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Floral Phenology Investigation of Exotic Apple Cultivars under Shopian District of Jammu and Kashmir

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ABSTRACT

The present investigation was conducted by Division of Fruit Science, SKUAST-Kashmir at Advanced Centre for Horticulture Development Zainapora, Shopian Jammu and Kashmir during 2012 and 2013 on floral phenology investigation of exotic apple cultivars to identify the varieties which bloom early, or mid-season and last. During the studies, 1st set of varieties Red Gravenstein, Braeburn and Ginger Gold recorded advanced pink bud (32.65,34.06 and 34.04 DARD), full bloom (45.70, 47.85 and 47.79 DARD), duration of flowering (16.57, 16.52 and 15.70 DARD), diameter of flower (4.76, 4.78 and 4.08cm), complete petal fall (55.65,58.52 and 57.20 DARD), flower colour (Whitish, Pinkish white and Whitish), pollen germination (51.43, 74.47 and 72.54) and pollen viability (54.75, 83.41and 68.20) respectively. The 2nd set of genotypes i.e. Gala Must, Royal Gala, Scarlet Spur, Oregon Spur, Golden Delicious and Red Gold noticed pink bud, full bloom, duration of flowering, diameter of flower and petal fall after 1st set. The 3rd set of cultivars i.e. Law Red Rome and Early Red One were found to show these stages later than earlier sets.

Key words: *Apple Pollination, Exotic Genotypes, Pollen Compatibility.*

INTRODUCTION

The productivity of apple in Jammu and Kashmir is 8.57 metric tons per hectare, when it is compared with the productivity of developed nations of the world, this figure is very low and there is plenty of difference in the productivity. In order to curtail this gap a number of factors has to be reviewed seriously and address them priority wise. Over 7,500 apple cultivars are known and used not only for fresh consumption, but also for consumption as processed materials, such as juice, pie, or cider[8].

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Apple and apple products, including juices and extracts, have beneficial effects on Alzheimer's disease, bone health, cognitive decline during normal aging, diabetes, and gastrointestinal protection from drug injury[13]. Apple is the most produced fruits in temperate climate areas and is expanding into subtropical and tropical areas[6]. However, recent global climate changes manifested in rising temperatures and late frosts in the flowering season caused poorer coloring of apple fruit skin and frost damage to pistils[30]. The central flowers had an intense but short stigmatic activity, whereas lateral flowers had a discrete but much longer stigmatic activity[18]. As apple (*Malus domestica*) shows gametophytic self and cross-incompatibility, and at least two genetically distinct cultivars are necessary for stable apple production. Therefore, pollination is an important and inseparable component in respect of regular and consistent production. In a fruit crop like apple, pollination is of utmost significance and its proportion and magnitude is primarily based upon appropriate selection of varieties[7]. The viability, tube growth and morphological homogeneity related to pollen quality are the most important properties in fruit trees. These properties are useful for plant breeders, geneticists, researchers, development departments and growers[5].

Apple industry of Jammu and Kashmir State got revolutionized with the introduction of Delicious group, which accounts for about 60 per cent of the total apple production. Fruit industry has become back bone of rural economy and nearly four million people are directly or indirectly involved with this industry, but due to the monoculture, economic returns of the growers have not grown as per their expectations. Therefore, stress is being laid on increasing the compatible varietal spectrum of fruit crops particularly apple. Lately State Horticulture Department has introduced some exotic cultivars of apple which are in bearing at "Advanced Centre for Horticulture Development Zainapora, Shopian" Jammu and Kashmir, India. Some of these newly introduced varieties have been found to hold promise in terms of productivity, quality and performance under valley conditions. The State Horticulture Department has now started supplying the planting material of these varieties to the farmers of the valley without knowing the pollination status of these Washington brought varieties. So it was the need of the hour to verify the pollination aspect of these varieties.

