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Insha Majid
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Aroosa Khalil
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Fouzea Nisar
Division of Vegetable Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Shaila Din
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Nowsheen Nazir
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Shabnam Ahad
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Sumaya Mumtaz
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Corresponding Author:
Insha Majid
Division of Fruit Science, SKUAST-K, Srinagar, Jammu and Kashmir, India

Comparative tree growth, fruit set, fruit yield and physical characteristics of some plum cultivars grown under temperate conditions of Kashmir

Insha Majid, Aroosa Khalil, Fouzea Nisar, Shaila Din, Nowsheen Nazir, Shabnam Ahad and Sumaya Mumtaz

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Abstract
An experiment was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar, Kashmir during the year 2017-18. The present study consisted of six plum cultivars viz. Burbank, Stanley, Friar, Wickson, Santa Rosa and Satsuma of uniform age replicated thrice in a Randomized Complete Block Design (RCBD). In the experimental year, tree cross section area, tree spread, initial fruit set, final fruit set, maturity, yield, yield efficiency, fruit weight, volume of fruit, stone weight, pulp weight of the fruit, pulp/stone ratio and adherence of stone to flesh were recorded. The data recorded revealed that tree cross sectional area was maximum in cultivar 'Santa Rosa' (33.14 cm^2) and minimum in cultivar 'Friar' (5.75 cm^2). The plum cultivar 'Satsuma' was found to have maximum tree spread (2.19 m) whereas minimum tree spread of 0.46 m was recorded in 'Friar'. Highest initial and final fruit set was recorded in cultivar 'Stanley' (61.28% and 30.78 %) whileas lowest initial and final fruit set was noticed in cultivar 'Santa Rosa' (46.15% and 17.54%). Cultivar 'Burbank' took minimum period of 95 days, while 'Friar' took maximum of 132 days to mature. Maximum fruit yield (11.55 kg/tree) was obtained in cultivar 'Stanley', however, minimum yield (6.43 kg/tree) was recorded in cultivar 'Santa Rosa'. Yield efficiency was observed to be maximum in cultivar Friar (1.84 kg/cm^2) and minimum in Santa Rosa (0.20 kg/cm^2). The fruit weight was maximum in cultivar 'Friar' (50.47 g) and minimum in the cultivar 'Satsuma' (38.81 g). The maximum fruit volume of 54.63 cm^3 was recorded in cultivar 'Santa Rosa whereas minimum fruit volume of 27.08 cm^3 was observed in cultivar 'Satsuma'. Stone weight was recorded to be highest in cultivar 'Stanley' (2.04 g) and lowest in 'Friar' (0.72 g). Pulp weight of the fruit was recorded to be maximum in 'Friar' (49.74 g) and minimum in 'Burbank' (37.73 g). Maximum pulp: stone ratio was recorded in cultivar 'Friar' (68.61) while the minimum pulp: stone ratio was recorded in 'Stanley' (19.05). Burbank, Wickson and Santa Rosa were cling stone type, two cultivars (Stanley and Friar) were free stone type and one cultivar (Satsuma) was semi cling stone type. The study concluded on the note that cultivars Stanley and Friar are better with respect to fruit set, yield, yield efficiency, fruit weight and free stone.

Keywords: Plum cultivars, fruit set, yield, yield efficiency and fruit weight

Introduction
Plums (*Prunus* spp.) are by far the most diverse of all the *Prunus* species and could be the most diverse of all deciduous fruit crop species which belongs to genus *Prunus* of sub family Prunoideae (*Amygdaloideae*) and family Rosaceae (Potter *et al*.,) [15]. It occupies a unique position amongst the stone fruits in world fruit production and ranks next to peaches in economic importance. This group contains 20-40 species (Okie and Hancock, [13]), that are distributed in different parts of world. It has large number of species, but the commercially grown cultivars belong to two species i.e. *Prunus domestica* L. (European plum) and *Prunus salicina* L. (Japanese plum), the former is hexaploid (2n = 6x = 48) and the latter is diploid (2n = 2x = 16). The European group of plum is native to areas between Black Sea and Caspian Sea and the adjoining areas of Persia and Asia Minor whereas the Japanese group of plum is native to China but was domesticated in Japan and subsequently was introduced to different parts of world. Most varieties of commercial importance in India belongs to the *salicina* group. In India, plum was first introduced in 1870 by Alexander Counts at Mashobra (Shimla) in Himachal Pradesh. In India, plums are commercially grown in the hilly regions of Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Uttar Pradesh and Tamil Nadu. Plums have a

