

Evaluation studies on exotic plum germplasm under Kashmir Conditions

Surendra Kumar Verma
(2013-A-999-M)



Division of Fruit Science
Faculty of Horticulture
**Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir**

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Thesis

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in partial fulfilment of requirement for the award of the degree of

**Master of Science in Horticulture
(Fruit Science)**

2016



Dedicated
To My
Beloved Parents



Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Fruit Science

Certificate – I

This is to certify that the thesis entitled “**Evaluation studies on exotic plum germplasm under Kashmir Conditions**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Fruit Science)**, to the Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by **Mr. Surendra Kumar Verma (Regd. No. 2013-A-999-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

(Dr. A. S. Sundouri)
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Advisory Committee

Endorsed

Prof. & Head,
Division of Fruit Science

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Fruit Science

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We, the members of the Advisory committee of **Mr. Surendra Kumar Verma (Regd. No. 2013-A-999-M)**, a candidate for the degree of **Master of Science in Horticulture (Fruit Science)**, have gone through the manuscript of the thesis entitled, **“Evaluation studies on exotic plum germplasm under Kashmir Conditions”** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

Advisory Committee

Chairman

Dr. A.S. Sundouri
Assistant Professor
(Fruit Science)
Ambri Apple Research Station,
SKUAST-Kashmir, Shopian

Members

Dr. M.K. Sharma
Associate Professor
Division of Fruit Science,
SKUAST-Kashmir

Dr. F.A. Khan
Associate Professor
(Plant Physiology)
Division of PHT,
SKUAST-Kashmir

Dr. T.A. Raja
Associate Professor (Statistics)
FVSc & AH., SKUAST-Kashmir

Dr. O.C. Sharma
Senior Scientist (Hort.),
CITH, Rangrett, Srinagar

Dr. A.A. Khan
Associate Professor
Division of Entomology, SKUAST-Kashmir
(Dean’s Nominee)

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Fruit Science

Certificate – III

This is to certify that the thesis, **“Evaluation studies on exotic plum germplasm under Kashmir Conditions”** submitted by **Mr. Surendra Kumar Verma (Regd. No. 2013-A-999-M)** to the Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Fruit Science)** was examined and approved by his Advisory Committee and external examiner on

Chairman
Advisory Committee

External Examiner

Prof. & Head
Division of Fruit Science

Dean,
Faculty of Horticulture,
SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Fruit Science

Name of the student : **Surendra Kumar Verma**

Registration No. : 2013-A-999-M

Major subject : **Fruit Science**

Minor subjects : Plant Physiology

Major advisor : **Dr. A.S. Sundouri**
Assistant Professor (Fruit Science),
Ambri Apple Research Station,
SKUAST-Kashmir, Shopian

Title of the Thesis : **“Evaluation studies on exotic plum germplasm under Kashmir Conditions”**

ABSTRACT

The present investigation entitled **“Evaluation studies on exotic plum germplasm under Kashmir conditions”** was carried out with the objective to study the phenological stages (vegetative and floral) and physico-chemical characters of different exotic plum cultivars and their grouping on the basis of their maturity.

Exotic plum cultivars have been introduced at Central Institute of Temperate Horticulture, Srinagar in order to increase the spectrum of existing germplasm and recommendation of better cultivars for their commercial cultivation. The present study consisted of fourteen different plum cultivars of uniform age replicated thrice in a Randomized Complete Block Design (RCBD). The data recorded revealed that the bud swell and tight cluster stage was first in cultivar Beauty on 30th March and 2nd April, respectively. The early date of first flower bloom was observed in cultivars Frontier, Red Beaut, Tarrol, Au-Rosa, Krassivica Plum and Beauty (7th April), while the date of full bloom (10th April), first petal fall (12th April) and complete petal fall (17th April) was reported late in cultivar Beauty. Maximum duration of flowering (15 days) was recorded in cultivars Frontier and Au-Rosa whereas minimum duration of flowering (9 days)

was registered in cultivar Red Plum. Highest number of flower per branch was recorded in cultivar Au-Rosa (104.83) whereas, highest percentage of fruit set was recorded in cultivar Krassivica Plum (52.85 %). Highest percentage of fruit drop was observed in cultivar Frontier (44.21 %). 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 (26.44 g) was recorded in cultivar Krassivica Plum. Most of the cultivars were cling stone type except Frontier, Au-Rosa and Grand Duke cultivars which were free stone type. Maximum values for total sugars was 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) was recorded in cultivar Au-Rosa (16.06 ⁰B), 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. On the basis of the fruit physical (fruit weight, fruit colour, fruit shape and stone adherence), fruit chemical (sweetness), yield and maturity period, cultivars “Frontier”, “Au- Rosa” and “Grand Duke” performed best. These cultivars can be further evaluated and used in breeding programme for further improvement of plum.

Keywords: Plum, Variation, Characterization, Evaluation.

Signature of Student

Signature of Major Advisor

Dated: _____

Dated: _____

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Chapter – 1

INTRODUCTION

Plum (*Prunus salicina* L.) is one of the most important stone fruit of temperate zone. It belongs to family *Rosaceae*, sub family *Prunoideae* and order Rosales. This group contains 20-40 species (Okie and Hancock 2008), that are distributed in different part of the world. This genus has a wide range of ploidy levels viz., the Japanese plum (*Prunus salicina* Lindl.), Myrobalan plum (*P. cerasifera* Ehrh.) and American plum (*P. americana* Marsh., *P. munsoniana* Wight and *P. angustifolia* Marsh) are diploid ($2n=2x=16$), *P. spinosa* L. ($2n=4x=32$) is tetraploid and the European plum (*P. domestica*) is hexaploid ($2n=6x=48$) (Shimada *et al.*, 1999). The most important commercial species of plum belong to only two groups viz., the European and Japanese types. The European plum has been reported to originate from Asia Minor as a diploid hybrid between *P. cerasifera* (Myrobalan plum) and the *P. spinosa* L., whereas, Japanese plum is native to China, although it became a commercial fruit of Japan and America.

Plum has assumed greater significance as fresh fruit and in processing industries. It is a delicious fruit prized both for its exquisite fresh fruit flavor and aroma. The fruits are fairly attractive but usually are soft, clingstone, round and heart shaped (Teskey and Shoemaker 1978). Besides having medicinal properties, it is fairly good source of carbohydrates (63.88 g), sugars (38.13 g), phosphorus (69 mg), potassium (732 mg) per 100 g of fresh weight and vitamin A (781IU) (Westwood, 1993). Plums are rich in sugars, Vitamins A, B (Thiamine), riboflavin and some minerals like calcium, phosphorous and iron. European plums are consumed dry and fresh while Japanese plums are mostly consumed fresh (Ertekin *et al.*, 2006). The dried plums are known as prunes. All plum cultivars cannot be used for drying purpose that is why it is said “all plums are not prunes but all prunes are plums”.

Plum requires varying type of climate ranging from subtropical plains to the temperate high hills. It thrives well in low hills and in the sub mountain tracts where high chilling fruit crops like apple and cherry not be grown profitably. European plum thrives best at 1300-2000 m above mean sea level and requires about 1000-1200 chilling hours (below 7.2°C) during winter to break rest period where as Japanese plum requires 700-1000 chilling hours (below 7.2°C) which is in mid hill areas located at an elevation of 1000-1600 m above mean sea level. Japanese type plums are usually borne laterally on short, thick spurs and twigs (Teskey and Shoemaker, 1978). The spurs are found mostly on 2-8-year-old wood and live for 5-8 years. Commonly, three flowers arise from one flower bud. Plum trees can grow in a variety of soil types. However, deep, well- drained, loamy soils are preferred. Plums are more tolerant to heavy or wet soils than most other stone fruit types. Plum are grown over the five continents of the world and production level exceeds 11 million tonnes (Milosevic and Milosevic 2012).

Plum is one of the important and widely cultivated stone fruits predominantly grown in temperate and sub-temperate regions of different states of India, which provide excellent and congenial climatic conditions for its cultivation. Plum is quite spread on earth, especially in the temperate northern hemisphere ranking fourth after apple, pear and peach (Vishnu *et al.*, 2012). European plum is mostly grown in temperate states viz., Jammu and Kashmir and Himachal Pradesh, whereas Japanese plum in sub temperate states like Punjab, Uttarakhand, hills of Uttar Pradesh and North Eastern states Sikkim and Arunachal Pradesh. In Jammu and Kashmir, plum occupy an area of 4,279 ha with a production of 11,658 MT (Anonymous, 2016). The total world production of the plum is 99,21,953 MT in which China occupied first rank (53,72,899 MT) followed by Serbia (6,62,631 MT) and USA (5,61,366 MT) whereas India is at 9th rank with annual production of 1,96,900 MT (FAO, 2016).

The common plum (*P. domestica*) is known for its diversity in fruit size, color, flavor 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, color, texture, aroma and quality. The *Domestica* plum require relatively more chilling for successful cultivation, whereas *Salicina* group can be grown under comparatively warmer conditions. Cultivar generally will not flourish well until and unless it is correctly identified and placed in its respective group and then recommended for commercial cultivation. Thus, there is a need to at least correctly place such cultivars in their respective groups, if varietal identification is not possible. This can be unrivalled through taxonomical studies, which could serve as an index for assigning correct status of a genotype. Santa Rosa is one of the leading cultivars of plum in hills of Jammu and Kashmir and occupies about 75 per cent of the total under plum cultivation. But, the predominance of the single cultivar leads to the glut in the market and 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 extend the ripening period to avoid the glut in the market. This is possible, if new exotic introductions are made and evaluated under the local climatic conditions.

The necessity of improving fruit quality is a priority for the modern plum culture. 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 under local conditions. Few exotic plum cultivars have been introduced at Central Institute of Temperate Horticulture, Srinagar with the objective to increase the size of existing germplasm and further their recommendation for commercial cultivation. Still there is no report regarding these new introductions under the temperate condition of Kashmir. These varieties exhibit tremendous variability in growth, yield and quality attributes. To bring more area under these new exotic varieties and to increase the total production of

plums is possible after proper evaluation on each aspect of these exotic cultivars with the following objectives:

- To study the phenological stages and morphological traits of exotic plum germplasm
- To evaluate their physico-chemical traits and yield attributes.
- To designate the plum germplasm according to their maturity period.

Chapter – 2

REVIEW OF LITERATURE

Plum (*Prunus salicina* L.) is one of the most important stone fruit of temperate zone. It belongs to family *Rosaceae*, sub family *Prunoideae* and order Rosales. Currently, the botanical classification for plum has a wide range of ploidy level viz; the Japanese plum (*Prunus salicina* L.) are diploid ($2n=2x=16$), *P. spinosa* L. ($2n=4x=32$) is tetraploid and the European plum (*P. domestica*) is hexaploid ($2n=6x=48$) (Shimada *et al.*, 1999). Botanically speaking, drupes are a fruit that have a soft, edible exocarp/mesocarp that surround a hard, lignified endocarp which in the case of *Prunus persica* is referred to as the stone or pit (Abbott *et al.*, 2007).

All stone fruits (apricot, peach, cherry and plum) are strictly self-incompatible, which promotes complete out breeding thus, very high genetic heterozygosity is accepted within the germplasm. However, heterozygosity within cultivars remained fixed because of their vegetative propagation through grafting, which limit the chance of increasing the diversity in orchards. Therefore, these cultivars have limited value as gene pool for breeding programs for production of improved cultivars. Generally, the genetic diversity is represented by wild, landraces, cultivars and plant materials available from the crosses through the breeding programs and other related species. Much of the genetic diversity is available in the wild types and landraces from the center of origin. Wild species are probable gene resources for the breeding objectives such as resistance to pests and diseases, more appropriate cultivars for table and industry, extending harvest season and developing new resistant and dwarfing rootstocks. Therefore, it is necessary to characterize and preserve these species (Demirsoy and Demirsoy, 2004).

According to Hallauer (2000) the two main factors needed for successful breeding programme are adequate genetic variation and effective selection.

Hence, selection from available cultivars has proved to be useful in the hands of fruits breeders to tap the available genetic variability in these populations. In this chapter, brief review of available literature on evaluation studies on exotic plum germplasm has been revealed under following headings:

- 2.1 Phenological stages
- 2.2 Leaf characters
- 2.3 Physical characters of fruits
- 2.4 Stone characters
- 2.5 Chemical traits of fruits
- 2.6 Fruit yield/harvesting

2.1 Phenological stages

2.1.1 Bud stage

Parez-paster *et al.* (2004) reported that apricot flower bud swell during 15th to 25th February and bud open during 26th to 27th February. Flower start to open during 7th March, full bloom during 7th to 9th March and complete petal fall during 10th to 14th March, respectively.

Sharma *et al.* (2012) observed that peach cultivar “Suncrest” was earliest in bud swell (20th February to 28th February), pink bud (1st March to 7th March) and full bloom (9th March to 15th March) but the petal fall stage (28th March) was late in July Elberta.

Thakur *et al.* (2014) reported that the time of bud burst and bud swell in the studies plum cultivars (Au- Rosa, Santa Rosa, Fortune, Queen Rosa and Florida 1-2) extended from second week of February to the second week of March.

2.1.2 Floral stages

Tomer and Singh, (1981) recorded earliest flowering in peach cultivar

Peshawari Gola and Flordasun was the last to bloom, with the minimum flowering duration (25th days), whereas the cultivar Safeda took the maximum period (40th days) to complete its flowering.

Faruqi *et al.* (1988) and Sharma and Sharma (1991) reported that the flowering period in apricot started from last week of February to middle of March, with the duration of 20th to 28th days and all the cultivars set fruit within 12-17 days after full bloom under appropriate climatic conditions with a good fruit set.

Khokhar and Agnihotri (1990) reported that the average dates of full bloom in cultivar Bonita, Early Amber, Flordared, Flordasun, and Shan- i-Punjab were 2nd, 3rd, 8th, 12th and 23rd March, respectively.

Bellini (1992) reported that the flowering time in 9 European plum selections was between 20th March and 1st April. Billini *et al.* (1992) reported that the early flowering was observed in Florida 1-2, mid flowering in Red Beaut, Fortune, Queen Rosa, Ruby Sweet and Santa Rosa and late flowering in cultivars Au- Rosa and Frontier plums. The average number of flowering days was 15th in the studied cultivars.

