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Performance of Plum (*Prunus salicina* L.) Genotypes in Subtropical North-Western India (Punjab)

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***Abstract*:** The present investigations were carried out at Punjab Agricultural University, Ludhiana during 2022-2023. Plants of seven plum genotypes were evaluated for their vegetative, flowering, fruiting, and yield characteristics. Maximum tree height and tree volume was in genotype Manake Lalri. Fruit maturity of existing cultivars of Punjab (Satluj Purple and Kala Amritsari) coincided with Frontier and Sharps Early. Genotype Sharps Early recorded maximum fruit set and high fruit retention. The time of harvesting of existing cultivars of Punjab - Satluj Purple and Kala Amritsari (pollinizer) almost coincided with genotypes Frontier and Sharps Early (1st fortnight of May). Apart from Kala Amritsari, other self-compatible genotypes were Sharps Early, Frontier, Manake Lalri, and Kataru Chak. Genotypes Frontier, and Manake Lalri exhibited freestone characteristic. Fruit yield was highest in Kala Amritsari followed by Satluj Purple, Frontier and Sharps Early. Fruit weight was maximum in Satluj Purple followed by Frontier and Sharps Early. Plum genotypes Sharps Early and Frontier are self-compatible, performed better than other genotypes in terms of maturity, yield and fruit quality and can be further evaluated under Punjab conditions.

Keywords: Plum, Genotypes, Self-compatible, *Prunus salicina*

The plum is an important stone fruit of temperate and sub-tropical regions of the world of Rosaceae family, sub family Prunoidea, order Rosales and genus *Prunus*. It ranks second to peaches in terms of economic importance, among all stone fruits (Vishnu et al 2012). It is a deciduous fruit crop, grown in areas having chilling cold winters and dry, hot summer season. There are 20-40 species of plum distributed in different parts of the world, but the main species of plum for commercial production are Japanese plum (*Prunus salicina* Lindl.) and European plum (*Prunus domestica* L.). These two species differ in their requirement of chilling hours and ploidy levels *viz*. the Japanese plum being diploid (2n=2x=16) and the European plum, hexaploid (2n=6x=48). The European plum is a diploid hybrid of *Prunus cerasifera* and *Prunus spinosa*. It thrives best at 1300-2000 m above mean sea level and requires 1000-2000 chilling hours during winter season. The center of origin of Japanese and European plum has been reported to be China and Asia minor, respectively. Major plum producing countries are China, European Union, USA, Serbia, Chile and Romania.Plum is usually a fruit crop of temperate region but it is being grown in both temperate and sub-tropical climate. Japanese plums are widely cultivated plum species in India. The fruits are an excellent source of vitamin K, C, A, minerals like potassium, antioxidants, dietary fibres and chemicals like tryptophan, quercetin and sorbitol, which regulate various body mechanisms and processes (Prajapati et al 2012). In India, it is commercially grown in warm temperate and and sub-tropical parts of Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Haryana and Punjab. Genotypes which require more than 300 chilling hours are commercially grown in temperate regions whereas those which require less than 300 chilling hours in the sub-tropical climate. In Punjab, sub-tropical plum is grown on area of 399 ha with an annual production of 7041 MT (Anonymous 2021). It is mainly cultivated in districts of Amritsar, Jalandhar, Gurdaspur, Hoshiarpur, Patiala and Kandi belt of Punjab. Plum cultivation in India and Punjab is gaining widespread popularity. It has become an important commercial fruit crop and its taste is cherished by consumers in fresh as well as processed form. Plum fruits are diverse in color, flavor, fruit size, aroma, and thus, is quite desirable in terms of fruit quality (Gonez-Pleza and Ledbetter 2010). The plum industry of Punjab is based on a single cultivar 'Satluj Purple'. It is self-unfruitful, low chilling and an early ripening variety which comes into the market when other fruits are scarce. There is a need to introduce new genotypes to break the monoculture of single variety of plum in the state. Plant introduction is an efficient method of plant breeding. Thus, screening and evaluation of germplasm on the basis of various morphological and physiological characteristics is an important step in introduction of a new variety. Newly introduced genotypes do not perform well until their performance, and character attributes are studied keenly under their new habitat and climate. Varietal characteristics such as fruiting behaviour, growth habits, yield characters, flowering behavior of any cultivar may depend on soil, climate, water table, rainfall, atmospheric parameters like temperature and humidity. Thus, performance of a variety may vary from one state to another depending on agro-

climatic conditions. This study is conducted in order to find out one or more genotypes which may perform well in terms of quality and yield parameters under Punjab conditions.