MATERIALS AND METHODS

The present investigation entitled "Floral phenology investigation of exotic apple cultivars under Shopian District of Jammu and Kashmir" was conducted at 'Advanced Centre for Horticulture Development Zainapora, Shopian Jammu and Kashmir during 2012 and 2013. Full bearing exotic apple cultivars spaced at 4m x 4m distance, uniform in age were selected for experimentation in apple orchard. All recommended package of practices for apple cultivation were followed as per schedule. Single tree in each variety constituted an experimental unit and each cultivar was replicated three times. The eleven genotypes used were Gala Must, Royal Gala, Early Red One, Law Red Rome, Scarlet Spur, Oregon Spur, Braeburn, Ginger Gold, Red Gravenstein, Golden Delicious and Red Gold. The phenological stages were observed visually like, date of advanced pink bud stage (when the buds appeared fully pink coloured), date of full bloom (when about 80-90% of flowers were open), the duration of flowering was worked out as the period (days) between the advanced pink bud and end of flowering, diameter of flower (diameter of the flower was measured in centimeters (cm) with a measuring scale), date of complete petal fall (This stage was observed visually when 90% of flowers showed petal fall), and in each tagged tree of each cultivar under study for both the years. The dates thus recorded were converted to days after reference date (DARD) fixed arbitrarily as 1st March. Flower colour was observed visually and recorded when experimental unit exhibited 100 per cent of open flowers. Freshly dehisced pollen grains were used for *in vitro* pollen germination and

pollen tube growth was observed for each genotype under microscope after 24 hours of incubation period at 22±2°C.Then pollens were left for 1 hour for staining and examined under microscope. For *in vitro* pollen viability analysis, Acetocarmine solution was prepared and pollens were left for one hour for staining and examined under microscope. The experiment was laid in randomized block design with eleven treatments and three replications. For statistical analysis Randomized Block Design was followed and cultivars were considered as variants. The observations recorded were subjected to statistical analysis as per the method of Analysis of Variance[11]. The significance and non-significance of the treatment effects were judged with the help of 'F' variance ratio test against the critical difference at 5% level.

RESULTS

Date of advanced pink bud

It is evident from the table-1 that maximum number (49.59 and 48.23 DARD) of days to reach the advanced pink bud stage noticed in the cultivar Law Red Rome followed by Early Red One (44.72 and 42.15 DARD) during 2012 and 2013 respectively. The minimum number (33.44 and 31.86 DARD) observed with Red Gravenstein, which was statistically at par with Ginger Gold (35.32 and 32.76 DARD) during the course of investigations.

Date of full bloom

Perusal of the data related to full bloom stage cited in table-2 indicates that the cultivar Red Gravenstein took minimum number of 46.23 and 45.18 DARD to attain this stage during the years 2012 and 2013 respectively as compared to other cultivars. The maximum number of 59.69 and 59.52 DARD to reach this stage noticed in Law Red Rome during the years 2012 and 2013, respectively.

Duration of flowering

It is evident from table-3 that minimum number (10.86 DARD) was required by cultivar Law Red Rome to complete its flowering followed by Early Red One (11.91 DARD) and maximum number (17.03 DARD) by Braeburn as against other varieties. During 2013, the minimum number of days 12.56 recorded in Law Red Rome followed by Royal Gala (13.19 days) and Gala Must (13.85 days). The cultivar Red Gravenstein took appreciably more number of days (16.48) followed by Braeburn and Ginger Gold (16.02 and 15.20 DARD) during 2013.

Diameter of flowering

The largest size of the flower recorded in the cultivar Red Gold with diameter of 5.23cm followed by 5.06cm in Golden Delicious, which was at par with 5.03cm as recorded in Gala Must during the first year of study. However, the minimum size of the flower (4.13cm diameter) noticed in Scarlet spur, which was at par with 4.16cm diameter as noticed in Ginger Gold during 2012 year (table-4). The largest diameter of the flower (5.30cm) recorded in Red Gravenstein during 2013 followed by 5.13cm in Golden Delicious and Gala Must (5.06cm), the minimum diameter (4.00cm) of the flower recorded in Ginger Gold followed by Scarlet spur 4.13cm.

