DUS CHARACTERIZATION OF JAPANESE PLUM (*Prunus salicina* Lindl.) GERMPLASM

Thesis

by

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submitted to

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CERTIFICATE-I

This is to certify that the thesis titled, "**DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Horticulture) Fruit Science** in the discipline of **Horticultural Sciences** to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 is a bonafide research work carried out by **Ms. Gauri Sood (H-2020-46-M)** daughter of Mr. Anil Sood under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place: Nauni, Solan (HP)
Dated:

_____
Dr RK Dogra
Major Advisor

CERTIFICATE-II

This is to certify that the thesis titled **"DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm"** submitted by **Ms. Gauri Sood (H-2020-46-M)** daughter of Mr. Anil Sood to the Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni) Solan (HP) – 173 230 India, in partial fulfilment of the requirements for the degree of **Master of Science (Horticulture) Fruit Science** in the discipline of **Horticultural Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

3/12/22

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Needless to say, all errors and omissions are mine!

Dated:
Place: Nauni, Solan **(Gauri Sood)**

CONTENTS

LIST OF ABBREVIATIONS

%	:	Per cent
^{o}Brix	:	Degree Brix
amsl	:	Above mean sea level
ANOVA	:	Analysis of variance
CD	:	Critical difference
DUS	:	Distinctness, Uniformity and Stability
Fig	:	Figure
cm	:	Centimetre
cv (s)	:	cultivar(s)
et al.	:	Co-workers
E-W	:	East-West
g	:	Gram
ha	:	Hectare
H.P.	:	Himachal Pradesh
i.e.	:	That is
NBPGR	:	National Bureau of Plant Genetic Resources
kg	:	Kilogram
m	:	Metre
mg	:	Milligram
ml	:	Millilitre
mm	:	Millimetre
MT	:	Metric Tonne
N-S	:	North-South
TSS	:	Total soluble solids
UPOV	:	International Union for the Protection of New Varieties of Plants
viz.	:	Namely

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Chapter-1

INTRODUCTION

A plum is a stone fruit tree in the family Rosaceae of *Prunus* genus, is naturally distributed in the cold regions of the Northern Hemisphere (Mabberley, 2017). Plums are temperate zone fruits, but they are widely grown throughout the world from the cold climate region of Siberia to the sub-tropical conditions of the Mediterranean region (Son, 2010). Plums are by far the most diverse of all the *Prunus* spp. and could be the most diverse of all deciduous fruit crops (Potter *et al.,*2007). It occupies a unique position amongst the stone fruits in world fruit production and ranks next to peaches in economic importance. Plum is one of the main group of fruits with about 6000 cultivars originating from Europe, Asia and the USA. It represents over 50 different species of *Prunus* that bear small fruits, which are generally larger than cherries and are unique by the presence of suture on one side, no terminal bud and relatively flat stone. Plum contains 20-40 species (Okie and Hancock, 2008) that are diverse in different parts of the world. It has large number of species but the commercially grown cultivars belong to two species *i.e., Prunus domestica* L. (European plum) and *Prunus salicina* L. (Japanese plum), the former is hexaploid (2n = 6x = 48) and the latter is diploid (2n = 2x = 16).

Japanese plum originated in the Yangtze river basin and was spread across Eastern China, where it has been cultivated for several thousand years. Japanese plum thrives well at an elevation of 1000-1600 m above mean sea level and requires 700-1000 chilling hours (below 7.2 ℃). Chanana (2001) suggested that plum can be grown in a wide range of subtropical and warm temperate climate. In India, plum was first introduced in 1870 by Alexander Coutts at Mashobra (Shimla) in Himachal Pradesh. It is grown on commercial scale under the mid-hills of Himachal Pradesh, Jammu & Kashmir, Uttarakhand in North India and to a limited extent in Nilgiri hills in South India, also some low chill cultivars of Japanese plum are successfully grown under subtropics with a total area of 19,000 hectares and a total production of 77,000 metric tonnes (Anonymous, 2020).

Himachal Pradesh ranked second in plum production in India with an annual production of 16,000 metric tonnes. The total area under plum cultivation was 8,560 hectares (Anonymous, 2019). Area under plum is consistently increasing in Himachal Pradesh.

Plums have a great range of flavour, aroma, texture, colour, size and other characteristics which makes their fruits more desirable than other horticultural crops (Westwood, 1978 & Baden and Byrne, 2012). The fruits constitute high nutritional value having high content of carbohydrates, minerals and vitamins that stimulate the body's health. Fresh fruits contain sugar (16–20 %), proteins (0.7 %), lipids (0.28 %), pectins, tannoid substances, citric acid, vitamin A and B and minerals like calcium, phosphorous, potassium and fluoride. Plums are appreciated for fresh consumption and also for dehydration and processing in different forms (jams, fruit compote, jellies, candied fruits, frozen fruits, cordials, brandy, etc.).

In the past fifteen years in Himachal Pradesh, increasing demands for fresh plums have contributed to the establishment and development of new, more intensive orchard system that are harvested earlier and supply better quality fruits to market (Blazek and Pistekova, 2009). The predominance of one or two cultivars lead to monoculture like situation and create gluts in the market because of which farmers do not get remunerative prices for their produce. To meet everchanging consumer preferences and expand the harvest season, there is a need for varietal diversification with genetically improved genotypes. The local strains are comparatively more tolerant against biotic and abiotic stresses. Hence, to sustain the production, productivity and quality of any crop in present trend of climate change there is an urgent need to assess the physio-chemical performance of locally existing germplasm.

Therefore, the proposed evaluation was envisaged to characterize various genotypes of plum to assess variability. The study will contribute to the knowledge about the genus *Prunus* and will be helpful in broadening the plum gene pool. Evaluation and characterization of the plum germplasm for its performance in the target area are the pivotal factors for its acceptance by the orchardists. Besides, the descriptors so developed are important for the proper documentation and classification of the variety to preserve authenticity and check biopiracy. Keeping in cognizance the overhead, it was projected to transmit out investigations on Japanese plum germplasm accessions available in the field gene bank of National Bureau of Plant Genetic Resources (NBPGR), Regional Station, Phagli, Shimla.

The present study was carried out with the following objective-

i. To characterize and evaluate Japanese Plum germplasm for growth, floral and fruit characteristics

Chapter-2

REVIEW OF LITERATURE

Japanese plum cultivation has risen over the last few decades. Every cultivar used must be well adapted to local environmental conditions, which is an important factor in successive growing. Therefore, cultivar testing plays an important role in current plum research (Kemp *et al.*, 1993 and Hartmann, 1997, 2004). DUS testing is a way of determining whether a newly bred variety differs from existing varieties within the same species (the Distinctness part), whether the characteristics used to establish distinctness are expressed uniformly (the Uniformity part) and that these characteristics do not change over subsequent generations (the Stability part).

