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Growth, flowering and fruiting behaviour of different exotic apple cultivars under high density planting system

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ABSTRACT

Investigations on the flowering behaviour of thirteen exotic cultivars of apple grafted on M9 T337 rootstock under high density plantation having age of four years was conducted in the Experimental Farm of Division of Fruit Science, SKUAST-K, Shalimar campus (J & K) during the year 2021 and 2022. Observations were recorded on growth, foliage, phenological, flowering, fruiting and yield related parameters. Earliest silver tip stage (13th-15th March) was observed in Red Braeburn and Elstar whereas all the flowering parameters was earliest commenced in Red Braeburn and late flowering parameters were noticed in Golden Clone B and Fuji Zehn Aztec. Maximum duration of flowering was recorded in Golden Delicious Reinders (15.33 days) whereas minimum duration was observed in 10.33 days. Maximum bloom density was recorded in Mitch Gala (14.68) apple while Super Chief Sandidge apple exhibited lowest bloom density (2.47). Red Braeburn, Red Velox and Fuji Zehn Aztec registered maximum values for number of cluster per branch (24.24), number of flowers per cluster (5.56) and number of fruits per cluster (5.00), respectively. Golden Delicious Reinders registered maximum growth parameters viz. plant height (3.28 m) and trunk girth (28.94 cm) along with maximum yield (30.01 kg/plant) and yield efficiency (1.90 kg/cm^2) whereas Super Chief Sandidge recorded highest fruit set (91.97 %) and fruit retention (79.43 %). Overall, it was concluded that Red Braeburn and Golden Delicious Reinders performed best in terms of flowering and yield parameters.

Key words: Apple, high density, exotic cultivar, M9 T337 rootstock, flowering.

INTRODUCTION

Kashmir valley is bestowed with different agroclimatic conditions through nature which is favourable for apple cultivation and a strong comparative advantage in its production; although the productivity of apples in Jammu and Kashmir is 11.99 MT/ha (Anonymous, 1). However, this productivity was highest among the other apple producing states in the country; which is still far below than the advanced apple growing countries of the world viz. New Zealand (59.74) and Chile (50.88) and also the share of A-grade fruits in Kashmir is low. Low productivity is mainly attributed to the conventional methods of planting system, non-availability of quality planting material, incidence of insect, pest and diseases, biennial bearing nature of commercial cultivars (Thakur *et al.*, 15). Apart from these, still majority of apple production comes from the plantation grafted on seedling rootstocks in the UT of J and K and from a single monoculture of Red Delicious apple which is also one of the causes of low productivity. Due to the vigorous nature of seedling rootstock, only 278 plants are planted per hectare which also limits the productivity. With stagnation in productivity, alarming threat of imported fruits and hike in the land prices necessitates farmers to adopt high-density plantation for which shifting from vigorous rootstock to size controlling clonal rootstock is a prerequisite (Tworkoski and Fazio, 13).

High density planting is a modern method of fruit cultivation that involves close planting of fruit trees, permitting small or dwarf plants with modified canopy for improved light interception, distribution and ease in mechanised field operations (Mir *et al.*, 8). Due to the increased number of trees per unit area, they provide better yield and return per unit area. Modern orchard planting systems are based on higher tree densities ranging from 1000 to 6000 trees per hectare. From the last decade, establishment of new orchards under high density plantation is under progress at quantum rate in the valley with new varieties raised on clonal rootstock. In this series SKUAST-Kashmir, also introduced exotic apple varieties since 2011 on different clonal rootstocks and took initiative to assess these new varieties on their phonological and flowering behaviour. Study pertaining to flowering behaviour of exotic cultivars of apple has significant implications on the apple production. Flowering is a key developmental transition in plants that occurs

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between the vegetative and reproductive phases. The limited reports on the floral biology of these newly introduced apple cultivars in the valley prompted us to analyze the behaviour of this critical biological event among thirteen exotic apple cultivars introduced in Kashmir. In the present investigation, the performance of the thirteen imported cultivars of apple grafted on M9-T337 planted in 2017 was studied during 2021 and 2022 for different growth, foliage, flowering, fruiting and yield parameters.

MATERIALS AND METHODS

The present investigations were carried out in the Experimental Farm of Division of Fruit Science, SKUAST-Kashmir, Shalimar campus, Srinagar (J & K) for two consecutive year during the year 2021 and 2022. Four-year-old plants of thirteen exotic apple cultivars grafted on M9T337 rootstock were evaluated for their phonological, flowering and yield contributing characters. Plants were planted at a spacing of 1.0 × 3.0 m and experiment was laid out in Randomized Complete Block Design (RCBD) with three replications having one tree per replication.