Date of complete petal fall

The recorded data revealed minimum number (57.49 DARD) taken by the cultivar Red Gravenstein to reach the final petal fall stage followed by Ginger Gold (59.28 DARD) during 2012 (Table-5) and similar trend was recorded in second year of study also**.** The maximum number (71.35 DARD) was taken by cultivar Law Red Rome to attain this stage followed by Early Red One (67.01 DARD) during first year of study and similar pattern of observations was registered during 2013 also.

Flower Colour

It is pertinent to mention here that varieties like Gala Must, Royal Gala, Law Red Rome, Oregon Spur, Braeburn, Red Gold and Golden Delicious were observed (Table-6) to have pinkish white flowers, whereas whitish coloured flowers were noticed in other varieties like Early Red One, Scarlet spur, Ginger Gold and Red Gravenstein during the years of study.

Pollen Germination

The maximum pollen germination (85.92 and 88.17%) percentage recorded in Golden Delicious followed by Red Gold (80.18 and

85.03%) during the years 2012 and 2013 respectively (Table-7). The minimum pollen germination (50.80 and 52.07%) percentage was observed in Red Gravenstein followed by Scarlet spur (63.43 and 66.07%), during both the years of study.

Pollen Viability

The highest pollen viability 86.10 and 89.73 per cent was noticed in cultivar Golden Delicious followed by 85.15 and 86.94 per cent in the Red Gold cultivar during both the years. The lowest pollen viability 52.84 and 56.66 per cent recorded in Red Gravenstein followed by 65.50 and 68.39 per cent in Scarlet spur cultivar during 2012 and 2013, respectively (Table-8). The pooled data was also in consonance with yearly observations presented above.

Table-1: Advanced pink bud stage of exotic apple cultivars

Genotypes	Days After Reference Date (DARD*)		Pooled
	2012	2013	
Gala Must	41.51	38.83	40.17
Royal Gala	41.78	39.18	40.48
Early Red One	44.72	42.15	43.43
Law Red Rome	49.59	48.23	48.91
Scarlet Spur	41.10	38.04	39.57
Oregon Spur	42.37	38.03	40.20
Braeburn	35.37	32.76	34.06
Ginger Gold	35.32	32.76	34.04
Red Gravenstein	33.44	31.86	32.65
Golden Delicious	41.39	38.65	40.02
Red Gold	40.45	38.14	39.29
CD(5%)	**0.99**	**0.84**	**0.63**
(DARD*) Fixed Arbitrarily as 1st March (2012 & 2013)			

Table-2: Full bloom stage of exotic apple cultivars

Genotypes	Days After Reference Date (DARD*)		Pooled
	2012	2013	
Gala Must	53.33	50.08	51.71
Royal Gala	52.14	49.10	50.62
Early Red One	53.79	54.85	54.82
Law Red Rome	59.69	59.52	59.61
Scarlet Spur	53.37	51.02	52.19
Oregon Spur	53.79	50.33	52.06
Braeburn	49.08	46.62	47.85
Ginger Gold	48.81	46.78	47.79
Red Gravenstein	46.23	45.18	45.70
Golden Delicious	52.03	50.02	51.02
Red Gold	53.80	50.15	51.97
CD(5%)	**3.76**	**1.63**	**1.84**
(DARD*) Fixed Arbitrary as 1st March (2012 & 2013)			

Table-3: Duration of flowering of exotic apple cultivars

Genotypes	Days After Reference Date (DARD*)		Pooled
	2012	2013	
Gala Must	13.99	13.85	13.92
Royal Gala	13.80	13.19	13.85
Early Red One	11.91	13.95	12.93
Law Red Rome	10.86	12.56	11.71
Scarlet Spur	14.08	15.04	14.56
Oregon Spur	12.91	15.01	13.96
Braeburn	17.03	16.02	16.52
Ginger Gold	16.21	15.20	15.70
Red Gravenstein	16.67	16.48	16.57
Golden Delicious	13.99	13.86	13.92
Red Gold	14.97	14.43	14.70
CD(5%)	**1.02**	**1.72**	**0.96**
(DARD*) Fixed Arbitrary as 1st March (2012 & 2013			