This chapter contains the relevant literature pertaining to the present study entitled **"DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm**." The available literature is reviewed under different headings as follows

2.1 Tree Characters
2.2 Foliage Characters
2.3 Flower Characters
2.4 Pollen Studies
2.5 Fruit Characters
2.6 Stone Characters
2.7 Biochemical Characteristics

2.1 TREE CHARACTERS

Prakash (1993) evaluated ten plum cultivars namely 'Alubukhara', 'Alucha Amritsari', 'Carinota', 'Dabba', 'Golden Lalri', 'Kala Amritsari', 'Kala Bahadurgarh', 'Kataroo Chak', 'Red Alubukhara' and 'Zardalu'. The tree height was observed maximum in 'Kataroo Chank' (54.40 m) and minimum in 'Carniota' (2.99 m).

Prakash *et al.* (2003) studied six plum cultivars namely 'Methley', 'Santa Rosa', 'Ramgarh Maynard', 'First Plum', 'New Plum' and 'Kabul Green Gage' under mid-hills of Uttaranchal in which maximum tree height was observed in 'First plum' (10.76 m) followed

by ‘Ramgarh Maynard’ (10.40 m) while the minimum tree height was recorded in ‘New Plum’ (4.07 m). Tree girth was found maximum in ‘First Plum’ (43.62 m), while it was minimum in ‘New Plum’ (16.37 m). Spread of the tree was found maximum in ‘Ramgarh Maynard’ (11.26 m) followed by ‘First Plum’ (10.54 m), ‘Methley’ (8.98 m), ‘Santa Rosa’ (8.54 m), ‘Kabul Green Gage’ (5.40 m) and the minimum was found in ‘New Plum’ (4.66 m). The growth habit was spreading for ‘Methley’, ‘Ramgarh Maynard’ and ‘New Plum’, upright for ‘Santa Rosa’ and ‘First Plum’ whereas, it was moderate growth with spreading habit for ‘Kabul Green Gage’.

Tandon (2006) studied six cultivars *viz*., ‘Black Amber’, ‘Cherry Plum’, ‘Queen Rosa’, ‘Ruby Sweet’, ‘Satluj Purple’ and ‘Shiro’. She observed that ‘Satluj Purple’ showed maximum tree height (4.00 m) and trunk girth (45.90 cm) whereas, ‘Black Amber’ recorded minimum plant height (2.50 m) and trunk girth (13.00 cm).

Sestras *et al.* (2007) studied five plum cultivars *viz.,* ‘Tuleu timpuriu’, ‘Vinete romanesti’, ‘Vinete de Italia’, ‘Valor’ and ‘Reine Claude d’Althan’. They reported maximum tree height in ‘Reine Claude d’Althan’ (5.96 m) and minimum in ‘Vinete de Italia’ (4.00 m). The tree diameter was found to be maximum in ‘Tuleu timpuriu’ (25.08 cm) and minimum in ‘Vinete romanesti’ (17.86 cm).

Sosna and Kortylewska (2010) conducted a study on plum cultivars namely ‘Amers’, ‘Kometa’, ‘Najdiena’, ‘Skoropłodnaja’ and ‘Shiro’ in which they observed that ‘Shiro’ grows strong or even very strong whereas, the trees of ‘Amers’ grew weakly or medium strongly.

Blazek and Pistekova (2012) evaluated nine plum cultivars *viz.,* ‘Bluefree’, ‘Cacanska Lepotica’, ‘Cacanska Rana’, ‘Domestic Prune’, ‘Empress’, ‘Herman’, ‘Sanctus Hubertus’, ‘Valor’ and ‘Wegierka Dabrowicka’. The study revealed the maximum vigour in ‘Sanctus Hubertus’ followed by ‘Cacanska Rana’ and ‘Herman’ and minimum vigour was observed in ‘Empress’ and ‘Valor’ cultivars.

Jun *et al.* (2015) studied Japanese plum cultivar ‘Summer Fantasia’ and its performance was compared to ‘Oishiwase’, ‘Purple Queen’, ‘Santa Rosa’, ‘Soldam’, and ‘Taiyo’ in which they recorded that the tree vigour was medium for ‘Summer Fantasia’, ‘Oishiwase’ and ‘Soldam’ while it was strong for ‘Purple Queen’, ‘Santa Rosa’ and ‘Taiyo’.

Tree Spread was spreading type in ‘Summer Fantasia’ and ‘Soldam’, semi-upright in ‘Oishiwase’ and upright in ‘Purple Queen’, ‘Santa Rosa’ and ‘Taiyo’.

Nisar *et al.* (2015) studied tree growth habit amongst sixteen genotypes. The results revealed seven plum genotypes were upright, three extremely upright, three semi-upright and three showed spreading growth habit.

Kumar (2016) studied eight plum cultivars *viz*., ‘Duarte’, ‘Black Amber’, ‘Friar’, ‘Shiro’, ‘Frontier’, ‘Santa Rosa’, ‘Red Beaut’ and ‘Mariposa’. He observed the maximum tree spread in ‘Shiro’ (2.14 m) whereas, minimum tree spread was found in ‘Friar’ (1.06 m).

Latifikhah *et al.* (2017) evaluated the performance of four different plum and prune genotypes namely ‘Ghohrood’, ‘Dobahreh’, ‘Khansar’ and ‘Plum No.1 of Mobarakeh’. The maximum tree height was found in ‘Ghohrood’ (3.5 m), followed by ‘Dobahreh’ (3.0 m), ‘Khansar’ (3.0 m) and the minimum was reported in ‘Plum No. I of Mobarakeh’ (2.5 m).

Kumar *et al.* (2018) conducted a trial on eight Japanese plum cultivars *viz.,* ‘Black Amber’, ‘Duarte’, ‘Friar’, ‘Shiro’, ‘Frontier’, ‘Mariposa’, ‘Red Beaut’ and ‘Santa Rosa’. It was concluded that the tree height in all the eight plum cultivars ranged between 2.04 m in ‘Friar’ to 3.98 m in ‘Red Beaut’ which was statistically at par with ‘Santa Rosa’ (3.65 m) and ‘Mariposa’ (3.48 m). The overall mean for tree height was recorded as 3.06 m. The maximum trunk girth was recorded in the cultivar ‘Santa Rosa’ (20.46 cm) which was statistically at par with ‘Red Beaut’ (20.16 cm), ‘Frontier’ (19.86 cm) and ‘Shiro’ (18.98 cm) whereas, the minimum girth was attained by the cultivar ‘Friar’ (13.06 cm).

Sharma *et al.* (2018) observed that maximum tree spread was found in the cultivar ‘Shiro’ (2.14 m) which was statistically higher than all other cultivars. Minimum tree spread was however, recorded for the cultivar ‘Friar’ (1.06 m) which was found to be statistically at par with cultivars ‘Black Amber’ and ‘Duarte’.

