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Varietal Characteristics of Exotic Plum Cultivars under Changing Climate Scenario of North Western Himalayas

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A B S T R A C T

Exotic plum cultivars that have been introduced from different countries and planted at Central Institute of Temperate Horticulture were studied for their various varietal characteristics. The study consisted of fourteen different plum cultivars of uniform age replicated thrice in a Randomized Complete Block Design (RCBD). All the cultivars under study had round fruit shape except Grand Duke and Au-Rosa which were oblong and heart shaped. Highest fruit weight (65.78 g) was recorded in cultivar Frontier while lowest fruit weight (26.44 g) was recorded in cultivar Krassivica Plum. Most of the cultivars were cling stone type except Frontier, Au-Rosa and Grand Duke which were free stone type. Maximum values for total sugars were recorded in cultivar Frontier (8.96%), reducing sugars in cultivar Monarch (6.98 %) and non-reducing sugars in cultivar Tarrol (2.78 %). Maximum total soluble solids (TSS) were recorded in cultivar Au-Rosa (16.06 ^{0}B), whereas, highest acidity was recorded in cultivar Black Amber (2.22 %) and sugar: acid ratio was registered in cultivar Frontier (7.59). Cultivar Red Plum matured earliest among all the cultivars whereas cultivar Grand Duke matured late. Maximum fruit yield (52.54 kg/tree) was registered in cultivar Frontier while minimum (18.07 kg/tree) was recorded in cultivar Kubio Plum. These cultivars can be further evaluated and used in breeding programme for further improvement of plum.

Introduction

Plum is one of the important and widely cultivated stone fruits ranking fourth after apple, pear and peach (Vishnu *et al.,* 2012). It is predominantly grown in temperate and sub-temperate regions of different states of India, which provide excellent and congenial climatic conditions for its cultivation. High chill plum is mostly grown in temperate climatic conditions of Jammu and Kashmir and Himachal Pradesh, whereas low chill in sub temperate climatic conditions of Punjab, Uttarakhand, hills of Uttar Pradesh and NER of Sikkim and Arunachal Pradesh.

Plum has assumed greater significance as fresh fruit and in processing industries. It is a delicious fruit prized both for its exquisite fresh fruit flavour and aroma. The fruits are

fairly attractive but usually are soft, clingstone, round and heart shaped (Teskey el. 1978). The common plum (*P. domestica*) is known for its diversity in fruit size, colour, flavour and is one of the most desirable plum species in terms of fruit quality (Gonez-Pleza and Ledbetter 2010). Plum species and cultivars are quite diverse in fruit characters such as fruit size, shape, colour, texture, aroma and quality depending on their climatic requirement and conditions. Newly introduced cultivars generally do not flourish well until and unless its performance and characterization is carried out simultaneously under the changing climatic conditions of their adaptation to new habitation and further recommended for commercial cultivation. This can be unrivalled through taxonomical studies, which could serve as an index for assigning correct status of a genotype.

The need of improving fruit quality is a priority for the modern plum culture under climate change scenario. The changes into plum culture completed with new varieties assessment and new research concerning the various phenological and physico-chemicals characteristics of the fruit according with the various ecological conditions. When growing the introduced plum cultivars, it is important to determine their characteristics in changing climatic scenario for their adaptation in local environment. Presently, Santa Rosa is the leading cultivar of plum in Himalayan states of Jammu and Kashmir and Himachal Pradesh, occupies about 75 per cent of the total under plum cultivation (Sundouri *et al.*, 2017). But, the predominance of the single cultivar leads to the glut in the market as e result the farmers do not get remunerative price for their produce and sometimes even they do not get back the cost of production Hence, there is a need to have extended ripening period to avoid the glut in the market. This can be possible, if new exotic introductions are thoroughly studied under changing climatic conditions for their performance and recommendations.

Few exotic plum cultivars have been introduced at Central Institute of Temperate Horticulture, Srinagar with the objective to increase the germplasm base and their further recommendation for commercial cultivation. The information regarding the performance of these new introductions under the temperate condition of Kashmir is lacking though varieties exhibit tremendous variability in growth, yield and quality attributes. Area expansion under these new exotic varieties and to increase the total production of plums is possible only after proper evaluation of these exotic cultivars on various physico-chemical traits, yield and to designate them according to their maturity period. Hence the present study was undertaken to fill this gap.

