotypes of low chilling apples with respect to vegetative characters

Variety	Plant height (m)			Plant spread (m)			Trunk girth (cm)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	3.76	3.76	3.76	3.53	3.58	3.56	35.00	35.60	35.30
2. Aziza	3.96	4.02	3.99	3.07	3.17	3.12	32.20	33.80	33.00
3. Chahla	4.66	4.68	4.67	4.35	4.36	4.36	36.80	37.20	37.00
4. Early McIntosh	4.56	4.60	4.58	2.85	2.89	2.87	32.20	32.60	32.40
5. Maayan	5.40	5.36	5.38	4.50	4.57	4.54	46.20	46.40	46.30
6. Michal	4.32	4.40	4.36	4.85	4.93	4.71	34.40	34.80	34.60
7. Parlin's Beauty	5.32	5.32	5.32	5.26	5.32	5.29	52.60	53.20	52.30
8. Red Baron	5.34	5.38	5.36	4.10	4.17	4.14	50.00	50.80	50.40
9. Red June	4.72	4.76	4.74	4.79	4.83	4.81	50.60	51.20	50.90
10. Schlomit	5.84	5.86	5.85	4.87	5.00	4.94	52.80	53.20	53.00
11. Tamma	4.06	4.14	4.10	3.55	3.57	3.56	44.00	45.40	44.70
12. Tropical Beauty	6.58	6.62	6.60	5.65	5.69	5.67	64.00	65.00	64.50
Grand mean	4.89	4.91	4.89	4.28	4.34	4.31	44.23	44.93	44.53
SE(±)	0.284	0.276	0.195	0.279	0.261	0.20	4.59	4.27	3.056
$CD_{0.05}$	0.57	0.56	0.39	0.56	0.53	0.40	9.26	8.63	6.05
CV (%)	9.21	8.91	8.91	10.32	9.53	10.38	16.39	15.04	15.35

Table 3. Performance of different genotypes of low chilling apples with respect to vegetative characters

Variety	Tree volume (m^3)			Shoot length (cm)			Leaf area (cm^2)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	24.64	25.32	24.98	30.43	30.20	30.31	33.56	33.38	33.47
2. Aziza	22.92	24.20	23.50	28.29	28.12	28.20	31.04	31.24	31.14
3. Chahla	46.28	46.68	46.48	33.79	34.12	33.95	28.88	28.92	28.90
4. Early McIntosh	19.50	20.20	19.85	28.56	28.36	28.47	34.92	34.70	34.81
5. Maayan	56.90	59.54	58.22	18.71	17.30	18.00	36.23	36.29	36.26
6. Michal	46.98	49.54	48.26	20.40	20.72	20.56	34.50	34.46	34.48
7. Parlin's Beauty	75.88	77.28	76.58	19.38	19.68	19.53	31.76	31.80	31.78
8. Red Baron	47.18	49.13	48.15	16.90	17.14	17.14	36.42	36.38	36.40
9. Red June	53.34	55.08	54.21	11.57	12.24	11.90	36.29	36.28	36.33
10. Schlomit	72.98	77.40	75.19	22.76	22.28	22.52	31.61	31.60	31.60
11. Tamma	26.80	27.66	27.23	25.07	25.54	25.30	35.32	35.20	35.26
12. Tropical Beauty	110.10	112.30	111.20	28.81	28.94	28.87	60.84	60.70	60.77
Grand mean	50.29	53.03	51.15	23.72	23.74	23.73	35.95	35.91	35.93
SE(±)	6.50	6.53	4.51	1.95	1.69	1.28	0.51	0.49	0.35
$CD_{0.05}$	13.13	13.20	8.93	3.94	3.41	2.53	1.03	1.00	0.69
CV (%)	20.43	19.48	19.73	13.01	11.23	12.13	2.24	2.19	2.18

Statistical analysis of data revealed that the maximum value for mean trunk girth was obtained for Tropical Beauty (64.5 cm) which was superior to others. Cultivars Schlomit (53.0 cm); Parlin's Beauty (52.3 cm); Red June (50.9 cm) and Red Baron (50.4 cm) were statistically at par with each other. The lowest value for trunk girth was observed in 'Early McIntosh' (32.4 cm).

iv) Tree volume

Perusal of data revealed that the tree volume values varied between 19.5 m^3 (Early McIntosh) and 110.1 m^3 (Tropical Beauty) during the first and between 20.2 m^3 (Early McIntosh) and 112.3 m^3 (Tropical Beauty) during second year of study. Maximum mean tree volume was observed for Tropical Beauty (111.2 m^3) which was statistically superior to all other genotypes, followed by Parlin's Beauty (76.58 m^3) and Schlomit (75.19 m^3). Genotypes Tamma, Anna, Aziza were at par with 'Early McIntosh' (19.95 m^3) which had lowest values for both the years of investigation.

v) Shoot length

The minimum and maximum values of shoot length were observed in genotypes Red June and Chahla, respectively in both the years of study. The shoot length varied from 11.57 centimetres to 33.79 centimetres and from 12.24 centimetres to 34.12 centimetres during the first and second year, respectively. Cultivar Chahla (33.95 cm) was statistically superior to others. The genotypes Anna (30.3 cm), Tropical Beauty (28.87 cm) and Early McIntosh (28.47 cm) were at par with each other. Red June depicted the lowest shoot length (11.9 cm).

vi) Leaf area

Genotype Tropical Beauty during the first and second year of investigation recorded maximum leaf area (60.84 cm^2 and 60.70 cm^2, respectively). Genotype Chahla registered minimum leaf area values in both the years (28.88 cm^2 and 28.92

cm^2, respectively). Statistically superior values were realized for cultivars Tropical Beauty (60.77 cm^2), followed by Red Baron (36.4 cm^2), Red June (36.33 cm^2) and Maayan (36.26 cm^2).

4.1.2.2 Flowering characters

The data on flowering characters are given in Table 4 and Table 5.

i) Date of bud burst

The earliest bud burst time was recorded for cultivar 'Anna' (26/2 and 8/3 in the year 1999-2000 and 2000-2001, respectively) followed by Chahla (26/2 and 17/2) and Maayan (2/3 and 21/2), respectively. 'Red Baron' was observed to be late and bud burst took place the last among the genotypes studied (21/3 and 14/3, respectively).

ii) Date of first flower open

Cultivar Anna and had the earliest flowering. The date of first flower open was 10/3 in year 1999-2000 and 22/2 in year 2000-2001, followed by Chahla (10/3 and 1/3) and Maayan (18/3 and 5/3). The late flowering was observed in 'Red June' (1/4 and 28/3, respectively).

iii) Days from bud burst to first flower open

Days from bud burst to first flower open varied from 8.2 to 8.6 (Red Baron) and 16.4 to 18.0 (Schlomit) during the two years of investigation. The maximum value for this character was recorded for Schlomit (17.2 days) which was significantly different from others, followed by Maayan (15.1 days) which was statistically superior than Anna (14.5 days) and Chahla (14.4 days). Minimum mean days was recorded for Red Baron (8.4 days). The analysis further showed that on the mean basis, different cultivars took 12.90 days in the year 1999-2000, whereas in 2000-2001, the cultivars took 12.95 days from bud burst to first flower open.

Table 4. Performance of different genotypes of low chilling apple with respect to flowering time characters

Variety	Bud burst time		First flower open		Full bloom time		Petal fall time	
	2000	2001	2000	2001	2000	2001	2000	2001
1. Anna	26/2	8/2	10/3	22/2	24/3	5/3	3/4	14/3
2. Aziza	12/3	18/2	22/3	30/2	30/3	9/3	8/4	17/3
3. Chahla	26/2	17/2	10/3	1/3	25/3	15/3	7/4	26/3
4. Early McIntosh	18/3	8/3	28/3	19/3	6/4	27/3	15/4	6/4
5. Maayan	2/3	21/2	18/3	5/3	2/4	29/3	9/4	6/4
6. Michal	11/3	28/2	25/3	12/3	4/4	23/3	12/4	2/4
7. Parlin's Beauty	18/3	28/2	28/3	8/3	8/4	19/3	17/4	28/3
8. Red Baron	21/3	14/3	29/3	23/3	9/4	2/4	15/4	9/4
9. Red June	16/3	14/3	1/4	28/3	10/4	7/4	18/4	16/4
10. Schlomit	7/3	18/2	25/3	4/3	5/4	16/3	11/4	24/3
11. Tamma	18/3	3/3	31/3	16/3	7/4	23/3	17/4	3/4
12. Tropical Beauty	20/3	5/3	2/4	18/3	9/4	26/3	17/4	4/4

Table 5. Performance of different genotypes of low chilling apples with respect to flowering characters