Kemp (1996) recorded the flowering time of four plum cultivars in Europe and observed that first flower opened from 5th April to 11th May and attained full bloom from 12th April to 19th May. Szabo and Nyeki (1996) reported that the flowering period varied from 4th to 15th days in various European plum cultivars.

Bal (1997) reported that in plum, flowering started in the second week of February and tree attained full bloom in 7th to 10th days after the first flower appeared. Mahajan *et al.* (2002) reported that the date of full bloom was earliest in Azar Shah and Red plum. While date of full bloom was latest in Black plum and Green Gage plums. Bali *et al.* (2004) reported that cultivar Black Beauty was an early blooming cultivar than the other studies plum cultivars.

Clark *et al.* (2005) reported the average full bloom date was 27th March for cultivar White Rock and 26th March for White County in peach. Chaudhary and

Mehta (2005) reported that under India subtropical conditions, peach flowering lasts for 12.9 ± 0.5 days from bud stage. The flower remained in bud stage for maximum period of 9.9 ± 0.1 days with range of 0.3 days.

Caliskan *et al.* (2006) observed that the date of full bloom was earliest in Black Diamond, Black Beauty and Oblinaja and latest was observed in President, October Sun and T.C. Sun cultivars of plum.

Verma *et al.* (2009) reported that the date of full bloom in peach ranged from 23rd January to 26th March. They further observed the greater difference of 109 days between the earliest and latest maturing accessions.

Levent (2010) observed that the full bloom period ranged from 13th March for Black Diamond to 4th April for T.C. Sun plum in Turkey. Cosmulescu *et al.* (2010) reported that the period between the beginning of flowering and the end varied from 14th to 17th days in plum cultivars and difference occurred between cultivars.

Sharma *et al.* (2012) observed that the maximum flowering duration in July Elberta and minimum in Glohaven followed by Early Elberta peach cultivars.

Milatovic *et al.* (2013) reported that the date of flowering of Japanese plum cultivar was 3rd March compared to the standard cultivar Cacanska Lipotica. The flowering started in plum 5th to 10th days earlier and last for 4th to 5th days longer in the area of Central Serbia.

Ondrasek *et al.* (2013) reported that the average date of the beginning of flowering of Stanley plum in the Lednice area was 18th April. Cultivar Zurna had the earliest beginning of flowering and Brigadirka had the last start of flowering.

Kumar *et al.* (2013) reported that the time of petal fall was earlier in plum cultivar Florida 1-2 (13th February) and last in cultivars Shiro 14-4 (16th March) followed by Queen Rosa and Ruby Sweet. He also reported that the flowering was earliest (second week of February) in Florida 1-2 and late (second week of March) in cultivar Shiro 14-4.

Singh *et al.* (2014) reported that the time of full blooming plum cultivars extended from 24th January in Saharanpur Prabhat and Pratap to 2nd February in Tropic Snow and Flordaglo. The longest duration (39 days) of flowering was recorded in Pratap and shortest (28 days) in Tropic Sweet and Early Grande.

Thakur *et al.* (2014) reported that the time of bud burst extended from second week of February to the second week of March in different plum cultivars. They further reported that the size and number of flowers per bud varied between 2 to 3. The cultivars were divided into three groups on the basis of flowering time i.e. early flowering (Florida 1-2), mid flowering (Red Beaut, Fortune, Queen Rosa, Ruby Sweet and Santa Rosa) and late flowering (Au- Rosa and Frontier).

2.1.3 Fruit set (%)

Almaguer *et al.* (1987) reported 6.3 and 16.3 per cent fruit-set in plum cultivars Shiro and Prune, whereas 1.1 and 8.1 per cent fruit-set was recorded in cultivars Titron and Green Gage, respectively.

Keulemans (1991) reported low percentage of fruit-set in two cultivars of plum which was due to the presence of self- pollen rather than insufficient pollen on the stigma. He concluded that low yield was due to insufficient cross pollination or pollination with unsuitable cultivars. Bajwa *et al.* (1991) reported that in Kala Amritsari cultivar, the fruit-set increased to 23 per cent when pollinated with Titron, while self-pollination resulted in 11.6 per cent fruit-set.

Childers *et al.* (1995) reported that self-fruitful, cultivars of European plums set 30 per cent fruit whether cross or self-pollinated whereas self-unfruitful cultivars set only 1.5 per cent fruits. He described most of Japanese cultivars of plum as self-unfruitful.

Sharma *et al.* (2012) reported highest fruit set per cent in cultivar “Early Elberta” (94.31%) whereas lowest fruit set (93.13%) was recorded in cultivar “Suncrest” of peach.

Ondrasek *et al.* (2013) reported highest fruit set in cultivar “Stanley”,

“Topper” and “Topking” while the “Nevena” and “Bystricka” had the lowest fruit set in the studied plum cultivars.

Kumar *et al.* (2013) reported the highest fruit set per cent in plum cultivar Shiro 14-4 (30%) whereas lowest (4.06%) was recorded in cultivar Ruby Sweet and Qween Rosa.

Shashi *et al.* (2014) examined the adaptation potential of peach varieties under lower Shiwalik Himalaya conditions. They observed that there occurred no significant difference in the fruit set of different cultivars except that for Snow Queen, Red Heaven and July Elberta which were having comparatively lower fruit set.

2.1.4 Fruit drop and fruit retention

Sharma *et al.* (2012) reported that the fruit drop was maximum (35.87%) in cultivar July Elberta and minimum (29.01%) in Suncrest cultivars of peach and also reported higher percentage of fruit retention (70.03%) in cultivar Suncrest and minimum fruit retention (60.74%) in July Elberta cultivars of peach.

2.1.5 Leaf characters

Kishore *et al.* (1991) characterized the leaves of *Prunus salicina* as sharp, pointed, medium in size and free from hair on lower surface.

Billini (1992) reported the leaves of plum cultivar, Firenze 90 was dark-green above and light grey-green below with crenate edge, tapered base and pointed apex. Graf (1992) reported that the leaves of *Prunus domestica* were dull green, ovate, 10 cm long and serrated at margins and the leaves of *Prunus salicina* were obovate, pointed and serrated at the margins and the leaves of *Prunus cerasifera* were ovate, 4-8 cm long, dark purple turning greenish bronze in late summers and having crenate margins.

Lal (1993) observed that leaf area in eight plum cultivars ranged from 13.82 to 42.71 cm² and the leaf fall occurred from 12th October till 19th November.

Mohapatra (1994) reported that the leaf petiole length in seven Japanese plum cultivars ranged from 1.1 to 2.0 cm. He also reported that the leaf area ranged from 10.75 to 23.09 cm² in all the cultivars.

Sharma *et al.* (2012) recorded maximum leaf area (53.68 and 54.49 cm²) in peach cultivar Early Elberta and minimum leaf area (40.58 and 40.07 cm²) in July Elberta during two consecutive years.

Chatzicharissis *et al.* (2013) reported that the leaf petiole length was highest in cherry cultivar Kapsiotica (5.29 cm) and lowest in Late Karamela Tripoleos (3.89 cm) however the maximum leaf petiole thickness was observed in cherry cultivar Napoleon Karamela (0.15 cm) and lowest in cultivar Kifisias Proimotero (0.11 cm).

Singh *et al.* (2015) reported that the leaf length was highest in peach cultivars Tropic Beauty (17.91 cm) Tropic Sweet (17.52 cm) and Tropic Snow (17.47 cm) and lowest in Pratap (14.37 cm). He also reported the leaf breadth was recorded highest in in peach cultivar Tropic Sweet (4.49 cm) and Tropic Snow (3.16 cm) and lowest was recorded in cultivar Pratap (2.56 cm). The maximum leaf area (47.72 cm²) observed in peach cultivar Tropic Sweet followed by Tropic Snow (46.87 cm²), Tropic Beauty (46.50 cm²) and the minimum (37.56 cm²) in Pratap.

2.2 Fruit characters

2.2.1 Fruit size

Hansche (1989) observed that in cultivars Valley Gem, Valley Sun, and Valley Red had large sized fruits with average weight of 135, 130 and 210 g, respectively. Rouse and Sherman (1989) reported that average fruit weight of peach cultivars Tropic Snow and Tropic Beauty was more than 110 g.

Khokhar and Agnihotri (1990) evaluated several low chilling peach cultivars and observed maximum fruit size and weight in Shan-i-Punjab and maximum fruit diameter in Early Amber. Fruit length and diameter was minimum in Flordasun.

Ozguven *et al.* (1997) recorded that the fruit weight ranged between 12.5 and 51.8 g, fruit diameter and length ranged from 32.5 to 41.7 mm and 27.6 to 49.3 mm, respectively. Sharma and Mohapatra (1997) reported that physico-chemical characteristics of 12 plum cultivars in Himachal Pradesh and found that in cultivar Santa Rosa fruit length was 3.97 cm and fruit breadth was 4.05cm.

Milatovic *et al.* (2006) observed that average fruit weight of cherry ranged from 16.5 g in cultivar Stella to 68.1 g in cultivar Selena.

Verma *et al.* (2007) observed that the maximum fruit size length \times breadth was 45.80×45.43 mm in cultivars Tarrol and minimum (20.40×22.01 mm) in Azarshah, respectively.

Singh *et al.* (2011) reported that the maximum values of fruit size ($45.02 \times 45.56 \times 43.15$ mm) were observed in cultivar Frontier. While the minimum value of fruit size ($28.81 \times 30.10 \times 27.40$ mm) was observed in cultivar Azarshah in the studies plum cultivars.

Kumar *et al.* (2013) reported that the fruit size (length \times breadth \times thickness) was maximum ($43.81\text{mm} \times 41.27$ mm $\times 40.26$ mm) in cultivars Ruby Sweet and minimum (31.79 mm $\times 33.12$ mm $\times 33.79$ mm) in Cherry plum.

Bhat *et al.* (2013) observed that the maximum fruit length and diameter were obtained in cultivar Conian Italy (37.06×38.19 mm) and lowest in cultivar Charmagz (31.20×29.00 mm) and Quetta (31.91×30.54 mm) in studied apricot cultivars.

Singh *et al.* (2014) reported the maximum fruit length (56.18 mm) and fruit breadth (59.30 mm) in Flordaglo whereas minimum fruit length (36.01 mm) and fruit breadth (40.52 mm) were observed in Valle Grande peach cultivars.

Thakur *et al.* (2014) observed maximum fruit length in cultivars Fortune (50.32 mm), Frontier (48.00 mm) and Queen Rosa (18.14 mm) and minimum fruit length was observed (28.59 mm) in Florida 1-2 in plum cultivars. He also reported that the maximum fruit breadth in plum cultivars Queen Rosa (50.48 mm), Ruby Sweet (49.09 mm) and Fortune (48.52 mm) and minimum (26.51 mm) in cultivar Florida 1-2.

2.2.2 Fruit weight

Kellerhals *et al.* (1991) reported that average fruit weight of plum cultivars ranged from 15 g to 56 g in the studied plum cultivars.

Verma *et al.* (2007) observed that the maximum fruit weight (69.03 g) was recorded in cultivar Tarrol, while the minimum fruit weight (6.41 g) in cultivar Azarshah in plum.

Levent (2010) conducted an experiment on determination on quality characteristics of some important Japanese plum cultivars and observed that fruit weight ranged from 46.71 g (Obilnaja) to 91.26 g (Black Diamond) whereas the cultivars, Black Diamond, Queen Rosa and October Sun recorded biggest fruits. Further also, reported that the maximum fruit weight (91.26 g) was observed in variety Black Diamond, while the minimum fruit weight (46.71 g) in cultivar Obilnaja in plum.

Singh *et al.* (2011) reported that the maximum fruit weight (62.19 g) was observed in variety Frontier, while the minimum fruit weight (14.40 g) in cultivar Azarshah in plum.

Ondrasek *et al.* (2013) observed that the average fruit weight in the plum cultivars was 35.2 g. The average fruit weight in cultivar Stanley was 37.3 g. The cultivars with the highest fruit weight were Tophit (65.43 g) and Grossa di Felicia (59.7 g) while the cultivars with the lowest fruit weights were De Nancy (9.52 g) and Bystricka (17.2 g). Cultivars with average fruit weights over 50 g included

Tophit (65.43 g), Grossa di Flicia (59.7 g), Pitestean 55.4 g), Ariel (55.0 g), Valor (52.2 g) and Karpatin (51.4 g).

Corneanu *et al.* (2013) reported that the studied an evaluation of new sweet Cherry cultivars released at the Fruit Growing Research Station Romania, for some physico- chemical properties of nine sweet cherry cultivars. The largest fruit weight was recorded in cultivars Alex (10.4 g), Ludovic (10.0 g), Anda (9.5 g), Cociu (9.5 g) and Paul (9.0 g), and lowest fruit weight was recorded in cultivar Mihai (7.3 g).

Chatzicharissis *et al.* (2013) reported that the in sweet cherry fruit weight was highest in cultivars Rainier (8.8 g), Fraoula Volou (7.3 g), Kifisias Proimotero (7.1 g) and Petrokeraso Tragano (6.9g), whereas the lowest fruit weight was recorded in cultivars Moshato Tragano (5.1 g) and Late Karamela Tripoleos (4.9 g).

Kumar *et al.* (2013) reported that the maximum fruit weight in plum cultivar Ruby Sweet (49.12 g) whereas the fruit weight was minimum in cultivar Cherry plum (25.12 g).

Shashi *et al.* (2014) observed highest fruit weight (69 g) in peach cultivars Pratap Grande, Florida Prince and July Elberta. Fruit weight was 52-57g in cultivars May Fire, Snow Queen and Florida Sun however the fruit weight was lowest (42 and 40 g) in cultivars Prabhat and Red Heaven.

Thakur *et al.* (2014) carried an experiment on floral and physico-chemical characters of Japanese plum cultivars and observed that the maximum fruits weight was recorded in cultivar Fortune (80.51 g) followed by Queen Rosa (80.19 g), and lowest in cultivar Florida 1-2 (29.20 g).

Thakur *et al.* (2014) reported highest fruit weight in plum cultivars Fortune (80.51 g) and Queen Rosa (80.19 g) and lowest in cultivar Florida 1-2 (29.20 g).