Materials and Methods

The present investigation was carried out at Central Institute of Temperate Horticulture (CITH), Srinagar, Kashmir during the year 2014-15. Twelve-year-old bearing plum trees of different cultivars having uniform size and vigour were selected for study. The experimental Farm is situated at an altitude of 1588 meter above mean sea level with latitude of 34.8’ and longitude of 74.83’ N. The trees were spaced 5×5 meters in square system of planting and uniform cultural practices as per package and practices were followed during the period of study. The orchard soil was moderately deep with medium fertility status. Fourteen cultivars of plum presented in table 1 were evaluated for different traits. Single tree in each cultivar constituted an experimental unit and each cultivar was replicated three times.

Hard and firm ripe fruits were harvested from the experimental trees at physiological maturity during early hours in the morning.

The fruit was immediately transferred to laboratory washed under running tap water, cleaned and dried with a piece of muslin cloth. Fruit length, fruit breadth, stone length and stone breadth was measured with digital Vernier's Calliper and expressed in mm. Fruit and stone weight was recorded on battery operated digital balance. Firmness of ten randomly selected fruits was measured with the help of a penetrometer (Model FT-327, USA) using 8 mm stainless steel probe and expressed in terms of Kg/cm^2. Solid soluble content (SSC) of juice were determined with the help of *Erma* hand refractometer in terms of degree Brix. Titratable acidity (TA) was calculated in terms of anhydrous malic acid by titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. Fruit juice pH (FPH) was measured with electronic pH electrode meter. The data recorded during the course of this study was analyzed statistically as per the procedures described by (Singh el al. 1973) and results are summarized in tables with average of three replications**.**

Results and Discussion

Fruit characters

Fruit length in different cultivars ranged from 30.0 mm to 50.42 mm, fruit breadth from 28.62 to 47.70 mm and fruit thickness from 27.18 to 44.56 mm. Maximum fruit length was measured in cultivar Grand Duke (50.42 mm) whereas minimum was observed in cultivar Krassivica Plum (30.0 mm). Maximum fruit breadth and fruit thickness was measured in cultivar Frontier (47.70 mm and 44.56 mm) whereas minimum fruit breadth was recorded in cultivar Krassivica Plum (28.62 mm and 27.18 mm). Fruit weight under present study ranged from 26.44 g to 65.78 g in different plum cultivars. Maximum fruit weight (65.78 g) was recorded in cultivar Frontier followed by Grand Duke (53.34 g) and minimum fruit weight was recorded in cultivar Krassivica Plum (26.44 g). This variation might be due to differences in genetic constitution of cultivars and crop load that appear to be responsible for difference in fruit weight and size. The results are in agreement to the findings of Ozakman *et al.,* (1995) and Chanana *et al.,* (1992) and Rouse and Sherman (1989) who reported that the cause of variation in fruit weight may be due to varied fruit size (length and breadth) and difference in crop load. The present findings are also in conformity with earlier studies conducted by Bal and Chohan (1981) and Mishra and Srivastava (1973). The variation in fruit breadth and thickness in peach and other Prunus species has also been reported by other workers (Chadha and Sankhayayan, 1974, Ladhar, 1978).

Fruit colour varied appreciably among the different plum cultivars. Red purple colour was possessed by five cultivars (Grand Duke, Black Amber, Au- Rosa, Kubio Plum and Krassivica Plum), red colour by five cultivars (Red Beaut, Tarrol, Burbank, Red Plum and Beauty), grey purple by Frontier and yellow colour by three cultivars viz; Au- Cherry, Kanto 5 and Monarch. Fruit flesh colour of different plum cultivars revealed that yellow orange colour was dominant with the traces of the other colours depending upon their genetic constitution and pigmentation. Yellow orange colour was found dominant in seven cultivars viz; Frontier, Red Beaut, Tarrol, Grand Duke, Red Plum, Burbank and Beauty, dark red flesh in cultivars Black Amber, Kubio Plum and Krassivica Plum, red flesh in cultivar Au-Rosa and yellow flesh in three cultivars viz; Au-Cherry, Kanto 5 and Monarch. Similar variations in the fruit and flesh colour have been reported by different workers (Singh *et al.,* 2011, Kumar *et al.,* 2013 and Tandon, 2006)

Present data revealed wide variation among the different plum cultivars for their fruit shape. Eight plum cultivars viz; Frontier, Red

Beaut, Tarrol, Burbank, Kanto 5, Kubio Plum, Monarch and Beauty were round, cultivars Red Plum and Krassivica Plum were ovate, cultivars Black Amber and Au- Cherry were elliptic, cultivar Grand Duke was oblong however cultivar Au- Rosa had heart shape. Variation in fruit shape was also reported by other workers (Sharma, 1999 and Tandon, 2006), which might be due to difference in genetic makeup of these cultivars and variation in climate of the region.