great range of flavour, aroma, texture, colour, size and other characteristics which makes their fruits desirable than other horticultural crops (Westwood, & Byren *et al*,) [20, 5]. Plums are important source of compounds influencing human health and preventing the occurrence of many diseases. Plums are mostly used for fresh consumption, but a small quantity is also processed into juices. The plum fruit is known for its cooling effect and is considered best to overcome the effect of jaundice. Fresh plums are rich in citric acid, sugars, vitamin A and B and minerals like calcium, phosphorous, potassium and fluoride. It is also low in calories (46 calories/100 g) and contain no saturated fats. It also contain certain health benefiting compounds such as dietary fiber, sorbitol and isatin which help to regulate the functioning of the body (Prajapati *et al*.,) [16]. Its area and production in India is 24,000 ha and 89,000 MT (Anonymous) [2] and in Jammu and Kashmir 4,083 ha and 11,860 MT respectively (Anonymous) [3]. Plum in Kashmir has good fruit quality in comparison with other commercially growing states in India. Plum trees need less care due to its hardy nature, enabling it to flourish well even in inferior soils where other fruits fail to grow. The trees of plum have wide range of adaptability to soil and climatic conditions. This fruit species also play significant role in the preservation of environment and effectively checks soil erosion. But in Kashmir unfortunately much attention is given for increasing the area and production of apple and pear but not to plum. Keeping these facts in mind, the present investigation was undertaken to assess comparative tree growth, fruit set, fruit yield and physical characteristics of some plum cultivars under temperate conditions of Kashmir.

Material and Method

The present investigation was carried out in the orchard of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Kashmir in the year 2017-18. Bearing plum trees of different cultivars of uniform age (4 years old), rootstock (seedling rootstock), vigour, health, bearing and agronomical practices were selected for the trial. The trees were planted in square system of planting and maintained under uniform cultural practices as per package and practices followed during the period of study. Six cultivars of plum viz, Burbank, Stanley, Friar, Wickson, Santa Rosa and Satsuma were investigated. The experimental design was randomized complete block design (RCBD). Each treatment comprised of a single plant and was replicated three times. The study focused on (i) Tree cross section area (cm^2), (ii) Tree spread (m), (iii) Initial fruit set (%), (iv) Final fruit set (%), (v) Maturity (DAFB), (vi) Yield (Kg/tree), (vii) Yield efficiency (Kg/cm^2), (viii) Fruit weight (g), (ix) Volume of fruit (cm^3), (x) Stone weight (g, (xi) Pulp weight of the fruit (g), (xii) Pulp/stone ratio, and (xiii) Adherence of stone to flesh (scale).Tree trunk cross sectional area of each experimental unit was measured 15cm above bud union and expressed as cubic centimetre using following formula:

$$TCSA = \frac{(girth)^2}{4\pi}$$

The spread of the trees was recorded by measuring width in North-South and East-West directions with the help of measuring tape and average of both the measurements was worked out and expressed the mean value in meters. Fruit set was determined by counting number of flower buds during full bloom and number of fruitlets at pea stage of four pre-selected branches in four directions (North, East, South and West) of the same tree and was calculated with the below mentioned formula:

$$\text{Initial fruit set (\%)} = \frac{\text{Number of fruitlets at pea stage}}{\text{Number of flowers}} \times 100$$

The fruits retained (final fruit set %) in all the cultivars were recorded one week before harvesting, averaged and expressed in percentage as under:

$$\text{Final fruit set (\%)} = \frac{\text{Number of fruits harvested}}{\text{Number of fruitlets at pea stage}} \times 100$$

The days taken for fruit maturity were estimated as the number of days from the date of full bloom to the date when the fruit was actually harvested. The crop harvested from each experimental unit was recorded and expressed in kilogram per tree. Yield efficiency of the tree was calculated and expressed as kilogram per cubic centimetres by using the formula given by Westwood (20)

$$\text{Yield efficiency} = \frac{\text{Yield (kg)}}{\text{TCSA } (cm^2)}$$

Ten fruits from each treatment in each replications were weighed individually on a sensitive monopan balance and average weight was recorded in grams. Fruit volume was calculated by using the formula given by Westwood [20] and was expressed in cubic centimetre.

Volume = $4.189\ ab^2$
Where,
a = ½ length of the fruit
b = ½ diameter of the fruit
The stones were separated from ten randomly selected fruits in each treatment and weighed separately. The average weight of stones was expressed as stone weight in grams. Pulp weight of ten randomly selected fruits were calculated by estimating the difference between the total weight of the fruit and the weight of the stone and was expressed in grams.
Pulp weight of fruit = Total weight of fruit - weight of stone
Pulp/stone ratio was determined by dividing the average pulp weight with the average stone weight of ten randomly selected fruits.

$$\text{Pulp to stone ratio} = \frac{\text{Pulp weight (g)}}{\text{Stone weight (g)}}$$

Stone adherence to flesh of fully ripe fruit were classified into following types viz. Free stone, Semi-freestone and Cling stone. The data generated were subjected to statistical analysis as per the procedures described by Gomez and Gomez [6].

