Himachal Journal of Agricultural Research 36 (1): 55-61, 2010

Studies on flower morphology and flowering behaviour of different apple pollinizers in mid hills of Himachal Pradesh

Roshan Anand, Nirmal Sharma and Girish Sharma
Department of Fruit Breeding and Genetic Resources
Dr. Y. S. Parmar University of Horticulture and Forestry,
Solan - 173 230,H.P., India.

Abstract

Flower buds are borne terminally on shoots or laterally on spurs of two or more years of age. Flower number per bud ranged from 5.00 to 5.80. Six stages of flower bud development were recorded after the dormancy till the pink bud stage was reached and on an average all the cultivars took 19 days for flower bud development. All the cultivars under study flowered between 15th to 27th March. Elstar was first and Arlet was last to flower. Stamen number, Stamen length, sepal length and pistil length varied between 13.67-20.00, 0.56-1.37 cm, 0.55-0.82 cm and 0.82-1.36 cm respectively. Maximum anthesis was recorded as 30.09% between 12 noon to 2 PM and highest dehiscence was recorded as 27.92% in the time interval 10 AM – 12 noon.

Key words: Flower morphology, apple pollinizers, Himachal Pradesh.

Introduction

Apple is an important member of family Rosaceae, sub family Pomoideae, and is native of South-Western Himalayan region. In India apple is extensively grown in Jammu and Kashmir, Himachal Pradesh and hills of Uttranchal, while in North-Eastern region is grown mainly in Arunachal Pradesh. Apple productivity in Himachal Pradesh has declined from 15.75 tonnes/ha in 1975-76 to 0.88 tonnes/ha in 1999-2000 (Anonymous, 2001). At present India is ranked 10th in the world apple cultivation scenario. In recent past, last decade or so low productivity of apple orchards has become a serious concern to the orchardists. The important factors which are responsible for low productivity are age old varieties, alternate bearing, lack of standard rootstocks, poor cultural practices, insufficient pollinators and above all the their inadequate proportion. In today's orcharding system, pollination is said to be the most critical and complex part of apple production. Apple cultivars do produce abundant bloom but fail to set adequately due to lack of pollination and unfavorable weather conditions. Due to global warming, the flowering of Delicious group of cultivars is not coinciding/overlapping with the earlier recommended pollinizing namely Golden Delicious, Tydeman's Early Worcester and Red Gold. Therefore, there is an urgent need to identify suitable pollinizers under varied agro-climatic apple cultivation sites/locations to overcome the problem standard rootstocks, poor cultural practices, insufficient pollinators and above all the their inadequate proportion. In today's orcharding system, pollination is said to be the most critical and complex part of apple production. Apple cultivars do produce abundant bloom but fail to set adequately due to lack of pollination and unfavorable weather conditions. Due to global warming, the flowering of Delicious group of cultivars is not coinciding/overlapping with the earlier recommended pollinizing namely Golden Delicious, Tydeman's Early Worcester and Red Gold. Therefore, there is an urgent need to identify suitable pollinizers under varied agro-climatic apple cultivation sites/locations to overcome the problem of low production. Prior to recommending a pollinizer for a particular apple production area it becomes utmost important that the flowering behaviour of the pollinizer is studied under the concerned agro-climatic conditions so that best combinations could be recommended. Besides flowering time, flower morphology, anthesis and dehiscence are also useful in classification of different varieties. Keeping in mind all this, experiment was planned to study the floral behavior of latest apple pollinizers.

Material and Methods

The experiment was conducted in the department of Fruit Breeding and Genetic Resources, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan. The cultivars taken for study were Arlet, Elstar, Extercross, Fuji, Gala, Hardiman, Jonadel, Red Fuji, Royal Gala, Ruspippin, Spartan, Spurtype Red Delicious and Summerland. For flower bud development studies, ten buds of each cultivar were tagged at the dormant stage for studying the bud development. Data on bud development was

recorded on alternate days to find out the number of days required from emergence to full development of bud in each cultivar. Time and duration of flowering was recorded from the day when first flower opened till the last flower opened and full bloom was considered when 75% flowers opened. Flower morphology was studied at the stage when flowers were fully open and expanded. Time of anthesis was observed by selecting fifty flowers on all sides of the tree of each cultivar and the number of opened flowers was counted at 8:00 AM. After that at an interval of two hours the number of opened flowers was counted till 6:00 PM. In order to avoid confusion the opened flowers were pinched at an interval of two hours. Dehiscence studies were carried on fifty flowers all around the plants and the dehiscence was recorded at an interval of two hours on the selected flowers from 8:00 AM to 6:00 PM with the help of magnifying glass. The dehisced anthers were removed with forcep to avoid recounting.

