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Effect of different methods of pollination on physio-chemical properties of plum cultivars under temperate regions of North India

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Abstract

Pollination in fruit crops is a major challenge to ensure fruit quality and production which affects the physio-chemical characteristics of many fruit crops, but the effects of cross-pollination on the fruit quality of plum (Prunus spps) are poorly known. As part of the effort to deal with this challenge, this study suggests how different aspects of pollination affect the fruit quality of plum fruits under Kashmir conditions. The present investigation was conducted on six-year-old bearing plants of different plum cultivars i.e. Burbank, Wickson, Santa Rosa, Satsuma, and Sharp's Early grown under controlled environment conditions. Plants were allocated to five treatments with four replications with all flowers on each plant receiving either: (1) Self-pollination (Autogamy) (2) Hand-pollination with compatible pollen or (3) Open pollination under environmental conditions. In this study, the data was recorded after fruit set by different methods of pollination. Various parameters viz., physical, chemical, color variability, and stone characters were studied. The results from the above investigation reveal that, the maximum red color (25.01) was reflected in cross-combination of Santa Rosa x Wickson followed by the cross-combination of Santa Rosa x Burbank (24.37). Fruit weight and fruit length were found maximum in cultivar Santa Rosa (51.42 g and 4.86 cm, respectively) under open pollination. Among all cross combinations, Santa Rosa x Wickson combination was best in terms of fruit weight (50.55 g). The maximum fruit density was recorded in cultivar Santa Rosa (0.173 m/V) under self-pollination and minimum under combination Santa Rosa x Sharp's Early (0.093 m/V). The maximum total sugars were recorded under the combination Wickson x Satsuma (9.05 %) and the minimum was recorded in cultivar Sharp's Early (6.50 %). Santa Rosa cultivar showed maximum SSC (16.20 oBrix) and minimum (12.38 oBrix) under open conditions. The stone weight of cultivar Burbank (1.79 g) was heavier than other cultivars under open pollination. The highest stone: pulp ratio (49.40) was recorded in cultivar Satsuma under open pollination, and a minimum (21.53) was recorded in cultivar Burbank under self-pollination. From this study, it was concluded that the best pollinizer for Santa Rosa was Wickson, Burbank, and Satsuma as they have high pollen viability and germination percentage. Open pollination is regarded as the best method of pollination having maximum fruit set and fruit retention followed by cross-pollination.

Keywords: *Plum, open pollination, self-pollination, cross-combinations, cultivars, color, quality.*

Introduction

Pollination is a vital process to sustain fruit production for the growing human population because more than 75% of fruit crops require some form of pollination. Furthermore, cross-pollination by a different genotype, compared with self-pollination by the same genotype, has major impacts on global fruit production because cross-pollination increases yield and improves quality attributes such as fruit mass, sweetness, acidity, and color intensity of many horticultural crops.

However, there is a limited understanding of how cross-pollination affects the yield and quality of some stone fruit crops. Plum (*Prunus spps.*) is the

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most common and widely used fruit, being grown in the world and belongs to the family Rosaceae. The commercially cultivated plum species *viz., Prunus domestica* and *Prunus salicana* is commonly known as the European and Japanese plum, respectively. [1] Flowers of plum (Prunus *spps*) are borne laterally on short and thick spurs which have viability for more than five to seven years. In a single spur, there are three to five flowers that arise from the axil of the leaf bud. Plum flowers profusely but fruit set percentage is low to very low. Many factors are responsible for the fruit set and low yield *viz.,* pollen source, pollination, self-unfruitful, self- infertility, and self-incompatibility. Diploid plum species such as *Prunus salicana* (Japanese) and *Prunus cerasifera* (Myrobalan) are mostly self-incompatible while hexaploid plum species *Prunusdomestica* (European) are self-fertile to partially fertile and partial fertile to self-incompatible.[2] Both in European and Japanese plums, the result of cross-pollination depends much more on the female parent than on the quality of the pollen. Good pollinators produce 50,000 pollen per flower. In Stanley and Italian plums, more than 70000 pollens were found.[3]