Results and Discussion

The data pertaining to different characteristics are presented in Table-1 and 2. Maximum trunk cross sectional area (33.14 cm^2) was recorded in cultivar Santa Rosa followed by Satsuma (23.10 cm^2) and Wickson (21.26 cm^2). Cultivar Burbank (19.38 cm^2) was statistically at par with cultivar Stanley (18.31 cm^2). Cultivar Friar recorded the lowest trunk

cross sectional area (5.75 cm^2) among the cultivars under study. Maximum tree spread (2.19 m) was recorded in the cultivar Satsuma which was statistically superior to all the other cultivars. Cultivar Wickson (1.78 m) was statistically at par with cultivar Santa Rosa (1.66 m). Cultivar Burbank (1.30 m) was statistically at par with cultivar Stanley (1.08 m). Minimum tree spread was recorded for the cultivar Friar (0.46 m). A significant variation was observed in percentage of initial fruit set among the plum cultivars under study. Maximum initial fruit set was recorded in cultivar Stanley (61.28%) followed by Friar (58.86%), Burbank (55.82%), Wickson (51.10%) and Satsuma (49.87%). The lowest initial fruit set was recorded in cultivar Santa Rosa (46.15%). Highest final fruit set

Table 1: Tree growth, fruit set and maturity of different plum cultivars

Cultivars	Parameters				
	TCSA (cm^2)	Tree spread (m)	Initial fruit set (%)	Final fruit set (%)	Maturity (DAFB)
Burbank	19.38	1.30	55.82	25.76 (5.17)	95
Stanley	18.31	1.08	61.28	30.78 (5.63)	125
Friar	5.75	0.46	58.86	28.79 (5.46)	132
Wickson	21.26	1.78	51.10	21.93 (4.79)	101
Santa Rosa	33.14	1.66	46.15	17.54 (4.31)	104
Satsuma	23.10	2.19	49.87	18.71 (4.43)	109
CD ($P \leq 0.05$)	1.253	0.201	1.116	0.097	1.418
C.V.	3.38	7.74	1.13	2.09	0.73

(33.85%) was recorded in cultivar Stanley (30.78%) followed by Friar (28.79%), Burbank (25.76%), Wickson (21.93%) and Satsuma (18.71%), however the lowest final fruit set was recorded in cultivar Santa Rosa (17.54%). The cultivar which matured earliest was Burbank (95 days) followed by Wickson (101 days), Santa Rosa (104 days), Satsuma (109 days) and Stanley (125 days), whereas cultivar Friar took longest time of 132 days to attain maturity. Highest yield was observed in cultivar Stanley (11.55 kg/tree) followed by Friar (10.54 kg/tree). The yield of Burbank was statistically less than Friar but was at par with Wickson (8.90 kg/tree). The yield of Santa Rosa (6.43 kg/tree) was at par with the yield observed in Satsuma (7.65 kg/tree), both being least yielders. Maximum yield efficiency was observed in cultivar Friar (1.84 kg/cm^2) which was statistically superior to all other cultivars. Yield efficiency of cultivar Stanley is 0.63 kg/cm^2 followed by Burbank which was statistically at par with Wickson (0.42 kg/cm^2). The lowest yield efficiency was recorded in cultivar Santa Rosa (0.20 kg/cm^2) which was statistically lower than Satsuma (0.33 kg/cm^2). The maximum fruit weight (50.47 g) was recorded in plum cultivar Friar which was statistically at par with Santa Rosa (50.23 g) but superior to Wickson (48.27 g) and Stanley (40.96 g). The lightest fruit weight was recorded in cultivar Satsuma (38.81 g) which was statistically at par with Burbank (39.49 g). Maximum fruit volume (54.36 cm^3) was recorded in Santa Rosa which was significantly superior to all the cultivars. Cultivar Friar (39.12 cm^3) was superior to Wickson (37.34 cm^3) which in turn was statistically superior to Stanley (33.74 cm^3), followed by Burbank (30.00 cm^3). The minimum fruit volume of 27.08 cm^3 was observed in Satsuma. Highest stone weight was recorded in Stanley (2.04 g) which was statistically higher among all the cultivars followed by Burbank (1.75 g) but superior to Santa Rosa (1.46 g) which was statistically superior to Wickson (1.13 g). Lowest stone weight was recorded in cultivar Friar (0.72 g) which was statistically at par with Satsuma (0.74 g). Maximum pulp weight of fruit was recorded in cultivar Friar (49.74g) which was statistically at par with Santa Rosa (48.78 g). The pulp weight of cultivars Wickson (47.14 g) was statistically superior to Stanley (38.91g) which in turn was statistically at par with Satsuma (38.07 g). Minimum pulp weight of fruit was recorded in Burbank (37.73 g). The maximum pulp to stone ratio (68.61) was recorded in the cultivar Friar followed by Satsuma (51.71) both being superior to cultivar Wickson (41.68) which in turn was statistically superior to Santa Rosa (33.49). The minimum pulp to stone ratio was recorded in cultivar Stanley (19.05) which was statistically at par with Burbank (21.55). The cultivars Burbank, Wickson and Santa Rosa were clingstone while Satsuma was semi-clingstone, whereas, Stanley and Friar were found to be freestone in nature.