Results and Discussion

Flowering habit: All the cultivars under study had similar pattern of flowering. Flower buds were borne terminally on shoots or laterally on spurs of two or more years of age. Cultivars had flowers both on spurs as well as on the tips of the shoots. The flowers on the spurs opened first and the flowers on tips of the shoots also opened earlier and flowers lateral on shoots opened late. The flower number per bud in the investigated cultivars ranged from 5.00 to 5.80. Further in the cultivars studied, there was no single genotype which did bear flower exclusively either on shoot tips or entirely on spurs only. This type of mixed flowering habit in apple has been earlier reported by Luckwill (1974) but Slor (1982) observed formation of flowers both on one year old shoots and spurs of subtropical cultivar Slor selected from 6/13 × Schlomit.

Flower bud development: The observations on flower bud development were recorded from the time the buds started showing growth activity after dormancy till the pink bud stage was reached. The observations on the time required for development of each stage are given in Table 1. Six stages of flower bud development were observed in different cultivars under study. Observations recorded on bud development of apple cultivars showed that on an average all cultivars under study, took 19 days from the initiation of growth till pink bud stage. Cultivar Ruspippin took minimum time of 16 days followed by Extercross (17 days), Elstar, Fuji and Red Fuji (18 days), Spartan, Spurtype Red Delicious, Summerland (19 days), Hardeman, Jonadel, Arlet and Gala each took 20 days to pass through various stages of flower bud development. The period of flower bud development from initiation of growth to pink bud stage ranged from 16 to 22 days in different apple cultivars may be attributed to differential development of floral parts at the present site of cultivation.

Table 1. Flower bud development in apple pollinizers

Cultivars	Number of days required for passing from one stage to other						Total no. of days
	I	II	III	IV	V	VI	
Arlet	5	4	4	2	3	2	20
Elstar	6	3	2	3	2	2	18
Extercross	6	3	2	2	2	2	17
Fuji	4	4	4	2	2	2	18
Gala	5	4	3	3	3	3	21
Hardeman	5	4	3	3	3	2	20
Jonadel	6	5	3	2	2	2	20
Red Fuji	5	4	2	3	2	2	18
Royal Gala	4	5	4	4	2	3	22
Ruspippin	4	3	2	2	2	3	16
Spartan	4	5	2	3	3	2	19
Spurtype Red Delicious	6	3	3	2	3	2	19
Summerland	5	4	2	3	3	2	19
Mean	5	3.9	2.8	2.6	2.5	2.2	19

The difference in flower bud development period may also be due to the genetic make-up of the individual which appear to be a principal factor in controlling flower bud development. Besides environmental factors like temperature, rainfall, relative humidity may directly or indirectly, singly or collectively could have played an important role during flower bud development period. Six stages of flower bud development have also been reported by Bist (1985) and Kumar (1988) in different apple cultivars, whereas Tamura *et. al.* (1987) reported seven stages of flower bud development in Spartan cultivar of apple.