2.2.3 Fruit shape

Chadha and Sankhyayan (1974) observed that fruit shape of peach cultivar Worlds Earliest was roundish whereas fruits of cultivars Early White Giant, July Elberta, Foster, Elberta and J.H. Hale were roundish oblate in shape.

Tomer and Singh (1981) found that cultivars Hales Early and Foster bore fruits of round cordate shape and fruits of cultivars Golden Blush were compressed cordate in shape.

Mishra *et al.* (1984) reported that fruit shape of peach cultivars Peshawari, Sure Crop, Florin and Early Stark Glo was roundish oval. Alton, J.H. Hale and July Elberta bore fruits of roundish ovate shape whereas fruit shape in case of Sah Pasand and Nishiki was roundish.

Singh *et al.* (2011) reported that the all plum cultivars were rounded except cultivar Au-Rosa (heart shape) and Au- Cherry (elliptic) in studied plum cultivars.

Milatovic *et al.* (2013) evaluation Japanese plums and reported that studied cultivars had predominantly round or round-flat shape of the fruit (SI= 0.69 to 0.98) with the exception of the cultivar Sorriso di Primavera, which recorded elongated (heart) shape of fruit (SI= 1.27).

2.2.4 Fruit and flesh colour

Singh *et al.* (2011) reported various colours of plum fruit in different cultivars viz; Black Amber, Cherry plum, Queen Rosa, Ruby Sweet and Shiro 14-4 had fruits with red purple colour, fruit colour was grey purple in Florida 1-2, Frontier, Laroda and Santa Rosa, red colour fruits were observed in Au- Amber, Au- Rosa and Red Beaut, only one variety Kanto 5 had yellow fruits. He also reported that the fruit flesh colours in different plum cultivars viz; Au- Amber, Queen Rosa, Laroda, Red Beaut and Santa Rosa had flesh with yellow colour, orange red in Black Amber, Cherry plum, Florida 1-2 and Ruby Sweet, yellow orange observed in Azarshah and Kanto 5.

Kumar *et al.* (2013) reported the various fruit colour in different plum cultivars viz; Florida 1-2, Cherry plum, Ruby Sweet, Queen Rosa, Shiro 14-4 and Black Amber in red purple, respectively.

Kumar *et al.* (2013) reported various fruit flesh colours in different plum cultivars viz. Florida 1-2, Cherry plum, Ruby Sweet, Queen Rosa and Shiro 14-4 in orange red, only one variety Black Amber had red purple fruits.

Thakur *et al.* (2014) observed various fruit colours in different studies plum cultivars viz; Florida 1-2, Frontier and Santa Rosa were grey purple and Au-Rosa, Queen Rosa and Ruby Sweet were in dark red. Only two cultivars Fortune and Red Beaut had red colour.

2.3 Stone characters

2.3.1 Stone size

Kumar *et al.* (2013) reported that the maximum stone size (length \times breadth \times thickness) was (22.37 \times 15.74 \times 7.13 mm) in cultivars Ruby Sweet and minimum was (15.48 \times 10.75 \times 5.62 mm) in Cherry plum.

Thakur *et al.* (2014) recorded maximum stone length in plum cultivars Frontier (20.47 mm) and Fortune (20.15 mm) and minimum (16.60 mm) in Au-Rosa however maximum stone breadth was recorded in cultivar Queen Rosa (18.77 mm) and the lowest in Florida 1-2 (13.10 mm) in plum cultivars.

Singh *et al.* (2014) reported that the average stone length ranged from 23.00 mm in peach cultivars Valle Grande to 42.02 mm in Saharanpur Prabhat. The maximum breadth of stone was (22.84 mm) in Flordaprince and minimum (18.14 mm) in Valle Grande.

2.3.2 Stone weight

Mohapatra (1994) reported stone weight between 0.60 g (Early Transparent Gage) and 1.85 g (Beauty) in the studied plum cultivars.

Milatovic *et al.* (2013) evaluation Japanese plums and observed that stone

weight ranged from 0.83 to 1.47 g and its share in the fruit weight was from 1.2 to 3.5 per cent, when compared to standard cultivar. Japanese plums had smaller stone and lower share of the stone in fruit weight.

Chatzicharissis *et al.* (2013) reported that the highest sweet cherry stone weight was in cultivars Napoleon Karamela (0.65 g), Karamela Lilantiou (0.65 g), Kifisias Proimotero (0.50 g) and Petrokeraso Tragano (0.50 g), whereas the lowest stone weight was recorded in cultivar Late Karamela Tripoleos (0.34 g).

Thakur *et al.* (2014) reported that the heaviest stone weight in cultivar Fortune (2.90 g) and smallest in cultivars Florida 1-2 and Red Beaut (0.95 g). Bostan (1997) recorded the lowest average fruit and stone weight (18.6 g and 0.84 g, respectively) in can and the highest (52.2 g and 2.15 g, respectively) in President cultivar of plum.

2.3.3 Pulp: stone ratio

Mohapatra (1994) reported that the pulp: stone ratio was highest in Frontier (55.02) and lowest in Beauty (20.08) cultivar of plum.

Singh *et al.* (2011) reported maximum fruit pulp: stone ratio (55.24) in plum cultivar Frontier, while the minimum fruit pulp: stone ratio (19.10) was in cultivar Au- Rosa.

Kumar *et al.* (2013) reported maximum pulp: stone ratio (41.52) in cultivar Ruby Sweet, while the minimum pulp: stone ratio (20.95) was observed in cultivar Black Amber.

Thakur *et al.* (2014) reported that the maximum pulp: stone ratio was found in plum cultivar Frontier (59.13) and Santa Rosa (49.23) while the minimum pulp: stone ratio (19.56) was observed in cultivar Florida 1-2.

2.3.4 Stone adherence

Singh *et al.* (2011) reported that plum cultivars Au-Rosa and Frontier were free stone however cultivar Shiro 14-4 was semi cling stone.

Kumar *et al.* (2013) reported that all the studied plum accessions were of clingstone type (Cherry plum, Queen Rosa, Ruby Sweet and Florida 1-2) except Shiro 14-4 (semi clingstone) and Black Amber (freestone).

Thakur *et al.* (2014) reported that all the studied plum accessions were of clingstone type (Queen Rosa, Ruby Sweet and Florida 1-2) except Frontier (freestone).

2.4 Chemical traits

2.4.1 Sugars

Singh *et al.* (2011) reported that the maximum total sugars (9.17%) were recorded in cultivar Azarshah, while the minimum total sugars was recorded (6.07) in cultivar Queen Rosa.

Kumar *et al.* (2013) reported that the maximum total sugars (8.95%) were recorded in plum cultivar Shiro 14-4 and the minimum total sugars was recorded (6.07%) in cultivar Queen Rosa.

Szalay *et al.* (2013) studied fruit quality parameters of foreign apricot cultivars in Hungary. They studied the phenological traits, morphological features and fruit quality of new cultivars (Laycot, Pinkcot, Sungiant, Sylred, Sylvecot and Veecot). The sugar content increased and acid content decreased during ripening. The higher sugar content was recorded in cultivar Laycot (16.0°B) and lowest was recorded in cultivars Pinkcot (10.0°B) and Veecot (10.0°B).

Kumar *et al.* (2013) reported that the maximum reducing sugars (6.21%) were observed in variety Ruby Sweet and the minimum reducing sugars (3.24%) in cultivar Queen Rosa in plum. He also reported that the maximum non-reducing sugars (4.15%) were observed in variety Shiro 14-4. While the minimum non-reducing sugar (0.69%) in cultivar Ruby Sweet.

Thakur *et al.* (2014) reported that the maximum total sugars (8.94%) were observed in plum cultivar Frontier and the minimum (7.14%) in cultivar Au-Rosa.

Thakur *et al.* (2014) reported that the maximum reducing sugars (7.73%) in plum cultivar Queen Rosa while the minimum reducing sugars (5.34%) were recorded in cultivar Au- Rosa.

Thakur *et al.* (2014) reported maximum non-reducing sugars (1.70%) in plum cultivar Au-Rosa and the minimum non-reducing sugars (1.02%) in cultivar Queen Rosa.

Jana (2015) studied the performance of some low chill peach, under eastern plateau regions of India and observed that maximum total sugars (13.5%) was recorded in the cv. Shan-i-Punjab.

2.4.2 Total soluble solids (TSS)

Verma *et al.* (2007) observed highest total soluble solids (TSS) content in plum cultivar Settler (19.47 °B) and lowest (11.60 °B) in cultivar Fortune.

Singh *et al.* (2011) reported that the maximum TSS (19.20 °B) were observed in variety Azarshah. While the minimum TSS (11.00 °B) in cultivar Au-Amber in plum.

Ondrasek *et al.* (2013) reported that in a plum collection, fruit had an average value of total soluble solids content of 16.3°B. The average content of soluble solids of Stanley fruit was 16.3°B. The highest average values in the whole collection were achieved by Topking (24 °B) and De Nancy (23 °B), while Cacak Early (12.1°B) and Herman (12.3°B) had the lowest values.

Kumar *et al.* (2013) observed the highest total soluble solids (TSS) content was in plum cultivar Black Amber (16.95°B) and lowest was recorded (9.75°B) in cultivar Queen Rosa.

Thakur *et al.* (2014) reported that the total soluble solids (TSS) in the

studied plum cultivars ranged from 12.19°B to 15.43°B. The maximum total soluble content was observed in Au- Rosa (15.43°B) and lowest was recorded in Red Beaut (12.19°B).

2.4.3 Titrable acidity (%)

Chaudhary *et al.* (1987) carried out investigations on 8 cultivars of plum and total soluble solids (19.66%) and lowest acidity (1.51%) in “Japanese Gold” which was followed by “Hollywood” with 17.66 per cent total soluble solids and 1.67 per cent acidity.

Kumar *et al.* (2013) observed the highest acidity content was in plum cultivar Florida 1-2 (2.59%) and lowest (1.12%) in cultivar Ruby Sweet.

Thakur *et al.* (2014) observed the highest titrable acidity content in plum cultivars Fortune (1.67%) and Frontier (1.45%) and lowest (1.11%) in cultivar Queen Rosa.

2.4.4 Sugar: acid ratio

Cantin *et al.* (2009) reported that the pH value in peach ranged from 3.5 to 3.9 in different cultivars. The maximum pH was observed in cultivar Mercil × VAC-9516 (3.9) and lowest was reported in cultivar Orion × VAC-9517 (3.5).

Singh *et al.* (2011) reported that the maximum sugar: acid ratio (7.09) was observed in cultivar Ruby Sweet and the minimum sugar: acid ratio (2.02) in cultivar Cacanska Rana plum. Milosevic and Milosevic (2011) reported that the value of pH in plum cultivars ranged from 3.33 in (Cacanska Lepotica) to 3.66 in (Stanley).

Kumar *et al.* (2013) reported that the maximum sugar: acid ratio (6.21) was observed in plum cultivar Ruby Sweet while the minimum sugar: acid ratio (2.40) was recorded in cultivar Florida 1-2.

Thakur *et al.* (2014) reported that the sugar: acid ratio ranged from 2.40 to 6.21 in plum cultivars Florida 1-2 and Ruby Sweet. The maximum sugar: acid

ratio (6.21) was observed in cultivar Ruby Sweet, while the minimum sugar: acid ratio (2.40) was recorded in cultivar Florida 1-2.

2.5 Time of maturity and yield

Kuden *et al.* (1994) reported that the ripening period of plum cultivars extended from June to the end of August and classified the cultivars according to their maturity time as early, mid and late season cultivars. They also studied the yield characteristics of the cultivars.

Ayanoglu and Yilmaz (1997) described harvest date and productivity of 37 selections of plum and classified them as very high, high, intermediate and low productivity cultivars. Bal (1997) reported 29.5 kg/tree yield in plum cultivar Satluj Purple and 40-50 kg/tree yield in Kala Amritsari.

Turcu *et al.* (1998) reported that the average annual yield of studied plum cultivars varied from 7.9 tons/hectare to 26.1tons/hectare. Vitanova *et al.* (1998) recorded the average yield per tree in 5 cultivars with the lowest (52.3 kg/tree) in Nevena and highest (125.0 kg/tree) in Strinava. Hartmann (1998) studied the yield and ripening time of plum cultivars and observed that the earliest to mature was Katinka and latest was Presenta.

Levent (2010) conducted an experiment on determination of quality characteristics of some important Japanese plum cultivars and observed that fruit maturation was earlier in Black Beauty and Obilnaja cultivars than those of other cultivars.

Sharma *et al.* (2012) reported that the peach cultivar Glohaven was earliest to mature followed by Suncrest and July Elberta whereas Early Elberta was late in maturity. They further reported that maximum yield and productivity were recorded in Early Elberta while as minimum yield and productivity was recorded in July Elberta.

Milatovic *et al.* (2013) evaluation Japanese plum and revealed some phenological and pomological properties of seven Japanese plum cultivars. They

reported that the time of maturing ranged from the end of June to the beginning of September.

Ondrasek *et al.* (2013) carried out pomological evaluation of plum cultivar and observed that the average date of the beginning of ripening of Stanley fruit in the Lednice region was 24th August. In the plum collection, the earliest beginning of ripening was in Ruth Gesteter which start 45 days before the cultivar Stanley.

Ondrasek *et al.* (2013) reported that the plum fruit yield of the whole collection of cultivars studied averaged 8 kg/tree. Stanley produced an average of 13.2 kg/tree. The highest yield was achieved by Tophit (17.10 kg/tree) and Cacak Fruiful (14.2 kg/tree). On the other hand, Nevena (2.02 kg/tree) and De Nancy (4 kg/tree) had the lowest yields. The differences between the highest and lowest producing cultivars were statistically significant. On the other hand, there were no significant differences among Cacak Fruiful, Top King, Cacak Best, Arbacher, Prezident and Topper. Cultivars with yields higher than 10 kg/tree included Tophit (17.1 kg), Cacak Fruiful (14.2 kg), Arbacher (13.5 kg), Stanley (13.2 kg), Topking (11.8 kg), Cacak Best (11.8 kg) and Topper (11.6 kg).