Plum flowers can produce fruit with higher mass, sweetness, and nutritional value following open pollination by bees compared with self-pollination. However, the heavier, firmer, less-malformed, and longer-lasting fruit follow bee pollination than autogamous pollination. The open- or bee-pollinated fruit possesses more results in heavier fruit and higher yield than autonomously pollinated fruit.[4] However, it is unclear whether the effects of open- or bee-pollination in these studies were the result of differences in the amount of pollen or source of pollen, i.e. cross-pollen, self-pollen that was deposited on stigma because the genotypes of the deposited pollen and the resulting seeds were unknown. The effects of different pollen source on fruit characteristics, including those of the endosperm, embryo, ovary, and accessory tissues are termed xenia.[5] The main objective of the study includes various aspects of pollination viz; open, self and different cross combinations which improve the pollination for better fruit set, fruit color, and quality in of plum fruits by different breeding improvement programs.

Materials and Methods

The experimental field was located in Union territory (UT) of Jammu and Kashmir in the north-western corner of India, which is located in the Division of Fruit Science, SKUAST-K, Shalimar, Srinagar situated at an altitude of 1588 meters above mean sea level and latitude of 34.14°N and longitude 74.87°E. Six-year-old bearing plants of different Japanese plum cultivars (Burbank, Satsuma, Wickson, and Santa Rosa) and European cultivar (Sharps Early) having good vigour, health, and bearing plants were grown at the spacing of 3 x 3 meters in a square system of planting and uniform cultural practices were followed during the period of study. The design of the experiment was RCBD with three replications with a single plant in each replication.

Twenty-five flowers in each pollination (open, self, and cross-pollination) method were selected separately and observations were recorded. In cross-pollination, all possible cross-combinations of cultivars selected for the study were made which showed synchronized flowering times. Flowers at the balloon stage were emasculated, bagged, and tagged and the pollen of the desired pollinizers was applied with the help of a brush in each cultivar. The pollinated flowers were covered with muslin cloth bags. Care was taken so as to avoid any contamination in pollen grains. Fruit weight (gm) and stone weight (gm) was recorded with the help of a digital weighing balance and physical parameters like fruit size in terms of fruit length (cm), fruit breadth (cm), stone length (mm), stone width (mm), stone thickness (mm) was measured with the help of Vernier's calliper. Pulp: the stone ratio was obtained by subtracting the average stone weight from the average fruit weight and dividing by the average stone weight. The fruit density (m/V) was calculated by the water displacement method as formula below.

$$\text{Fruit density (m/V)} = \frac{\text{Mass of the fruit}}{\text{Volume occupied by the fruit}}$$

The fruit color was recorded with the help of self-contained colour measurement (Color Flex) Hunter Lab to test the chromaticity values. The chroma meter was calibrated using a standard calibration plate before each use. The colorimeter measured three variables; L*, a*, and b*. The values of hue angle (h*) and chroma (C*) were computed from both a* and b*, where h* is a measure of the color of the sample and C* is a measure of the intensity of that color. The soluble solid content (°Brix) of fruit pulp was determined by Digital Hand Refractometer (Erma, Japan). The refractometer was calibrated with distilled water before use and then a few drops of fruit pulp were placed on the prism of the refractometer. Acidity was

expressed as the percent of malic acid as the method given in AOAC.[6] Total sugars, reducing sugars, and non-reducing sugars expressed in percentage were estimated by the method suggested by AOAC.[6] Ascorbic acid content was expressed in mg/100gm of pulp and was estimated using 2, 6 -dichlorophenol indophenol dye using visual titration method AOAC. [6] The observations recorded were subjected to statistical analysis as per the method suggested by Snedecor and Cochran.[7] The significant difference in the means was tested against the critical difference at 5 percent significance.