The data on various vegetative growth parameters were recorded on visual basis, viz. silver tip stage was recorded when the flower buds started showing silvery appearance at the tips), green tip stage when the vegetative buds started emerging), tight cluster, pink bud stage was recorded when the top of the flower buds started showing pink colour, initial bloom date (10 % flower opens), full bloom date (about 80 % of flower opens), flowering duration (days taken from the date of initial bloom to the date of initial petal fall stage) and petal fall date (about 80 per cent of flowers shed petals). Bloom density was worked out as total number of blossoms divided by trunk cross sectional area in each tagged plant. The total number of clusters/branch (1.0 m), number of flowers/cluster and number of fruits/cluster under each replication and each treatment were counted and averaged. Plant height (m), plant spread (m) was measured with the help of measuring pole at the end of the season whereas trunk girth (cm) were measured with the help of vernier calliper. Leaf area (cm^2) was recorded in the month of August with leaf area meter. Fruit set and fruit retention were recorded as per standard methods (Westwood, 16). The fruits harvested from each replication and each treatment was recorded and average yield was expressed in kilogram per tree. Yield efficiency was calculated as suggested by Westwood (16).

$$\text{Yield efficiency (kg/cm}^2\text{)} = \frac{\text{Yield (kg) / tree}}{\text{Trunk cross-sectional area}}$$

Trunk cross sectional area was calculated as per standard formulae TCSA = $\text{girth}^2/4\pi$ given by Westwood (16). Data generated from the present experiment were computed, tabulated and was statistically analyzed as per the procedure given by Sahu (9). The level of significance was tested for different variable at 5 per cent level of significance.

RESULTS AND DISCUSSION

Significant variations were observed among different cultivars in achieving the different growth and floral stages from silver tip to petal fall stage (Fig. 1). Earliest (13^{th} - 15^{th} March) silver tip stage was recorded in Elstar and Red Braeburn followed by Super Chief Sandidge and Pinova (14^{th} - 16^{th} March) whereas green tip stage was earliest observed in Red Braeburn (18^{th} – 20^{th} March) which was closely followed by Elstar (19^{th} – 21^{st} March) and Decosta Robijn (21^{st} – 23^{rd} March). Tight cluster stage (26^{th} - 28^{th} March) and Pink bud stage (1^{st} - 3^{rd} April) was early commenced in Red Braeburn followed by Elstar (28^{th} – 30^{th} March & 3^{rd} - 5^{th} April) and Red Chief (3^{rd} – 5^{th} April). Red Braeburn also showed early initial bloom when 10 per cent of the flowers were opened i.e. on 7^{th} – 9^{th} April closely followed by Elstar and Red Chief i.e. on 8^{th} – 10^{th} April. Early full bloom i.e. when 80 per cent of the flowers were opened was observed in Red Braeburn and Red Chief (13^{th} – 15^{th} April) closely followed by Pinova (14^{th} – 16^{th} April). All the above observed stages viz. silver tip (23^{rd} – 25^{th} March), green tip (28^{th} – 30^{th} March), tight cluster (4^{th} – 6^{th} April), pink bud (9^{th} – 11^{th} April), initial bloom (14^{th} – 16^{th} April) and full bloom (20^{th} – 22^{nd} April) was commenced late in Fuji Zehn Aztec. Early and late petal fall was observed from 21^{st} -23^{rd} April (Red Braeburn and Red Chief) and 30^{th} April – 1^{st} May (Golden Clone B). Variations in phonological and flowering behaviour in the present study could be attributed to the genetic makeup of the genotype and difference in the chilling requirements of these cultivars (Sharma *et al.*, 10). Results obtained are in accordance with the earlier findings of Kumar and

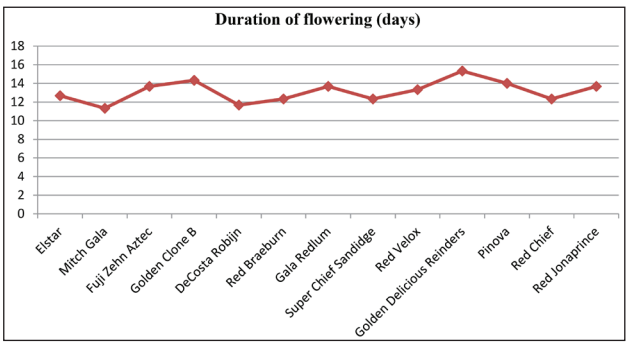

Fig. 1. Duration of flowering in different exotic apple cultivars.

Mir (5) and Wani *et al.* (14). Cultivars differences in photosensitivity and temperature response may also contribute to these discrepancies (Jindal and Mankotia, 3). Researchers also claimed that the start of the flowering period was significantly influenced by the cultivation site, cultivar, altitude, ecological and cultural conditions (Gray and Brady, 2).