Time and Duration of flowering: From the data given in Table 2, it is evident that cultivars taken for study flowered at different time i.e. 15th March to 27th March. Cultivar Elstar was the first to come in flowering (15th March), followed by Spurtype Red Delecious on 19th March whereas Arlet was the last to come into flowering (27th March). Cultivar Elstar attained peak flowering in a short period of seven days. From the data it is revealed that the cultivars Elstar, Joandel, Spartan and Spurtype Red Delicious had the longest flowering period of 19 days followed by Red Fuji and Summerland (18 days). Cultivars Arlet, Extercross, Fuji and Royal Gala had the shortest flowering period of 16 days each. The total duration of flowering ranged from 16 to 19 days in different cultivars and all the cultivars attained full bloom within 11-14 days after start of flowering. The variation in date of start of flowering may be due to their genetic make-up as well as agro-climatic conditions. Variation in duration of flowering between different cultivars may be attributed to differential development of floral parts in various cultivars. Zhu *et. al.*(1997) studied the effect of temperature on apple flower bud formation and found that temperature (13-20°) significantly influenced the flower bud formation. Similar observations on role of temperature in the bud development before blossoming in Cox's Orange Pippin has been observed by Tromp and Romar (1987), which resulted in the extension of full bloom period over a period of 30-40 days. The mean duration of flowering under the present studies was 17.46 days which is in line with the findings of Blazek *et. al.* (1983). Kumar (1996) also reported flowering period of 15-18 days in 1994 and 12-19 in 1995 in different apple cultivars. The flowering period of cultivar Jonadel (pollinizer) overlapped with the flowering period of cultivars Red Fuji, Royal Gala and Gala. Similarly Spartan and Ruspippin cultivars overlapped with Arlet and Summerland on the basis of peak flowering period.

Table 2. Time and duration of flowering in some apple pollinizers

Cultivars	Start of Flowering	Peak Flowering	Date of opening last flower	Total flowering days
Arlet	27/03	06/04	11/04	16
Elstar	15/03	27/03	02/04	19
Extercross	22/03	01/04	06/04	16
Fuji	20/03	31/03	04/04	16
Gala	24/03	03/04	09/04	17
Hardeman	20/03	31/03	05/04	17
Jonadel	21/03	03/04	08/04	19
Red Fuji	21/03	02/04	10/04	18
Royal Gala	24/03	04/04	10/04	16
Ruspippin	23/03	02/04	08/04	17
Spartan	26/03	08/04	13/04	19
Spurtype Red Delicious	19/03	31/03	07/04	19
Summerland	25/03	05/04	11/04	18
Mean	-	-	-	17.46

Flower morphology: From the Table 3 it is seen that the maximum number of flowers (5.80) per bud was recorded in Fuji and the lowest (5.00) in cultivars Arlet, Hardeman, Red Fuji and Spurtype Red Delicious. On an average each cultivar had 5.21 flowers per bud. Cultivar Fuji was significantly different from other cultivars. Cultivars Gala ((5.40), Spartan (5.40), Elstar (5.30), Jonadel (5.30), Ruspippin (5.00) were statistically similar in respect of flower per bud. Cultivars Extercross (5.10), Summerland, Royal Gala, Arlet and Red Fuji were statistically at par

with each other. The highest number of stamens were recorded in cultivars Arlet, Red Fuji and Spartan (20.00) while Elstar and Summerland had lowest number of stamens (13.67), Each cultivar on an average had 18.26 stamens per flower. Cultivars Extercross, Hardeman, Jonadel, Ruspippin, Royal Gala, Gala and Fuji were statistically at par with each other. The observations in respect of sepal morphology revealed that on an average the sepal length of all the cultivars under study was 0.67 cm. The cultivars Arlet and Spartan had the maximum sepal length (0.82 cm) and were statistically at par with Jonadel (0.76 cm), whereas, the shortest sepal length was observed in cultivar Royal Gala (0.55 cm) and Fuji (0.56 cm). Cultivars Extercross (0.69 cm), Hardeman, Red Fuji and Summerland were statistically at par with each other.

Table 3. Flower morphology of apple cultivars

Cultivars	Flowers per bud	Stamen number	Sepal Length (cm)	Pistil number	Pistil length (cm)	Stamen length (cm)
Arlet	5.00	20.00	0.82	5	0.63	0.56
Elstar	5.30	13.67	0.61	5	0.69	0.61
Extercross	5.10	19.67	0.69	5	0.66	0.57
Fuji	5.80	18.33	0.56	5	0.77	0.78
Gala	5.40	18.33	0.59	5	0.78	0.58
Hardeman	5.00	19.33	0.68	5	0.73	0.61
Jonadel	5.30	19.33	0.76	5	0.93	0.81
Red Fuji	5.00	20.00	0.69	5	0.88	0.59
Royal Gala	5.10	19.00	0.55	5	0.63	0.69
Ruspippin	5.20	19.33	0.62	5	0.80	0.62
Spartan	5.40	20.00	0.82	5	1.36	1.37
Spurtype Red Delicious	5.00	16.67	0.60	5	0.71	0.63
Summerland	5.10	13.67	0.68	5	1.06	0.69
Mean	5.21	18.26	0.67	5	0.82	0.70
CD (P=0.05)	0.22	1.75	0.06		0.14	0.06