Results and Discussion

Comparison of different pollination methods in terms of physico-chemical parameters and color appearance of plum fruits.

A different source of pollen also caused several variations in the fruit and stone characteristics of seed parents. Results showed that (Table 1) all cross-pollination treatments partially caused an increase or decrease in fruit and stone characteristics in both parents. In different pollination methods, Santa Rosa recorded maximum fruit weight (51.42 gm) under open pollination followed by cross combination Santa Rosa x Wickson (50.55 gm) in cross-pollination and least 47.96 gm in cultivar Santa Rosa in self-pollination method. Fruit size is the major quantitative inherited factor determining yield, fruit quality and consumer acceptability.[8] Large fruited cultivars are preferred both for fresh consumption and for processing purposes. Fruit size depends upon the genotype, effective pollination, fertilization prevailing climatic conditions, and cultural practices adopted to maintain the plant health.[9] Similarly, closer spacing between plants of the same and other species affects the fruit size due to competition for light, nutrition, and water.[10] Similar observations were also recorded who reported the variation in different physical characteristics of the plum cultivars.[11-13] The observations of the present study, with regard to various physical characters are following the results.[14] The pollen from different sources affects readily discernible characteristics of fruit and seed in the period immediately following fertilization and as such immediate or direct effects are termed as "Xenia" and have been described in many species.[15] The effect of pollen sources on the quality and quantity of fruits and nuts in some plant species.[5] The pollen mixture significantly increased fruit and seed weight.[16] The results of the present investigation are supported.[17] [18]

Effect of different methods of pollination on fruit color of plums

Fruit color depicted in fig 1 (A, B & C) indicates that the maximum red color (25.01) was reflected in the cross combination of Santa Rosa x Wickson followed by cross combination of Santa Rosa x Burbank (24.37) under cross-pollination. Similarly, the highest color intensities as recorded in the cross combination of Santa Rosa x Sharp's Early (102.41). Our results are supported by the findings [19] [20] who reported that cultivar Stanley had L*, a* and b* of 25.70, 1.53 and -3.70 respectively. However, skin color depends upon plant location, the temperature of the location, tree growth habits, the microclimate of the tree canopy and light distribution and is significantly affected by the prevailing environmental conditions of the growing area.[21]

Effect of different methods of pollination on chemical properties of plum fruits

The effect on the chemical properties of fruits is depicted in tables 2 and 3. The titratable acidity under open pollination ranged from 1.13 to 1.27% among all cultivars. Maximum (9.31 %) total sugars were recorded in cultivars Santa Rosa and minimum (7.43 %) in cultivar Satsuma under study. Ascorbic Acid ranged between 9.00 to 10.21 mg/100 gm. The soluble solid content was recorded to be highest in cultivar Santa Rosa (16.20 °B) and lowest in Wickson (12.38 °B). In self-pollination, titratable acidity showed variation from 1.15 to 1.29 % among different cultivars. The maximum (9.61 %) total sugar was noticed in cultivar Santa Rosa and the minimum (7.62 %) in cultivar Wickson. Ascorbic Acid ranged from 9.16 to 10.09 mg/100 gm. The soluble solid content was recorded to be highest in cultivar Santa Rosa (14.80 °B) and lowest in Burbank (12.72 °B). In cross-pollination titratable acidity showed variation from 1.15 to 1.27 % among different cultivars. Maximum (9.49 %) total sugar in cross combination, Santa x Wickson, and minimum (7.59 %) in combination Satsuma x Sharp's Early was observed in cultivars under study. Ascorbic acid ranged from 8.90 to 9.97 mg/100. Soluble solid content was recorded to be highest in combination Santa Rosa x Wickson (14.52 °B) and lowest in Wickson x Satsuma (13.11 °B).

Soluble solids content is a critical factor in determining fruit quality and early-season plum cultivars are

Table 1: Physical parameters of different plum cultivars under open and self-pollination.