MATERIAL AND METHODS

The study was conducted on 9 years old, uniform trees of seven plum genotypes viz. Sharps Early, Frontier, Manake Lalri, Kataru Chak, Yellow Alubokhara, Satluj Purple and Kala Amritsari at, Punjab Agricultural University, Ludhiana, Punjab during the year 2022. Four trees planted at a spacing of 5×5m, per genotype were selected to serve as four replications. The university is situated at a latitude and longitude of 30º 90'N and 75º 80'E, respectively at an elevation of 244 m above mean sea level. The sub-tropical region provides 733 mm rainfall along with 250 to 300 chilling hours to plum trees annually. The maximum temperature rise is observed in the months of May-June (≥45ºC) while the minimum in January (≤ 5ºC). The experiment was laid out in completely randomized block design .The data was analyzed using SAS 9.3 software. The genotypes were analyzed and observed for their vegetative, flowering, fruiting and yield characteristics by using the techniques given below:

Tree height, girth and volume: The tree height was determined with the help of measuring pole while a measuring tape was used to measure tree girth. Tree volume was determined by formula mentioned by Kishor et al (2018).

Period of leaf fall and emergence: Period of leaf fall consisted of days when 10% of leaves were shed till more than 90% of leaves had fallen off while leaf emergence was noted from the date when 10% of the leaves were sprouted till the tree regained 90% of the foliage.

Start of flowering, full bloom: Start of flowering was observed when 5 per cent flower buds opened on the tree and when 75 per cent flowering had taken place, the date was recorded for full bloom.

Fruit set percentage: Four branches were tagged on each side of the tree and the total flowers were counted on each branch. The fruit set was recorded two weeks after full bloom and calculated by the formula given below:

$$\text{Fruit set (\%)} = \frac{\text{Number of fruits set}}{\text{Total number of flowers}} \times 100$$

$$\text{Fruit drop (\%)} = \frac{\text{Number of fruits dropped}}{\text{Number of fruits set}} \times 100$$

Fruit retention (%): The fruits on the tagged branches were counted two weeks before harvesting and the fruit retention was calculated:

$$\text{Fruit retention (\%)} = \frac{\text{Number of fruits set - Number of fruits dropped}}{\text{Number of fruits set}} \times 100$$

Fruit maturity: The date on which more than 70% of fruits on the tagged branches attained 50% colour was noted as time of fruit maturity.

Fruit weight, yield, size and self-compatibility: Fruit weight was measured with the help of pan balance and fruit yield by multiplying average fruit weight with total number of fruits per tree. Fruit size was measured with the help of vernier caliper. To analyze and record the self-compatibility status of the genotypes, branches on all sides of the plum tree were tagged and some flowers were covered with muslin bags before anthesis while other flowers were kept open. The trees where the fruit set was observed on the covered flowers were labeled as self-compatible and others self-incompatible.

RESULTS AND DISCUSSION

Vegetative characteristics: The maximum tree height (5.45 m) was in genotype 'Manake Lalri' and which is statistically at par with Yellow Alubokhara (5.30 m). Minimum tree height was in 'Kala Amritsari' (2.15m) followed by 'Frontier' and 'Sharps Early'. Kumar et al (2018) also observed lower plant height in genotypes Frontier and Mariposa in the hilly regions of Himachal Pradesh. Tree girth was maximum in genotype Manake Lalri (61.12 cm) which is statistically at par with genotypes Yellow Alubokhara and Kataru Chak. Minimum tree girth was in Satluj Purple (43.10 cm) closely followed by Frontier. The mean tree volume ranged between 7.56 (m^3) and 24.44 (m^3), suchdiverse growth characteristics were also been recorded by Kumar et al (2013). The variation in tree height, tree girth and tree volume among different plum genotypes may be due to their genetic constitution and adaptability to different soil and climatic conditions (Chaurasiya and Mishra 2017). Plums are deciduous trees, hence shed their leaves at start of autumn and start growing new ones within 3 to 4 months of shedding.. Leaf fall started from 3rd week of October and continued up to 3rd week of January in different plum genotypes (Table 1). The leaf fall started earliest in genotype Satluj Purple (11 October-26 December) while Manake Lalri was last to shed its leaves (15 December to 23 January). Leaf emergence started from 2nd week of February and continued up to 3^{rdt} week of March in plum genotypes during the present studies. Thus, leaf fall and leaf emergence started early in genotypes Satluj Purple, Frontier, and Sharps Early and the period of leaf fall varied from 6 to 8 weeks whereas leaf emergence varied from 3 to 4 weeks in plum genotypes.