Table-4: Flower diameter of exotic apple cultivars

Genotypes	2012	2013	Pooled
Gala Must	5.03	5.06	5.05
Royal Gala	4.43	4.73	4.58
Early Red One	4.86	4.66	4.76
Law Red Rome	4.66	4.73	4.70
Scarlet Spur	4.13	4.13	4.13
Oregon Spur	4.63	4.86	4.75
Braeburn	4.76	4.80	4.78
Ginger Gold	4.16	4.00	4.08
Red Gravenstein	4.23	5.30	4.76
Golden Delicious	5.06	5.13	5.10
Red Gold	5.23	5.03	5.13
C D(5%)	**0.41**	**0.57**	**0.34**

Table-5: Complete petal fall of exotic apple cultivars

Genotypes	Days After Reference Date (DARD*)		Pooled
	2012	2013	
Gala Must	63.63	59.65	61.64
Royal Gala	63.73	59.29	61.51
Early Red One	67.01	63.90	65.46
Law Red Rome	71.35	69.17	70.26
Scarlet Spur	63.09	59.67	61.38
Oregon Spur	63.24	59.20	61.22
Braeburn	61.30	55.74	58.52
Ginger Gold	59.28	55.13	57.20
Red Gravenstein	57.49	53.82	55.65
Golden Delicious	64.19	58.92	61.55
Red Gold	63.96	59.33	61.64
C D(5%)	**0.97**	**1.24**	**0.76**
(DARD*) Fixed Arbitrary as 1st March (2012 & 2013			

Table-6: Flower colour of exotic apple cultivars

Genotypes	2012	2013
Gala Must	Pinkish White	Pinkish White
Royal Gala	Pinkish White	Pinkish White
Early Red One	Whitish	Whitish
Law Red Rome	Pinkish White	Pinkish White
Scarlet Spur	Whitish	Whitish
Oregon Spur	Pinkish White	Pinkish White
Braeburn	Pinkish White	Pinkish White
Ginger Gold	Whitish	Whitish
Red Gravenstein	Whitish	Whitish
Golden Delicious	Pinkish White	Pinkish White
Red Gold	Pinkish White	Pinkish White

Table-7: Pollen germination percentage of exotic apple cultivars

Genotypes	2012	2013	Pooled
Gala Must	74.79 (8.70)	75.98 (8.77)	75.38 (8.73)
Royal Gala	67.76 (8.29)	69.13 (8.37)	68.44 (8.33)
Early Red One	65.73 (8.16)	66.75 (8.23)	66.24 (8.19)
Law Red Rome	70.17 (8.43)	70.82 (8.47)	70.49 (8.45)
Scarlet Spur	63.43 (8.02)	66.07 (8.18)	64.75 (8.10)
Oregon Spur	64.29 (8.07)	67.68 (8.28)	65.98 (8.18)
Braeburn	73.46 (8.62)	75.48 (8.74)	74.47 (8.68)
Ginger Gold	71.78 (8.53)	73.30 (8.61)	72.54 (8.57)
Red Gravenstein	50.80 (7.19)	52.07 (7.28)	51.43 (7.23)
Golden Delicious	85.92 (9.32)	88.17 (9.44)	87.04 (9.38)
Red Gold	80.18 (9.00)	85.03 (9.27)	82.61 (9.14)
CD(5%)	**0.28**	**0.26**	**0.18**
Square root transformation values given in parentheses			