Corneanu *et al.* (2013) studied the physico-chemical properties of nine sweet cherry cultivars released at the Fruit Growing Research Station Romania. The highest yield was recorded in cultivars Margo (17.4 kg/tree) and Ludovic (13.5 kg/tree) followed by Anda (11.8 kg/tree), Paul (11.8 kg/tree) and Alex (10.3 kg/tree).

Chatzicharissis *et al.* (2013) reported that the highest fruit productivity in Sweet cherry was recorded in cultivars Late Karamela Tripoleos (115 kg/tree) followed by Rainier (99 kg/tree) and the lowest fruit productivity was recorded in cultivars Kapsiotika (30 kg/tree), Napoleon Karamela (35 kg/tree) and Moshato Tragano (35kg/tree).

Shashi *et al.* (2014) observed that the highest yield of 91 kg was reported for Shan-i- Punjab whereas the lowest yield was recorded in Red Heaven, Snow Queen and July Elberta peach cultivars.

Chapter- 3

MATERIALS AND METHODS

The present investigation entitled “Evaluation studies on exotic plum germplasm under Kashmir condition” was carried out at Central Institute of Temperate Horticulture (CITH), Srinagar, Kashmir during the year 2014. The experimental details are as follows:

3.1 Material

Twelve-year-old bearing plum trees of different cultivars having good, vigour, health, bearing and agronomic practices were selected for experimentation at Experimental Farm of Central Institute of Temperate Horticulture (CITH) Srinagar, situated at an altitude of 1588 meter above mean sea level and latitude of 34.8’ and longitude 74.83’ N. The orchard soil was moderately deep with medium fertility status. 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.

3.2 Treatments

Fourteen cultivars of plum viz., Monarch, Frontier, Red Beaut, Tarrol, Beauty, Grand Duke, Black Amber, Burbank, Au- Cherry, Au- Rosa, Kanto-5, Krassivica Plum, Kubio-Plum and Red Plum were evaluated. Single tree in each cultivar constituted an experimental unit and each cultivar was replicated three times.

3.3 Plum cultivar used in present study

S. No.	Name of cultivars	Species	Origin
1	Frontier	<i>Prunus salicina</i>	USA
2	Red Beaut	<i>Prunus salicina</i>	California
3	Tarrol	<i>Prunus salicina</i>	China
4	Grand Duke	<i>Prunus domestica</i>	England
5	Black Amber	<i>Prunus salicina</i>	USA
6	Burbank	<i>Prunus salicina</i>	Burbank
7	Au-Cherry	<i>Prunus salicina</i>	USA
8	Au-Rosa	<i>Prunus salicina</i>	USA
9	Kanto 5	<i>Prunus salicina</i>	China
10	Kubio Plum	Unknown	Unknown
11	Red Plum	Inter species	USA
12	Krassivica Plum	Inter species	USSR
13	Monarch	<i>Prunus domestica</i>	England
14	Beauty	<i>Prunus salicina</i>	Burbank

3.4 Phenological stages

Four representative branches from each treatment were chosen for the study of various phenological stages. The branches were selected at random, giving due regard to the four directions of the tree canopy, to ensure precision.

Phenological stages observed were:

3.4.1 Bud swell (date)

When over 50 per cent or more of the terminal buds were enlarged and bud

scale split, exposing the green colour of the leaves, the stage was regarded as bud swell stage and date were recorded.

3.4.2 Tight cluster (date)

Date of tight cluster was recorded when blossom buds mostly exposed and tightly grouped and the date was recorded.

3.4.3 Open cluster (date)

Open cluster was recorded when blossom buds open at tip and date was recorded accordingly.

3.4.4 First bloom (date)

First bloom was recorded when 10 per cent flower had opened and the date was recorded accordingly.

3.4.5 Full bloom (date)

Full bloom was recorded on the date when 80 per cent of flowers had opened.

3.4.6 First petal fall (date)

This stage was recorded when the experimental trees exhibited 10 per cent of the petal fall.

3.4.7 Complete petal fall (date)

This stage was recorded when the experimental trees exhibited 80 per cent of the petal fall.

3.4.8 Duration of flowering (days)

The number of days taken from the date of opening of first flower to the date of opening of last flower was taken as the duration of flowering.

3.4.9 Number of flower per branch

The total number of flowers per branch of each experimental unit were

counted and averaged.

3.4.10 Fruit set

Fruit set was measured by counting number of flower buds during full blooming and mature number of fruits at pea stage of four pre-selected branches in four directions (N, E, S, W) of the same tree. Fruit set was calculated from number of flowers and mature fruits on individual branches. Flowers were counted during full bloom and the number of fruits remaining on the same branches was recorded before harvest.

$$\text{Per cent of fruit set} = \frac{\text{No. of fruitlets at pea stage}}{\text{No. of flowers}} \times 100$$

3.4.11 Fruit drop

The fruits dropped after initial fruit set were counted and the percentage of fruit drop was calculated. The fruit drop was determined by dividing the number of fruits initially set to the number of fruits retained at harvest and multiplied by 100.

$$\text{Fruit drop (\%)} = \frac{\text{No. of fruits initially set}}{\text{No. of fruits retained at harvest}} \times 100$$

3.4.12 Fruit retention

The fruits retained in all the cultivars were recorded one week before harvesting, averaged and expressed in percentage as under:

$$\text{Fruit retention (\%)} = \frac{\text{No. of fruits harvested}}{\text{No. of fruitlets at pea stage}} \times 100$$

3.5 Leaf characteristics

3.5.1 Leaf length

Leaf length of the mature leaf was measured with digital Vernier Calliper and expressed in mm.

3.5.2 Leaf breadth

Leaf breadth of the mature leaf was measured with digital Vernier Calliper and expressed in mm.

3.5.3 Petiole length

Petiole length was measured from the base of the petiole to its conjunction with the lamina, with the help of Vernier Calliper and expressed in mm.

3.5.4 Petiole thickness

Petiole thickness of leaf was measured from the base of the petiole to its conjunction with the lamina, with the help of Vernier Calliper and expressed in mm.

3.5.5 Leaf area (cm²)

Five leaves from each quadrant were picked from each cultivar and their leaf area was measured by using leaf area meter and reading was averaged in cm².

3.5.6 Leaf Colour

The following leaf color was visually recognized as per the descriptor (IBPGR, Rome, 1984)

- Pale green
- Green
- Dark green
- Other

3.5.7 Leaf margin

The leaf margin was examined for the presence or absence of serration in each cultivars.

- Crenate

- Serrate
- Bicrenate
- Biserrate

3.6 Physical characteristics

3.6.1 Fruit weight

The weight of 15 randomly selected fruits from each treatment in each replication was taken on a top pan balance and the average weight per fruit was expressed in grams (g).

3.6.2 Fruit length

The length of 15 randomly selected fruits from each treatment in each replication was measured with the help of digital Vernier calliper. The fruit length was measured between calyx and style ends and the average were expressed in mm.

3.6.3 Fruit breadth

The diameter between cheeks of 15 randomly selected fruits was measured with the help of digital Vernier calliper and the average was expressed in mm.

3.6.4 Fruit size

The length and breadth of individual fruits was recorded. The length was measured from base to apex, and breadth from side to side with the suture halfway between. The measurements were taken with the help of Vernier Calliper. The sample fruits of each treatment were measured. The average of all the readings thus obtained was calculated in mm.

3.6.5 Fruit colour

A random sample of five fruits from each treatment will be taken and individual fruits were recorded the horticultural colour chart by the Royal Horticultural Society.

3.6.6 Fruit colour

A random sample of five fruits from each treatment will be taken and individual fruits were recorded the horticultural colour chart by the Royal Horticultural Society

3.6.7 Stone characteristics

3.7 Stone weight

The stone weight was recorded in grams with the help of electronic balance and the mean weight was expressed in gram (g).

3.7.1 Stone length

The length of fruits stones measured from each treatment in each replication on each sampling date were picked and length was measured in centimeters (cm) with the help of Vernier Calliper and average length of fruit stone was recorded.

3.7.2 Stone breadth

It was recorded in centimeters (cm) in the same manner as stone length.

3.7.3 Stone size

The average stone size was obtained by extracting the stones from the fruit samples and freeing them from adhering flesh and weighing in a sensitive monopan balance in gram (g) and dividing the collective weight obtained by the number of stones.

3.7.4 Pulp: stone ratio

Pulp: stone ratio was obtained by subtracting the average stone weight from the average fruit weight and divided by average stone weight.

$$\text{Pulp : stone ratio} = \frac{\text{Fruit weight} - \text{Stone weight}}{\text{Stone weight}}$$

3.7.5 Stone adherence

Stone adherence to flesh of fully ripe fruit were classified into following types:

- Free stone
- Semi-freestone
- Cling stone

3.8 Date of maturity

The date of maturity was determined by visualizing proper fruit size, colour changes and ease in picking.

3.8.1 Yield/tree

The entire fruit which reached to its maturity was harvested by hand picking from each tree, weighed by a field balance and yield was recorded in kilograms (kg).

3.9 Chemical characteristics

3.9.1 Total soluble solids (TSS)

The total soluble solid content of fruit was directly determined with Zeise hand refractometer. The prism of the refractometer was washed with distilled water before taking each reading. A drop of fresh juice of fruit was taken on the prism of refractometer and the line of refractometer gave the per cent total soluble solids present in the fruit. Temperature corrections were applied when the reading were recorded at temperature other than 20°C (A.O.A.C., 1984).

3.9.2 Titrable acidity

The per cent titrable acidity (as malic acid) was estimated by titrating a known quantity of homogenized juice against 0.1 N NaOH solution using phenolphthalein as indicator. The acidity was expressed in terms of malic acid as percentage of total titrable acidity.

$$\text{Titrate acidity (\%)} = \frac{\text{Titrate value} \times 0.1 \times \text{Equivalent weight of acid} \times \text{Dilution factor} \times 100}{\text{Weight of sample} \times \text{volume of filtrate for estimation} \times 1000}$$

3.9.3 Total sugars

Lane and Eynon's volumetric method was employed for the estimation of sugars. 250 ml of juice extract remaining after the estimation of acid was used. To this 250 ml of juice extract, 5 ml of saturated lead acetate solution was added. The solution was filtered into a flask containing 5 ml of potassium oxalate so that the excess of lead was removed. The solution was filtered again. Out of this filtrate 50 ml was taken for total sugars estimation. To this 50 ml, 5 ml of concentrated hydrochloric acid was added and was left as such overnight. Next day the excess of hydrochloric acid was neutralized with concentrated sodium hydroxide (NaOH) solution using phenolphthalein as indicator and final volume was made to 100 ml. This solution was then used for titrating 10 ml of mixed Fehling solution using methylene blue as indicator. Brick-red colour was considered as end point of the titration.

3.9.4 Reducing sugar

The filtrate left after taking 50 ml for total sugars was used for estimation of reducing sugars. For this, 10 ml of mixed Fehling solution (5ml Fehling A+ 5 ml Fehling B) was taken in titration flasks. About 30-40 ml of distilled water was added to it. This solution was then titrated against the fruit juice extract, using methylene blue as indicator, till brick red colour (end point) appears.

$$\text{Reducing sugar (\%)} = \frac{\text{Fehling's factor} \times \text{Dilution} \times 100}{\text{Titrate value} \times \text{weight of sample}}$$

3.9.5 Non- reducing sugar

Non-reducing sugars were calculated by subtracting reducing sugars from total sugars and multiplying the difference by 0.95 which is standard factor. Non-reducing sugar content was also expressed as percentage of fresh pulp weight.

3.9.6 Fruit juice pH

The pH was determined by using digital pH meter. The pH meter was first calibrated using buffers of pH 4.0 and pH 7.0 at room temperature. The sample was then taken in the 100 ml beaker, stirred and electrode of pH meter was put in it and direct reading from pH meter was taken when the reading stabilized.

3.10 Statistical analysis

The statistical methods described to analyze and interpret the data. The experimental design was randomized complete block design (RCBD). Each treatment comprised of a single plant and was replicated three times. The test of significance was made with 5 per cent level of significance.

Chapter-4

EXPERIMENTAL FINDINGS

The results of the study entitle “Evaluation studies on exotic plum germplasm under Kashmir conditions” conducted at the Central Institute of Temperate Horticulture (CITH), Srinagar, Jammu and Kashmir during the year 2014 are presented in this chapter. Data pertaining to various parameters for evaluation were statistically analysed and results are described as follows:

4.1 Phenological stages

The observations pertaining to bud swell, tight cluster, open cluster, first bloom, full bloom, first petal fall, complete petal fall, fruit set and duration of flowering on the exotic plum cultivars are presented here under.

4.1.1 Bud swell

The date of bud swell ranged from 30th March to 8th April in Beauty and Kubio plum cultivars, respectively (Table 1). The earliest bud swell was observed on 30th March in cultivar Beauty, 1st April in cultivar Frontier and Krassivica Plum, 2nd April in cultivar Red Beaut, Tarrol and Au-Rosa and 3rd April in cultivar Monarch and Au- Cherry. Late bud swell was observed in cultivars Kubio Plum (8th April), Grand duke (5th April), Black Amber (4th April), Burbank (4th April), Kanto-5 (4th April) and Red Plum (4th April).

4.1.2 Tight cluster

The date of earlier tight cluster was observed in cultivar Beauty (2nd April), followed by cultivars Frontier, Red Beaut, Tarrol, Au-Rosa and Krassivica Plum (4th April). However late tight cluster was observed in cultivars Kubio Plum on (11th April) and in cultivars Grand Duke, Black Amber, Burbank, Kanto-5 and Red plum on 7th April (Table 1).



Bud swell stage



Tight cluster stage



Open cluster stage

Plate 1 : Different vegetative bud stages of exotic plum cultivars



10% flowering stage



85% flowering stage (full bloom)



Petal fall stage

Plate 2: Different floral bud stages of exotic plum cultivars

4.1.3 Open cluster

The date of earlier open cluster was first observed in cultivar Beauty, Frontier, Red Beaut, Tarrol, Au-Rosa and Krassicica Plum (5th April), whereas, cultivars it was 7th April in Au-Cherry and 9th April in cultivars Grand Duke, Black Amber, Burbank, Kanto-5, Red Plum and Monarch (Table 1). The late open cluster was observed in cultivar Kubio Plum (14th April) during the present studies.