Figures within parenthesis are transformed values

In all the cultivars, the numbers of pistils were five per flower. Maximum pistil length was recorded in cultivar Spartan (1.36 cm) and shortest in cultivars Arlet and Royal Gala (0.63 cm). Cultivars Jonadel and Summerland were statistically at par with each other and rest of the cultivars were also at par each other. The stamen length in the cultivars ranged between 0.56 to 1.37 cm. The cultivars Spartan had the longest stamens (1.37 cm) and was significantly different from other cultivars whereas shortest stamens were recorded in cultivar Arlet (0.56 cm). Cultivars Royal Gala and Summerland were statistically at par with each other. Cultivars Summerland, Ruspippin, Elstar, Hardeman, Red Fuji and Gala were also statistically at par with each other. The flower morphology in the present investigation confirmed to the standard systematic description of sub family pomoideae universally. The flower characteristics are largely stable characters compared to the morphological characters which are more prone to variation. The number of pistils, petals and sepals in sub family pomoideae are five, the study also confirmed the above observation. The average number of flowers per bud ranged between 5.00 to 5.80, sepal length varied between 0.55 to 0.82 cm and stamen length from 0.56 to 1.37 cm in the cultivars studied and the observations are in accordance with the findings of Kumar (1988).

Anthesis

During anthesis, the outer scales were found to be loosened on account of the developing calyx in all the cultivars. Due to the pressure exerted by the developing corolla, the calyx segments and the buds gradually separated out. A day before anthesis, the petals were folded but on the day of anthesis these started separating out from each other and anther and stigma became visible from the top. The king/central flower of the inflorescence/floral cluster in the axis was the first to open in all the cultivars under study. Flower buds for studying anthesis were marked on day prior to anthesis at 6:00 PM and the flowers opened between 6:00 PM to 8:00 AM were recorded at 8:00 AM on the next day. There after

the observations on anthesis was recorded at two hours interval. It was observed that maximum anthesis (30.09%) occurred between 12:00 noon to 2:00 PM followed by 24.78 % between 10:00 AM to 12:00 noon.

Table 4. Percentage of anthesis in some apple cultivars at two hours interval

Cultivars	Percentage of Flowers opened between					
	6 – 8 AM	8–10 AM	10AM-12 noon	12 – 2 PM	2 – 4 PM	4 – 6 PM
Arlet	8.66 (2.94)	10.94 (3.30)	22.93 (4.78)	31.92 (5.64)	9.37 (3.06)	6.84 (2.58)
Elstar	7.33 (2.70)	10.79 (3.28)	21.68 (4.65)	32.25 (5.67)	10.74 (3.26)	10.35 (3.21)
Extercross	6.66 (2.57)	10.71 (3.26)	21.65 (4.64)	26.54 (5.15)	8.63 (2.93)	6.48 (2.48)
Fuji	8.00 (2.81)	13.04 (3.61)	27.42 (5.22)	26.41 (5.13)	9.37 (3.06)	8.59 (2.90)
Gala	12.67 (3.55)	15.25 (3.90)	22.52 (4.74)	24.43 (4.94)	9.23 (3.03)	6.84 (2.58)
Hardeman	6.00 (2.42)	10.68 (3.25)	31.71 (5.61)	33.91 (5.81)	8.59 (2.91)	5.82 (2.41)
Jonadel	10.00 (3.15)	13.36 (3.64)	30.95 (5.54)	31.97 (5.65)	9.25 (3.04)	6.08 (2.46)
Red Fuji	11.33 (3.34)	15.77 (3.96)	24.07 (4.90)	27.32 (5.22)	11.51 (3.37)	9.35 (3.01)
Royal Gala	8.66 (2.94)	13.15 (3.61)	20.12 (4.48)	33.21 (5.75)	10.75 (3.26)	7.92 (2.79)
Ruspippin	12.00 (3.45)	15.16 (3.89)	22.35 (4.72)	25.31 (4.81)	11.34 (3.36)	7.96 (2:79)
Spartan	12.67 (3.54)	14.55 (3.80)	23.15 (4.81)	33.81 (5.81)	10.59 (3.25)	5.92 (2.43)
Spurtype Red Delicious	13.33 (3.60)	15.46 (3.92)	27.88 (5.28)	31.68 (5.62)	8.63 (2.91)	5.79 (2.40)
Summerland	12.67 (3.55)	14.52 (3.80)	25.78 (5.05)	32.48 (5.69)	10.72 (3.27)	6.13 (2.47)
Mean	10.00 (3.12)	13.34 (3.63)	24.78 (4.95)	30.09 (5.46)	9.90 (3.13)	7.16 (2.63)
CD (P=0.05)	3.64 (0.57)	3.16 (0.44)	5.95 (2.69)	5.15 (0.46)	3.24 (0.52)	3.89 (0.71)