Majid *et al.* (2020) carried out a study on six cultivars of plum *viz.,* ‘Burbank’, ‘Stanley’, ‘Friar’, ‘Wickson’, ‘Santa Rosa’ and ‘Satsuma’. Maximum tree spread was recorded in the cultivar ‘Satsuma’ (2.19 m) which was statistically superior to all the other cultivars. Cultivar ‘Wickson’ (1.78 m) was statistically at par with cultivar ‘Santa Rosa’ (1.66

m). Cultivar 'Burbank' (1.30 m) was statistically at par with cultivar 'Stanley' (1.08 m). Minimum tree spread was recorded for the cultivar 'Friar' (0.46 m).

Głowacka *et al.* (2021) studied preserved plum cultivars in Poland in which most of the Japanese plum cultivars were dominated by a spreading canopy. 'Black Amber', 'Blue Gigant', 'Gauota' and 'Herkules' trees had an upright habit and 'Dofi Sandra', 'Naidyona', 'Skoroplodnaya' and 'Vanier' were conical.

2.2 FOLIAGE CHARACTERS

Sharma (1999) carried out studies on ten plum cultivars *viz.,* 'Au-Amber', 'Au-Rosa', 'Florida 1-2', 'Frontier', 'Kanto-5', 'Red Ace', 'Red Beaut', 'Santa Rosa', 'Sweet Early' and 'Tarrol'. He observed maximum leaf area in 'Red Beaut' (17.51 cm^2) while, minimum leaf area was found in 'Au-Rosa' (10.13 cm^2).

Tandon (2006) evaluated six plum cultivars *viz.,* 'Black Amber', 'Cherry Plum', 'Queen Rosa', 'Ruby Sweet', 'Satluj Purple' and 'Shiro'. She observed the time of leaf emergence was earliest in 'Satluj Purple' (25th January) whereas, the time of leaf emergence was late in 'Shiro' (24th February).

Holland *et al.* (2007) evaluated the plum cultivar 'Shezifon' in which the leaf length was recorded (7 cm) long, width (4 cm) wide and petiole length (1.4 cm) was observed. The blade margins were crenate with a nearly smooth upper surface. The colour of a mature leaf was green (RHS137A for the upper surface and RHS137C for the lower surface).

Sedaghathoor *et al.* (2009) evaluated eight plum and prune cultivars that are commonly grown by fruits growers of Guilan province (North of Iran, Rasht). The cultivars were 'Baraghan', Red variety 'Ghermez', 'Shablon', Ghatreh Tala variety 'Golden drop', 'Peyvandi', 'Ghandi', 'Plastic' and Sour Prune variety 'Bur Alooche'. The maximum leaf size was observed in 'Ghandi' (25.84 cm^2) cultivar and the minimum leaf size was related to 'Plastic' (9.57 cm^2) cultivar.

Aran *et al.* (2012) evaluated thirty-five plum genotypes in which the maximum leaf length (61.3 mm) and minimum leaf length (31.0 mm) was observed. The maximum leaf width was (34.5 mm) and minimum leaf width was (7.8 mm). Petiole length was maximum (17.9 mm) and minimum was (7.5 mm), while maximum leaf length/leaf width ratio was (5.49) and minimum (1.17).

Thakur (2012) studied eight plum cultivars namely 'Au-Rosa', 'Florida 1-2', 'Fortune', 'Frontier', 'Queen Rosa', 'Red Beaut', 'Ruby Sweet' and 'Santa Rosa'. He observed that the time of bud burst extended from second week of February to the second week of March.

Nisar *et al.* (2015) carried out a study on sixteen plum genotypes in which leaf area was recorded. The leaf area was found maximum in 'SY2' (26.37 cm^2) and minimum in 'DR2' (10.66 cm^2).

Kumar (2016) evaluated eight plum varieties *viz.,* 'Duarte', 'Black Amber', 'Friar', 'Shiro', 'Frontier', 'Santa Rosa', 'Red Beaut' and 'Mariposa'. The time of bud burst was earliest in 'Red Beaut' on 7th February whereas, it was comparatively late in 'Shiro' *i.e.,* on 10th March.

Verma (2016) evaluated fourteen exotic plum cultivars under Kashmir conditions. The cultivars under study were 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Black Amber', 'Burbank', 'Au-Cherry', 'Au-Rosa', 'Kanto 5', 'Kubio Plum', 'Red Plum', 'Krassivica Plum', 'Monarch' and 'Beauty'. The maximum leaf length was observed in cultivar 'Frontier' (116.13 mm) and minimum leaf length in cultivar 'Red Beaut' (99.33 mm). However, leaf breadth was recorded maximum in cultivar 'Au-Rosa' (49.66 mm) and minimum in cultivar 'Burbank' (33.26 mm).

Latifikhah *et al.* (2017) evaluated the performance of four different plum and prune genotypes namely 'Ghohrood', 'Dobahreh', 'Khansar' and 'Plum No.1 of Mobarakeh'. They observed maximum leaf length in 'Dobahreh' (11 cm) and minimum was found in 'Khansar' (7.7 cm). Maximum leaf width was recorded in 'Dobahreh' (6.5 cm) and minimum in 'Khansar' (3.3 cm). Length of petiole was found maximum in 'Dobahreh' (16 cm) and minimum in 'Ghohrood' (13 cm). While leaf length/leaf width was found maximum in 'Khansar' (2.33) and minimum in 'Dobahreh' (1.69).

Kumar *et al.* (2018) carried out a study on eight Japanese plum cultivars named as 'Black Amber', 'Duarte', 'Friar', 'Shiro', 'Frontier', 'Mariposa', 'Red Beaut' and 'Santa Rosa'. They observed that average leaf area ranged from 12.53 cm^2 to 18.36 cm^2. The

maximum leaf area was espied in 'Red Beaut' (18.36 cm^2) whereas, minimum was recorded in 'Black Amber' (12.53 cm^2).

Sundouri *et al.* (2018) studied fourteen plum cultivars *viz*., 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Black Amber', 'Burbank', 'Au-Cherry', 'Au-Rosa', 'Kanto-5', 'Kubio Plum', 'Red Plum', 'Krassivica Plum', 'Monarch' and 'Beauty' in which they recorded the maximum leaf breadth in 'Au-Rosa' (49.66 mm) and minimum leaf breadth was observed in 'Burbank' (33.26 mm).

Majid *et al.* (2020) carried out a study on leaf characters among six cultivars of plum *viz.,* 'Burbank', 'Stanley', 'Friar', 'Wickson', 'Santa Rosa' and 'Satsuma'. Leaf length was found maximum in 'Santa Rosa' (12 cm) while minimum in 'Stanley' (6.80 cm). Leaf breadth was maximum in 'Santa Rosa' (5.63 cm) and minimum in 'Burbank' (3.90 cm). Leaf area was found maximum in 'Santa Rosa' (64.73 cm^2) and minimum in 'Stanley' (19.69 cm^2).