4.1.4 First bloom

Data on date of first bloom (10% flower are open) was presented in Table 2. Among the cultivars studied, the earlier first bloom was observed in cultivars Frontier, Red Beaut, Tarrol, Au-Rosa, Krassivica Plum and Beauty (7th April) followed by cultivar Au-Cherry (9th April). These cultivars were considered to the earlier in blooming whereas cultivars Grand Duke and Red Plum (12th April), Black Amber, Burbank and Kanto-5 (11th April) were mid to late blooming and cultivar Kubio Plum (17th April) and Monarch (13th April) were late blooming.

4.1.5 Full bloom

Beauty and Tarrol were earliest in completion of full bloom (10th April) followed by Frontier, Red Beaut, Au-Cherry, Au-Rosa and Krassivica Plum (12th April) (Table 2). These cultivars were considered to the earlier in blooming whereas cultivars Black Amber, Burbank, Kanto-5 (14th April) and Red Plum (15th April) were found to be mid to late blooming and cultivar Kubio Plum (21th April) and Grand Duke (16th April) late blooming during the present studies.

4.1.5 First petal fall

Data on date of first petal fall (10% petal fall) was presented in Table 2. Among the cultivars under studied, the earliest petal fall was observed in cultivar Beauty (12th April) followed by Tarrol (14th April). These cultivars were considered to the earlier in first petal fall followed by cultivars Frontier, Red Beaut, Au-Rosa, Krassivica Plum (15th April) and Au-Cherry (16th April). First petal fall was recorded in cultivar Kubio Plum (24th April) followed by Black Amber, Burbank, Kanto-5, Red Plum (17th April) and Grand Duke, Monarch (19th April).

Table 1: Phenology of vegetative bud stages of exotic plum cultivars

Cultivars	Date of bud swell	Date of tight cluster	Date of open cluster
Frontier	1 st April	4 th April	5 th April
Red Beaut	2 nd April	4 th April	5 th April
Tarrol	2 nd April	4 th April	5 th April
Grand Duke	5 th April	7 th April	9 th April
Black Amber	4 th April	7 th April	9 th April
Burbank	4 th April	7 th April	9 th April
Au-Cherry	3 rd April	5 th April	7 th April
Au-Rosa	2 nd April	4 th April	5 th April
Kanto 5	4 th April	7 th April	9 th April
Kubio Plum	8 th April	11 th April	14 th April
Red Plum	4 th April	7 th April	9 th April
Krassivica Plum	1 st April	4 th April	5 th April
Monarch	3 rd April	6 th April	9 th April
Beauty	30 th March	2 nd April	5 th April

Table 2: Phenology of floral bud stages of exotic plum cultivars

Cultivars	Date of first bloom	Date of full bloom	Date of first petal fall	Date of complete petal fall	Duration of flowering
Frontier	7 th April	12 th April	15 th April	21 th April	15 Days
Red Beaut	7 th April	12 th April	15 th April	19 th April	13 Days
Tarrol	7 th April	10 th April	14 th April	18 th April	12 Days
Grand Duke	12 th April	16 th April	19 th April	23 th April	12 Days
Black Amber	11 th April	14 th April	17 th April	21 th April	11 Days
Burbank	11 th April	14 th April	17 th April	21 th April	11 Days
Au-Cherry	9 th April	12 th April	16 th April	19 th April	11 Days
Au-Rosa	7 th April	12 th April	15 th April	21 th April	15 Days
Kanto 5	11 th April	14 th April	17 th April	22 th April	12 Days
Kubio Plum	17 th April	21 st April	24 th April	28 th April	11 Days
Red Plum	12 th April	15 th April	17 th April	20 th April	9 Days
Krassivica Plum	7 th April	12 th April	15 th April	20 th April	14 Days
Monarch	13 th April	17 th April	19 th April	23 th April	11 Days
Beauty	7 th April	10 th April	12 th April	17 th April	11 Days

4.1.5 Complete petal fall

Data on date of complete petal fall (85% petal fall) was presented in Table 2. Among the cultivars studied the earliest complete petal fall was observed in cultivar Beauty (17th April) followed by Tarrol (18th April), Red Beaut and Au-Cherry (19th April). These cultivars were considered had earlier complete petal fall, whereas complete petal fall was observed on 20th April Red Plum, Krassivica Plum. Complete petal fall observed on 21st April in cultivars Frontier, Black Amber, Burbank, Au-Rosa and on 22nd April in cultivar Kanto-5 which was considered as mid while it was observed in cultivar Kubio Plum on (28th April) and Grand Duke and Monarch on 23th April which was late complete petal fall.

4.1.5 Duration of flowering

Duration of flowering varied from 9 to 15 days among the cultivars taken for evaluation study (Table 2). Maximum duration of flowering (15 days) was recorded in cultivars Frontier and Au-Rosa and minimum (9 days) was recorded in cultivar Red Plum. Flowering duration (11 days) was recorded in cultivar Black Amber, Burbank, Au-Cherry, Kubio Plum, Monarch and Beauty, whereas (12 days) in cultivar Tarrol, Grand Duke and Kanto-5 and Krassivica Plum (14 days).

4.2 Foliage characters

4.2.1 Leaf length

The leaf length of the studied exotic plum cultivars ranged from 92.33 mm to 116.13 mm (Table 3). The largest leaf length was observed in cultivar Frontier (116.13 mm) which was statistically at par with cultivar Krassivica Plum (115.80 mm) and Monarch (115.66 mm). Cultivar Au-Rosa (112.56 mm) were statistically at par with cultivars Beauty (112.46 mm), Tarrol (112.50 mm) and Black Amber (111.96 mm). Cultivar Red plum (107.06 mm) were statistically at par with cultivar Kubio Plum (105.93 mm) followed by cultivars Grand Duke (102.76 mm) and Au -Cherry (102.33 mm). The minimum leaf length was recorded in cultivar Red Beaut (92.33 mm) which was statistically at par with cultivar Burbank (94.16

mm) and Kanto-5 (97.70 mm). The coefficient of variation for the leaf breadth was 5.89 per cent.

4.2.1 Leaf breadth

Perusal of data presented in the Table 3 revealed significant difference exists in the leaf breadth of different plum cultivars. Leaf breadth ranges from 33.46 mm (Burbank) to 49.66 mm (Au- Rosa). The maximum mean leaf breadth (49.66 mm) was recorded in cultivar Au- Rosa and it is significantly higher than all the other cultivars, the cultivar Red Plum (47.90 mm) was statistically at par with cultivar Grand Duke (47.83 mm) whereas, cultivar Frontier (43.33 mm) was statistically at par with Kanto 5 (41.80 mm), Tarrol (41.66 mm) and Beauty (41.20 mm). The minimum mean leaf breadth (33.26 mm) was observed in cultivar Burbank followed by Red Beaut (35.46 mm), Kubio Plum (36.00 mm), Monarch (37.50 mm) and Black Amber (39.00 mm) was significantly different from each other.

4.2.3 Leaf area

Statistical analysis among different plum cultivars showed highly significant differences and the values ranged from 31.24 cm² Au-Rosa to 56.22 cm² Burbank (Table 3). Leaf area of cultivars Krassivica Plum (52.27 cm²) was statistically higher than cultivars Frontier (51.28 cm²) and Red Plum (50.90 cm²), whereas, cultivar Grand Duke (48.92 cm²) was statistically at par with cultivars Tarrol (47.12 cm²) and Beauty (47.10 cm²). Black Amber recorded (44.14 cm²) leaf area which was statistically at par with cultivars Monarch (43.34 cm²), Au Cherry (42.84 cm²) and Kanto 5 (41.02 cm²). The minimum mean leaf area (31.24 cm²) was observed in cultivar Burbank which was significantly lower than cultivar Kubio Plum (37.98 cm²). The coefficient of variance for leaf area were 4.11 per cent, respectively.

4.2.3 Petiole length

A significant variation was observed in petiole length among exotic plum

cultivar under studies (Table 3.) The maximum petiole length was recorded in cultivar Grand Duke (21.17 mm) which was statistically at par with cultivar Kanto-5 (21.00 mm), Au-Cherry (20.33 mm), Krassivica Plum (19.58 mm), Frontier (19.57 mm), Red Beaut (19.52), Monarch (18.75 mm), Au-Rosa (18.31 mm) to each other respectively. whereas minimum petiole length was recorded in Burbank (13.96 mm) which was statistically at par with cultivar Kubio Plum (14.58 mm) Tarrol (15.78 mm) Red Plum (16.75 mm), Black Amber (16.79), and Beauty (16.96 mm) respectively. The coefficient of variance for petiole length was 7.97 per cent.

4.2.3 Petiole thickness

A significant variation was observed in petiole thickness among exotic plum cultivars under studies (Table 3). The petiole thickness was recorded maximum in cultivar Frontier (1.67 mm) and it was statistically at par with cultivars Red Beaut (1.60 mm), Beauty (1.58 mm), Burbank (1.56 mm), Grand Duke (1.50 mm), Red Plum (1.44 mm) and Tarrol (1.43 mm), whereas petiole thickness was recorded minimum in cultivars Au- Cherry and Au- Rosa (1.17 mm) followed by Black Amber (1.19 mm), Kubio Plum (1.21 mm), Krassivica Plum (1.28 mm), Monarch (1.29 mm) and Kanto 5 (1.36 mm), respectively. The coefficient of variance for petiole thickness were 9.65 per cent.

4.1.6 Leaf margin

Leaf margin was categorized as crenate to serrate type (Table 3). Only cultivars viz; Grand Duke had crenate type of leaf margin, whereas it was serrate type in rest of the 13 plum cultivas understudy viz; Frontier, Red Beaut, Tarrol, Black Amber, Burbank, Au-Cherry, Au- Rosa, Kanto 5, Kubio Plum, Red Plum, Krassivica Plum, Monarch and Beauty.

Table 3: Leaf characteristics of exotic plum cultivars

Cultivars	Leaf length (mm)	Leaf breadth (mm)	Leaf area (cm ²)	Petiole length (mm)	Petiole thickness (mm)	Leaf margin
Frontier	116.13	43.33	51.28	19.57	1.67	Serrate
Red Beaut	92.33	35.46	32.42	19.52	1.60	Serrate
Tarrol	112.50	41.66	47.12	15.78	1.43	Serrate
Grand Duke	102.76	47.83	48.92	21.17	1.50	Crenate
Black Amber	111.96	39.00	44.14	16.79	1.19	Serrate
Burbank	94.16	33.26	31.24	13.96	1.56	Serrate
Au-Cherry	102.33	42.40	42.84	20.33	1.17	Serrate
Au-Rosa	112.56	49.66	56.22	18.31	1.17	Serrate
Kanto 5	97.70	41.80	41.02	21.00	1.36	Serrate
Kubio Plum	105.93	36.00	37.98	14.58	1.21	Serrate
Red Plum	107.06	47.90	50.90	16.73	1.44	Serrate
Krassivica Plum	115.80	44.70	52.27	19.58	1.28	Serrate
Monarch	115.66	37.50	43.34	18.75	1.29	Serrate
Beauty	112.46	41.20	47.10	16.96	1.58	Serrate
Mean	107.09	41.41	44.77	18.08	1.38	-
CD_(0.05)	1.61	1.58	0.88	2.44	0.23	-
CV	5.89	10.82	4.11	7.97	9.65	-

4.3.1 Number of flower per branch

The number of flowers per branch among the cultivars under studied ranged from 64.91 to 104.84. The cultivar Au- Rosa (104.84) had maximum no. of flowers per branch followed by cultivars Red Plum (103.98), Au-Chery (102.55) and Monarch (101.65). Cultivar Black Amber (99.35) was statistically at par with cultivars Kubio Plum (98.44) and Beauty (96.87). The minimum number of flowers per branch was recorded in cultivar Kanto 5 (64.91), respectively. The coefficient of variation for number of flowers per branch were 5.36 per cent respectively.

4.3.2 Fruit set

A significant variation was observed in percentage of fruit set among exotic plum cultivars under study (Table 4). Maximum fruit set was recorded in cultivar Frontier (52.44) which was statistically at par with cultivar Red Plum (51.78) and Beauty (50.74). But differs significantly with cultivar Krassivica Plum (49.92), Monarch (49.28), Kanto 5 (48.92), Grand Duke (48.14) and Red Beaut (47.54) whereas, Au- Rosa (45.98) was statistically at par with cultivar Kubio Plum (45.56), Burbank (45.40), Tarrol (45.28) and Au- Cherry (43.84) respectively. The minimum fruit set was recorded in cultivar Black Amber (40.88) which was differs significantly from rest of the plum cultivars under studies, the coefficient of variance for fruit set were 9.11 per cent,

4.3.3 Fruit drop

A significant variation was observed in fruit drop among exotic plum cultivars under studies (Table 4). The fruit drop was recorded maximum in cultivar Frontier (44.21) which was statistically higher than cultivar Grand Duke (43.44) and Red Plum (43.08). Cultivar Tarrol (42.85) was statistically at par with cultivar Krassivica Plum (42.24), Au- Rosa (41.20) and Beauty (42.16), respectively. Whereas fruit set was recorded minimum in cultivar Burbank (32.14) followed by Au- Cherry (34.52) and Monarch (35.09). The coefficient of variance for fruit set were 3.40 per cent.

Table 4: Fruit set, fruit drop and fruit retention in exotic plum

Cultivars	No. of flower/branch	Fruit set (%)	Fruit drop (%)	Fruit Retention (%)
Frontier	91.44	52.44	44.21	55.59
Red Beaut	88.89	47.54	37.85	61.48
Tarrol	85.53	45.28	42.85	56.15
Grand Duke	81.46	48.14	43.44	56.56
Black Amber	99.35	40.88	38.73	60.27
Burbank	89.02	45.40	32.14	67.86
Au-Cherry	102.55	43.84	34.52	65.48
Au-Rosa	104.84	45.98	41.20	58.80
Kanto 5	64.91	48.92	40.01	59.99
Kubio Plum	98.44	45.56	37.00	62.63
Red Plum	103.98	51.78	43.08	56.92
Krassivica Plum	74.39	49.92	42.24	57.76
Monarch	101.65	49.28	35.09	64.91
Beauty	96.87	50.74	42.16	57.84
Mean	91.66	47.55	39.60	60.16
CD_{0.05}	2.07	1.88	0.26	1.08
CV	5.36	9.11	3.40	4.00

4.3.4 Fruit retention

Fruit retention among exotic plum cultivars under studies (Table 4). The maximum fruit retains (67.86 %) was observed in cultivar Burbank followed by Au- Cherry (65.48 %), Monarch (64.91 %) and Red Beaut (61.48 %). However minimum number of fruits retain in cultivar Frontier (55.59 %) followed by Grand Duke (56.56 %) and Red Plum (56.92 %) respectively. The coefficient of variance for fruit retention were 4.00 per cent.