Cultivars	Open Pollination				Self-Pollination			
	Fruit weight (gm)	Fruit length (cm)	Fruit breadth (cm)	Fruit density (m/V)	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Fruit density (m/V)
Burbank	41.89	4.69	3.82	0.134	38.76	4.67	4.55	0.131
Santa Rosa	51.42	4.86	3.74	0.102	47.93	4.71	4.63	0.173
Satsuma	40.86	3.79	3.85	0.144	35.91	3.45	3.36	0.133
Sharp's Early	32.29	3.76	3.42	0.118	29.72	3.67	3.35	0.122
Wickson	49.16	4.24	4.19	0.136	45.98	4.16	4.15	0.141
Mean	43.12	4.27	3.80	0.126	39.66	4.13	4.01	0.140
CD (0.05)	2.59	0.16	0.27	0.009	3.05	0.04	0.03	0.023

Table 2: Chemical parameters in different plum cultivars under open and self-pollination.

Cultivars	Open Pollination						Self-Pollination					
	Acidity (%)	Reducing sugars (%)	Non- reducing sugars (%)	Total sugars (%)	Ascorbic acid (mg/100 g)	S.S.C (°Brix)	Acidity (%)	Reducing sugar (%)	Non- reducing (%)	Total sugars (%)	Ascorbic acid (mg/100 gm)	S.S.C (°Brix)
Burbank	1.27	6.31	1.49	7.88	10.21	12.75	1.29	6.36	1.72	8.17	10.09	12.72
Santa Rosa	1.21	7.48	1.73	9.31	9.66	14.80	1.25	7.41	2.09	9.61	9.68	14.83
Satsuma	1.19	5.81	1.53	7.43	9.45	12.62	1.19	5.61	1.09	7.76	9.56	12.97
Sharp's Early	1.13	6.72	1.34	8.14	9.35	14.42	1.15	7.40	1.05	8.50	9.16	14.04
Wickson	1.18	6.50	2.13	8.75	9.00	12.38	1.21	6.50	1.06	7.62	9.34	13.61
Mean	1.19	6.56	1.64	8.30	9.53	13.39	1.21	6.65	1.40	8.33	9.56	13.63
CD (0.05)	0.05	0.47	0.32	0.58	0.48	0.83	0.05	0.43	0.19	0.81	0.46	1.18

Table 3: Physio-chemical parameters of different plum cultivars under various cross-combinations.

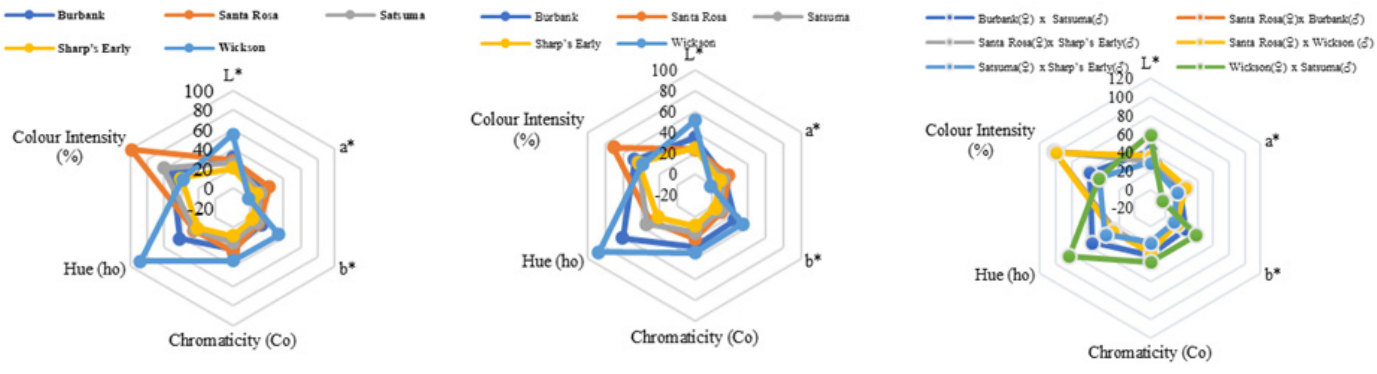
Cultivars	Fruit weight (gm)	Fruit length (cm)	Fruit breadth (cm)	Fruit Density (m/V)	Acidity (%)	Reducing sugar (%)	Non- reducing (%)	Total sugars (%)	Ascorbic acid (mg/100 g)	S.S.C (°Brix)
Burbank(♀) x Satsuma(♂)	40.46	4.76	4.65	0.128	1.27	6.70	1.33	8.10	9.97	13.17
Santa Rosa(♀)x Burbank(♂)	50.16	4.91	4.79	0.112	1.23	7.98	1.13	9.17	9.45	14.08
Santa Rosa(♀)x Sharp's Early(♂)	41.28	4.74	4.64	0.093	1.20	7.82	1.11	8.99	9.63	14.49
Santa Rosa(♀) x Wickson(♂)	50.55	4.87	4.78	0.102	1.20	8.18	1.24	9.49	9.93	14.52
Satsuma(♀) x Sharp's Early(♂)	40.24	3.76	3.69	0.145	1.20	6.36	1.17	7.59	9.92	12.69
Wickson(♀) x Satsuma(♂)	49.57	4.24	4.10	0.138	1.15	6.94	1.43	8.45	8.90	13.11
Mean	45.37	4.55	4.44	0.119	1.20	7.33	1.23	8.63	9.63	13.67
CD (0.05)	2.51	0.05	0.05	0.006	0.04	0.45	0.19	0.36	0.50	1.01