Selka *et al.* (2021) carried out research which focused on five cultivars of plum from different agroecological regions. The average lengths of plum leaves varied between 5.92 to 6 cm for the mountainous regions like Ain Nehala and Henaya and between 4.49 cm to 4.90 cm for the Tellian plain (Maghnia and Ghazaouet). The average width of plum leaves were 2.77 cm to 2.80 cm for the regions of Ain Nehala and Henaya; 1.65 cm to 1.93 cm for the regions of Maghnia and Ghazaouet, respectively.

Abd Elaziz *et al.* (2022) conducted an experiment on mature plum trees of 'Pioneer' and 'Hollywood' plum cultivars. The experiment extended for two successive seasons in which the leaf area in the first season was found 29.86 cm^2 in 'Pioneer' and 32.14 cm^2 in 'Hollywood'. In the second season leaf area was 27.64 cm^2 in 'Pioneer' and 31.37 cm^2 in 'Hollywood'.

2.3 FLOWER CHARACTERS

Sharma (1999) carried out a study on ten plum cultivars *viz*., 'Au-Amber', 'Au-Rosa', 'Florida 1-2', 'Frontier', 'Kanto-5', 'Red Ace', 'Red Beaut', 'Santa Rosa', 'Sweet Early' and 'Tarrol'. He reported that sepals were longest in 'Florida 1-2' and shortest in 'Kanto-5'. The maximum sepal breadth was diarized in 'Frontier' (0.44 cm) while minimum was reported in 'Kanto-5' (0.23 cm).

Prakash *et al.* (2003) studied six plum cultivars *viz.,* 'Methley', 'Santa Rosa', 'Ramgarh Maynard', 'First Plum', 'New Plum' and 'Kabul Green Gage' under mid-hills of Uttaranchal in which they recorded the time and duration of flowering in different plum cultivars and indicated that cultivar 'Kabul Green Gage' was the earliest in flowering (13th February) while 'New Plum' showed delayed flowering (27th February). 'Methley' showed maximum duration of flowering (15 days).

Holland *et al.* (2007) evaluated the plum cultivar 'Shezifon' for flower diameter and reported its range from 1.7 to 2.1 cm with white smooth petals. The style was straight with the stigma emerging above the anther's height at anthesis along-with green (RHS144A) sepal colour.

Blazek and Pistekova (2009) studied flower characters of twenty-three cultivars of plum. The first flowers appeared on the cultivars 'Topfirst' and 'Topstar Plus' on 14th April whereas, the late flowering was observed in cultivars 'Katinka' and 'Ruth Gerstetter' on 1st May. Within the group of early flowering belonged 'Katinka', 'Ruth Gerstetter', 'Topfirst' and 'Topstar Plus'. Cultivars 'Jojo' and 'Tegera' started flowering on average, only one day later. The late start of flowering was recorded with 'Valjevka', 'Oneida' and 'Top 2000' about one week later than the first group.

Son (2010) analysed fourteen plum cultivars *viz*., 'Black Diamond', 'Black Beauty', 'Obilnaja', 'Black Amber', 'Globe Sun', 'Bella Di Barbiano', 'Fortune', 'Queen Rosa', 'Angeleno', 'Original Sun', 'Autumn Giant', 'President', 'October Sun' and 'T.C. Sun' for days from full bloom. He observed the mean Days from Full Bloom was earliest for 'Black Diamond', 'Black Beauty' and 'Oblinaja' than the other cultivars. The late flowering cultivars were 'President', 'October Sun' and 'T.C. Sun'.

Ganji *et al.* (2011) evaluated eighteen plum cultivars. Based on the position of stigma relative to that of the anthers, cultivars were classified into three groups; the same level as anthers ('Blu Fre', 'Angelono', 'Friar', 'No.16', 'Zuccella', 'Sugar' and 'Tee Blue'); above the anthers ('Early Golden', 'Ghatreh Tala', 'Simka', 'Regina d' Italia' and 'President'); below the anthers ('Black Amber', 'Laroda', 'Stanley', 'Queen Rosa', 'No.17' and 'Germez Damavand').

Milatovic *et al.* (2011) studied seven plum cultivars *viz*., 'Sorriso di', 'Primavera', 'Obilnaja', 'Strival', 'Black Amber', 'T.C. Sun', 'Angeleno' and 'Autumn Giant'. They

observed that the average beginning of flowering for Japanese plum cultivars in Central Serbia was in the third week of March compared to the standard cultivar. The flowering of Japanese plum cultivars started 5 - 10 days earlier and lasted for 4 - 5 days longer.

Aran *et al.* (2012) evaluated thirty-five plum genotypes in which maximum number of days to achieve full bloom was 9 days and minimum was 5 days. The beginning of flowering was maximum on day 5 and minimum on day 1 whereas, the end of flowering was for maximum 23 days and minimum for 15 days. The flowering period lasted maximum for 20 days and minimum for 12 days.

Thakur (2012) evaluated the plum cultivars namely 'Au-Rosa', 'Florida 1-2', 'Fortune', 'Frontier', 'Queen Rosa', 'Red Beaut', 'Ruby Sweet' and 'Santa Rosa' and came to the conclusion that they can be divided into three groups on the basis of flowering time *i.e.,* early flowering in 'Florida 1-2', mid flowering in 'Red Beaut', 'Fortune', 'Queen Rosa', 'Ruby Sweet' and 'Santa Rosa' and late flowering in 'Au-Rosa' and 'Frontier'. The average total number of flowering days observed in all the cultivars under study was 15.37.

Kumar (2016) observed eight plum cultivars *viz.*, 'Duarte', 'Black Amber', 'Friar', 'Shiro', 'Frontier', 'Santa Rosa', 'Red Beaut' and 'Mariposa'. 'Red Beaut' cultivar was first to open its flowers (13th February) whereas, 'Friar' was the last to show this character on 12th March. Full bloom in 'Red Beaut' was recorded on 22nd February while in 'Black Amber' it was recorded on 26th March.

Verma (2016) studied fourteen plum cultivars *viz.*, 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Black Amber', 'Burbank', 'Au-Cherry', 'Au-Rosa', 'Kanto 5', 'Kubio Plum', 'Red Plum', 'Krassivica Plum', 'Monarch' and 'Beauty'. He observed that the duration of flowering ranged from 9 to 15 days amongst the cultivars. Maximum duration of 15 days was recorded in cultivars 'Frontier' and 'Au-Rosa' and minimum duration of flowering was recorded in 'Red Plum' (9 days).