Variety	Days from bud burst to first flower open			Days from first flower to full bloom			Days from full bloom to petal fall		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	14.6	14.4	14.5	14.0	13.0	13.5	9.2	9.4	9.3
2. Aziza	10.6	11.4	11.0	8.4	9.4	8.9	8.0	8.2	8.1
3. Chahla	14.4	14.4	14.4	15.4	14.4	14.9	12.4	11.6	12.0
4. Early McIntosh	10.2	11.0	10.6	8.2	8.0	8.1	9.2	9.4	9.3
5. Maayan	15.8	14.4	15.1	14.0	14.2	14.1	7.0	7.2	7.1
6. Michal	14.0	14.0	14.0	9.0	10.6	9.8	8.0	8.8	8.4
7. Parlin's Beauty	10.2	10.4	10.3	9.8	11.2	10.5	8.6	9.0	8.8
8. Red Baron	8.2	8.6	8.4	10.0	9.6	9.8	6.2	7.2	6.7
9. Red June	14.0	14.2	14.1	9.6	9.4	9.5	7.6	8.4	8.0
10. Schlomit	18.0	16.4	17.2	10.4	11.6	11.0	6.4	7.8	7.1
11. Tamma	12.8	13.0	12.9	7.6	7.4	7.5	10.6	10.0	10.3
12. Tropical Beauty	12.0	13.2	12.6	7.4	7.8	7.6	8.0	8.6	8.3
Grand mean	12.90	12.95	12.92	10.32	10.55	10.43	8.43	8.8	8.62
SE(±)	0.408	0.437	0.293	0.368	0.359	0.252	0.389	0.395	0.276
$CD_{0.05}$	0.82	0.88	0.58	0.74	0.73	0.50	0.79	0.80	0.55
CV (%)	5.34	5.34	5.08	5.70	5.38	5.42	7.29	7.11	7.16

iv) Date of full bloom

In genotype Anna, full bloom was obtained the earliest (24/3 and 25/3 in year 1999-2000 and 2000-2001) followed by Chahla (25/3 and 15/3) and Aziza (30/3 and 9/3). 'Red June' was last to obtain the full bloom stage on 10/4 and 7/4, respectively.

v) Days from first flower to full bloom

The genotypes under investigation showed considerable variation for duration of first flower to full bloom for both the years. This duration varied from 7.4 days (Tropical Beauty) to 15.4 days (Chahla) in the first year and from 7.4 days (Tamma) to 14.4 days (Chahla) in second year of study. In both the years, the maximum number of days from first flower open to full bloom were taken by Chahla (14.9 days) which was significantly different from all other genotypes. 'Maayan' (14.1 days) and 'Anna' (13.8 days) followed 'Chahla'. Cultivars Tamma and Tropical Beauty took least number of days from first flower open to full bloom, 7.5 and 7.6 days, respectively.

Analysis further revealed difference in the days from first flowers to full bloom in two years of study in same genotype. Cultivars Aziza, Michal, Parlin's Beauty, Schlomit took 1.0; 1.6; 1.4 and 1.2 more days, respectively to attain full bloom (2000-2001), while Anna, Chahla, Red Baron took 1.0, 1.0, 0.6 less day for full bloom stage (2000-2001).

vi) Date of petal fall

In both the years of study, the petal fall was observed to be earliest in 'Anna' (3/4 in year 1999-2000 and 14/3 in year 2000-2001), followed by 'Aziza' (8/4 and 17/3) and 'Chahla' (7/4 and 26/3, respectively). Amongst the twelve cultivars studied, late petal fall was seen in 'Red June' (18/4 and 16/4, respectively).

vii) Days from full bloom to petal fall

The number of days taken by different genotypes studied ranged between 6.7 to 12.0. The maximum number of days from full bloom to petal fall was recorded for 'Chahla' (12.0 days) followed by 'Tamma' (10.3 days), 'Anna' and 'Early McIntosh' (9.3 days each). The lowest number of days for this character was observed for genotype Red Baron (6.7 days).

viii) Number of flowers per unit shoot length

The cultivar Chahla showed maximum number of flowers per unit shoot length (46.2), followed by Tropical Beauty (36.54) and Aziza (36.45). Two year data further revealed that flowers per unit shoot length ranged from a low of 10.94 (Tamma) to as high as 46.2 (Chahla).

Significant decrease in number of flowers per unit shoot length was observed in 2000-2001. In the year 1999-2000, flowers per shoot length was 30.48 which decreased to 20.20 flowers during the year 2000-2001.

4.1.2.3 Fruit characters

The data on various fruit characters viz., number of fruits set per unit shoot length, number of fruits per plant, fruit weight, fruit length, fruit breadth, fruit yield, TSS, titratable acidity, reducing sugar, total sugar, non-reducing sugar are given in Tables 6, 7, 8 and 9.

i) Number of fruits set per unit shoot length

Number of fruits set per unit shoot length varied from 5.35 (Tamma) to 15.88 (Parlin's Beauty) during first year and from 2.7 (Tamma) to 17.75 (Tropical Beauty) during the second year of investigation. The highest number of fruits set per shoot

Table 6. Performance of different genotypes of low chilling apples with respect to flowering and fruiting characters

Variety	Number of flowers per unit shoot length (65 cm)			Number of fruits set per unit shoot length (65 cm)			Number of fruits per plant		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	24.83	17.56	21.19	7.85	5.52	6.68	58.80	43.80	51.30
2. Aziza	47.45	25.44	36.45	15.13	9.27	12.20	72.80	128.80	100.80
3. Chahla	67.66	24.73	46.20	15.00	5.21	10.11	55.00	32.80	43.90
4. Early McIntosh	26.46	22.94	24.70	11.47	7.04	9.25	38.80	23.20	31.00
5. Maayan	28.73	19.13	23.93	11.02	6.51	8.76	41.40	27.40	34.40
6. Michal	19.41	13.89	16.65	5.35	4.72	5.03	69.00	81.20	75.10
7. Parlin's Beauty	52.43	18.22	35.33	15.88	7.54	11.71	77.80	111.20	94.50
8. Red Baron	22.33	16.08	19.20	8.99	4.21	6.68	87.00	118.60	103.00
9. Red June	14.55	11.02	12.78	9.30	6.45	7.87	101.80	102.40	102.10
10. Schlomit	14.96	25.45	20.21	5.50	9.72	7.61	23.80	19.80	21.80
11. Tamma	13.34	8.55	10.94	5.35	2.70	4.03	27.20	22.40	24.80
12. Tropical Beauty	33.66	39.41	36.54	14.75	15.75	15.25	122.20	142.60	132.40
Grand mean	30.48	20.20	25.34	10.47	7.05	8.76	64.63	71.18	67.92
SE(±)	5.29	3.05	3.24	1.00	1.04	0.723	6.52	5.02	4.03
$CD_{0.05}$	10.69	6.16	6.42	2.02	2.10	1.43	13.17	10.14	7.98
CV (%)	27.47	23.89	28.67	15.22	23.33	18.44	15.97	11.15	13.28

Table 7. Performance of different genotypes of low chilling apples with respect to fruit characters

Variety	Fruit weight (g)			Fruit length (mm)			Fruit breadth (mm)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	108.50	105.20	106.80	60.41	61.40	60.90	55.16	56.20	55.68
2. Aziza	114.10	114.80	114.40	58.88	58.82	58.85	64.80	65.26	65.03
3. Chahla	109.60	107.20	108.40	63.81	65.28	64.55	57.26	58.28	57.77
4. Early McIntosh	78.58	78.98	78.78	48.20	49.28	48.74	59.00	60.72	59.86
5. Maayan	86.10	86.56	86.33	51.96	52.10	52.03	59.80	61.74	60.77
6. Michal	98.10	104.70	101.10	51.30	54.20	52.75	59.75	64.86	62.30
7. Parlin's Beauty	127.80	117.50	122.60	55.82	51.34	53.58	74.93	66.86	70.89
8. Red Baron	110.80	107.80	109.30	54.44	52.96	53.70	66.39	65.64	66.01
9. Red June	30.54	30.92	30.73	34.98	35.82	35.40	41.48	40.90	41.19
10. Schlomit	122.60	126.40	124.50	67.44	59.32	63.38	56.22	57.68	56.95
11. Tamma	120.40	123.00	121.70	58.50	61.32	59.91	66.32	66.32	66.32
12. Tropical Beauty	130.80	128.90	129.80	57.14	56.24	56.69	67.04	68.66	67.85
Grand mean	103.15	102.60	102.10	55.24	54.84	55.04	60.68	61.09	60.89
SE(±)	3.45	8.03	4.36	1.19	1.05	0.82	1.54	0.98	0.903
$CD_{0.05}$	6.97	16.22	8.63	2.40	2.12	1.63	3.11	1.98	1.79
CV (%)	5.30	12.38	9.57	3.41	3.03	3.34	4.01	2.55	3.32

length was observed in the genotype Tropical Beauty (15.25) which was statistically superior to all other cultivars studied. Cultivars Aziza (12.2) and Parlin's Beauty (11.71) followed Tropical Beauty and were statistically at par with one another. The lowest fruit set was observed in cultivar Tamma (4.03).