4.4 Fruit physio-chemical characters

4.4.1 Fruit colour

Fruit colour varied greatly among the different plum cultivars. Red purple colour possessed by cultivar (Grand Duke, Black Amber, Au- Rosa, Kubio Plum and Krassivica Plum), red colour by cultivar (Red beaut, Tarrol, Burbank, Red Plum and Beauty), grey purple by only plum cultivar (Frontier), yellow colour was observed in cultivar (Au- Cherry, Kanto 5 and Monarch), respectively.

4.4.2 Flesh colour

Data on the fruit flesh colour among the different plum cultivars revealed that yellow orange colour is dominant with the traces of the other colour depending upon their genetic constitution and pigmentation. Yellow orange colour was dominant in seven cultivars (Frontier, Red Beaut, Tarrol, Grand Duke, Red Plum, Burbank and Beauty), dark red flesh was observed in three cultivars (Black Amber, Kubio Plum and Krassivica Plum), red flesh only cultivar Au- Rosa, yellow flesh in three cultivars (Au- Cherry, Kanto 5 and Monarch), respectively.

Table 5 : Qualitative characteristics of exotic plum cultivars

Cultivars	Fruit colour	Flesh colour	Fruit shape
Frontier	Grey purple	Yellow orange	Round
Red Beaut	Red	Yellow orange	Round
Tarrol	Red	Yellow orange	Round
Grand Duke	Red purple	Yellow orange	Oblong
Black Amber	Red purple	Dark red	Elliptic
Burbank	Red	Yellow orange	Round
Au-Cherry	Yellow	Yellow	Elliptic
Au-Rosa	Red purple	Red	Heart shape
Kanto 5	Yellow	Yellow	Round
Kubio Plum	Red purple	Dark red	Round
Red Plum	Red	Yellow orange	Ovate
Krassivica Plum	Red purple	Dark red	Ovate
Monarch	Yellow	Yellow	Round
Beauty	Red	Yellow orange	Round

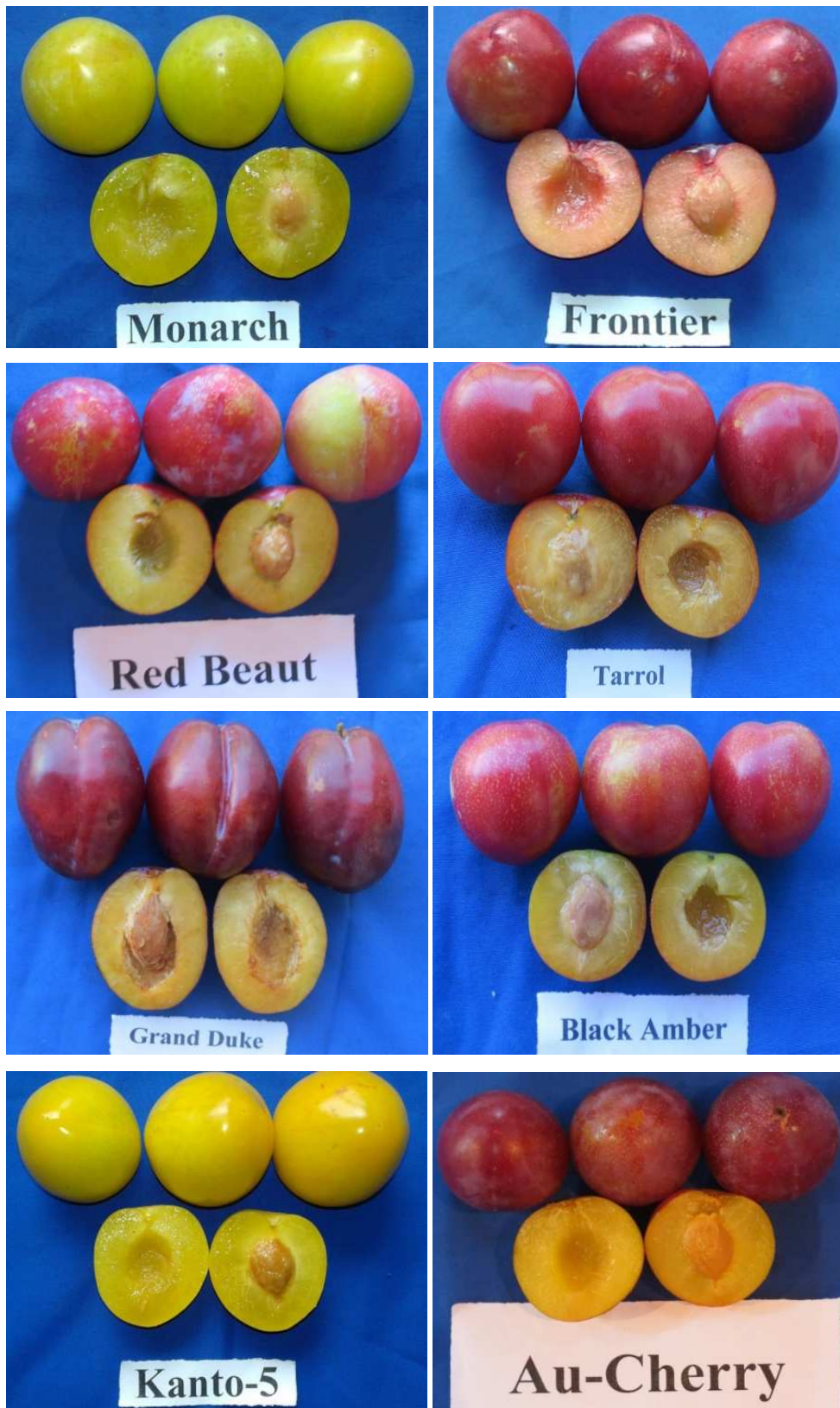


Plate 3: Characteristics features of different exotic plum cultivars

Contd...

Plate-3 contd...



4.4.4 Fruit shape

Data revealed that wide variation was observed among the different plum cultivars for their fruit shape (Table 5). Eight plum cultivar viz; (Frontier, Red Beaut, Tarrol, Burbank, Kanto 5, Kubio Plum, Monarch and Beauty) had rounded, two plum cultivars (Red Plum and Krassivica Plum) had ovate, two cultivar (Black Amber and Au- Cherry) had elliptic, cultivar (Grand Duke) had oblong and cultivar (Au- Rosa) had heart shape.

4.5 Fruit physical characters

4.5.1 Fruit weight

The perusal of the data presented in (Table 6) revealed that maximum fruit weight (65.78 g) was recorded in cultivar Frontier which was statistically higher among all the studied cultivars followed by cultivars Grand Duke (53.34 g) and Kanto 5 (51.72 g) whereas, cultivar Red Beaut registered of fruit weight of (48.91 g) which was significantly at par with cultivar Beauty (47.65 g). The minimum fruit weight was recorded in cultivar Krassivica Plum (26.44 g) followed by cultivars Kubio Plum (28.45 g), Black Amber (34.82 g), Red Plum (36.56), Au-Rosa (38.92 g) and Tarrol (42.40 g), respectively. Coefficient of variation value for fruit was 10.23 per cent.

4.5.2 Fruit size

Fruit size was recorded in terms of fruit length, fruit breadth and fruit thickness and presented in Table 6.

4.5.2.1 Fruit length

It is apparent from the data presented in Table 6 that the fruit length in different cultivars was ranging from 30.00 mm to 50.42 mm. Maximum fruit length was measured in cultivar Grand Duke (50.42 mm) which was significantly at par with cultivar Frontier (50.02 mm), whereas minimum fruit length was measured in cultivar Krassivica Plum (30.00 mm) was statistically at par with cultivar Kanto 5 (30.45 mm), Black Amber (30.85) and Kubio Plum (32.28 mm). The cultivar Beauty (43.44 mm) was statistically at par with Monarch (43.32 mm) and Burbank (43.30 mm), while the cultivar Red Beaut (46.72 mm) was statistically at par with Au- Rosa (46.00 mm). Coefficient of variation for fruit length was 7.36 per cent.

Table 6: Physical fruit characteristics of exotic plum cultivars

Cultivars	Fruit weight (g)	Fruit size (mm)		
		Length	Breadth	Thickness
Frontier	65.78	50.02	47.70	44.56
Red Beaut	48.91	46.72	44.28	38.67
Tarrol	42.40	33.70	29.86	27.44
Grand Duke	53.34	50.42	47.00	44.22
Black Amber	34.82	30.85	30.57	28.85
Burbank	46.11	43.30	38.23	35.44
Au-Cherry	44.61	35.89	42.49	38.36
Au-Rosa	38.92	46.00	35.07	31.09
Kanto 5	51.72	30.45	30.97	27.70
Kubio Plum	28.45	32.28	30.99	27.48
Red Plum	36.56	38.44	32.93	28.95
Krassivica Plum	26.44	30.00	28.62	27.18
Monarch	44.87	43.32	40.97	36.85
Beauty	47.65	43.44	40.58	38.39
Mean	43.61	39.63	37.16	33.94
CD_{0.05}	1.17	0.88	2.21	1.30
CV	10.23	7.36	11.33	5.52

4.5.2.2 Fruit breadth (mm)

Fruit breadth in different studied plum cultivars ranged from 28.62 mm to 47.70 mm (Table 6). Maximum fruit breadth was measured in cultivar Frontier (47.70 mm) which was significantly at par with Grand Duke (47.00 mm). Cultivar Kubio Plum (30.99 mm) was statistically at par with Kanto 5 (30.97 mm), Black Amber (30.57 mm) and Red Plum (32.93 mm), respectively. While cultivar Monarch (40.97 mm) was significantly at par with Beauty (40.58 mm) and Red Beut (44.28 mm). Minimum fruit breadth was recorded in cultivar Krassivica plum fruits registered (28.62 mm) and was statistically at par with cultivar Tarrol (29.86 mm), Au- Rosa (35.07 mm) and Burbank (38.23 mm), respectively. Coefficient of variation for fruit length was 11.33 per cent.

4.5.2.3 Fruit thickness (mm)

It is apparent from the data presented in Table 6 that the fruit thickness in different cultivars ranged from 27.18 mm to 44.56 mm. Maximum fruit thickness was measured in Frontier (44.56 mm) which was significantly at par with Grand Duke (44.22 mm). Cultivar Red Plum (28.95 mm) was statistically at par with Black Amber (28.85 mm), respectively. While cultivar Beauty (38.39 mm) was significantly at par with Au- Cherry (38.36 mm) and Red Beut (38.67 mm). Minimum fruit thickness was recorded in Krassivica Plum fruits registered (27.18 mm) and was significantly at par with Tarrol (27.44 mm), Kubio Plum (27.48 mm) and Kanto 5 (27.70 mm), respectively. Coefficient of variation for fruit length was 5.52 per cent.

4.5 Stone characteristics

4.5.1 Stone size

Stone size was measured in term of stone length and stone breadth and presented in Table 7

4.5.3 Stone length

It is apparent from the data given in Table 7 that the stone length was

ranged from 10.58 mm to 21.70 mm. The highest stone length was observed in cultivar Grand Duke (21.70 mm). Cultivar Au- Cherry (12.91 mm) was statistically at par with Beauty (12.86), Frontier (12.82 mm), Red Beaut (12.73 mm) and Krassivica Plum (12.15 mm), respectively. Whereas cultivar Tarrol (14.66) was statistically at par with Burbank (14.64 mm) and Black Amber (14.59 mm). The minimum stone length was recorded in Red Plum (10.58 mm) followed by the cultivars Kanto 5 and Kubio Plum recorded (11.88) mm, and (11.35) mm stone length, respectively. Coefficient of variation was 11.31 per cent.

4.5.4 Stone breadth

It is witnessed from the data presented in Table 7 that the stone breadth differs significantly among cultivars. Stone with maximum breadth was recorded in Grand Duke (14.94 mm) followed by cultivar Burbank (10.93 mm), Red Beaut (10.80 mm) and Black Amber (10.76 mm), respectively. Cultivar Krassivica Plum (6.99 mm), Au- Cherry (6.62 mm), Frontier (6.44 mm) and Tarrol (6.13 mm) were statistically at par with each other for stone breadth. Cultivar Red Plum (7.82 mm), Kubio Plum (7.47 mm) and Monarch (7.18 mm) were significantly at par with each other. Whereas minimum stone breadth was observed cultivar Kanto 5 (4.87 mm) were statistically at par with Beauty (5.97 mm) and Au- Rosa (5.64 mm). The coefficient of variation for this character was 7.19 per cent.

4.5.5 Stone weight

Significant differences were found in the stone weight among different plum cultivars (Table 7). Highest stone weight was recorded in Grand Duke (1.86 g) which was statistically higher among all the cultivars. While cultivar Red Beaut (1.84 g) were statistically at par with Monarch, Frontier, Tarrol, Beauty, Red Plum, Au- Rosa, Burbank and Black Amber which recorded 1.52 g, 1.48 g, 1.31 g, 1.22 g, 1.18 g, 1.17 g, 1.16 g and 1.00 g, respectively whereas, lowest stone weight was recorded in Au-Cherry and Kubio Plum (0.89 g) which was statistically at par with Kanto 5 (0.90 g) and Krassivica Plum (0.94 g), respectively. Coefficient of variation for stone weight were 2.12 per cent.