Table-8: Pollen viability percentage of exotic apple cultivars

Genotypes	2012	2013	Pooled
Gala Must	83.15 (9.17)	83.30 (9.18)	83.22 (9.17)
Royal Gala	76.89 (8.82)	79.72 (8.98)	78.31 (8.90)
Early Red One	73.80 (8.64)	77.14 (8.83)	75.47 (8.74)
Law Red Rome	75.79 (8.76)	76.06 (8.77)	75.93 (8.77)
Scarlet Spur	65.50 (8.15)	68.39 (8.32)	66.94 (8.24)
Oregon Spur	80.95 (9.05)	81.06(9.05)	81.01 (9.05)
Braeburn	82.16 (9.11)	84.67 (9.25)	83.41 (9.18)
Ginger Gold	67.20 (8.25)	69.21 (8.37)	68.20 (8.31)
Red Gravenstein	52.84 (7.33)	56.66 (7.59)	54.75 (7.46)
Golden Delicious	86.10 (9.33)	89.73 (9.52)	87.92 (9.42)
Red Gold	85.15 (9.28)	86.94 (9.37)	86.04 (9.32)
CD(5%)	**0.18**	**0.14**	**0.11**
Square root transformation values given in parentheses			

DISCUSSION

Date of advanced pink bud

Similar variations were recorded in the date of advanced pink bud with 'Red Gravenstein' exhibiting early advance pink bud at 32.65DARD and 'Law Red Rome' was the last (48.91DARD) to exhibit this stage. The differences in the phenological stages may be due to their genetic differences or the differential chilling requirements of these varieties may be the reason for such variations. Further these varieties may be different in their photo sensitivity and response to temperature resulting in such variations. These results are in consonance with the results of[12] who has reported that beginning of blooming depends highly on the site of cultivation. Beginning of bloom can be observed with highest accuracy which indicates the genetic differences among varieties the best. It was reported that high spring temperature causes shorter blooming period and main bloom takes only few days for the whole cultivar assortment[4].

Date of full bloom

Date of full bloom stage was observed first of all (45.70 DARD) in 'Red Gravenstein' and very late (59.61 DARD) in 'Law Red Rome'. The relative bloom time of the cultivar is the time a specific cultivar blooms compared to the chosen or standard cultivar. It was reported that during the 20 years period neither relative time of bloom nor the order of full bloom occurred at the same time in any two years[29].

Duration of flowering

In the present study the duration of flowering (advanced pink bud to end of flowering) ranged from 11.71 days in Law Red Rome to 16.57 days in Red Gravenstein. The results are in accordance with the findings of[3] who reported 17 days of flowering in apples. The duration of 10-17 days in different apple cultivars and suggested long flowering duration to be more useful as pollinizers[16].Similar observations were reported that the Quinte and Vista Bella flowered earliest and the Mantet and Mio flowered relatively late[20]. According to[26] and[27] flowering duration in apple ranged from 10-17 days in Himachal Pradesh. Flowering date and period varies according to cultivar aptitude as well as ecological and cultural conditions[9]. According to[14] an eight day difference existed in the blooming time of apple at 119 locations across Europe. The concept of bloom time can greatly vary over years at the same location and the length of bloom period was affected more by number of rainy days than the amount of rain[29].

Diameter of flowering

In the present study the diameter of flowers varied significantly between the varieties tested. The diameter of flowers in varieties like Red Gold, Golden Delicious and Gala Must was significantly larger in comparison to other varieties. Flower size being a genetic character varies from variety to variety within species. Reproductive success including fruit production increases with increase in inflorescence size[10]. It was found that visits per inflorescence, flowers visited per visit and visits per flower increases with the increase in inflorescence size[22]. The present studies therefore, substantiate the higher fruit set obtained in pollinations involving Red Gold, Golden Delicious and Gala Must as parents.

Date of complete petal fall

The final petal fall (55.65 DARD) was recorded first of all in the cultivar 'Red Gravenstein' and last of all (70.26 DARD) in 'Law Red Rome' variety. These differential results may be due to the different requirements of temperature, cultural practices followed and ecological conditions of the cultivars, as the average temperature during bloom period may affect the flowering duration. These results are in conformity with the findings of[9] who reported that beginning of flowering; full bloom and end of flowering were two weeks later during 2007 than 2006 year. Such divergent results might be due to the difference between the temperatures during early stage of vegetative development. Average temperature in March and April which is normal in flowering period of apple in research area was 7.3 and 11.9^{o}C in 2006 and 6.0 and 7.9^{o}C in 2007, respectively.