Significant decrease in number of fruits set per unit shoot length within genotype was recorded in year 1999-2000 (10.47 fruits/ 65 cm) as compared to 7.05 fruits per 65 cm shoot length in year 2000-2001.

ii) Number of fruits per plant at harvest

The genotypes under study showed considerable variation for number of fruits per plant at harvest for both the years, it varied from 23.8 fruits (Schlomit) to 122.2 fruits (Tropical Beauty) in first year and from 19.8 fruits (Schlomit) to 142.6 fruits (Tropical Beauty) in the second year. 'Tropical Beauty' (132.4) showed highest number of fruits per plant at harvest. 'Red Baron' (103.0), 'Red June' (102.1), 'Aziza' (100.8) and 'Parlin's Beauty' (94.5) followed 'Tropical Beauty' and were statistically at par with each other. Cultivar Schlomit (21.8) showed lowest value (both the years) and was at par with Tamma (24.8).

There was difference in number of fruits per plant at harvest in both years of study. The mean number of fruits per plant was 64.63 in first year (1999-2000) which rose to 71.18 in second year (2000-2001).

iii) Mean fruit weight (g)

Highest value for the character mean fruit weight was observed for 'Tropical Beauty' (129.8 g), followed by 'Schlomit' (124.5 g), 'Parlin's Beauty' (122.6 g) and 'Tamma' (121.7 g). These genotypes were statistically at par with each other, but were significantly superior to others. 'Red June' gave 30.73 grams fruit weight which was lowest amongst all cultivars studied.

iv) Mean fruit length (mm)

The fruit length ranged between 34.98 millimetres (Red June) to 67.0 millimetres (Schlomit) in the first year and 35.82 millimetres (Red June) to 65.28 millimetres (Chahla) in second year. 'Chahla' (64.55 mm) and 'Schlomit' (63.38 mm) during both the year were significantly superior to others, followed by 'Anna' (60.9 mm), 'Tamma' (59.91 mm), 'Aziza' (58.85 mm) which were statistically at par with each other. The lowest mean fruit length was recorded in 'Red June' (30.73 mm).

Two year observation on mean fruit length showed that mean value decreased from 55.24 millimetres (1999-2000) to 54.84 millimetres (2000-2001).

v) Mean fruit breadth (mm)

Cultivar Parlin's Beauty (70.89 mm) registered the highest value for fruit breadth and differed significantly from all others. Cultivars Tropical Beauty (67.85 mm), Tamma (66.32 mm), Red Baron (66.01 mm), Aziza (65.03 mm), followed Parlin's Beauty and were statistically at par with each other. 'Red June' (41.19 mm) showed the lowest value in both the years of study.

The analysis, further on the basis of mean fruit breadth reveaved that mean value slightly increased from 60.68 millimetres in year 1999-2000 to 61.09 millimetres in year 2000-2001.

vi) Fruit yield (Kg/plant)

The maximum and the minimum fruit yield were found in cultivars Tropical Beauty and Early McIntosh, respectively in both the years of study. Statistical analysis of the data depicted that 'Tropical Beauty' (15.82 kg) showed maximum fruit yield which was significantly different from others. Cultivars Parlin's Beauty

Table 8. Performance of different genotypes of low chilling apples with respect to fruit characters

Variety	Fruit yield (kg/plant)			TSS (°Brix)			Titratable acidity (%)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	5.00	4.32	4.66	9.20	9.42	9.31	0.20	0.17	0.18
2. Aziza	7.50	12.60	10.05	11.78	12.46	12.12	0.36	0.40	0.38
3. Chahla	5.20	3.14	4.17	9.34	9.44	9.39	0.38	0.40	0.39
4. Early McIntosh	2.70	1.76	2.23	11.04	11.16	11.10	0.27	0.26	0.26
5. Maayan	3.60	2.30	2.95	8.96	9.10	9.03	0.34	0.32	0.33
6. Michal	5.56	7.10	6.33	9.46	10.32	9.89	0.41	0.42	0.42
7. Parlin's Beauty	9.96	12.34	11.15	11.38	11.86	11.62	0.68	0.69	0.68
8. Red Baron	8.98	11.30	10.14	11.90	12.24	12.07	0.42	0.43	0.43
9. Red June	2.82	2.90	2.86	13.42	13.56	13.47	0.55	0.56	0.55
10. Schlomit	2.92	2.38	2.65	9.20	9.14	9.17	0.47	0.47	0.47
11. Tamma	3.16	2.48	2.82	11.74	11.78	11.76	0.88	0.90	0.89
12. Tropical Beauty	14.62	17.02	15.82	13.24	13.40	12.12	0.36	0.34	0.35
Grand mean	6.00	6.64	6.319	10.89	11.16	10.92	0.44	0.45	0.44
SE(±)	0.578	0.483	0.37	0.98	0.26	0.20	0.012	0.012	0.0087
$CD_{0.05}$	1.17	0.98	0.73	1.98	0.53	0.40	0.02	0.02	0.02
CV (%)	15.28	11.47	13.10	14.26	4.00	10.48	4.37	4.27	4.43

Table 9. Performance of different genotypes of low chilling apples with respect to fruit characters

Variety	Reducing sugar (%)			Total sugar (%)			Non-reducing sugar (%)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
1. Anna	3.77	3.79	3.78	4.52	4.67	4.59	0.71	0.84	0.77
2. Aziza	4.67	4.80	4.73	5.80	6.76	6.28	1.07	1.93	1.49
3. Chahla	4.63	4.72	4.67	5.85	5.97	5.91	1.16	1.19	1.17
4. Early McIntosh	3.96	3.93	3.94	4.74	4.87	4.80	0.73	0.90	0.81
5. Maayan	3.73	3.75	3.74	4.99	5.12	5.05	1.21	1.32	1.26
6. Michal	4.48	4.22	4.35	5.56	5.46	5.51	1.03	1.18	1.10
7. Parlin's Beauty	6.49	6.49	6.49	8.20	8.45	8.32	1.62	1.86	1.74
8. Red Baron	3.83	4.15	3.98	5.40	5.60	5.50	1.50	1.38	1.44
9. Red June	5.10	5.16	5.13	5.64	5.76	5.70	0.51	0.57	0.54
10. Schlomit	3.74	3.80	3.77	4.89	4.72	4.80	1.09	0.87	0.98
11. Tamma	4.50	4.39	4.44	5.00	4.90	4.85	0.30	0.49	0.40
12. Tropical Beauty	6.40	6.50	6.45	8.62	8.34	8.48	2.10	1.74	1.92
Grand mean	4.61	4.64	4.63	5.76	5.89	5.82	1.09	1.19	1.14
SE(±)	0.075	0.11	0.066	0.12	0.17	0.10	0.12	0.178	0.11
$CD_{0.05}$	0.15	0.22	0.13	0.24	0.34	0.20	0.24	0.36	0.22
CV (%)	2.59	3.73	3.20	3.29	4.59	3.94	17.41	23.77	20.76

(11.05 kg), Red Baron (10.14 kg) and Aziza (10.05 kg) were statistically at par with each other. Lowest yield per plant was recorded in Early McIntosh (2.23 kg/plant).

The yield per plant was seen to slightly increase from 6.0 kilograms per plant in 1999-2000 to 6.64 kilograms per plant in year 2000-2001.

vii) Total soluble solids (TSS)

Cultivar Red June with highest total soluble solids (13.47°Brix) was observed to be significantly different from all cultivars studied. Genotypes Tropical Beauty (12.12), Aziza (12.12) and Red Baron (12.07) were statistically at par with each other. Lowest value was recorded in 'Maayan' (9.03).

viii) Titratable acidity (%)

Per cent titratable acidity was recorded maximum in fruits of cultivar Tamma (0.89 %), followed by Parlin's Beauty (0.68 %) and Red June (0.55 %). These genotypes were significantly superior to others in the parameter studied. Lowest value was recorded in 'Anna' (0.18 %).

ix) Reducing sugar (%)

Highest value of reducing sugar was recorded in fruits of 'Parlin's Beauty' (6.49 %) and 'Tropical Beauty' (6.45 %), respectively, both being statistically at par with each other, but were significantly higher as compared to the other cultivars and was followed by 'Red June' (5.13 %). The lowest value was observed for 'Schlomit' (3.77 %), followed by 'Anna' (3.78 %), 'Maayan' (3.74 %), all being at par with each other.

x) Total sugar (%)

Two year observation on total sugar of different cultivars showed that it ranged between 4.59 to 8.48 per cent. 'Tropical Beauty' (8.48 %) and 'Parlin's

Beauty' (8.32 %) recorded the highest values of total sugar in sequence which were significantly superior to others, followed by 'Aziza' (6.28 %) and 'Red June' (5.7 %). The lowest value of 4.59 per cent sugar was observed in 'Anna'.