Table 7: Stone characteristics of exotic plum cultivars

Cultivars	Stone size (mm)		Stone weight (g)	Pulp : Stone Ratio	Stone adherence
	Length	Breadth			
Frontier	12.82	6.44	1.48	43.44	Free stone
Red Beaut	12.73	10.80	1.84	25.58	Cling stone
Tarrol	14.66	6.13	1.31	31.36	Cling stone
Grand Duke	21.70	14.94	1.86	27.67	Free stone
Black Amber	14.59	10.76	1.00	33.82	Cling stone
Burbank	14.64	10.93	1.16	38.75	Cling stone
Au-Cherry	12.91	6.62	0.89	49.12	Cling stone
Au-Rosa	15.00	5.64	1.17	32.26	Free stone
Kanto 5	11.88	4.87	0.90	56.46	Cling stone
Kubio Plum	11.35	7.47	0.89	30.96	Semi cling stone
Red Plum	10.58	7.82	1.18	29.98	Cling stone
Krassivica Plum	12.15	6.99	0.94	27.12	Cling stone
Monarch	15.71	7.18	1.52	28.51	Cling stone
Beauty	12.86	5.97	1.22	38.05	Semi cling stone
Mean	13.82	8.04	1.24	35.22	-
CD_{0.05}	0.31	0.36	0.50	0.82	-
CV	11.31	7.19	2.12	9.26	-

4.5.6 Pulp: stone ratio

Perusal of data revealed significant differences in the pulp: stone ratio of cultivars evaluated (Table 7). Pulp: stone ratio ranged from minimum 25.58 to maximum 56.46. The maximum pulp: stone ratio was recorded in Kanto 5 (56.46) followed by Au- Cherry (49.12) and Frontier (43.44) whereas cultivar Burbank (38.75) was statistically at par with Beauty (38.05), respectively. Cultivar Monarch (28.51) was statistically at par with Grand Duke (27.67) and Krassivica Plum (27.12) while the minimum pulp: stone ratio was recorded in Red Beaut (25.58) followed by Au- Rosa (32.26), Tarrol (31.36), Kubio Plum (30.96) and Red Plum (29.98). Coefficient of variation for pulp/stone ratio was 9.26 per cent, pulp: stone ratio (25.58-56.46),

4.5.7 Stone adherence

Adherence of stone to the fruit flesh was categorized as cling, semi cling and free stone type (Table 7). Of the total 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 cultivar Kubio Plum and Beauty was semi cling stone type.

4.6 Fruit chemical characters

4.6.1 Total sugars

The data presented in Table 8 that total sugars among the cultivars evaluated differed significantly. Total sugars ranged from 5.41 to 8.96. Maximum total sugars was recorded in cultivar Frontier (8.96) which was statistically at par with Black Amber (8.67), Tarrol (8.44) and Krassivica Plum (8.41) whereas, cultivar Kanto 5 (7.84) was statistically at par with Grand Duke (7.66), Au- Cherry (7.63) and Beauty (7.17), respectively. Minimum total sugars was recorded in Red Plum (5.41) and was statistically at par with Au- Rosa (5.67). The coefficient of variation for total soluble solids was 5.23 per cent.

Table 8: Physico-chemical characteristics of plum cultivars

Cultivars	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

4.6.2 Reducing sugars (%)

Reducing sugars ranged from 3.88 per cent to 6.98 per cent (Table 8). Maximum reducing sugars was recorded in cultivar Monarch (6.98 %) which was statistically at par with Frontier (6.64 %), Au- Cherry (6.59 %) and Krassivica Plum (6.36 %) to each other. Cultivar Black Amber (5.86 %) were statistically at par with Kubio Plum (5.58 %), Beauty (5.55 %), Tarrol (5.45 %), Red Plum (5.37 %), Red Beaut (5.31 %) and Grand Duke (5.19 %), respectively. Minimum reducing sugar was recorded in Au-Rosa (3.88 %) and was statistically at par with cultivars Kanto 5 (4.95) and Burbank (4.54). The coefficient of variation for reducing sugars was 10.05 per cent.

4.6.3 Non-reducing sugars (%)

Under the present investigation, maximum non-reducing sugars was recorded in cultivar Tarrol (2.78) and was statistically at par with Kanto 5 (2.77), Black Amber (2.66), Grand Duke (2.34), Kubio Plum (2.34) and Frontier (2.20). Cultivar Krassivica Plum (1.94) were statistically at par with Au- Rosa (1.70), Burbank (1.54), Beauty (1.53), Red Beaut (1.50), and Monarch (1.15), respectively. Minimum non-reducing sugars was recorded in Red Plum (0.38) were statistically at par with Au- Cherry (0.98). The coefficient of variation for total soluble solids was 10.52 per cent.

4.6.4 Total soluble solids

In the cultivars studied, maximum total soluble solids was recorded in Au-Rosa (16.06^oB) which was statistically at par with Tarrol (15.13^oB) and Monarch (15.06^oB). Minimum TSS was recorded in cultivar Krassivica Plum (10.00^oB) and was statistically at par with Black Amber (10.60^oB) and Kubio Plum (10.60^oB). Cultivar Frontier (14.86^oB) was statistically at par with Kanto 5 (14.80^oB), Red Beaut (14.03^oB), Beauty (13.06^oB) and Burbank (13.03^oB), whereas cultivar Au-Rosa (11.80^oB) with Red Plum (11.70^oB) and Grand Duke (11.23^oB) were

statistically at par with each other for total soluble solids. The coefficient of variation for total soluble solids was 5.97 per cent.

4.6.5 Acidity (%)

It is evident from the data that there exist great variability among different plum cultivars (Table 8). Acidity ranged from 1.18 to 2.22. Maximum acidity was recorded in Black Amber (2.22) which was statistically at par with Au- Cherry (2.20) and Burbank (2.10). Minimum acidity was recorded in Frontier (1.18) and was statistically at par with Au- Cherry (1.29), Beauty (1.31), Red Plum (1.32), Tarrol (1.32) and Kubio Plum (1.38) whereas, Red Beaut (1.49) with Krassivica Plum (1.65), Grand Duke (1.69), Monarch (1.75) and Kanto 5 (1.83) were statistically at par with each other for acidity. The coefficient of variation for acidity was 10.51 per cent.

4.6.6 Sugar: acid ratio

Perusal of data revealed significant differences in the sugar: acid ratio of cultivars evaluated (Table 7). Sugar: acid ratio ranged from 2.93 to 7.58. The maximum sugar: acid ratio was recorded in cultivar Frontier (7.58) followed by cultivars Tarrol (6.38), Krassivica Plum (5.09), Beauty (5.47) and Kubio Plum (5.83). Cultivar Red Beaut (4.62) was statistically at par with Monarch (4.68), Grand Duke (4.53), Red Plum (4.09) with Kanto 5 (4.28) and Au- Rosa (4.29). While the minimum sugar: acid ratio was recorded in Burbank (2.93). Coefficient of variation for sugar/acid ratio was 7.76 per cent.

4.6.7 Juice pH

Significant differences were found in the pH of juice of the studied plum cultivars (Table 8). Highest pH was recorded in Monarch (4.2) which was statistically at par with Krassivica Plum (4.1), Au- Cherry (4.1) and Burbank (4.0) while the lowest pH was observed in cultivar Beauty (3.1) which was statistically at par with Red Plum (3.3) and Kubio Plum (3.3) however no difference was observed in juice pH of cultivars Au-Rosa, Tarrol, Kanto 5, Black Amber, Red

Beaut, Frontier and Grand Duke. The coefficient of variation for juice pH was 4.08 per cent, respectively.

4.7 Fruit yield/harvesting

Fruit yield/harvesting was recorded in term of date of maturity and yield per tree and presented in Table 9

4.8 Date of maturity

In the present investigation the data recorded on date of maturity was presented in Table 9. Fruits of Red Plum cultivar were the earliest to mature (28th May), it was closely followed by fruits of Frontier, Tarrol and Au- Rosa on 2nd June, Au- Cherry and Krassivica Plum on 5th June, Black Amber, Monarch and Beauty on 7th, 8th, 9th June, respectively, while that cultivar Burbank and Kanto 5 fruits mature 10th to 12th June. The cultivar Kubio Plum and Grand Duke were mature late from 20th June to 26th June respectively.

4.9 Yield/tree (kg)

Perusal of data presented in Table 9 revealed significant differences among cultivars with respect to fruit yield. Yield per tree in different cultivars ranged from 18.07 kg to 52.54 kg per tree. The highest yield per tree was recorded in Frontier (52.54 kg) which was statistically higher of all other cultivars. The yield of cultivar Beauty (45.31 kg) which was statistically at par with Grand Duke (42.49 kg) and Au-Cherry (44.13 kg). However, the yield of cultivar Tarrol (35.00 kg) was statistically at par with cultivars Burbank (35.18) and Monarch (37.55 kg), respectively. Minimum fruit yield was recorded in cultivar Kubio Plum (18.07 kg).

Table 9: Maturity date and yield characteristics of plum cultivars

Cultivars	Date of maturity	Yield/tree (kg)
Frontier	2 nd June	52.54
Red Beaut	6 th June	32.24
Tarrol	2 nd June	35.00
Grand Duke	26 th June	42.49
Black Amber	7 th June	22.66
Burbank	10 th June	35.18
Au-Cherry	5 th June	44.13
Au-Rosa	2 nd June	22.95
Kanto 5	12 th June	40.35
Kubio Plum	20 th June	18.07
Red Plum	28 th May	30.57
Krassivica Plum	5 th June	26.56
Monarch	8 th June	37.55
Beauty	9 th June	45.31
Mean	-	34.68
CD_{0.05}	-	1.43
CV	-	6.83

Chapter-5

DISCUSSION

The present investigation entitled “Evaluation studies on exotic Plum cultivars under Kashmir conditions” was conducted at the Central Institute of Temperate Horticulture (CITH) Srinagar, Jammu and Kashmir, as it was realized that no work has been done in this area although area has immense potential for its commercial cultivation. The major emphasis in this investigation was given to identify the best cultivars which are superior in yield and fruit quality. Result obtained from the present studies are discussed below:

5.1 Phenological stages

The earliest date of bud swell was observed in cultivar Beauty (30th March) and late bud well was observed in cultivar Kubio Plum (8th April). The date of tight cluster was earliest observed in cultivar Beauty (2nd April) and tight cluster date was late in cultivar Kubio Plum (11th April). Date of open cluster was earliest in cultivar Beauty (5th April) whereas it was late in cultivar Kubio Plum (14th April).

The date of first bloom was observed in cultivars Frontier, Red Beaut, Tarrol, Au-Rosa, Krassivica Plum and Beauty on 7th April and late bloom was observed in cultivar Kubio Plum (17th April) during the present studies. The date of full bloom was recorded in cultivars Beauty and Tarrol on 10th April and late was observed in cultivar Grand Duke (16th April) and Kubio Plum (21th April). The duration of flowering in the studied cultivars ranged from 9 to 15 days. Maximum duration of flowering was recorded in cultivars Frontier and Au-Rosa (15 days), however minimum duration was observed in cultivar Red Plum (9 days).

The number of flowers per branch among the studied cultivars ranged from 64.91 to 104.84. Maximum flowers per branch were observed in cultivar Au-Rosa (104.84) and lowest were observed in cultivar Kanto 5 (64.91). The early

date of first petal fall was observed in cultivar Beauty (12th April) and late in cultivars Grand Duke and Monarch (19th April). Date of complete petal fall was observed earlier in cultivar Beauty (17th April) and late was observed in cultivar Kubio Plum (28th April).

Highest fruit set was recorded in cultivar Frontier (52.44 %) whereas as lowest fruit set was recorded in cultivar Black Amber (40.88 %). Fruit drop was maximum in cultivar Frontier (44.21 %) and minimum in cultivar Burbank (32.14 %). The fruit retention was maximum in cultivar Burbank (67.86 %) whereas, minimum fruit retention was recorded in cultivar Frontier (55.59 %).

The similar variations in traits different also observed by Sud (1979), Kumar *et al.* (2013), Aulakh (1999) and Josan *et al.* (1999) in plum cultivars. These traits depend on environmental conditions (temperature, altitude, rainfall etc.) and may change every year (Liverani *et al.*, 2010). Cosmulescu *et al.* (2010) stated that 'flowering time duration' is a feature which is influenced both by climatic as well as genetic factor.

Variable duration of flowering in different plum cultivars were also reported by Jovancevic (1977) and Milosevic (2010). They concluded that high variation in flowering period pave the way for developing late flowering plum to avoid damage due to spring frost under mid hill conditions. Similar variation in duration of flowering in plum has been reported by Bellini *et al.* (1992), Vargas *et al.* (2001) and Vitanova *et al.* (1998). They attributed these variations to the genetic makeup of the cultivars and their response to existing soil and climatic conditions.

Higher fruit set under present investigation may be better due to more nutrient availability and weed control. These results are in accordance with the findings of Autio *et al.* (1991), Thakur *et al.* (1993) and Mehraj *et al.* (2014), who reported that an adequate nitrogen supply to the first leaf emerging in the spring as well as to the flower was critical for fruit set. Higher fruit drop in the present

study may be due to decrease in soil moisture and nutrient losses which resulted in low fruit retention and higher fruit drop leading to lower yield. These results are in accordance with the findings of Thakur *et al.* (1993), Bajawa *et al.* (1993) and Mehraj *et al.* (2014).

5.2 Foliage characters

Maximum leaf length was observed in cultivar Frontier (116.13 mm) and minimum leaf length was recorded in cultivar Red Beaut (92.33 mm) however, maximum leaf breadth (49.66 mm) was recorded in cultivar Au-Rosa and minimum leaf breadth (33.26 mm) was observed in cultivar Burbank. The leaf area (cm²) of the studied exotic plum cultivars ranged from 31.24 cm² (Red Beaut) to 56.22 cm² (Frontier).

The petiole length was maximum in cultivar Grand Duke (21.17 mm) followed by Au-Cherry (20.33 mm), whereas minimum petiole length was recorded in cultivar Burbank (13.96 mm). Maximum petiole thickness was recorded in cultivar Frontier (1.67 mm) and minimum petiole thickness was recorded in cultivar Au-Cherry and Au-Rosa (1.17 mm). Leaf margin was categorized as crenate and serrate. Only cultivar Grand Duke had crenate type of leaf margin, whereas it was serrate type in rest of thirteen plum cultivars under study. Similar variation was reported by Chalak *et al.* (2006) in peach.