Kwon *et al.* (2018) evaluated sixty-three accessions from the plum germplasm collection for flower petal arrangement in which 38 accessions showed the free shape, whereas 18 accessions showed touching and 7 accessions showed overlapping shapes. The petal shapes also varied as elliptic (13 accessions), circular (18 accessions), oblate (31 accessions) and obovate (1 accession). Regarding the stigma's position in relation to the

anthers most accessions showed them being at the same level (50 accessions), whereas (6 accessions) showed a lower stigma level and (7 accessions) showed a higher positioning of the stigma.

Kour (2018) carried a study on six cultivars of Japanese plum *viz.,* 'Satluj Purple', 'Kala Noki', 'Dhariwal', 'Manaka', 'Gurda' and 'Alu Bokhara Amritsari'. The flowering in cultivars of plum commenced in different times 'Kala Noki', 'Dhariwala' and 'Satluj Purple' were earliest to flower on 3rd February, 4th February and 5th February followed by 'Gurda' and 'Manaka' which started flowering on 8th and 12th February whereas, 'Alu Bokhara Amritsari' was last to flower in the end of February *i.e.,* on 23rd February. The minimum time interval between appearance of first flower and full bloom varied from 6 to 13 days. The longest full bloom period of 13 days was observed in 'Alu Bokhara Amritsari' and shortest period of 6 days was noticed in 'Dhariwala'.

Butac *et al.* (2019) conducted an experiment with six *Prunus domestica* cultivars *viz.,* 'Tita', 'Carpatin', 'Roman', 'Romanta', 'Agent' and 'Andreea' while, four *Prunus salicina* cultivars were evaluated *viz.,* 'Eldorado', 'Black Star', 'Black Beauty' and 'Angeleno'. They observed that plum blooms in mid-April depending on weather conditions. The European plum cultivars bloomed between 5th to 22nd April and Japanese plum cultivars blossomed almost ten days earlier than European cultivars between 30th March to 11th April.

Imrak *et al.* (2019) carried out a study on three Japanese plum cultivars namely 'Black Diamond', 'Angeleno' and 'Friar'. They recorded full bloom in 'Black Diamond' on 12th March, in 'Angeleno' it was on 15th March and in 'Friar' 13th March for the first season, while for the second season 'Black Diamond' full bloomed on 10th March, 'Angeleno' 14th March and 'Friar' on 12th March.

Głowacka *et al.* (2021) studied preserved plum cultivars in Poland in the experimental orchard at Dabrowice, the trees of the earliest Japanese plum cultivars began flowering in the first week of April and ended flowering in the second week of April. Late cultivars started flowering in the second week of April and ended in the third week of April.

Nicolas-Almansa *et al.* (2021) assayed three F_1 progenies from intraspecific crosses of Japanese plum: 'Black Splendor' × 'Pioneer' (BS × PIO); 'Red Beauty' × 'Black Splendor' (RB × BS) and 'Red Beauty' × 'Santa Rosa Precoz' (RB × SRP) with 121, 103 and 103

seedlings, respectively. BS×PIO showed flowering time earlier, some individuals achieved full bloom between 20th January and 1st February depending on the year.

Abd Elaziz *et al.* (2022) conducted an experiment on mature plum trees of 'Pioneer' and 'Hollywood' plum cultivars. The experiment extended for two successive seasons in which the onset of flowering for the first season was 1st March for 'Pioneer' and 5th March for 'Hollywood', while for the second season the onset of flowering was 2nd February for 'Pioneer' and 5th February for 'Hollywood'. Whereas, full bloom was recorded on 15th March for 'Pioneer' and 18th March for 'Hollywood' in the first season, while it was 25th February for 'Pioneer' and 28th February for 'Hollywood' in the second season.

2.4 POLLEN STUDIES

Mohapatra (1994) studied various plum cultivars namely 'Alu Bokhara', 'Beauty', 'Black Chamba', 'Fazii Manani', 'Santa Rosa' and 'Staking Delicious' falling under Japanese plum group, 'Early Transparent Gage', 'Golden Drop', 'Monarch' and 'Victoria' under European group and 'Myrobalan' under Cherry group. Pollen studies revealed in Japanese group as ascertained by acetocarmine stain test ranged between 79.01 per cent in case of 'Black Chamba' and 94.92 per cent in case of 'Alu Bokhara'.

Sharma (1999) observed ten plum cultivars *viz*., 'Au-Amber', 'Au-Rosa', 'Florida 1-2', 'Frontier', 'Kanto-5', 'Red Ace', 'Red Beaut', 'Santa Rosa', 'Sweet Early' and 'Tarrol' in which the pollen viability varied from 77.08 to 93.05 per cent under staining test using acetocarmine (1 %) solution. In 'Red Beaut' no pollen viability was observed.

Tandon (2006) studied six Japanese plum cultivars 'Black Amber', 'Cherry Plum', 'Queen Rosa', 'Ruby Sweet', 'Satluj Purple' and 'Shiro' and observed pollen viability in all the plum introductions as tested by acetocarmine (1 %) varied from 67.40 per cent to 89.45 per cent whereas, for erythrosine B (0.1 %) ranged from 63.12 to 84.25 per cent, respectively. *In vitro* pollen germination was maximum in 'Satluj Purple' (76.20 %) and minimum in 'Black Amber' (64.85 %).

Nencetti *et al.* (2008) carried out a study on fifty-five Japanese plum cultivars and fourteen selections. Germinability of pollen grains was found to be ranging from 0 per cent to 30 per cent intermediate and 90 per cent high.

Sharafi (2011) conducted an experiment in which five favourable genotypes of plum ('Pl_1', 'Pl_2', 'Pl_3', 'Pl_4' and 'Pl_5') were selected in which highest pollen germination was recorded in 'Pl_3' (96.3 %) and the least pollen germination was observed in 'Pl_4' (48.9 %).

Thakur (2012) evaluated 'Au-Rosa', 'Florida 1-2', 'Fortune', 'Frontier', 'Queen Rosa', 'Red Beaut', 'Ruby Sweet' and 'Santa Rosa'. He reported the pollen viability in acetocarmine (1 %) solution ranged from 72.60 per cent to 84.6 per cent. Pollen germination was found highest in 'Santa Rosa' (66.57 %).

Sharafi *et al.* (2013) evaluated ten cultivars of plum namely 'Sardroud alcha', 'Sari alcha', 'Gojah soltan', 'Zari alcha', 'Sayyd alcha', 'Shalyl alcha', 'Ouji biz alcha', 'Ala alcha', 'Eet alcha' and 'Maragheh alcha'. Pollen germination was observed highest in 'Gojah soltan' (97.1 %) and the least was found in 'Shalyl alcha' (55.8 %).

Thakur *et al.* (2014) carried out a study on eight plum cultivars *viz.,* 'Au-Rosa', 'Florida 1-2', 'Fortune', 'Frontier', 'Queen Rosa', 'Red Beaut', 'Ruby Sweet' and 'Santa Rosa'. They observed that the highest pollen germination was found in 'Santa Rosa' (66.57 %).