The two year observation showed that mean total sugar in fruit slightly increased from 5.76 per cent in 1999-2000 to 5.89 per cent in year 2000-2001.

xi) Non-reducing sugar (%)

The mean values of non-reducing sugar ranged between 0.40 to 1.92 per cent. The per cent non-reducing was found to be maximum in fruits of 'Tropical Beauty' (1.92%), followed by 'Parlin's Beauty' (1.74 %); both being statistically at par with each other. Minimum value of non-reducing sugar was recorded in fruit of cultivar 'Tamma' (0.40 %).

4.2 PARAMETERS OF VARIABILITY PERTAINING TO GROWTH, FLOWERING, FRUITING AND YIELD CHARACTERS

The parameters of variability viz., mean, range, genotypic variance, phenotypic variance, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), environmental coefficient of variation (ECV), heritability in broad sense, genetic advance and genetic gain (genetic advance as per cent of mean) are presented in Tables 10, 11 and 12.

The data presented in Table 10 revealed that among growth characters, the genotypic variance was highest for the character tree volume (1420.8) and lowest value for the character plant height (1.35).

Phenotypic variance was highest for the character tree volume (1522.6) and lowest for plant height (1.54). Genotypic coefficient of variation was highest for the character tree volume (73.69) and lowest for the character plant height (23.76). Phenotypic coefficient of variation was highest for the character tree volume (76.29)

Table 10. Variability parameters for growth characters in low chilling apples

Character	Mean	Range	Variance		Coefficient of variation		Environmental coefficient of variation (%)	Heritability (%) (broad sense)	Genetic advance	Genetic gain (%)
			Genotypic	Phenotypic	Genotypic (%)	Phenotypic (%)				
Plant height (m)	4.89	2.9-6.8	1.35	1.54	23.76	25.38	8.91	87.66	2.25	46.00
Plant spread (m)	4.29	2.15-5.95	7.36	7.56	63.24	64.09	10.42	97.35	5.51	128.44
Trunk girth (cm)	44.53	24-81	980.30	1027.00	70.31	71.97	15.35	95.45	63.01	141.51
Tree volume (m^3)	51.15	7.0-116.0	1420.80	1522.60	73.69	76.29	19.73	93.31	75.0	146.63
Shoot length (cm)	23.73	9.0-39.1	82.80	91.08	38.35	40.22	12.13	90.91	17.87	75.32
Leaf area (cm^2)	35.93	28.4-61.7	133.60	134.30	32.17	32.25	2.33	99.48	23.75	66.10

Table 11. Variability parameters for flowering characters in low chilling apples

Character	Mean	Range	Variance		Coefficient of variation		Environmental coefficient of variation (%)	Heritability (%) (broad sense)	Genetic advance	Genetic gain (%)
			Genotypic	Phenotypic	Genotypic (%)	Phenotypic (%)				
Days from bud burst to first flower open	12.92	8-19	12.05	12.48	26.87	27.34	5.08	96.55	7.03	54.38
Days from first flower open to full bloom	10.43	7-16	12.52	12.84	33.92	34.35	5.42	97.51	7.20	69.01
Days from full bloom to petal fall	8.62	6-13	4.35	4.72	24.20	25.22	7.06	92.16	4.12	47.85
Number of flowers per unit shoot length (65 cm)	25.34	6.25-66.63	227.15	279.92	59.48	66.02	28.67	81.15	27.97	110.37

and lowest for the character plant height (25.38). Tree volume (19.73) and leaf area (2.33) showed highest and lowest environmental coefficient of variation, respectively.

Heritability per cent (broad sense) was observed highest for the character leaf area (99.48 %) and lowest for the character plant height (87.66 %). Genetic gain values (genetic advance as per cent of mean) was highest for the character tree volume (146.63 %) and lowest for plant height (46.0 %).

The appraisal of Table 11 revealed that among variability parameters for flowering characters, phenotypic variance in all the traits was higher than genotypic variance and phenotypic coefficient of variation was higher than genotypic coefficient of variation.

Genotypic variance was highest in the character number of flowers per unit shoot length (227.15) and lowest value was observed for the character days from full bloom to petal fall (4.35). The value of phenotypic variance was highest for number of flowers per unit shoot length (279.92) and lowest for the character days from full bloom to petal fall (4.72).

Genotypic coefficient of variation was highest for the character, number of flowers per unit shoot length (59.48) and lowest for the character days from full bloom to petal fall (24.2). The highest value for phenotypic coefficient of variation was observed for number of flowers per unit shoot length (66.02) and lowest for the character days from full bloom to petal fall (25.22).

Among the environmental coefficient of variation, the highest value was recorded for the character number of flowers per unit shoot length (28.67) and lowest value for the character days from bud burst to first flower open (5.08). Heritability (broad sense) was highest for the characters days from first flower open to full bloom (97.51 %), closely followed by days from bud burst to first flower

open (96.55 %) and lowest value for the character number of flowers per unit shoot length (81.45 %).

Genetic gain (genetic advance as % mean) was highest for the character number of flowers per unit shoot length (110.37 %). The lowest value was observed for the character days from full bloom to petal fall (47.85 %).

The data given in Table 12 revealed that among fruit and fruiting characters, the genotypic variance was highest for the character number of fruits per plant (2842.3), followed by fruit weight (1497.0), fruit length (122.7) and fruit breadth (120.09) and lowest for the character titratable acidity (0.07). Phenotypic variance was observed to be highest for the character number of fruits per plant (2923.6), followed by fruit weight (1592.5) and lowest value was recorded for the character titratable acidity (0.07).

Phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits. The phenotypic coefficient of variation (99.68) and genotypic coefficient of variation (98.81) were highest for the character fruit yield per plant, whereas, the lowest values were observed in the character mean fruit breadth (PCV: 18.3; GCV: 18.0).

Environmental coefficient of variation had lower values as compared to genotypic coefficient of variation and phenotypic coefficient of variation. The highest environmental coefficient of variation was recorded for the character non-reducing sugar in fruit (21.49), followed by the character number of fruits set per unit shoot length (18.44), number of fruits per plant (13.23) and fruit yield per plant (13.14) and lowest for the character reducing sugar (3.05).

Among the heritability values, the highest estimate was observed for the character titratable acidity (99.46 %) closely followed by reducing sugar (98.94 %).

Table 12. Variability parameters for fruit and fruiting characters in low chilling apples

Character	Mean	Range	Variance		Coefficient of variation		Environmental coefficient of variation (%)	Heritability (%) (broad sense)	Genetic advance	Genetic gain (%)
			Genotypic	Phenotypic	Genotypic (%)	Phenotypic (%)				
Number of fruits set per unit shoot length (65 cm)	8.76	2.32-17.88	19.84	22.45	50.84	54.09	18.44	88.37	13.39	67.49
Number of fruits per plant	67.92	15-153	2842.30	2923.60	78.49	79.61	13.23	97.21	108.20	159.40
Fruit weight (g)	102.10	29.2-139.5	1497.00	1592.50	37.90	39.08	9.57	94.00	77.27	75.68
Fruit length (mm)	55.04	32.3-68.7	122.70	126.10	20.13	20.41	3.35	97.00	22.51	40.89
Fruit breadth (mm)	60.89	35.2-79.8	120.09	124.19	18.00	18.30	3.33	96.70	22.20	36.46
Fruit yield (kg/plant)	6.32	1.5-18.5	39.00	39.69	98.81	99.68	13.14	98.26	12.75	201.74
TSS (°Brix)	10.92	8.5-14.0	4.20	5.51	18.97	21.50	10.48	76.23	3.69	33.79
Titratable acidity (%)	0.44	0.14-0.72	0.07	0.07038	60.13	60.29	4.43	99.46	0.54	123.53
Total sugar (%)	5.81	4.39-8.9	3.42	3.47	31.83	32.07	3.85	98.56	3.78	65.06
Reducing sugar (%)	4.63	3.5-6.72	1.87	1.89	29.53	29.71	3.05	98.94	2.80	60.52
Non-reducing sugar (%)	1.14	0.27-2.42	0.42	0.48	56.85	60.52	21.49	87.50	1.25	109.54

total sugar (98.56 %); fruit yield per plant (98.26 %). The lowest value was observed for the character TSS (76.23 %).

Genetic gain (genetic advance as % of mean) was found maximum for the character fruit yield per plant (201.74 %), followed by the characters, number of fruit per plant (159.4 %), titratable acidity (123.53 %). The minimum value was found for the character TSS (33.79 %).

DISCUSSION

Chapter-5

DISCUSSION

The present study entitled, "Evaluation of low chilling apples under mid hills of H.P. (*Malus* x *domestica* Borkh)" was carried out during the year 1999-2000 and 2000-2001 with the objectives of studying various horticulturally important traits and heritability in low chilling apples.