Rozpara *et al.* (2008) in cherry, Kaur and Kaundal (2009) in peach and Fathia *et al.* (2013) also reported similar type of variation in different leaf characters (leaf length, leaf breadth, leaf area, petiole length and petiole thickness) obtained in present studies which are in accordance with the findings of Gonzales (1992) and Wang *et al.* (2006) who reported that the traits viz, leaf length, leaf breadth, leaf area, petiole length and petiole thickness are genetically inherited characters which varied from variety to variety, age of tree, location and fertility status of the soil.

5.3 Physico-chemical characters

5.3.1 Fruit size

Fruit size was measured as fruit length x fruit breadth x fruit thickness. The fruit length in different cultivars was ranging 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 in 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).

Similar type variation with respect to fruit size has been reported by Mohapatra and Sharma (1997) they reported that physical characters such as fruit weight was maximum in cultivar Frontier (62.19 g) and minimum in cultivar Azarshah (14.40 g). Robertson *et al.* (1992) recorded heaviest fruit weight in cultivar Fortune (80.51 g) followed by Queen Rosa (80.19 g) and smallest in Florida1-2 (29.20 g). Balik (2004) and Caliskan *et al.* (2006) reported that fruit weight ranged from 46.71 g (Obilnaja) to 91.26 g (Black Diamond). In a study, Karamursel *et al.* (2007) reported that fruit weight of President cultivar was 57.04 g. Different soil and climatic conditions and management practices could be the reason for differences in fruit weight. Further the variation might be due to differences in genetic constitution of cultivars and crop load that appear to be responsible for difference in fruit weight. The results are in agreement to the findings of Bisla and Chitkara (1980), Ozakman *et al.* (1995) and Chanana *et al.* (1992). 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.

Similar type variation was also reported by Singh *et al.* (2011). Kumar *et al.* (2013) reported similar results in which fruit length was maximum in cultivar Ruby Sweet (43.81 mm) and minimum (31.79 mm) in cultivar Cherry Plum. 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 greatly 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 Au- Cherry, Kanto 5 and Monarch.

The flesh colour of fruit among the different plum cultivars revealed that yellow orange colour is dominant with the traces of the other colour depending upon their genetic constitution and pigmentation. Yellow orange colour was found dominant in seven cultivars 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 Au-Cherry, Kanto 5 and Monarch. Similar variations in the fruit and flesh colour characters have been reported by different workers (Singh *et al.* 2011, Kumar *et al.* 2013, Sharma, 1999 and Tandon, 2006).

Present data revealed that wide variation was observed among the different plum cultivars for their fruit shape. Eight plum cultivars Frontier, Red Beaut, Tarrol, Burbank, Kanto 5, Kubio Plum, Monarch and Beauty were round, cultivars Red Plum and Krassivica Plum were ovate, two cultivars Black Amber and Au- Cherry were elliptic, cultivar Grand Duke was oblong however cultivar Au- Rosa had heart shape. Similar results have been reported by other workers (Sharma, 1999 and Tandon, 2006). The variation in fruit shape might be due to

difference in agro-ecological and adaphic conditions, genetic makeup of plum cultivars and most important is the nature and place of origin.

5.3.2 Fruits stone characters

During the study of stone size such as stone length and stone breadth. The stone length and breadth 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 total 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.

Similar type of variation in stone size has also been reported by Kumar *et al.* (2013) and Josan *et al.* (1999). Variation in pulp: stone ratio in plum has been reported by Thakur *et al.* (2014), Tripathi *et al.* (1984) and Josan *et al.* (1999) 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, 2013 and Tandon 2006).

5.4 Chemical characters

Different cultivars were studied with respect to fruit chemical characters such as total sugars, reducing sugar, non-reducing sugar, TSS, acidity, sugar acid ratio and juice pH. 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 was 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).

Maximum total soluble solids (TSS) were recorded in cultivar Au- Rosa (16.06°B) while the lowest was recorded in cultivar Krassivica Plum (10.0°B) in present study. 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).

Similar type of variation has also been reported by Son (2010) and Paunovic *et al.* (1994). He observed that in different plum cultivars, the total sugars varied from 7.14 per cent (Au- Rosa) to 8.94 per cent (Frontier), Thakur *et al.* (2014) reported that the total sugar content ranged from 6.07 per cent (Queen Rosa) to 8.95 per cent (Shiro 14-4). Variation in reducing sugar in plum has also been reported by Erturk *et al.* (2009) and (Nergiz and Yildiez, 2010) while Son (2010) reported that the sugar: acid ratio in plum cultivars ranged from 7.93 to 4.29 and non-reducing sugar ranged from 0.69 per cent (Ruby Sweet) to 4.15 per cent (Shiro 1-4). Josan *et al.* (1999) also observed that mean TSS ranged from 9.72°B to 16.95°B in different cultivars of plum. The results are also in agreement with those obtained by Singh *et al.* (1973) and Tomar *et al.* (1984) who reported that TSS content in peach varied between 9.8 to 15.8°Brix in cultivar Sharbati. Josan *et al.* (1999) have also recorded lowest acidity in Ruby Sweet and highest in Florida 1-2 plum. Similar, results have also been reported by Singh *et al.*, (1973), Dirlewanger *et al.* (1999) and Promchot *et al.*, (2008) in peach and nectarines. 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 varied by the agro-climatic conditions and nutritional factors (Nergiz and Yildiez, 2010).

5.5 Yield character

In the present study, the date of fruits 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).

Similar type of variation has also been reported by Balik (2004) and Sharma *et al.* (1993) who reported that the time of maturity of plum cultivars ranged from the middle of June to the first week of September. Caliskan (2006) reported that plum cultivar Autumn Giant, T.C Sun and Angeleno were the late

ripening cultivars and matured in the first week of September. These different findings are most likely attributed to the characteristics of different species of fruit. Also the differences in date may 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.

Chapter-6

SUMMARY & CONCLUSION

The present investigation entitled “Evaluation studies on exotic plum germplasm under Kashmir conditions” was conducted at Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir during the year 2014.

Different exotic plum cultivars were evaluated for phenological stages and physico-chemical characters which were studied under different sub headings viz; bud stage, floral stage and leaf characters of plum cultivars, physico-chemical characters viz; physical fruit characters, stone characters, chemical traits and fruit yield or harvesting. The date of bud swell, tight cluster, open cluster, date of first bloom, full bloom, first petal fall, complete petal fall, no. of flowers per branch, fruit set, fruit drop, fruit retention, leaf length, leaf breadth, leaf area, petiole length, petiole thickness and leaf margin were studied under phenological stages in plum cultivars. Whereas characters like fruit weight, fruit length, fruit breadth, fruit thickness, fruit shape, fruit colour, flesh colour, stone weight, stone length, stone breadth, pulp: stone ratio, stone adherence, total sugars, reducing sugar, non-reducing sugar, TSS, acidity, sugar: acid ratio, juice pH, date of maturity and yield per tree (kg) were studied under fruit physico-chemical characters.

The important findings are summarized as under:-

- Significant differences were recorded among the evaluated cultivars for bud swell stage. The bud swell was noticed quite early in cultivar ‘Beauty’, ‘Frontier’, ‘Krassivica Plum’, ‘Red Beaut’, ‘Tarrol’ and ‘Au-Rosa’ and late in cultivar ‘Kubio Plum’.
- Tight cluster was observed earliest in cultivar ‘Beauty’, ‘Frontier’, ‘Red Beaut’, ‘Tarrol’, ‘Au-Rosa’ and ‘Krassivica Plum’, and late in cultivar ‘Kubio Plum’.

- Open cluster was observed earliest in cultivar 'Beauty', 'Frontier', 'Red Beaut', 'Tarrol', 'Au-Rosa' and 'Krassivica Plum' and late in cultivar 'Kubio Plum'.
- Among the cultivar studied, cultivar 'Beauty', 'Frontier', 'Red Beaut', 'Tarrol', 'Au-Rosa' and 'Krassivica Plum' blooms first while cultivar 'Kubio Plum' was late in blooming. Full bloom was earliest in cultivars 'Beauty' and 'Tarrol' and late in cultivar 'Kubio Plum'.
- Petal fall stage was recorded earlier in cultivar 'Beauty' and late in cultivars 'Grand Duke' and Monarch'. The complete petal fall stage was earliest in cultivar 'Beauty' and late in cultivars 'Grand Duke' and Monarch'.
- The duration of flowering ranged from 9 to 15 days among the studied cultivars. Maximum duration of 15 days was recorded in cultivars 'Frontier' and 'Au- Rosa' and minimum duration of flowering (9 days) was recorded in cultivar 'Red Plum'.
- Among the cultivars evaluated, cultivar 'Frontier' had maximum leaf length whereas lowest in cultivar 'Red Beaut'. Cultivar 'Au-Rosa' had maximum leaf breadth while cultivar 'Burbank' had minimum leaf breadth. Maximum leaf area per blade was recorded in cultivar 'Krassivica Plum' whereas minimum in leaf area in cultivar 'Burbank'.
- Cultivar 'Grand Duke' showed highest petiole length whereas cultivar 'Burbank' had lowest value for petiole length. Maximum petiole thickness was recorded in cultivar 'Frontier' and minimum was recorded in cultivar 'Au-Cherry'.
- Leaf margin was categorized as crenate and serrate types. Only cultivar 'Grand Duke' had crenate type of leaf margin whereas rest of cultivar had serrate type of leaf margin.

- Maximum number of flowers per branch was registered in cultivar 'Au-Rosa' and minimum in cultivar 'Kanto 5'.
- Highest fruit set was recorded in cultivar 'Frontier' and lowest in cultivar 'Black Amber'. Maximum fruit drop was recorded in cultivar 'Frontier' and minimum in cultivar 'Burbank'. Highest fruit retention was recorded in cultivar 'Burbank' and lowest in cultivar 'Frontier'.
- Cultivars 'Grand Duke', 'Black Amber', 'Au-Rosa', 'Kubio Plum' and 'Krassivica Plum' was red purple with respect to fruit colour, red colour was noticed in cultivars 'Red Beaut', 'Tarrol', 'Burbank', 'Red Plum' and 'Beauty', grey purple in 'Frontier' and yellow in cultivars 'Au-Cherry', 'Kanto 5' and 'Monarch'. Fruit flesh colour was yellow orange in cultivars 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Burbank', 'Red Plum' and 'Beauty', dark red in cultivars 'Black Amber', 'Kubio Plum' and 'Krassivica Plum', red in cultivar 'Au-Rosa' and yellow in cultivars 'Au-Cherry', 'Kanto 5' and 'Monarch'.
- Shape of fruit was round in cultivars 'Frontier', 'Red Beaut', 'Tarrol', 'Burbank', 'Kanto 5', 'Kubio Plum', 'Monarch' and 'Beauty', ovate in cultivars 'Red Plum' and 'Krassivica Plum', elliptic in cultivars 'Black Amber' and 'Au-Cherry', oblong in cultivar 'Grand Duke' and heart shape in cultivar 'Au-Rosa'.
- Fruit weight of different plum cultivars ranged between 26.44 g (Krassivica Plum) to 65.78 g (Frontier). Maximum fruit length and fruit breadth was recorded in 'Grand Duke' (50.42 mm) and 'Frontier' (47.70 mm), respectively whereas minimum fruit length and fruit breadth was registered in cultivar 'Krassiviva Plum' (30.00 mm and 28.62 mm). Maximum fruit thickness was recorded in cultivar 'Frontier' (44.56 mm) and minimum was in 'Krassivica Plum' (27.18 mm).

- Stone weight of plum cultivars ranged between 0.89 g (Au-Cherry and Kubio Plum) to 1.86 g (Grand Duke), stone length varied from 10.58 mm (Red Plum) to 21.70 mm (Grand Duke) whereas stone breadth varied from 4.87 mm (Kanto 5) to 14.94 mm (Grand Duke). Highest pulp: stone ratio was recorded in cultivar 'Kanto 5' (56.46) and lowest was recorded in cultivar 'Red Beaut' (25.58).
- Cultivars 'Red Plum', 'Red Beaut', 'Tarrol', 'Burbank', 'Kanto 5', 'Kubio Plum', 'Black Amber', 'Au-Cherry' and 'Krassivica Plum' were cling types whereas cultivars 'Frontier', 'Grand Duke' and 'Au-Rosa' were free stone type cultivars.
- Maximum total soluble solids were recorded in cultivar 'Au-Rosa' (16.06 %) and minimum in cultivar 'Krassivica Plum' (10.00 %), whereas maximum total sugars content was recorded in cultivar 'Frontier' (8.96 %) and lowest in cultivar 'Red Plum' (5.41 %). Reducing sugar and non-reducing sugars ranged between 3.88 per cent (Au-Rosa) to 6.98 per cent (Monarch) and 0.38 per cent (Red Plum) to 2.78 per cent (Tarrol), respectively.
- Minimum titrable acidity content was observed in cultivar 'Frontier' (1.18 %) and maximum in 'Black Amber' (2.22 %) whereas maximum sugar: acid ratio was observed in cultivar 'Frontier' (7.58) and minimum in cultivar 'Burbank' (2.93). The highest juice pH was recorded in cultivar 'Monarch' (4.2) and lowest in cultivar 'Beauty' (3.1).
- Plum cultivar 'Red Plum' matured and harvested much earlier than all other cultivars however in cultivar 'Grand Duke' matured late in comparison to other cultivars. Maximum yield per trees was observed in cultivar 'Frontier' (52.54 kg) and minimum yield was observed in cultivar 'Kubio Plum' (18.07 kg).

On the basis of fruit weight and yield, the best cultivar was 'Frontier' whereas Au-Rosa was best with respect to sweetness of fruit. 'Frontier', 'Grand Duke' and 'Au- Rosa' were best cultivars as they free from 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. The cultivar with distinct superiority in yield and quality characteristics are recommended for commercial adaption and in further improvement programmes through breeding.

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Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Fruit Science

Certificate

Certified that all the corrections/amendments as suggested by External Examiner Dr. M.A. Dalal, Former Prof. & Head, Division of Fruit Science, SKUAST-Kashmir during Viva-Voce examination held on 04.10.2016 have been incorporated in the manuscript entitled “**Evaluation studies on exotic plum germplasm under Kashmir Conditions**” submitted by **Mr. Surendra Kumar Verma (Regd. No. 2013-A-999-M)**.

(Dr. A.S. Sundouri)
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