Kwon *et al.* (2017) studied five plum cultivars as candidate pollinizers for 'Summer Fantasia'. Pollen germination percentage ranged between 4.99 per cent to 18.74 per cent in 2014 and between 0.88 per cent to 14.12 per cent in 2016. 'Formosa', 'Oishiwase', and 'Taiyo' showed higher and more stable pollen germination percentages compared to the other cultivars. In particular, the pollen germination of 'Purple Queen' significantly decreased from 17.10 per cent in 2014 to 1.64 per cent in 2016.

Kour (2018) carried out a study in six cultivars of Japanese plum *viz.,* 'Satluj Purple', 'Kala Noki', 'Dhariwal', 'Manaka', 'Gurda' and 'Alu Bokhara Amritsari'. Highest pollen viability was recorded in 'Satluj Purple' (94.7 %) and lowest in 'Gurda' (80.5 %). Further, highest pollen germination in 20 per cent, 15 per cent and 10 per cent sucrose solution was found in cultivar 'Satluj Purple' (64.1 %, 62.5 % and 56.6 %), respectively. While the least pollen germination was recorded in 'Alu Bokhara Amritsari' 60.3 per cent at 20 per cent sucrose solution and 54.5 per cent and 51.8 per cent in 'Gurda' at 15 per cent and 10 per cent sucrose solution, respectively.

Dongariyal *et al.* (2020) evaluated two Japanese plum cultivars namely 'Satluj Purple' and 'Kala Amritsari' in which they reported that the cultivar 'Satluj Purple' exhibited high pollen viability per cent (90.45 %) as compared to 'Kala Amritsari' (81.32 %). The data on pollen germination showed the maximum pollen germination in 'Satluj Purple' was 39.54 per cent whereas, 'Kala Amritsari' had 36.76 per cent germination.

Abd Elaziz *et al.* (2022) conducted an experiment on mature plum trees of 'Pioneer' and 'Hollywood' plum cultivars. Pollen viability of 97.23 per cent was recorded in 'Hollywood' and 96.97 per cent was recorded in 'Pioneer' during the first season. On the contrary pollen viability of 99.18 per cent was recorded in 'Hollywood' and 90.55 per cent in 'Pioneer' during the second season.

2.5 FRUIT CHARACTERS

Prakash (1993) carried out a study on ten plum cultivars *viz*., 'Alubukhara', 'Alucha Amritsari', 'Carinota', 'Dabba', 'Golden Lalri', 'Kala Amritsari', 'Kala Bahadurgarh', 'Kataroo Chak', 'Red Alubukhara' and 'Zardalu'. The yield/tree was observed maximum in cultivar 'Carniota' (57.88 kg) followed by 'Red Alubukhara' (47.75 kg), whereas it was negligible in 'Alucha Amritsari' (3.63 kg).

Matta *et al*. (1996) evaluated eleven plum cultivars on Lovell rootstock in which they observed that the plum yields in Alabama ranged from 39 to 149 pounds (17.7 to 67.7 kg) per tree depending upon the cultivar. Harvest date ranged from 27th May to 28th June depending upon the cultivar and year. As indicated by harvest date 'May Ripe', 'Methley', and 'Six Weeks' were early producers whereas 'Morris', 'Frontier' and 'Explorer' were late producers.

Sharma (1999) evaluated ten plum cultivars *viz.*, 'Au-Amber', 'Au-Rosa', 'Florida 1-2', 'Frontier', 'Kanto-5', 'Red Ace', 'Red Beaut', 'Santa Rosa', 'Sweet Early' and 'Tarrol'. He observed that the fruit firmness varied from 0.83 kg/cm^2 in 'Red Ace' to 2.49 kg/cm^2 in 'Frontier' and 'Red Beaut'.

Szabo and Nyeki (2001) studied various Japanese plum cultivars in which fruit yield was maximum in 'Methley' (48 kg/tree), followed by 'Burbank' (39 kg/tree), 'Shiro' (33.3 kg/tree), 'Duarte' (24.8 kg/tree) and the minimum yield was found in 'Santa Rosa' (12 kg/tree), followed by 'Elephant Heart' (13 kg/tree).

Prakash *et al.* (2003) studied six plum cultivars *viz.,* 'Methley', 'Santa Rosa', 'Ramgarh Maynard', 'First Plum', 'New Plum' and 'Kabul Green Gage' under mid-hills of Uttaranchal. They recorded that the maximum fruit yield was found in 'Santa Rosa' (56.06 kg/tree) and minimum in 'New Plum' (13.66 kg/tree). Fruit weight was maximum in 'Santa Rosa' (25.74 g) and minimum in 'Kabul Green Gage' (7.17 g), respectively. Fruit length and breadth was found maximum in 'Santa Rosa' (3.51 cm -3.45 cm), while minimum in 'Kabul Green Gage' (2.20 cm -2.19 cm), consequently.

Turkmen *et al.* (2003) studied fifteen varieties of plum at two different locations according to which better results were obtained from plums at Turkmenkoy than Adana. 'Sorriso di Primavera' had the maximum yield values both in Turkmenkoy and Adana (18.92 kg/tree and 7.64 kg/tree, respectively). 'Sorriso di Primavera' was followed with 'T.C. Sun' (13.06 kg/tree in Turkmenkoy and 3.80 kg/tree in Adana). Most of the plum cultivars did not fruit in Adana, except 'T.C. Sun' bigger sized fruits were obtained in Adana. The maximum fruit size was obtained from 'Bella di Barbiano' (86.89 g) in Adana region and 'T.C. Sun' (91.00 g) in Turkmenkoy.

Kang *et al.* (2005) conducted an experiment on thirty-four plum accessions. The fruit shape was predominantly of four types – cordate, round, flattened round and oblong. The accessions on fruit colour were grouped into yellow or greenish yellow, orange, orange red, greyed orange, purple, purple brown, red purple and dark brown. The fruit size and weight varied from 0.9 x 1.9 cm – 4.0 x 4.2 cm and 4.3 g – 30 g, respectively. Most of the germplasm showed the presence of fruit suture.

Tandon (2006) evaluated six plum cultivars *viz.,* 'Black Amber', 'Cherry Plum', 'Queen Rosa', 'Ruby Sweet', 'Satluj Purple' and 'Shiro'. The study revealed that the fruit set ranged from 4.06 per cent in 'Ruby Sweet' to 37.37 per cent in 'Shiro' under open pollination and as 0.27 per cent in 'Black Amber' to 35.36 per cent in 'Shiro' upon selfing (bagging).