Table 4: Stone parameters of different plum cultivars under open and self-pollination.

Cultivars	Open Pollination					Self-Pollination				
	Stone weight (gm)	Stone length (mm)	Stone width (mm)	Stone thickness (mm)	Pulp : stone ratio	Stone weight (g)	Stone length (mm)	Stone width (mm)	Stone thickness (mm)	Pulp : stone ratio
Burbank	1.79	23.92	15.98	8.50	22.35	1.72	22.40	15.55	7.74	21.53
Santa Rosa	1.47	26.64	17.96	8.80	34.27	1.49	25.03	15.79	7.93	31.23
Satsuma	0.81	17.74	14.42	7.01	49.40	0.82	17.83	14.51	5.94	44.79
Sharp's Early	0.78	26.16	16.57	6.47	41.12	0.69	23.66	15.42	5.96	37.50
Wickson	1.18	21.60	17.17	6.67	42.66	1.13	22.33	15.38	6.06	39.91
Mean	1.20	23.21	16.42	7.49	37.95	1.17	22.25	15.33	6.73	34.99
CD (0.05)	0.08	1.21	0.73	0.72	3.17	0.11	1.49	0.98	0.51	3.47

Table 5: Stone parameters of different plum cross combination

Parameters / Cross combinations	Stone weight (g)	Stone length (mm)	Stone width (mm)	Stone thick-ness (mm)	Pulp: Stone ratio
Burbank(♀) x Satsuma(♂)	1.75	24.60	15.36	7.61	22.10
Santa Rosa(♀)x Burbank(♂)	1.55	25.20	15.69	8.48	32.28
Santa Rosa(♀) x Sharp's Early(♂)	1.51	24.98	15.62	8.37	26.55
Santa Rosa(♀) x Wickson(♂)	1.44	26.40	15.49	8.27	35.15
Satsuma(♀) x Sharp's Early(♂)	0.81	19.35	13.96	6.22	49.10
Wickson(♀) x Satsuma(♂)	1.20	22.90	14.64	6.50	40.11
Mean	1.37	23.90	15.13	7.58	34.21
CD (0.05)	0.11	1.87	0.99	0.33	3.03



A B C

Fig 1: Fruit color intensity of different plum cultivars under A) open pollination, B) self-pollination and C) cross-pollination