Fig 2 depicts that the duration of flowering under the present study in different cultivars lasted for less than two weeks except Golden Clone B (14.33 days), Golden Delicious Reinders (15.33 days) and Pinova (14.00 days), however minimum number of days for duration of flowering was registered by Mitch Gala (11.33 days). Sharma *et al.* (11) also reported that flowering duration in apples ranged from 10 to 17 days under Himachal Pradesh conditions. Differences among varieties in flowering duration may also 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.

Significant results were obtained for all the flowering parameters and data was presented in Fig. 3. Bloom density was found highest in Mitch Gala (14.68) apple which shows statistically at par results with Red Jonaprince (11.69) whereas lowest bloom density was recorded in cultivar Super Chief Sandidge (2.47). High bloom density in Mitch Gala may be due to the fact that it had smaller TCSA as compared to other cultivars under study. Differences in bloom density among the cultivars may be due to the fact that some of the cultivars have alternate bearing or biennial bearing habit due to which their bloom density is high during on-year and low during the off- year. Also, cultivars with regular bearing habit have the tendency to bear profusely eg. 'Gala' group varieties due to which they have high bloom density (Toth, 12). Red Braeburn cultivar recorded maximum number of clusters per branch (24.24) which was statistically at par with Pinova (22.44) and Red Chief (21.83) however minimum number of clusters per branch was recorded in Super Chief Sandidge (8.50) (Fig. 1). Kwon *et al.* (6) also reported

Fig. 2. Phenological and flowering stages of different exotic apple cultivars.

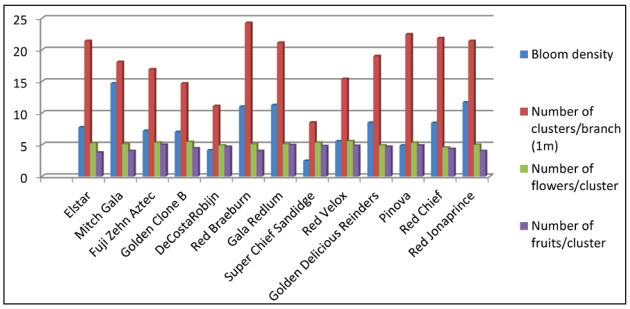

Fig. 3. Flowering parameters of different exotic apple cultivars.

more number of clusters per branch on dwarfing clonal rootstocks than semi-dwarf and seedlings/ vigorous rootstocks. Number of flowers/cluster ranged from 4.56 (Red Chief) and 5.56 (Red Velox) which was statistically at par with Golden Clone B (5.44) whereas number of fruits/cluster (at fruit set stage) varied from 3.78 (Elstar) to 5.00 (Fuji Zehn Aztec) which was statistically at par with Gala Redlum (4.94), Pinova (4.89) and Red Velox (4.83) among different cultivars in the present study. Differences in number of clusters/meter of branch, number of flowers/ cluster and number of fruits/cluster (at fruit set) studied in the present study among different cultivars may be due to genetic constitution of cultivars can be attributed to hormonal fluctuations and environmental interaction within the plant influencing these traits.

Significant results were obtained for all the studied growth and foliage parameters (Table 1). Pooled data of two years reported that Golden Delicious Reinders recorded maximum plant height (3.28 m) which also registered maximum trunk girth (28.94 cm) and both the parameters were statistically at par with Fuji Zehn Aztec (3.21 m and 27.67 cm) whereas minimum plant height and trunk girth was measured in Red Velox (2.80 m) and Mitch Gala (15.70 cm). Varietal character and genetic makeup of the scion cultivar are responsible for such differences in case of plant vigour. The superior plant vigour may be due to lower bloom density as clear from the (Fig. 1) as most of the metabolites were utilized for growth and vice-versa. Plant spread was measured maximum in Pinova (1.21 m) which was statistically at par with most of the cultivars under study, however minimum plant spread was recorded in Red Braeburn (1.03 m). Present results are in accordance with the previous results of Singh (13) and Sharma *et al.* (10) for various plant vigour parameters under high hill conditions and mid-hill conditions of Himachal Pradesh, respectively. Maximum leaf area (47.24 cm^2) was recorded for Pinova which was statistically at par with Fuji Zehn Aztec (44.66 cm^2) whereas minimum leaf area (19.65 cm^2) was recorded in Super Chief Sandidge.

Data pertaining to fruiting and yield is presented in Table 2 which indicates that there was a significant difference among all the studied cultivars. Super Chief Sandidge registered highest fruit set (91.97 %) and fruit retention (79.43 %) which was statistically at par with Golden Delicious Reinders (91.40 %), Golden Clone B (90.63 %) and DeCosta Robijin (90.32 %) in case of fruit set whereas Super Chief

Table 1: Growth and foliage parameters of different apple cultivars.