The salient findings of present investigations have been discussed as under:

5.1 ANALYSIS OF VARIANCE

The analysis of variance for the characters viz. plant height, plant spread, trunk girth, tree volume, shoot length, leaf area, days from bud burst to first flower open, days from first flower open to full bloom, days from full bloom to petal fall, number of flowers per unit shoot length, number of fruits set per unit shoot length, number of fruits per plant at harvest, fruit weight (g), fruit length (mm), fruit breadth (mm), fruit yield, TSS, titratable acidity (%), total sugar (%), reducing sugar (%) and non-reducing sugar (%) revealed that the genotypes studied differed significantly. The present study on evaluation of low chill apples revealed that the genotypes evaluated were genetically different. Nakayama and Saito (1970) found significant differences among the varieties of apple for fruit and leaf characteristics. Many other workers have also reported variability in apple for characters like tree size, yield (Longley, 1960), colour of leaf blade, dorsal surface pubescence, length/width ratio, petiole colour and petiole thickness (Blazek, 1997), girth, height and mean tree spread (Chadha and Sharma, 1975).

In preliminary evaluation of genetic resources of apple (H.P.), Rathore (1986) observed variability in respect of date of flowering, date of full bloom, date of harvest, yield per plant, fruit weight, length and diameters. Variability has been

also observed for characters like trunk girth, fruit yield, fruit length and breadth (Gautam and Chauhan, 1986), fruit shape, size, ripening and flowering characters (Bernkoff, 1990), germination rate, number of long shoots, internode length, spur frequency and spur coefficient (Xin and Shen, 1992).

The genotype x year interaction (GY) was found to be significant for the characters days from bud burst to first flower open, days from first flower to full bloom, number of flowers per unit shoot length, number of fruits set per unit shoot length, number of fruits per plant, fruit length, fruit breadth, fruit yield, total sugar and non-reducing sugar (Table 1). This indicated that there were real differential effects of genotypes with the variation in the years. It is to be mentioned that the conclusion are drawn on the basis of pooling of two year data only.

5.2 EVALUATION OF LOW CHILLING APPLES

5.2.1 Plant characters

Many workers have reported the importance of various plant characters such as tree size, vigour and growth habit in the identification and description of different low chilling apples in marginal areas (Dadlani *et al.*, 1980; Gautam and Chauhan, 1986; Armas Reyes *et al.*, 1987; Subhadrabandhu and Punsri, 1987; Finetto and Hussein, 1990; Verheij, 1990).

The low chill cultivars of apple under the present study were found to vary markedly in their growth habits. Cultivar 'Tropical Beauty' was the best genotype for the growth habit with superior characters like plant height (6.6 m), plant spread (5.67 m), trunk girth (64.5 cm), tree volume (111.2 m^3) and leaf area (60.77 cm^2). Cultivar 'Schlomit' and 'Parlin's Beauty' closely followed 'Tropical Beauty' for the characters viz., plant height, plant spread, trunk girth and tree volume (Table 13). The results of the study are in accordance with the findings of Gautam and Chauhan (1986) who recorded maximum trunk girth and average per tree cumulative pruning weight in 'Tropical Beauty'. However, girth and pruning weight of 'Parlin's Beauty'

Table 13. Promising genotypes for different characters in low chilling apples

Character	Genotypes having highest value	Genotypes having lowest value	Promising genotypes at par/ closely followed the highest
1. Plant height	Tropical Beauty	Anna	Schlomit, Red Baron, Maayan
2. Mean plant spread	Tropical Beauty	Early McIntosh	Parlin's Beauty, Schlomit, Red June
3. Trunk girth	Tropical Beauty	Early McIntosh	Schlomit, Parlin's Beauty, Red June, Red Baron
4. Tree volume	Tropical Beauty	Early McIntosh	Parlin's Beauty, Schlomit
5. Shoot length	Chahla	Red June	Anna, Tropical Beauty, Early McIntosh
6. Leaf area	Tropical Beauty	Chahla	Red Baron, Red June, Maayan
7. Date of bud burst	Red Baron (late)	Anna (Earliest)	Chahla, Maayan (early)
8. Date of first flower open	Red June (late)	Anna (Earliest)	Chahla, Maayan (early)
9. Days from bud burst to first flower open	Schlomit	Red Baron	Maayan, Anna, Chahla
10. Date of full bloom flowering	Red June (late)	Anna (Earliest)	Chahla, Aziza (early)
11. Days from first flower to full bloom	Chahla	Tamma, Tropical Beauty	Maayan, Anna
12. Date of petal fall	Red June (late)	Anna (Earliest)	Chahla, Aziza (early)
13. Days from full bloom to petal fall	Chahla	Red Baron	Tamma, Anna, Early McIntosh
14. Number of flowers per unit shoot length	Chahla	Tamma	Tropical Beauty, Aziza
15. Number of fruits set per unit shoot length	Tropical Beauty	Tamma	Parlin's Beauty, Aziza
16. Number of fruits per plant at harvest	Tropical Beauty	Schlomit	Red Baron, Red June, Aziza, Parlin's Beauty
17. Mean fruit weight	Tropical Beauty	Red June	Schlomit, Parlin's Beauty, Tamma
18. Mean fruit length	Chahla, Schlomit	Red June	Anna, Tamma, Aziza
19. Mean fruit breadth	Parlin's Beauty	Red June	Tropical Beauty, Tamma, Red Baron, Aziza
20. Fruit yield	Tropical Beauty	Early McIntosh	Parlin's Beauty, Red Baron, Aziza
21. Total soluble solids	Red June	Maayan	Tropical Beauty, Aziza, Red Baron
22. Titratable acidity	Tamma	Anna	Parlin's Beauty, Red June
23. Reducing sugar	Parlin's Beauty, Tropical Beauty	Schlomit	Red June
24. Total sugar	Tropical Beauty, Parlin's Beauty	Anna	Aziza, Red June
25. Non-reducing sugar	Tropical Beauty	Tamma	Parlin's Beauty

were the least among the low chill apples studied by them which are in contradiction with the results of present investigation.

5.2.2 Flowering characters

The time and duration of flowering are important traits in the classification of apple with respect to their chilling requirements under different regions and were investigated by several workers (Aguila, 1986; Bist and Sharma, 1986; Subhadrabandhu and Watanawongvijit, 1990; Ramizer and Saavedra, 1990; Panhwar, 1995; Bepete and Jackson, 1995; Finetto, 1997). In the present study, a considerable variation was observed in flowering time in different cultivars. In both the years of observation, cultivar 'Anna' was found to be early in flowering character and also in other associated characters like earliest in bud break (8/2), first flower open (22/2), full bloom flowering (5/3) and petal fall (14/3). This indicated least chilling requirement of cultivar 'Anna' among those under study. 'Chahla' and 'Maayan' followed 'Anna' with respect to early flowering time. The finding of early flowering of 'Anna' and Maayan in the study under consideration was in accordance with the result of Bepete and Jackson (1995) under Marondera conditions of Zimbabwe having only 417 hours of chilling. Anna flowered every year, two weeks before another low chilling apple cultivar Dorsett Golden under the subtropical conditions of Sindh, Pakistan receiving 100-550 chill hours (Panhwar, 1995) and 'Anna' also flowered earlier than Dorsett Golden and Ein Shermer on MM106 under conditions of 700 hours chilling (Finetto and Hussein, 1990).

Cultivar 'Chahla' in present study was found to be superior in respect of having long duration from first flower open to full bloom (14.9 days), long duration from full bloom to petal (12.0 days), high number of flowers per unit shoot length (46.20). The long flowering duration of cultivar Chahla may have enabled the process of fertilization and later fruit setting (10.11 fruits set per unit shoot length 65 cm) which was next to 'Tropical Beauty' (15.25 fruits) and 'Aziza' (12.2 fruits). This may have resulted in high yields of these cultivars.

5.2.3 Fruiting characters

Apple yields and fruit quality are greatly influenced by a number of factors, including the interaction of photoperiod and temperature, length of rest period, disease resistance, soil conditions, winter hardiness and inherent vigour of growth.

Different low chilling apples under study showed marked variation in fruit yield per plant and other components of fruit yield. 'Tropical Beauty' was found to be superior cultivar for characters like fruit yield (15.82 kg/plant), fruit weight (129.8 g), number of fruits per plant at harvest (132.4 fruits), number of fruits set per unit shoot length (15.25 fruits/65 cm). The study also indicated that 'Parlin's Beauty' (11.15 kg/plant) and 'Aziza' (10.05 kg/plant) were also good in yield performance, whereas, cultivar Tamma was found to be low cropper (2.82 kg/plant). These observations are similar to those recorded by Gautam and Chauhan (1986) who observed in 'Tropical Beauty' highest average cumulative yield of 69.09 kilograms per plant during 1980-1983. Cultivars Anna, Maayan, Michal in the study were low in yield performance. Similar observations have also been reported by Verheij (1990), Panhwar (1995). However, in the conditions of Marondera, Zimbabwe having 417 hours of chilling, cultivars Anna, Michal and Maayan fruited heavily and gave an yield of 156, 122 and 171 kilograms per plant, respectively in four cropping seasons (Bepete and Jackson, 1995).