Holland *et al.* (2007) evaluated the plum cultivar 'Shezifon' and observed very small almost rounded fruit with an average weight of 7.63 ± 0.22 g. The fruit shape was rounded with a negligible, almost invisible longitudinal indentation. The skin colour of fully mature fruit was dark blue (RHS103A-79A) with an intense grey cover. Flesh colour was yellow green (RHS146A). The flesh was quite firm and had a juicy and pleasant fine texture.

Blazek and Pistekova (2009) evaluated twenty-three cultivars of plum where, the most adherent stones were recorded in 'Bluefre' and sometimes also in 'Oneida', 'Empress', 'Presenta', 'Valor' and 'Elena'.

Lozano *et al.* (2009) studied six Japanese plum cultivars *viz*., 'Black Amber', 'Suplumeleven', 'Fortune', 'Larry Ann', 'Suplumsix' and 'Songold' amongst which the maximum fruit firmness was found in the cultivar 'Larry Ann' (10.96 N) and the minimum was docketed in 'Black Amber' (5.5 N).

Son (2010) analysed fourteen plum cultivars *viz*., 'Black Diamond', 'Black Beauty', 'Obilnaja', 'Black Amber', 'Globe Sun', 'Bella Di Barbiano', 'Fortune', 'Queen Rosa', 'Angeleno', 'Original Sun', 'Autumn Giant', 'President', 'October Sun' and 'T.C. Sun' in which the time of maturity of the plum cultivars ranged from the middle of June to the first week of September.

Ganji *et al.* (2011) evaluated eighteen plum cultivars according to which the maximum fruit yield (30-35 kg/tree) was observed in 'Resident' and 'No. 16', while minimum fruit yield (5-10 kg/tree) was found in 'Blu Fre', 'Ghermez Damavand', 'Tee Blue', 'Black Amber' and 'Sugar' cultivars. Fruit weight was found maximum in 'Queen Rosa' (105.8 g) while, minimum in 'Tee Blue' (16.9 g).

Thakur (2012) studied eight plum cultivars *viz.,* 'Au-Rosa', 'Florida 1-2', 'Fortune', 'Frontier', 'Queen Rosa', 'Red Beaut', 'Ruby Sweet' and 'Santa Rosa'. The maximum fruit weight was found in 'Fortune' (80.51 g), followed by 'Queen Rosa' (80.19 g) and minimum in 'Florida 1-2' (29.20 g).

Bozhkova (2014) studied twelve plum cultivars according to which fruits of the cultivars 'Haganta', 'President' and 'Tuleu Timpuriu' were evaluated on the basis of quality. As a whole, the studied plum cultivars had fruits of good colouration with an exception of 'Miragrande' and 'Pacific'.

Nisar *et al.* (2015) carried out a study on sixteen plum genotypes for fruit shape. The data revealed that nine genotypes had round fruits (56.25 %) and remaining seven had oval shaped fruits (43.75 %). Observations illustrated that four plum genotypes had dark red (25 %), other four had reddish brown (25 %) and remaining eight had yellow-coloured fruits (50 %). Fruit length was maximum in 'LY1' (4.43 cm) and minimum in 'SY4' (1.90 cm). Fruit

diameter was maximum in ‘DR1’ (5.65 cm) and minimum in ‘DR4’ (2.41 cm). The maximum weight of flesh was recorded in ‘LY1’ (64.00 g) and the minimum in ‘SY3’ (3.93 g). The maximum number of flowers were recorded in ‘RB1’ and the minimum in ‘RB4’. The maximum fruit set was recorded in ‘RB1’ (42 %) and minimum in ‘RB4’ (15 %).

Kumar (2016) carried out a study on eight plum cultivars *viz*., ‘Duarte’, ‘Black Amber’, ‘Friar’, ‘Shiro’, ‘Frontier’, ‘Santa Rosa’, ‘Red Beaut’ and ‘Mariposa’. He noticed that the fruit drop was found maximum in ‘Red Beaut’ (80.47 %), followed by ‘Mariposa’ (77.26 %) and minimum in ‘Shiro’ (61.05 %). ‘Shiro’ had maximum fruit retention (34.89 %) while, minimum was inscribed in ‘Santa Rosa’ (11.63 %).

Verma (2016) evaluated fourteen exotic plum germplasm in Kashmir conditions in which fruit colour varied greatly amongst the different plum cultivars. Red purple colour was possessed by four cultivars *viz.*, ‘Grand Duke’, ‘Black Amber’, ‘Kubio Plum’ and Krassivica Plum, red colour by five cultivars namely ‘Red Beaut’, ‘Tarrol’, ‘Burbank’, ‘Red plum’ and ‘Beauty’, grey purple colour was possessed by ‘Frontier’ and yellow colour by three cultivars ‘Au-Cherry’, ‘Kanto-5’ and ‘Monarch’.

Kishor *et al.* (2017) evaluated twelve variants of plums which were collected from different villages of Nainital. The maximum fruit weight (72.71 g), fruit volume (69.33 cc), fruit length (5.25 cm), fruit diameter (5.04 cm) and pulp weight (68.32 g) were recorded in ‘Collection-8’ while, the minimum fruit weight (13.08 g), fruit volume (12.33 cc), fruit length (2.74 cm), fruit diameter (2.68 cm) and pulp weight (11.24 g) were recorded in ‘Collection-11’. Whereas, the maximum fruit firmness was recorded in ‘Collection-6’ (5.53 lb/inch^2), while minimum in ‘Collection-3’ (1.40 lb/inch^2).

Latifikhah *et al.* (2017) evaluated the performance of four different plum and prune genotypes namely ‘Ghohrood’, ‘Dobahreh’, ‘Khansar’ and ‘Plum No.1 of Mobarakeh’. They observed that fruit length was maximum in ‘Plum No.1 of Mobarakeh’ (56 mm) and minimum in ‘Dobahreh’ (31 mm), while the fruit width was maximum in ‘Ghohrood’ (45 mm) and minimum in ‘Dobahreh’ (33 mm). Maximum fruit cavity depth was found in ‘Ghohrood’ (3.3 mm) and minimum in ‘Dobahreh’ (1.6 mm), while fruit cavity width was maximum in ‘Khansar’ (5.2 mm) and minimum in ‘Dobahreh’ (2.1 mm). Fruit weight was maximum in ‘Ghohrood’ (50 g) and minimum in ‘Dobahreh’ (23 mm). Time of fruit ripening

was 28th July for ‘Ghohrood’ and ‘Dobahreh’, 21st September for ‘Khansar’ and 12th October for ‘Plum No.1 of Mobarakeh’.

Blazek *et al.* (2018) evaluated eight plum cultivars namely ‘Amatka’, ‘Cacanska lepotica’, ‘Dwarf’, ‘Kamir’, ‘Samera’, ‘Simona’, ‘Stana’ and ‘Stanley’. The maximum yield was recorded in ‘Stana’ (13.1 kg) while, the minimum yield was inscribed in ‘Dwarf’ (7.14 kg).