Santa Rosa Satsuma Burbank Wickson Sharp's Early

Plate-1: Plum fruits under open pollination

Santa Rosa Satsuma Burbank Wickson Sharp's Early

Plate-2: Plum fruits under self-pollination

Burbank x Satsuma | Santa Rosa x Wickson | Santa Rosa x Sharp's Early | Santa Rosa x Burbank | Wickson x Satsuma | Satsuma x Sharp's Early

Plate-3: Plum fruits under a different cross-combination

usually characterized by lower soluble solid content than late-season plum cultivars. As fruits mature, the sugars become the main component of the soluble solids. Soluble solid content, to a large extent, determines the flavor of the fruit is a cultivar-specific trait, but is also dependent on the level of fruit borne by trees and weather conditions. The soluble solid content in the studied cultivars ranged from 11.80% to 16.10% and these values are in accordance with the findings [12] [14] [22] [23] [24] which reported TSS values ranging from 9.70 % to 16.95% in different cultivars of plum. Similar observations were recorded by Son (2010) [11] who reported soluble solids content varying from 11.53 to 16.06% in set of different cultivars of plum. Similar results regarding fruit acidity reported values ranging from 0.57% (Stanley) to 1.64% (Sorriso di Primavera).[25] [26] The SSC: acid ratio was found in the range of 6.01 to 28.77. A similar range of variations was also reported.[27] The relationship between soluble solid content and total acids has an important role in consumer acceptance of plum cultivars. Plums with soluble solid content ≥12.0% had ~ 75% consumer acceptance, regardless of total acids.[9] Similar type of variation has also been reported.[11] [28] The chemicals constitute the different cultivars depend on the different rate of conversion of complex organic acids into simple sugars at the time of maturity and has been variated by the agro-climatic conditions and nutritional factors.[29]

Effect of different methods of pollination on fruit stone characters

The effect of pollination on stone characters is depicted in tables (4 & 5) Maximum stone weight was recorded in cultivars Sharp's Early under self-pollination (0.69 gm), followed by cultivar under open pollination (0.78 gm) and cross combination of Satsuma x Sharp's Early (0.81 gm). However, pulp: stone ratio was recorded maximum in cultivar Satsuma under open pollination (49.40) and cross-pollination (44.79) where as it is 49.10 in the cross combination of Satsuma x Sharp's Early. A similar type of variation in stone size has also been reported. [12] [23] Variation in pulp: stone ratio in plum has been reported by [23] [29] and found that pulp: stone ratio ranged from 59.13 % to 19.56 %. Variations in stone weight have been reported [30] which ranged from 2.90 gm in cultivar Fortune and 0.95 gm in Red Beauty. The variation in pulp: stone ratio depends on the fruit size and weight of the fruit. Higher pulp: stone ratio in some cultivars may be due to higher fruit weight and less stone weight. The variability concerning stone adherence in different plum cultivars might be due to varietal characteristics. A similar type of variation has also been reported by other workers.[31] [32]

Conclusion

Results of the above study, concluded that the European plum cultivar will set fruit with their own pollen and can produce better crops with pollinizers. On other hand, most Japanese plum require a pollinizer for pollination and a better fruit set. Under open and cross-pollination, the physio-chemical attributes of the plum fruit were increased up to a maximum level as compared to self-pollination and also improved fruit color and intensity i.e. darkness, redness, etc. So, the grower needs to manage pollination efficiency by setting the amount of pollinizer plants, bees and other pollinating insects to ensure fruit production and quality of fruit for the future challenge of two billion small farmers worldwide.

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Conflict of interest

The authors declare no conflict of interest.

Author contribution

Anil Sharma: Data curation; Formal analysis; Investigation; Writing – original draft. **A.S Sundouri:** Project administration; Methodology. **Amit Kumar:** Conceptualization; Visualization; Supervision. **J P Rathore:** Visualization. **Harsimrat K. Bons**: Methodology; Visualization.

Ethical guidelines

Ethics approval was not required for this research work.

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