The fruit yield per plant in present investigation were low, which may be due to drought like conditions which prevailed at the time of flower initiation and differentiation, also during the flowering period and later hails at fruit development stages markedly reduced the yields (Appendix-II).

5.2.4 Fruit characters

Cultivar Tropical Beauty and Parlin's Beauty in the present investigation were found to be superior in fruit characters like high total sugar content (8.48%

and 8.32%), high reducing sugar (6.45%.and 6.49%) and non-reducing sugar (1.92% and 1.74%, respectively). These observations are in line with findings of Gautam and Chauhan (1986), however, the fruit weight of these varieties in the present study were slightly smaller which may be due to the adverse effects of the weather during the course of investigation.

5.3 VARIABILITY STUDIES

Genetic variation is a prerequisite for any improvement in crop. Selection is necessary based upon phenotype. The efficiency of this activity determines the success of a breeding programme. Selection is perhaps the most important activity in all plant breeding programmes. The efficiency of selection largely depends on the extent of genetic variability present in a population and the heritability of the concerned character (Johnson, 1909). Vavilov (1951) was of the view that wider the variability present in any crop, the better are the chances of selecting desired types. According to Fisher (1918), the continuous variation exhibited by quantitative traits with which plant breeders deal includes the heritable and non-heritable components. The heritable component is the consequence of genotypes and the non-heritable part is mainly due to the unknown environmental factors. The direct assessment of genotype.is very difficult in the existing material and thus the study of phenotypic variability for various traits is of paramount significance.

For any breeding programme to be successful, the first requirement is the correct selection/ choice of the parent, which largely depends upon the quantum of variability it possess for the desirable characters. Larger the variability present in the material, greater will be the scope for improvement of a trait or number of traits.

The present work on evaluation of low chill apples was carried out to assess the variability present in different cultivars. The study revealed that genotypes differed significantly for various characters. The promising genotypes for various characters under study have been presented in Table 13. 'Tropical Beauty' was the

best genotype for the characters like plant height, plant spread, trunk girth, tree volume, leaf area, number of fruits set per unit shoot length, number of fruits per plant at harvest, fruit yield, fruit weight, total sugar and non-reducing sugar (Plate I). 'Parlin's Beauty' was the best genotype for characters, fruit breadth, reducing sugar and was recorded as promising next to 'Tropical Beauty' for characters like plant spread, tree volume, mean fruit weight, fruit yield and non-reducing sugar. 'Chahla' was superior genotype for high number of flowers per unit shoot length (46.20), shoot length (34.12 cm), fruit length (64.55 mm) and long duration of flowering. 'Anna' was the best genotype for early flowering character (Plate II). Characters like fruit weight (30.73 g), fruit length (35.40 mm), fruit breadth (41.19 mm), fruit yield (2.86 kg/plant) were least in cultivar Red June.

The analysis of variance in the present work indicated significant genetic differences for all twenty one characters studied. With a view to know the cause or nature of observed variability, the material studied was split into phenotypic and genotypic variances. The study revealed that for all the traits investigated, the phenotypic variances were markedly higher compared to the genotypic variances. The phenotypic variance for character, number of fruits per plant was found to be 2923.6 compared to the genotypic variance which was 2842.3, the phenotypic variance of this character was 1.02 times higher than genotypic variance. The phenotypic variance for character fruit weight was about 1.06 times higher than its genotypic variance (1497.0). Watkins and Spangelo (1970) while studying the components of genotypic variance of apple trees also observed similar trends.

Appreciable range of variation for all the characters studied in the present investigation on low chill apples was observed. The character number of fruits per plant showed highest range of variability which varied from 15 fruits per plant to 153 fruits per plant. The character fruit weight was in tandem showing high range of variability varying from 29.29 grams to 139.5 grams. The character titratable acidity showed lowest value of variability (0.14% to 0.72%). Phenotype is the product of combined action of genotype and environment. The expression of each trait is conditioned by genetic factors and the environmental ones, therefore, the range of

Plate I. Fruits of low chilling apple varieties

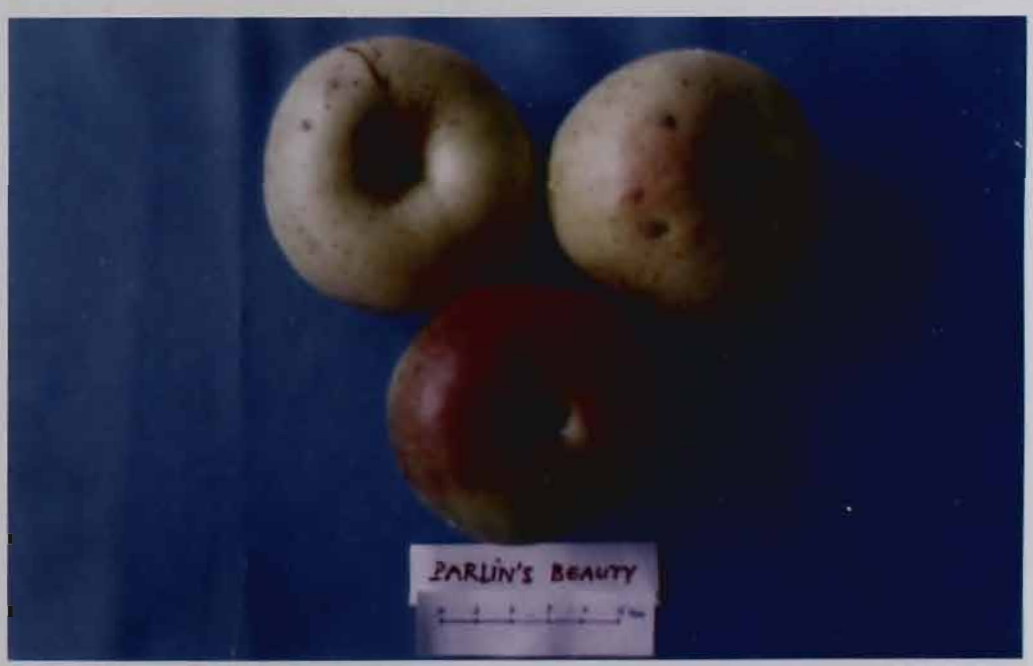
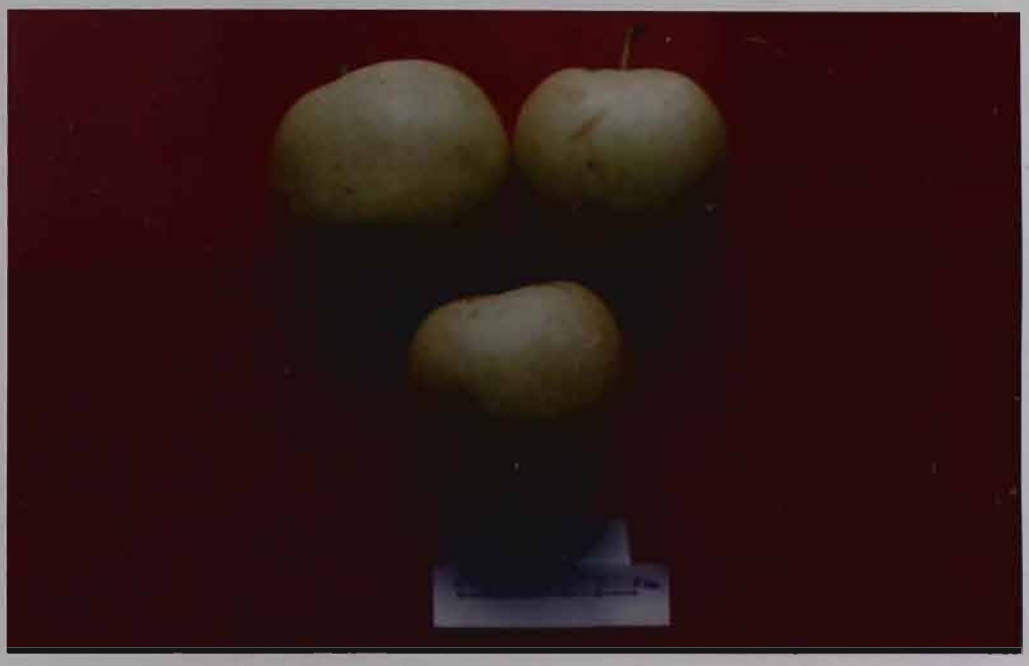


Plate II. Fruits of low chilling apple varieties



variability and magnitude of phenotypic variance does not reflect as to which character shows highest degree of variation and relative amount of genetic and non-genetic components of variation. In order to find the proportion of genetic and non-genetic components of variation, coefficient of variability was calculated which are the independent units of measurement of characters.