Figures within parenthesis are transformed values

The magnitude of anthesis before 10:00 AM (10.00 %) and after 2:00 PM (9.90 %) was rather low in all the cultivars. The percentage of anthesis in most of the cultivars increased gradually from 8:00 AM to 2:00 PM after which it declined. Maximum percentage of anthesis at 12:00 noon to 2:00 PM was found in cultivar Hardeman (33.91%) and minimum was found in cultivar Gala (24.43%). The anthesis observed between 6:00 to 8:00 AM in the cultivars Spurtype Red Delicious. Gala, Spartan, Summerland, Ruspippin, Red Fuji and Gala did not differ much and were statistically at par with each other. Cultivars Red Fuji, Spurtype Red Delicious, Gala, Ruspippin, Spartan, Summarred, Joandel, Royal Gala and Fuji were at par between 8:00 to 10:00 AM and maximum anthesis during the recorded period was observed in cultivar Red Fuji (15.77%) followed by Spurtype Red Delicious (15.46%). The mean anthesis between 12:00 noon to 2:00 PM was highest in cultivar Hardeman (33.91%) and least anthesis was seen in cultivar Gala (24.43%). In cultivars Arlet, Jonadel, Spurtype Red Delicious the anthesis during this period was almost same. The low rate of anthesis was recorded in the morning hours and it was maximum (30.09%) between 12:00 noon to 2:00 PM. Kumar (1988) and Kumar (1996) also found gradual increase in percent anthesis from 8 AM to 2 PM after which it declined in all the cultivars. According to Singh and Dhuria (1960), the rate and time of anthesis was found to vary in different fruits and are influenced by temperature and relative humidity.

Dehiscence: The dehiscence was seen to take place only after the flowers had opened completely in all the cultivars. During dehiscence the anther lobes started splitting. The bursting of the anther lobes started from the top and gradually extended towards the base. Once the anther splitting was complete a yellow powdery mass of pollen grains was seen on the anther lobes. The dehiscence was random i.e. any anther could dehisce first. From

the data presented in table 5, it is seen that dehiscence in all the cultivars increased gradually from 8:00 AM to 12:00 noon, after which it gradually decreased.

Table 5. Percentage of anther dehisced at two hours interval

Cultivars	Percentage of anther dehisced between				
	8-10 AM	10AM-12 noon	12 noon-2 PM	2-4 PM	4-6 PM
Arlet	10.67 (3.24)	22.46 (4.73)	23.97 (4.89)	11.42 (3.37)	8.59 (2.93)
Elstar	8.66 (2.94)	25.58 (5.05)	24.61 (4.95	11.75 (3.42)	8.89 (2.97)
Extercross	7.33 (2.70)	29.52 (5.42)	27.32 (5.22)	8.57 (2.92)	8.30 (2.87)
Fuji	12.67 (3.55)	26.49 (5.14)	25.76 (5.07)	15.28 (3.90)	9.84 (3.13)
Gala	8.66 (2.94)	19.99 (4.46)	21.48 (4.62)	12.97 (3.59)	8.13 (2.85)
Hardeman	12.67 (3.55)	30.76 (5.54)	27.78 (5.26)	16.66 (4.07)	10.92 (3.30)
Jonadel	9.33 (3.04)	25.73 (5.06)	24.73 (4.97)	11.69 (3.41)	8.83 (2.97)
Red Fuji	11.33 (3.63)	30.07 (5.48)	26.09 (5.10)	12.69 (3.56)	9.70 (3.11)
Royal Gala	9.33 (3.04)	28.39 (5.31)	26.03 (5.09)	12.69 (3.55)	10.74 (3.26)
Ruspippin	14.67 (3.81)	26.54 (5.14)	24.49 (4.94)	17.45 (4.17)	10.58 (3.25)
Spartan	11.33 (3.33)	30.90 (5.55)	23.60 (4.58)	16.14 (4.01)	12.28 (3.48)
Spurtype Red Delicious	8.66 (2.94)	33.59 (5.79)	28.68 95.34)	13.93 (3.72)	10.80 (3.28)
Summerland	11.33 (3.34)	33.03 (5.74)	27.97 (5.28)	14.28 (3.76)	12.48 (3.51)
Mean	10.51 (3.23)	27.92 (5.26)	25.57 (5.02)	13.50 (3.65)	10.00 (3.14)
CD (P=0.05)	3.87 (0.57)	4.64 (0.44)	3.66 (0.36)	2.93 (0.39)	2.43 (0.35)