Table 2: Physical fruit and stone characteristics of different plum cultivars

Cultivars	Parameters							
	Yield (Kg/tree)	Yield efficiency (Kg/cm^2)	Fruit weight (g)	Fruit volume (cm^3)	Stone weight (g)	Pulp weight of fruit (g)	Pulp/stone ratio	Adherence of stone to flesh
Burbank	9.50	0.49	39.49	30.00	1.75	37.73	21.55	Clingstone
Stanley	11.55	0.63	40.96	33.74	2.04	38.91	19.05	Freestone
Friar	10.54	1.84	50.47	39.12	0.72	49.74	68.61	Freestone
Wickson	8.90	0.42	48.27	37.34	1.13	47.14	41.68	Clingstone
Santa Rosa	6.43	0.20	50.23	54.36	1.46	48.78	33.49	Clingstone
Satsuma	7.65	0.33	38.81	27.08	0.74	38.07	51.71	Semi- clingstone
CD ($P \leq 0.05$)	0.842	0.088	0.980	1.32	0.101	0.985	3.360	-
C.V.	1.61	2.57	1.24	2.04	4.09	1.29	5.12	-

Pictorial view of fruit of different plum cultivars

The tree spread varied from 0.46 m to 2.19 m, and such variations in growth characteristics has also been observed by Kumar *et al.* [7]. Cultivar Santa Rosa had maximum TCSA and Friar had minimum TCSA. Similar results was observed by Prakash *et al.* [17] and Kumar *et al.* [8]. Kumar *et al.* [8] reported lowest fruit retention in cultivar Santa Rosa (11.63%), which supports the results of the present study. These variations in fruit set percentages might be due to their genetic makeup as suitable growth and vigour was necessary for optimum photosynthesis to supply enough carbohydrates for strong fruit sink and higher yield (Arzani, 4). Fruit set depends on availability of compatible pollen, pollinating insects, prevailing temperature and humidity. Occurrence of rainfall at flowering may reduce the fruit set. The cultivar Friar took maximum number of days (132 days) to reach maturity whereas cultivar Burbank took minimum number of days (95 days) to reach maturity. These results are in line with Moghaddam *et al.* [12] who reported 125 days maturity period for Friar. The fruit development depends on the cultivar chilling requirements and temperature sums from blossoming to harvest period in general. However, Alburquerque *et al.* [1] stated that in many cases, harvest time was not related to the blossoming time, as later-flowering cultivars may be harvested earlier than earlier-flowering cultivars. Yield efficiency was highest in cultivar Friar (1.23 kg/cm^2) while as lowest yield efficiency was recorded in Santa Rosa (0.14 kg/cm^2). This is probably due to their high vigour and high TCSA, and also low yields (Singh and Kaundal, 18; Peppelman *et al.*, 14). The yield efficiency ranged from 0.20 kg/cm^2 (Santa Rosa) to 1.84 kg/cm^2 (Friar) and such variation in yield efficiency has also been observed by Milosevic *et al.* [11]. In the present study, fruit weight varied from 38.81g (Satsuma) to 50.47 (Friar) which was found to be in accordance with the results of Kumar *et al.* [8]. The fruit volume varied from 27.08 cm^3 (Satsuma) to 54.36 cm^3 (Santa Rosa) which was in agreement with the findings of Kumar *et al.* [7] and Madalina *et al.* [9]. Stone weight varied from 0.72 g to 2.04 g among the cultivars under study, which was observed to be in accordance with the work of Sundouri *et al.* [19]. Cultivar Stanley had maximum stone weight (2.04 g) and cultivar Friar recorded the minimum stone weight (0.72 g). Similar results were observed by Moghaddam *et al.* [12] and Milosevic and Milosevic [10]. Further, Moghaddam *et al.* [12], Sundouri *et al.* [19] and Kumar *et al.* (2018), reported adherence of stone to flesh in Stanley and Friar to be free stone and Santa Rosa and Burbank to be clinging stone respectively, which supports the results observed in the present study.

Conclusion

From the present study, it can be concluded that cultivars 'Stanley' and 'Friar' proved to be promising with respect to better fruit set, yield, yield efficiency good fruit size, pulp weight of fruit and free stone. These two cultivars can also prove helpful in stretching the season and increasing the duration of harvest time is important to be able to send an adequate supply of fresh fruit to market, due to its high demand and high price.

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