Stone characters

Length and breadth of stone in different cultivars ranged from 10.58 mm (Red Plum) to 21.70 mm (Grand Duke) and 4.47 mm (Kanto 5) to 14.94 mm (Grand Duke), respectively. Stone weight ranged from 0.89 g to 1.84 g in studied cultivars. Highest stone weight was recorded in cultivar Grand Duke (1.86 g) and lowest was recorded in Au-Cherry and Kubio Plum (0.89 g). Maximum pulp: stone ratio was recorded in cultivar Kanto 5 (56.46) and the minimum pulp: stone ratio was recorded in cultivar Red Beaut (25.58).

Adherence of stone to the fruit flesh was categorized as cling, semi cling and free stone types. Among the different cultivars under investigation, nine cultivars (Red Beaut, Tarrol, Black Amber, Burbank, Au- Cherry, Kanto 5, Red Plum, Krassivica Plum and Monarch) were cling stone type, three cultivars (Frontier, Grand Duke and Au- Rosa) were free stone type and two cultivars (Kubio Plum and Beauty) were semi cling stone type.

Variation in pulp: stone ratio in plum has been reported by Thakur *et al.,* (2014) and Josan *et al.,* (1999). They found that pulp: stone ratio ranged from 59.13 per cent to 19.56 per cent. Variation in stone weight has been reported by Dhatt *et al.,* (1992), Vukojevic *et al.,* (2012) which ranged from 2.90 g in cultivar Fortune and 0.95 g in Red Beaut. 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 with respect to stone adherence in different plum cultivars might be due to varietal characteristics. Similar type of variation has also been reported by other workers (Singh *et al.,* 2011, Sharma and Verma, 2012 and Tandon 2006).

Chemical characters

Fruit chemical characters of different plum cultivars such as total sugars, reducing sugar, non-reducing sugar, TSS, acidity, sugar acid ratio and juice pH was recorded under the present study. Maximum total sugars were recorded in cultivar Frontier (8.96 per cent) and minimum total sugars were recorded in cultivar Red Plum (5.41 per cent). Reducing sugar ranged from 3.88 per cent (Au-Rosa) to 6.98 per cent (Monarch) whereas non-reducing sugar ranged from 0.38 per cent (Red Plum) to 2.78 per cent (Tarrol) under present investigation.

Maximum total soluble solids (TSS) were recorded in cultivar Au- Rosa (16.06^{o}B) while the lowest was recorded in cultivar Krassivica Plum (10.0 ^{o}B). Fruit acidity of different plum cultivars ranged from 1.18 to 2.22 %. The maximum acidity was recorded in cultivar Black Amber (2.22 %) and minimum acidity was recorded in cultivar Frontier (1.18%). Maximum sugar: acid ratio was recorded in cultivar Frontier (7.58 %) and the minimum sugar: acid ratio was recorded in cultivar Burbank (2.93 %). The pH of juice was maximum in cultivar Monarch (4.2) and lowest in cultivar Beauty (3.1).

Significant differences in fruit juice pH among different cultivars and their parents was reported by Milosevic and Milosevic (2011) in

plum and values ranged from 3.35 (Cacanska Lepotica) to 0.04 (Stanley). Similar type of variation in fruit juice pH in plum has also been reported by other workers (Nergiz and Yildiz, 2010, Tomas-Barberan *et al.,* 2001). Sugar: acid ratio is an important factor in determining the consumer acceptability of any edible fruit. Variation in reducing and non-reducing sugar, TSS, acidity and pH of juice may be due to genetical makeup of plum cultivars (Erturk *et al.,* 2009) and may also be affected by agro-climatic conditions, management practices, location and storage conditions (Josan *et al.,* 1999) and Sharma (1994). The chemicals constitute of the different cultivars depends on the different rate of conversions of complex organic acids into simple sugars at the time of maturity and has been variated by the agro-climatic conditions and nutritional factors (Nergiz and Yildiez, 2010) (Table 2–4).