The partitioning of the variance into its components allows to estimate the relative importance of the various determinants of the phenotype, in particular the role of hereditary versus environment. Further, the relative importance can be answered only if it is expressed in terms of the variance attributable to the different sources of variation. The highest phenotypic coefficient of variation was observed for the characters fruit yield per plant (99.68%), followed by number of fruits per plant (79.61%), tree volume (76.26%), trunk girth (71.97%), number of flowers per unit shoot length (66.02%), plant spread (64.09%), non-reducing sugar (60.52%) and titratable acidity (60.29%). Number of authors have found significant differences in respect of coefficient of variation i.e. leaf area, fruit skin, length and weight (Nakayama and Saito, 1970), tree vigour, time of blossoming, fruit maturity and yield (Chadha and Sharma, 1975), fruit size and yield in low chill apples (Rathore, 1986), trunk girth, cumulative yield (Gautam and Chauhan, 1986), tree to tree variability in yield (Goldwin and Ermen, 1989), tree to tree variability in fruit quality, fruit weight and maturity (Volf *et al.*, 1993). Individuals differing in phenotypic values, indicate that improvement could be expected for the characters which shows higher phenotypic coefficient of variation. The present investigation also indicated relatively low phenotypic coefficient of variation for the traits like reducing sugar (29.71%), days from bud burst to first flower open (27.34%), plant height (25.38%), days from full bloom to petal fall (25.22%), TSS (21.5%), fruit length (20.41%) and fruit breadth (18.30%). The low variation for the above characters indicated highly stable nature of those characters among different genotypes studied, therefore have less scope for improvement.

The investigation further revealed that estimates of genotypic coefficient of variation were lower in magnitude compared to phenotypic coefficients of variation

for all the twenty one parameters studied. Amongst all the traits, highest phenotypic coefficient of variation was obtained for fruit yield per plant (99.68%), which was about 1.01 times more than the genotypic coefficient of variation (98.81%). The phenotypic and genotypic coefficients of variation were comparatively high for other characters like number of fruits per plant, tree volume, trunk girth, plant spread, titratable acidity, number of flowers per unit shoot length, non-reducing sugar and number of fruits set per unit shoot length. The findings revealed appreciable diversity of the characters evaluated and thereby indicate greater scope for future improvement. The variability parameters (Table 10) further showed that variation in respect of environmental component for all the characters was low indicating the reliability of the data pertaining to traits taken for the study. The environmental coefficient of variation for leaf area was the lowest (2.33%) and the character indicated highest stability. Genetic variance if high for some traits with low environmental variance, it is expected that the progeny will be similar to the selected phenotype. However, if the genetic variance is low and environmental variance is high, the resulted progeny may be much different from the selected phenotype.

The success of any breeding programme is the net result of the magnitude and nature of genotypic and non-genotypic variation present in different characters. Economically most important character i.e. the yield is very complex in inheritance and is extensively influenced by different environmental conditions. Heritability is a convenient expression of the phenotypic value which serves as a guide to the breeding value or as a degree of agreement between the phenotypic and the breeding value. Therefore, the study of heritability and genetic advance are of paramount significance to estimate the scope of improvement by selection. This is for the fact that selection is based on phenotypic value, and it is essential to establish what is the probability of the selected phenotype that gives rise to the same progeny. Heritability magnitudes indicate the reliability with which the genotype will be recognized by its phenotypic expression.

In the present study, high heritability estimates were recorded for all the characters studied. The character leaf area showed the highest value of heritability estimate (99.48%), followed by titratable acidity (99.46%), reducing sugar (98.94%), total sugar (98.56%). The character total soluble solids showed lowest value of heritability. The high heritability estimate for fruit yield (98.26%) recorded in the present work was not in accordance with the findings of Sedova (1970) who postulated low heritability for characters like high yield, large fruit and growth habit in apple. High heritability for fruit weight (94.0%) in the present study are similar to the findings of Serova (1989) who suggested the possibility of selecting parents by phenotypes but are in contradiction with the work of Bukarchuk (1979) who reported low heritability for fruit weight. The resultant variation in the results could be due to the different genetic make up of the tested genotypes. A number of workers in apple have reported fairly high coefficient of heritability for characters like fruit weight (Serova, 1989). leaf length, leaf shape index, fruit length and diameter and fruit shape index (Shin *et al.*, 1986), harvest date (Tancred *et al.*, 1995), vigour assessed by circumference of the trunk (Durel *et al.*, 1998). Low heritability values have been obtained for fruit size (Boicheva, 1976) growth habit (Sedov, 1970) and relatively moderate heritability values for apple fruit characteristics like size, texture, juice content, attractiveness and russeting (Durel *et al.*, 1998).

The high values of heritability obtained in the present study for different characters along with other characters studied by various research workers over the world support the hypothesis that selection on the basis of phenotype for these characters will be effective, as they would be less influenced by the environmental effects. Blinova *et al.* (1979) indicated the ineffectivity of selection of varieties by phenotype for those characters which had low coefficient of heritability in apple.

The estimation of components of genetic variability is a pre-requisite for any systematic breeding programme. Since selections are based on phenotypes, it is important to have an idea of how they correspond to their genotype and breeding values. Johnson *et al.*, 1955 while studying estimates of genetics and environmental

variability further impressed upon that heritability values in tandem with the estimation of genetic gain (GG) were of greater utility than heritability values alone in forecasting the effect of selection. High heritability estimates in ally with high genetic advance as per cent of mean (GG) were obtained in the present work for the characters viz., fruit yield per plant (98.26%) and (201.74%), number of fruits per plant (97.21% and 159.40%), tree volume (93.31% and 146.63%), trunk girth (95.45% and 141.51%), plant spread (97.35% and 128.44%), titratable acidity (99.46% and 123.53%), number of flowers per unit shoot length (81.15% and 110.37%) respectively. Present findings indicate that selection would be effective for these characters. High heritability and high genetic advance values indicated the presence of additive gene action for these traits (Johnson *et al.*, 1955; Murawski and Fischer, 1979). Chandrababu and Sharma (1999) in Almond observed higher genotypic and phenotypic coefficient of variance, heritability and genetic advance indicating predominance of additive gene action for characters like yield, number of flowers per unit shoot length, fruit set, mean fruit weight etc.

CONCLUSION

From the present work on low chill apples, it can be concluded that the range of variability was quite high for all the characters studied. 'Tropical Beauty' was the best genotype for almost all the growth characters, fruit and fruiting characters. 'Parlin's Beauty' was promising genotype next to 'Tropical Beauty'. Cultivar Chahla was the best genotype in respect of profuse flowers and long duration of flowering. 'Anna' was earliest genotype for flowering characters (early bud burst, early in first flower to open, early full bloom, early petal fall). The characters like fruit yield per plant, number of fruits per plant, tree volume, trunk girth, plant spread, number of flowers per unit shoot length and number of fruits set per unit shoot length had comparatively high genotypic coefficient of variation (GCV), phenotypic coefficient of variance (PCV), heritability and genetic gain (Genetic advance as per cent of mean), so more emphasis required on these traits during selection process to increase yield in low chilling apples.

SUMMARY

Chapter-6

SUMMARY

The present investigation entitled, "Evaluation of low chilling apples under mid hills of Himachal Pradesh (*Malus* x *domestica* Borkh)" was carried out at the Department of Fruit Breeding and Genetic Resources, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) in the year 1999-2000 and 2000-2001. Twelve low chilling apple genotypes viz., Anna, Aziza, Chahla, Early McIntosh, Maayan, Michal, Parlin's Beauty, Red Baron, Red June, Schlomit, Tamma and Tropical Beauty were evaluated.

Observations were recorded on the characters viz., plant height, mean plant spread, trunk girth, tree volume, shoot length, leaf area, date of bud burst, date of first flower open, days from bud burst to first flower open, date of full bloom, days from first flower to full bloom, date of petal fall, days from full bloom to petal fall, number of flowers per unit shoot length, number of fruits set per unit shoot length, number of fruits per plant at harvest, mean fruit weight, mean fruit length, mean fruit breadth, fruit yield, total soluble solids, titratable acidity, reducing sugar, total sugar and non-reducing sugar. The results obtained in the investigation have been summarized as below:

The results revealed that there was a wide range of variation in the low chilling apple germplasm for almost all the characters studied. The analysis of variance indicated significant differences among the genotypes for various traits, the genotypes evaluated were genetically different. 'Tropical Beauty' was the best genotype for the characters like plant height, plant spread, trunk girth, tree volume, leaf area, number of fruits set per unit shoot length, number of fruits per plant at harvest, fruit yield, fruit weight, total sugar and non-reducing sugar. 'Parlin's Beauty' was the best genotype for characters fruit breadth, reducing sugar and was

recorded as a promising next to 'Tropical Beauty' for characters like plant spread, tree volume, mean fruit weight, fruit yield and non-reducing sugar. 'Chahla' was superior genotype for high number of flowers per unit shoot length, shoot length, fruit length and long duration of flowering. 'Anna' was the best genotype for early flowering character.