Start and duration of flowering and full bloom: Flowering initiated earliest in Satluj Purple (9th Feb) followed by Kala Amritsari (11th Feb), Frontier and Sharps Early (12th Feb and 13thFeb, respectively). Full bloom also commenced early in Satluj Purple (14thFeb), Kala Amritsari (17th Feb), Frontier

(17th Feb) and Sharps Early (19th Feb). The time of flower initiation depends on temperature, altitude and other environmental conditions and thus, depict some variation every year (Mahato et al 2015). The duration of flowering varies from 6 to 8 days in different plum genotypes. Minimum duration (6 days) was in genotypes Frontier, Kataru Chak,and Satluj Purple and maximum (8 days) in Yellow Alubokhara. Kour (2018) noted floral parameters and flowering characteristics of sub-tropical plum cultivars Satluj Purple, Manaka and found that Satluj Purple started flowering on 5thFebruary and full bloom of Manaka and Satluj Purple lasted for 9 days. Sharma (2018) observed that the initiation of flowering in Frontier took place in 3rd week of February under mid hills of Himachal Pradesh whereas under the present studies the initiation in these genotypes took place in 2nd week of February. This difference might be due to early completion of chilling hours under sub-tropical climate of Punjab as compared to hills of Himachal Pradesh.

Fruit set, drop and retention: Fruit set in the seven plum genotypes ranged from 12.09% to 53.56 % (Table 2). Highest fruit set (53.56%) was in Sharps Early which is statistically at par with Satluj Purple and Frontier. Minimum fruit set was in Kataru Chak (12.09%) and Yellow Alubokhara (15.72%). Milatovic et al (2021) observed similar variation in final fruit set (17.7% to 49.7%) of different plum cultivars. Maximum fruit drop was in Kataru Chak (76.44%) and Manake Lalri (76.14%) which was significantly higher than all the genotypes. Minimum fruit drop was in Frontier (46.23%) and Sharps Early (47.67%). Fruit retention also varied significantly during the present studies. Fruit retention was highest in Frontier (53.77%) and Sharps Early (52.33%). Lowest fruit retention was in genotype Manake Lalri (23.85%) followed by Kataru Chak (23.56%). Saini (2020) also found lower fruit drop and higher fruit retention in Satluj Purple plum grafted on Kabul Green Gage rootstock. Higher fruit drop in Kataru Chak and Manake Lalri may be due to overbearing, thin pedicel and environmental stress.

Fruit maturity and duration of harvesting: Earliest fruit maturity was in Satluj Purple (1st May), followed by Kala Amritsari, Frontier (both 4th May) and Sharps Early (5th May) while duration of harvesting varied from 6 to 11 days in different plum genotypes. Minimum duration of harvesting was in Yellow Alubokhara (6 days) whereas maximum duration in Kala Amritsari (11 days) followed by Satluj Purple

Table 1. Vegetative and flowering characteristics of plum genotypes

Genotypes	T.H (m)	T.G (m)	T.V (m^3)	Period of leaf fall	Period of leaf emergence	Start of flowering	Time of full bloom	Duration of flowering
Sharps arly	3.85	49.12	17.87	20 Oct- 04 Dec	11 Feb-8 Mar	13 Feb	19 Feb	7 days
Frontier	3.50	43.87	16.43	24 Oct-10 Dec	9 Feb-5 Mar	12 Feb	17 Feb	6 days
Yellow Alubokhara	5.30	56.50	22.74	26 Oct-15 Dec	15 Feb-11 Mar	19 Feb	26 Feb	8 days
Manake Lalri	5.45	61.12	24.44	15 Dec-23 Jan	15 Feb-17 Mar	20 Feb	26 Feb	7 days
Kataru Chak	4.47	56.37	20.30	10 Dec-11 Feb	27 Feb-14 Mar	01 Mar	06 Mar	6 days
Satluj Purple	4.24	43.12	19.10	11 Oct-26 Dec	26 Feb-4 Mar	09 Feb	14 Feb	6 days
Kala Amritsari	2.15	46.27	7.56	24 Oct-5 Jan	7 Feb-6 Mar	11 Feb	17 Feb	7 days
CD (p=0.05)	0.70	10.87	1.15					