The differences in the phenological stages may be due to their genetic differences

or the differential chilling requirements of these varieties may be the reason for such variations. Further these varieties may be different in their photo sensitivity and response to temperature resulting in such variations. These results are in consonance with the results of[12] who has reported that beginning of blooming depends highly on the site of cultivation. Beginning of bloom can be observed with highest accuracy which indicates the genetic differences among varieties the best. It was reported that high spring temperature causes shorter blooming period and main bloom takes only few days for the whole cultivar assortment[4]. The stability of the blooming order of varieties in the case of 86 varieties for 20 years were investigated and pointed out that beginning of blooming never shows same trend even under similar circumstances[28]. According to him 10 years of observations can be informative but cannot define the place of a variety in the blooming order.

Colour of Flower

Red Gold variety with pinkish white flowers had large sized flowers with maximum diameter of 5.13cm whereas the flowers of Early Red One were smaller in size with 4.08cm diameter and whitish in colour**.** Flower colour furnishes visual attraction to the pollinators and therefore increases the chances of better pollination and fertilization. As per the report of[23] insect vision extends from ultraviolet (UV) to yellow orange and exhibit greater sensitivity to some specific colour range. Bumble bee (*Bombus*) and honeybees (*Apis sp*.) have trichromatic vision and so is the case in the moth, *Deilephia*. The hypothesis put forward by[15] that bees are able to recognize only yellow, blue green, blue and UV, and not the red colour.

Pollen Germination

The maximum pollen germination (87.04%) was recorded in 'Golden Delicious' and minimum (51.43%) was found in 'Red Gravenstein'. Pollen tube length at least diameter of pollen grain or twice the length of pollen grain was considered to be germinated. Pollen being a rich source of Auxin and Gibberellins which have been isolated from the pollen of a number of temperate fruit plants[17] and helps in pollen tube growth. The variations in pollen dehiscence, germination, viability and stigma receptivity may be due to the genetic differences between the cultivars or these may be because of some environmental conditions particularly temperature during the flowering period. These results are in conformity with the findings of[2] who reported that temperature is a basic factor for the control of environmental conditions and influences pollen grain germination and longevity. The cultivars/genotypes with high pollen germination percentage were not necessarily having high pollen tube length[24]. This phenomenon indicates genetic differences among the genotypes, reported by many researchers in different fruit cultivars species[1,21,25].

Pollen Viability

The highest pollen viability (87.92%) was observed in 'Golden Delicious' and lowest (54.75%) in 'Red Gravenstein'. The highest stigma receptivity (96.54%) was noticed in 'Braeburn' and lowest (69.94%) in 'Red Gravenstein'. Pollen viability and stigma receptivity indicate the fertility and fertilization ability of a specie/variety and are therefore considered essential features as for as reproductive capacity of a fruit crop is concerned. The pollen grain may have the capacity to germinate, but does not due to improper conditions. It may even germinate but not have the ability to fertilize an ovule because of some form of incompatibility. Sometimes, cultivars produce high quantity of pollens but not with high quality such as low pollen germination percentage or low pollen tube growth, some of the pollen may be sterile or not viable[19,31].

CONCLUSION

The research programme was conducted to overcome the monoculture of delicious group of apple varieties to enhance the varietal spectrum with quality produce and to reach with the developed nations in terms of apple productivity. It is possible only when farmers

will take care of time to time scientific interventions with emphasis on the recommendations of scholars, institutions or universities planting of compatible varieties, planting proper ratio of pollinizers in the orchards, Use of regular bearing, high yielding, scab resistant varieties and introductions from Horticulture advanced countries, knowledge of blooming time of varieties, varieties which bloom together or in sequence. Once the pollination status of these varieties is verified it will certainly change horticulture outlook in the state by enhancing the varietal spectrum in the public domain and mitigate the monoculture system in valley very soon. The assured increase in the production of horticulture produce will definitely show its impact on socio-economic conditions of the farmers dependent on this industry. It will help the state development department to cope up or abreast with the horticulture developed nations in terms of productivity and quality production.

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