Table.1 Plum cultivars used in study

Cultivar	Fruit colour	Flesh colour	Fruit shape	Maturity	Stone adherence
Frontier	Grey purple	Yellow orange	Round	2nd June	Free stone
Red Beaut	Red	Yellow orange	Round	6th June	Cling stone
Tarrol	Red	Yellow orange	Round	2nd June	Cling stone
Grand Duke	Red purple	Yellow orange	Oblong	26th June	Free stone
Black Amber	Red purple	Dark red	Elliptic	7th June	Cling stone
Burbank	Red	Yellow orange	Round	10th June	Cling stone
Au-Cherry	Yellow	Yellow	Elliptic	5th June	Cling stone
Au-Rosa	Red purple	Red	Heart shape	2nd June	Free stone
Kanto 5	Yellow	Yellow	Round	12th June	Cling stone
Kubio Plum	Red purple	Dark red	Round	20th June	Semi cling stone
Red Plum	Red	Yellow orange	Ovate	28th May	Cling stone
Krassivica Plum	Red purple	Dark red	Ovate	5th June	Cling stone
Monarch	Yellow	Yellow	Round	8th June	Cling stone
Beauty	Red	Yellow orange	Round	9th June	Semi cling stone

Table.2 Qualitative characters of plum cultivars

Cultivar	Fruit weight (g)	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Yield/ tree (kg)	Stone length (mm)	Stone breadth (mm)	Stone weight (g)	Pulp : stone ratio (%)
Frontier	65.78	50.02	47.70	44.56	52.54	12.82	6.44	1.48	43.44
Red Beaut	48.91	46.72	44.28	38.67	32.24	12.73	10.80	1.84	25.58
Tarrol	42.40	33.70	29.86	27.44	35.00	14.66	6.13	1.31	31.36
Grand Duke	53.34	50.42	47.00	44.22	42.49	21.70	14.94	1.86	27.67
Black Amber	34.82	30.85	30.57	28.85	22.66	14.59	10.76	1.00	33.82
Burbank	46.11	43.30	38.23	35.44	35.18	14.64	10.93	1.16	38.75
Au-Cherry	44.61	35.89	42.49	38.36	44.13	12.91	6.62	0.89	49.12
Au-Rosa	38.92	46.00	35.07	31.09	22.95	15.00	5.64	1.17	32.26
Kanto 5	51.72	30.45	30.97	27.70	40.35	11.88	4.87	0.90	56.46
Kubio Plum	28.45	32.28	30.99	27.48	18.07	11.35	7.47	0.89	30.96
Red Plum	36.56	38.44	32.93	28.95	30.57	10.58	7.82	1.18	29.98
Krassivica Plum	26.44	30.00	28.62	27.18	26.56	12.15	6.99	0.94	27.12
Monarch	44.87	43.32	40.97	36.85	37.55	15.71	7.18	1.52	28.51
Beauty	47.65	43.44	40.58	38.39	45.31	12.86	5.97	1.22	38.05
Mean	**43.61**	**39.63**	**37.16**	**33.94**	**34.68**	**13.82**	**8.04**	**1.24**	**35.22**
$CD_{0.05}$	**1.17**	**0.88**	**2.21**	**1.30**	**1.43**	**0.31**	**0.36**	**0.50**	**0.82**
CV	**10.23**	**7.36**	**11.33**	**5.52**	**5.54**	**11.31**	**7.19**	**2.12**	**9.26**

Table.3 Quantitative characters of plum cultivars

Cultivar	Total sugars (%)	Reducing sugars (%)	Non- reducing sugars (%)	TSS (%)	Acidity (%)	Sugar: acid ratio	Juice pH
Frontier	8.96	6.64	2.20	14.86	1.18	7.59	3.7
Red Beaut	6.89	5.31	1.50	14.03	1.49	4.62	3.7
Tarrol	8.44	5.45	2.78	15.13	1.32	6.39	3.6
Grand Duke	7.66	5.19	2.34	11.23	1.69	4.53	3.9
Black Amber	8.67	5.86	2.66	10.60	2.22	3.90	3.7
Burbank	6.17	4.54	1.54	13.03	2.10	2.93	4.0
Au-Cherry	7.63	6.59	0.98	11.80	2.20	3.46	4.1
Au-Rosa	5.67	3.88	1.70	16.06	1.29	4.29	3.6
Kanto 5	7.84	4.95	2.77	14.80	1.83	4.28	3.7
Kubio Plum	8.05	5.58	2.34	10.60	1.38	5.83	3.3
Red Plum	5.41	5.37	0.38	11.70	1.32	4.09	3.3
Krassivica Plum	8.41	6.36	1.94	10.00	1.65	5.09	4.1
Monarch	8.20	6.98	1.15	15.06	1.75	4.68	4.2
Beauty	7.17	5.55	1.53	13.06	1.31	5.47	3.1
Mean	**7.51**	**5.31**	**1.82**	**12.56**	**1.66**	**4.35**	**3.40**
$CD_{0.05}$	**0.62**	**0.09**	**0.34**	**1.30**	**0.29**	**0.06**	**0.25**
CV	**5.23**	**10.05**	**10.92**	**5.97**	**10.51**	**7.76**	**4.08**