Figures within parenthesis are transformed values

On an average, highest percentage of dehiscence was recorded from 10:00 AM to 12:00 noon (27.92%), followed by 25.57 % between 12:00 non to 2:00 PM. The highest percentage of dehiscence was observed in cultivar Surtype Red Delicious (33.59%) between 10.00 AM to 12:00 noon followed by Summerred (33.03%) in the same time period. Cultivars Ruspippin, Fuji, Hardeman, Red Fuji, Spartan and Summerred were statistically at par with each other in respect of percent dehiscence between 8:00 AM to 10:00 AM. The percent dehiscence in cultivars Spurtype Red Delicious, Summerred, Spartan, Hardeman, Red Fuji and Extercross was also same and did not differ statistically between 10:00 AM to 12:00 noon. The rate of anther dehiscence was recorded to be higher between 10 AM to 12 noon. Further dehiscence started only after complete flower opening in all the cultivars. The percentage of dehiscence was low initially but by mid day it reached a peak and decreased slightly from 12 noon to 2 PM and thereafter it declined rapidly upto 6 PM. Similar dehiscence pattern has been reported by Kumar *et al.* (1999).

References

Annonymous 2001. Directorate of Horticulture. Govt. of Himachal Pradesh, Shimla.

Bist HS 1985. Studies on flowering, pollination and fruit set in low chilling cultivars of apple (*Malus domestica* Borkh.). M Sc Thesis submitted to HPKVV, College of Agriculture, Solan (unpublished).

Blazek J, Paprstein F and Kucera J 1983. Flowering phenology of apple cultivars. Vedecke Praceovocnsrske 9:101-02.

Kumar S 1988. Studies on flowering, pollination and fruit set in some new introduction of apple. M Sc Thesis submitted to Dr YS Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh (unpublished).

Kumar R 1996. Studies on hybridization in apple (*Malus* × *domestica* Borkh.). Ph D Thesis submitted to Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh (unpublished) .

Kumar R, Sharma RL and Walia DP 1999. Evolution of cross compatibility/incompatibility in cross among six apple cultivars. J. Hill Res. **12** (2):126-29.

Luckwill LC 1974. Control of growth and fruitfulness of apple trees. *In*: Physiology of tree crops (eds. Luckwill LC and Cutting CV). Academic Press, London, New York. pp. 239-54.

Singh JP and Dhuria HS 1960. Studies on floral biology of sweet lime. Indian J. Hort. 6:258.

Slor E 1982. Slor, a new subtropical apple cultivar. Hassadeh **62** (9):1580-82.

Tamura T, Hirata Y, Suzuki T, Imakawa S and Fuhui H 1987. Diameter of flower primordial as an indicator of the differentiation of developmental stages of apple flower primordial. *Memoris of the Faculty of Agriculturae Hokkaido University.* 15(2):152-158 (Hort. Abst. **57**:6217).

Tromp J and Romar CAR 1987. Temperature and fruit set in apples. Fruittlett. **77** (1):24-26.

Zhu LH, Barsboom O and Tromp J 1997. The effect of temperature on flower bud formation in apple formation in apple including some morphological aspects. Scientia Horticulturae **70** (1):1-8.

VIR SOFTECH