T.H: tree height, T.G: tree girth, T.V: tree volume, m: meter, m^3: meter cube

Table 2. Fruit set, drop, retention (%), maturing and harvesting time, self-compatibility and yield characteristics of plum genotypes

Genotypes	Fruit set (%)	Fruit Drop (%)	Fruit retention (%)	Time of fruit maturing	Duration of harvest	Average no. of fruits per tree	Fruit yield per tree (kg)	Self-compatibility status
Sharps early	53.56	47.67	52.33	5-12 May	8 days	1108.25	29.96	S.C
Frontier	50.23	46.23	53.77	4-12 May	9 days	1025.75	31.12	S.C
Yellow Alubokhara	15.72	54.03	45.96	25-30 May	6 days	32.00	0.47	I.C
Manake Lalri	42.29	76.14	23.85	12-20 May	9 days	4095.25	21.10	S.C
Kataru Chak	12.09	76.44	23.56	14-21 May	8 days	582.50	8.71	S.C
Satluj Purple	51.87	56.72	43.27	1-10 May	10 days	847.71	35.18	I.C
Kala Amritsari	44.63	50.13	49.86	4-14 May	11 days	3001.00	40.00	S.C
CD (p=0.05)	3.09	1.39	1.09			177.82	1.22	

Kg: kilogram, S.C: self-compatible, I.C: incompatible

(10 days). Other than genetic makeup and environment, orchard management techniques such as water, nutrients, canopy plant growth regulators also influence fruit maturity. The examination of data shows that plum genotypes begin maturing in the 1st week of May and continue through to the last week of the month under sub-tropical conditions of Punjab. On the basis of fruit maturity, these genotypes can be distinguished into 2 groups i.e early and mid-maturing. Early group consisted of genotypes which mature in the 1st fortnight of May (Satluj Purple, Kala Amritsari, Frontier and Sharps Early), mid group consisted of genotypes which mature in 2nd fortnight of May (Manake Lalri, Kataru Chak, and Yellow Alubokhara).

Fruit yield and self-compatibility status: Average number of fruits varied significantly in different plum genotypes (Table 2). The highest number of average fruits were observed in genotype Manake Lalri (4095.25) followed by Kala Amritsari (3001) which is significantly higher than all other genotypes. The genotype Yellow Alubokhara produced lowest number of fruits (32). Average fruit yield also varied significantly from one genotype to another and ranged between 0.47 kg to 40.00 kg. Kang et al (2005) also found that fruit yield in different plum genotypes varied from 0.24 kg/tree to 32 kg/tree.

Maximum fruit yield (40.0 kg) was in Kala Amritsari which was significantly higher than all other genotypes and was followed by Satluj Purple, Frontier, Sharps Early. Minimum fruit yield (0.47 kg) in Yellow Alubokhara genotype, may be attributed to the significantly low number of fruits produced per tree. Higher fruit yield in Kala Amritsari may be due to more number of fruits whereas higher fruit yield in Satluj Purple, Frontier, Sharps Early was due to higher fruit weight. Average yield per tree depends on pollination, orchard management, vegetative growth, nutrition and also the genetic makeup of the plant (Thakur et al 2023). Genotypes Frontier, Sharps Early, Manake Lalri, Kala Amritsari and Kataru Chak were self compatible in nature. These genotypes do not require any pollinizer for fruit set and are self-sufficient. This characteristic is entirely dependent on genetic constitution of the plant.