Parameters / Cultivars	Plant height (m)	Plant spread (m)	Trunk girth (cm)	Leaf area (cm^2)
Elstar	3.07	1.10	24.95	38.54
Mitch Gala	2.93	1.13	15.70	35.38
Fuji Zehn Aztec	3.21	1.21	27.67	44.66
Golden Clone B	3.08	1.13	25.64	37.85
DeCosta Robijn	2.90	1.15	16.75	43.36
Red Braeburn	3.03	1.03	20.71	31.11
Gala Redlum	3.12	1.15	24.11	20.52
Super Chief Sandidge	2.83	1.16	19.44	19.65
Red Velox	2.80	1.11	16.02	21.35
Golden Delicious Reinders	3.28	1.18	28.94	36.34
Pinova	2.96	1.21	18.95	47.24
Red Chief	3.10	1.15	22.54	22.52
Red Jonaprince	2.90	1.18	17.19	24.26
$CD_{0.05}$	0.16	0.11	1.40	2.68

Table 2: Fruit set and fruit retention percentage of different apple cultivars.

Parameters / Cultivars	Fruit set (%)	Fruit retention (%)	Fruit yield (kg/plant)	Yield efficiency (kg/cm^2)
Elstar	87.55	77.27	24.28	0.81
Mitch Gala	81.52	69.55	12.19	0.91
Fuji Zehn Aztec	88.00	74.71	26.94	1.60
Golden Clone B	90.63	75.20	18.35	0.92
DeCostaRobijn	90.32	67.61	16.48	0.60
Red Braeburn	83.46	71.99	11.80	0.90
Gala Redlum	85.27	75.91	21.24	1.62
Super Chief Sandidge	91.97	79.43	17.73	1.24
Red Velox	83.60	70.92	14.36	1.03
Golden Delicious Reinders	91.40	74.74	30.01	1.90
Pinova	85.79	73.50	21.25	1.52
Red Chief	80.35	66.18	19.53	1.39
Red Jonaprince	82.01	69.67	21.88	1.76
$CD_{0.05}$	2.83	1.43	3.20	0.55

Sandidge showed statistically higher results for fruit retention. Lowest fruit set (80.35 %) and fruit retention (66.18 %) was observed in Red Chief apple. Maximum fruit yield per plant (30.01 kg) was obtained in cultivar Golden Delicious Reinders and was statistically at par with Fuji Zehn Aztec (26.94 kg) however minimum fruit yield was obtained in cultivar Red Braeburn (11.80 kg/plant). Singh (13) also reported higher setting and retention of fruits in different apple cultivars under Kinnaur conditions of Himachal Pradesh. The fruit set and retention is affected by number of factors like genetic makeup of cultivars, i.e. self-compatible or self-incompatible, placement of pollinizer in an orchard, current climatic conditions at the time of flowering (Sharma *et al*., 11), closeness or farness from the compatible pollen source, bee activity, stigma receptivity, pollen germination, pollen tube growth, diploid or triploid nature of varieties, post bloom temperature and the fertilization process (Lata *et al*., 7). The reason for low fruit set could be the prevalence of self-incompatibility while in the present study set was higher as nature of cultivars were divergent and directly or indirectly may have promoted cross pollination that resulted in higher set. Yield efficiency was recorded highest in cultivar Golden Delicious Reinders (1.90 kg/cm^2) apple and was statistically at par with Red Jonaprince (1.76 kg/cm^2), Gala Redlum (1.62 kg/cm^2), Fuji Zehn Aztec (1.60 kg/cm^2), Pinova (1.52 kg/cm^2), Red Chief (1.39 kg/cm^2) whereas lowest yield efficiency was recorded in cultivar DeCosta Robijin (0.60 kg/cm^2) (Table 1). The higher a variety's yield efficiency, the higher will be its production, productivity and profit. Yield efficiency is a key determinant of tree's productivity (Kiprijanovski *et al*., 4) which is due to factors such as bearing habit, genetics, spur density, pollination, alternate bearing, hormonal fluctuations, environmental adaptability and other factors interacting with one another.

Overall results showed that cultivar Red Braeburn was earliest in the commencement of all the phenologcal and flowering stages followed by Elstar however Golden Delicious Reinders flowered for longer duration, better growth parameters and also gave maximum fruit set and fruit yield followed by Fuji Zehn Aztec.

AUTHORS' CONTRIBUTION

All the authors involved in this study contributed to the study design, fieldwork, and cartography works. Data analysis and interpretation of the data (GN, AK, AA, MKS and BD); Writing manuscript (GN).

DECLARATION

The authors declare that there is no conflict of interest.

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