Table.4 Physico-chemical characteristics of plum cultivars

Cultivar	Total sugars (%)	Reducing sugars (%)	Non- reducing sugars (%)	TSS (%)	Acidity (%)	Sugar: acid ratio	Juice pH
Frontier	8.96	6.64	2.20	14.86	1.18	7.59	3.7
Red Beaut	6.89	5.31	1.50	14.03	1.49	4.62	3.7
Tarrol	8.44	5.45	2.78	15.13	1.32	6.39	3.6
Grand Duke	7.66	5.19	2.34	11.23	1.69	4.53	3.9
Black Amber	8.67	5.86	2.66	10.60	2.22	3.90	3.7
Burbank	6.17	4.54	1.54	13.03	2.10	2.93	4.0
Au-Cherry	7.63	6.59	0.98	11.80	2.20	3.46	4.1
Au-Rosa	5.67	3.88	1.70	16.06	1.29	4.29	3.6
Kanto 5	7.84	4.95	2.77	14.80	1.83	4.28	3.7
Kubio Plum	8.05	5.58	2.34	10.60	1.38	5.83	3.3
Red Plum	5.41	5.37	0.38	11.70	1.32	4.09	3.3
Krassivica Plum	8.41	6.36	1.94	10.00	1.65	5.09	4.1
Monarch	8.20	6.98	1.15	15.06	1.75	4.68	4.2
Beauty	7.17	5.55	1.53	13.06	1.31	5.47	3.1
Mean	**7.51**	**5.31**	**1.82**	**12.56**	**1.66**	**4.35**	**3.40**
$CD_{0.05}$	**0.62**	**0.09**	**0.34**	**1.30**	**0.29**	**0.06**	**0.25**
CV	**5.23**	**10.05**	**10.92**	**5.97**	**10.51**	**7.76**	**4.08**

Fig.1 Variability in fruit shape, size and colour of plum cultivars under study

Legend: A- Heart Shape;
B- Elliptic Shape;
C- Oblong Shape;
D- Round Shape;
E- Ovate Shape

Yield

In the present study, fruit maturity was earliest in cultivar Red Plum (28th May) and late in cultivar Grand Duke (26th June). The yield per tree in different cultivars ranged from 18.07 kg to 52.54 kg. The maximum yield per tree was recorded in cultivar Frontier (52.54 kg) and minimum yield was recorded in cultivar Kubio Plum (18.07 kg). The time of maturity of plum cultivars ranged from the middle of June to the first week of September Balik (2004) and Sharma and Jason (1993). These different findings are most likely attributed to the characteristics of different species of fruit. Further, the differences in fruit maturity may also be the result of different ecological conditions.

The yield potential of a plum crop is inherently dependent upon their adaptation to agro-climatic conditions and management practices. The ultimate objective of the grower is to have high yield, which is highly variable among the different cultivars and is genetically controlled. However, yield generally depends on the health of tree, nutrition, age of plants, cultural practices adopted, pest and disease incidence and finally climatic conditions of cultivated area (Balik (2004).

It is concluded, on the basis of various physic-chemical characteristics as well as yield, the cultivar 'Frontier' was found to be the best, whereas, Au-Rosa was best with respect to sweetness of fruit. Cultivars viz; 'Frontier', 'Grand Duke' and 'Au- Rosa' were free stone. On the basis of harvesting date, all the cultivars under study were grouped into early (last week of May), mid (third week of June) and late (last week of June) cultivar. Cultivars viz; Red Plum, Frontier, Tarrol and Au-Rosa were early, Red Beaut, Monarch, Beauty, Krassivica Plum, Black Amber, Au-Cherry and Burbank were mid season and Grande Duke, Kento-5 and Kubio Plum were late to harvest. The cultivar with distinct superiority in yield and quality characteristics were recommended for commercial adaption and in further improvement programmes through breeding.

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