Fruit shape and its adherence to the stone: Fruits of different plum genotypes are of four shapes *viz*. round, heart, elliptic and oblate (Table 3). Three genotypes were observed having round shaped fruits (Frontier, Satluj Purple, and Kataru Chak), two with oblate shaped fruits (Yellow Alubokhara and Kala Amritsari), one with elliptic and heart shaped fruits (Manake Lalri and Sharps Early) respectively. Major characteristic exhibited by plum genotypes was clingstone as three out of seven genotypes were having this character while only two genotypes *viz.* Frontier and Kataru Chak were freestone and the other two genotypes exhibited semi-cling type characteristics (Manake Lalri and Sharps Early). Thakur et al (2023) observed clingstone and freestone characteristic of genotypes Satluj Purple and Frontier, respectively. The shape of fruit of plum genotypes Frontier was in accordance with Sundouri et al (2017) who also noted the round shaped fruits of the genotype.

Fruit weight, length and diameter: Maximum fruit weight (41.5 g) was in Satluj Purple, followed by Frontier and Sharps Early which recorded fruit weight of 31.12 g and 29.96 g respectively. Minimum fruit weight (2.57 g) was in Manake Lalri. The variations in fruit weight of different plum genotypes were due to inter-varietal differences, variation in genetic makeup, which is further governed by the sizes of fruit cells and intercellular spaces between them. The results obtained are in close conformity with the investigations conducted by Milosevic (2013) and Blazek and Pistekova (2009). Maximum fruit length (45.10 mm) and fruit diameter (41.23 mm) was in Satluj Purple and these were significantly higher than all other genotypes. It was followed by Frontier and Sharps Early with fruit size of 34.07 mm length and 32.53 mm diameter and 33.56 mm length and 30.47 mm in diameter, respectively. Minimum fruit size (6.3 mm length and 6.78 mm diameter) was in genotype Manake Lalri which is significantly

Table 3. Size, colour and fruiting characters of different plum genotypes

Genotypes	Fruit shape	Adherence to stone	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Peel colour	Flesh colour
Sharps Early	Heart	Semi-cling	29.96	33.56	30.47	Red-purple	Red
Frontier	Round	Freestone	31.12	34.07	32.53	Grey-purple	Yellow-orange
Yellow Alubokhara	Oblate	Clingstone	13.21	24.25	29.12	Green yellow	Yellow
Manake Lalri	Elliptic	Semi-cling	2.57	6.34	6.78	Red-yellow	Red-yellow
Kataru Chak	Round	Freestone	11.50	20.12	21.00	Orange-yellow	Yellow
Satluj Purple	Round	Clingstone	41.50	45.10	41.23	Red-purple	Yellow-orange
Kala Amritsari	Oblate	Clingstone	13.21	21.02	23.23	Dark purple	Yellow
CD (p=0.05)			2.23	1.44	1.42		

lower than all other genotypes. The fruit weight of genotype Kala Amritsari varies from the results obtained by Kamat et al (2020) who observed that the mean weight of Kala Amritsari ranged between 19.83 and 40.10 g. Sundouri et al (2018) recorded varied results for weight, length and breadth of genotype Frontier. The differences in results may be due to nutritional and environmental variations.

Peel colour and flesh colour: Plums exhibit wide variation in colors due to differences in their genetic makeup. Plums can be classified according to different shades of three primary colors *viz*. yellow, red and purple. Genotypes Yellow Alubokhara and Manake Lalri fall under the category of yellow plums while genotypes Sharpa Early and Satluj Purple exhibited mixed shades of red and purple colour. Genotypes Satluj Purple, Frontier and Kala Amritsari have varied shades of purple. Thakur et al (2023) observed purplish black skin colour of Kala Amritsari and reddish-purple in Satluj Purple, which is similar to current studies. Maximum plum genotypes had a shade of purple peel, making it the most common peel color. Red-yellow skin color was in Manake Lalri. Distinct greenish-yellow color with orange blush and grey-purple color was observed in the peels of genotypes Yellow Alubokhara and Frontier, respectively. Yellow was the most common flesh color found in fruits of plum genotypes (Yellow Alubokhara, Kataru Chak, Kala Amritsari). The results obtained in this present study regarding peel and flesh color of genotype Frontier is similar to those reported by Sundouri et al (2017).

CONCLUSIONS

Plum genotypes Sharps Early and Frontier performed better as compared to other genotypes on the basis of growth, yield and self-compatibility status and thus can be further evaluated for cultivation under sub-tropical conditions of Punjab which would help in breaking the existing monoculture of cultivar 'Satluj Purple' in the state.

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