The characters studied showed appreciable range of variation. The character, number of fruits per plant reflected the highest range of variability and the character fruit weight was in tandem showing high range of variability. The lowest value of variability was recorded for character titratable acidity. The phenotypic variances were found to be higher than the genotypic variances for all the characters under investigation. Phenotypic coefficient of variation was higher than the genotypic coefficient of variation. Phenotypic and genotypic coefficient of variation were the highest for the characters fruit yield per plant and number of fruits per plant at harvest and least estimates were for mean fruit breadth.

The variation in respect of environmental component for all characters studied was low indicating the reliability of the data pertaining to traits taken for the study. The lowest value of environmental coefficient of variation for leaf area indicated its highest stability.

High heritability estimates in broad sense were recorded for all the characters studied. The character leaf area showed the highest value of heritability estimates and least heritability estimate was recorded for total soluble solids. The characters fruit yield per plant, number of fruits per plant, tree volume, trunk girth, plant spread, number of flowers per unit shoot length, number of fruits set per unit shoot length and titratable acidity had comparatively high genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic gain (Genetic advance as per cent mean).

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APPENDICES

APPENDIX-I

1. ANOVA table (Days from bud burst to first flower open)

Source of variation	df	SS	MSS	F
Genotype (g)	11	667.82	60.711	140.87
Year (y)	1	0.075	0.075	0.17
Replication (r)	4	1.9500	0.48	1.13
Genotype x Year	11	18.825	1.7114	3.97
Pooled error	92	39.650	0.43	
Total	119	728.32		

2. ANOVA table (Days from first flowers to full bloom)

Source of variation	df	SS	MSS	F
Genotype (g)	11	692.27	62.933	197.05
Year (y)	1	1.6333	1.6333	5.11
Replication (r)	4	2.2167	0.554	1.74
Genotype x Year	11	21.969	1.9970	6.25
Pooled error	92	29.383	0.319	
Total	119	747.47		

3. ANOVA table (number of flowers per unit shoot length)

Source of variation	df	SS	MSS	F
Genotype (g)	11	13073.5	1188.5	22.52
Year (y)	1	3172.4	3172.4	60.11
Replication (r)	4	251.94	62.986	1.19
Genotype x Year	11	6586.6	598.78	11.35
Pooled error	92	4855.2	52.774	
Total	119	27940.0		

4. ANOVA table (Number of fruits set per unit shoot length)

Source of variation	df	SS	MSS	F
Genotype (g)	11	1119.8	101.8	38.94
Year (y)	1	349.35	349.35	133.63
Replication (r)	4	2.4707	0.61	0.24
Genotype x Year	11	405.71	36.882	14.11
Pooled error	92	240.53	2.6144	
Total	119	2117.8		

Contd.

5. ANOVA table (Number of fruits per plant)

Source of variation	df	SS	MSS	F
Genotype (g)	11	15.7220	14293.0	175.8
Year (y)	1	1274.0	1274.0	15.67
Replication (r)	4	288.53	33.133	0.40
Genotype x Year	11	16192.0	1472.0	18.11
Pooled error	92	7479.9	81.303	
Total	119	182450.0		

6. ANOVA table (Fruit yield)

Source of variation	df	SS	MSS	F
Genotype (g)	11	2152.4	195.67	285.32
Year (y)	1	12.097	12.097	17.64
Replication (r)	4	2.3238	0.58	0.85
Genotype x Year	11	120.97	10.998	16.04
Pooled error	92	63.092	0.685	
Total	119	2350.9		

7. ANOVA table (Fruit length)

Source of variation	df	SS	MSS	F
Genotype (g)	11	6789.1	617.19	182.66
Year (y)	1	4.80	4.80	1.42
Replication (r)	4	28.069	7.0172	2.08
Genotype x Year	11	271.2	24.655	7.30
Pooled error	92	310.86	3.3789	
Total	119	7404.1		

8. ANOVA table (Fruit breadth)

Source of variation	df	SS	MSS	F
Genotype (g)	11	6650.0	604.55	148.06
Year (y)	1	5.1502	5.1502	1.26
Replication (r)	4	14.152	3.5386	0.87
Genotype x Year	11	259.77	23.615	5.78
Pooled error	92	375.65	4.0831	
Total	119	7304.8		

Contd..

9. ANOVA table (Total sugar)

Source of variation	df	SS	MSS	F
Genotype (g)	11	188.67	17.152	326.66
Year (y)	1	0.54	0.54	10.28
Replication (r)	4	0.364	0.091	1.73
Genotype x Year	11	2.5720	0.233	4.45
Pooled error	92	4.8306	0.052	
Total	119	196.98		

10. ANOVA table (Non-reducing sugar)

Source of variation	df	SS	MSS	F
Genotype (g)	11	23.853	2.1684	38.43
Year (y)	1	0.314	0.314	5.57
Replication (r)	4	0.273	0.068	1.21
Genotype x Year	11	2.4485	0.222	3.91
Pooled error	92	5.1912	0.056	
Total	119	32.08		

APPENDIX-II

Meteorological data recorded at UHF, Nauni from August 1999 to July 2001

Month	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Average evaporation (mm)
	Maximum	Minimum			
1999					
August	26.6	19.2	78.0	146.2	3.4
September	27.8	17.9	88.2	149.4	2.7
October	27.3	10.5	68.2	-	2.6
November	24.6	5.5	91.0	-	2.0
December	21.5	2.6	67.2	3.0	1.7
2000					
January	18.6	3.8	55.0	64.7	1.6
February	16.8	2.4	57.0	121.5	1.6
March	22.7	2.4	44.0	47.9	3.3
April	30.8	12.7	34.0	59.4	5.8
May	31.8	17.8	54.0	119.0	4.4
June	28.6	18.4	70.0	392.5	3.2
July	27.3	20.0	86.0	592.7	2.1
August	28.8	19.7	81.0	125.3	2.5
September	28.5	16.0	68.0	6.9	3.2
October	28.2	10.7	52.0	-	3.5
November	23.2	7.2	50.0	-	1.9
December	21.9	2.7	42.0	-	1.9
2001					
January	19.8	1.8	50.0	25.8	1.8
February	22.5	4.3	41.0	5.0	2.6
March	24.5	7.9	45.0	56.5	4.0
April	27.8	12.9	48.0	54.8	5.2
May	31.7	17.1	55.0	68.2	6.0
June	28.4	18.5	78.0	320.2	4.3
July	27.5	20.0	82.0	155.6	3.0

CURRICULUM VITAE

Name	:	Gian Duc Chua
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Date of Birth	:	20.04.1971
Sex	:	Male
Marital Status	:	Married
Nationality	:	Vietnamese

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Certificate/ degree	Class/ grade	Board/ University	Year
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B.Sc. Agriculture	First	Can Tho University, Vietnam	1994

Whether sponsored by some state/ Central Govt./Univ./SAARC	:	NA
Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period	:	M.Sc. – Indian Council for cultural relations (ICCR)

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THESIS ABSTRACT

Title of Thesis	:	Evaluation of low chilling apples under mid hills of H.P. (*Malus x domestica* Borkh.)
Name of the Student	:	Gian Duc Chua
Admission Number	:	H-99-6-M
Major Advisor	:	Dr. Girish Sharma, Asstt. Professor
Major Field	:	Fruit Breeding and Genetic Resources
Minor Field	:	i) Genetics ii) Biotechnology
Degree Awarded	:	M.Sc. Horticulture (Fruit Breeding and Genetic Resources)
Year of Award of Degree	:	2001
Number of pages in Thesis	:	67+vii+IV
Number of words in Abstract	:	255

Twelve low chilling apple varieties were evaluated under mid hill conditions of Himachal Pradesh at around 1250 meters (m.s.l.), 31°N latitude and 77°E longitude. The data on vegetative, flowering, fruit and fruiting characters were recorded for two years (1999-2001). The result of investigation revealed that there was a wide range of variability in the low chilling apple germplasm for almost all the characters studied. The analysis of variance indicated that the genotypes evaluated were genetically different. 'Tropical Beauty' was the best genotype for almost all the growth characters, fruit and fruiting characters. 'Parlin's Beauty' was promising genotype next to 'Tropical Beauty'. 'Chahla' was the best genotype in respect of profuse flowers and long duration of flowering. 'Anna' was earliest genotype for flowering characters. Phenotypic variances were considerably higher than the genotypic variances for all the traits studied. Phenotypic and genotypic coefficient of variation were highest for the characters fruit yield per plant and number of fruits per plant at harvest and least estimates were for mean fruit breadth. High heritability estimates in broad sense were recorded for all the characters studied. The character leaf area showed the highest value of heritability estimates and least heritability estimate was recorded for total soluble solids. The characters fruit yield, number of fruits per plant, tree volume, trunk girth, plant spread, number of flowers per unit shoot length, number of fruits set per unit shoot length had comparatively high genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic gain (genetic advance as per cent mean).

Signature of Major Advisor

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