Kumar *et al.* (2018) carried out a study on eight cultivars of plum namely ‘Black Amber’, ‘Duarte’, ‘Friar’, ‘Shiro’, ‘Frontier’, ‘Mariposa’, ‘Red Beaut’ and ‘Santa Rosa’. Fruit length was maximum in cultivar ‘Frontier’ (45.99 mm) whereas, minimum was recorded in ‘Shiro’ (33.92 mm). The maximum fruit breadth was recorded in cultivar ‘Frontier’ (46.38 mm) while, the minimum fruit breadth was recorded in the cultivar ‘Shiro’ (33.93 mm). The maximum fruit weight was obtained in the cultivar ‘Frontier’ (60.00 g) whereas, minimum fruit weight was recorded in ‘Shiro’ (24.63 g). Maximum fruit volume was recorded in the cultivar ‘Frontier’ (61.70 cm^3), followed by ‘Mariposa’ (58.70 cm^3) while, minimum fruit volume was observed in ‘Shiro’ (25.38 cm^3). The flesh colour of fruit was red purple in ‘Duarte’, ‘Frontier’ and ‘Mariposa’; orange red in ‘Black Amber’; while yellow in ‘Friar’, ‘Shiro’, ‘Santa Rosa’ and ‘Red Beaut’. Maximum fruit firmness was recorded in the cultivar ‘Black Amber’ (2.42 kg/cm^2) while, minimum fruit firmness was observed in the cultivar ‘Duarte’ (1.76 kg/cm^2). The maximum yield was recorded in the cultivar ‘Shiro’ (7.30 kg/tree). However, minimum yield was recorded in ‘Red Beaut’ (3.76 kg/tree).

Butac *et al.* (2019) studied various European and Japanese plum cultivars in which they observed that the maximum fruit size of Japanese plum was from the cultivar ‘Black Star’ (70.9 g) and ‘Black Beauty’ (62.5 g). Fruit colour ranged from reddish (‘Agent’, ‘Andreea’, ‘Roman’, ‘El Dorado’) to dark blue (‘Romanta’, ‘Tita’, ‘Angeleno’, ‘Black Beauty’ and Black Star’).

Imrak *et al.* (2019) carried out a study on three Japanese plum cultivars namely ‘Black Diamond’, ‘Angeleno’ and ‘Friar’. The maximum fruit weight was recorded in ‘Black Diamond’ (110.4 g). The fruit firmness ratio was observed maximum in ‘Angeleno’ (8.3-8.5 lb) and minimum in ‘Black Diamond’ (5.50-5.59 lb).

Bilal *et al.* (2021) carried out a study on four plum cultivars namely 'D-Agen', 'President', 'Blue Free' and 'Ruby Red'. They observed that the fruit weight was maximum in 'Ruby Red' (64.89 g) and minimum in 'D-Agen' (27.44 g). Fruit volume was found maximum in 'President' (62.44 ml) and minimum in 'D-Agen' (31.22 ml). Fruit length was recorded maximum in 'President' (50.39 mm) and minimum in 'D-Agen' (40.2 mm).

Głowacka *et al.* (2021) studied conserved plum cultivars at Poland amongst the thirty-six cultivars assessed: four cultivars were classified as small-fruited (20–25 g), fifteen as medium (26–40 g), nine as large (41–55 g), two as large or very large (56–70 g) and six as very large (over 70 g).

Abd Elaziz *et al.* (2022) conducted an experiment on mature plum trees of 'Pioneer' and 'Hollywood' plum cultivars. Yield in 'Pioneer' cultivar was 52.69 and 49.32 kg/tree for both seasons. 'Hollywood' plum had a total yield of 13.57 and 12.94 kg/tree in both seasons. Regarding fruit weight 'Pioneer' had a fruit weight of 74.53 g and 73.27 g in first and second season respectively, while 'Hollywood' cultivar had a fruit weight of 41.29 g and 39.83 g in both seasons, respectively.

2.6 STONE CHARACTERS

Prakash (1993) studied ten plum cultivars *viz*., 'Alubukhara', 'Alucha Amritsari', 'Carinota', 'Dabba', 'Golden Lalri', 'Kala Amritsari', 'Kala Bahadurgarh', 'Kataroo Chak', 'Red Alubukhara' and 'Zardalu'. He further reported that the maximum (20.73) pulp/stone ratio was observed in 'Red Alubukhara' closely followed by 'Golden Lalri', 'Dabba', 'Zardalu' and 'Kataroo Chak' while the minimum was found in 'Alucha Amritsari' (10.30), followed by 'Carniota'.

Sharma (1999) studied ten plum cultivars *viz*., 'Au-Amber', 'Au-Rosa', 'Florida 1-2', 'Frontier', 'Kanto-5', 'Red Ace', 'Red Beaut', 'Santa Rosa', 'Sweet Early' and 'Tarrol'. He recorded maximum stone weight in 'Red Ace' followed by 'Sweet Early', 'Tarrol', 'Red Beaut', 'Au-Rosa', 'Florida 1-2', 'Au-Amber' and 'Kanto-5'.

Prakash *et al.* (2003) studied six plum cultivars *viz.,* 'Methley', 'Santa Rosa', 'Ramgarh Maynard', 'First Plum', 'New Plum' and 'Kabul Green Gage' under mid-hills of Uttaranchal in which they recorded that the maximum stone weight was found in 'Santa Rosa' (0.94 g), followed by 'New Plum' (0.72 g) while the minimum stone weight was

observed in ‘First Plum’ (0.50 g). Pulp/stone ratio was found maximum in ‘Santa Rosa’ (26.29) and minimum in ‘Kabul Green Gage’ (12.41).

Holland *et al.* (2007) evaluated the plum cultivar ‘Shezifon’. They observed that the small ovate stone was a little acute in both sides and was almost free. The average value for stone was 0.41 ± 0.01 g in weight, 1.88 ± 0.53 mm in length and 0.93 ± 0.01 mm in width.

Blazek and Pistekova (2009) evaluated twenty-three cultivars of plum in which they studied that the maximum stone weight was recorded in ‘Topgigant Plus’ (2.4 g) whereas, the minimum value of stone weight was recorded in ‘Katinka’ (1.0 g).

Sedaghathoor *et al.* (2009) evaluated eight plum and prune cultivars that are commonly grown by fruits growers of Guilan province (North of Iran, Rasht). The cultivars were ‘Baraghan’, Red cultivar ‘Ghermez’, ‘Shablon’, Ghatreh Tala variety ‘Golden drop’, ‘Peyvandi’, ‘Ghandi’ and ‘Plastic’ and lastly a Sour Prune variety ‘Bur Alooche’. The maximum pulp/stone ratio belonged to ‘Ghandi’ (29.32), followed by ‘Peyvandi’ (29.01), ‘Shablon’ (25.17) and ‘Plastic’ cultivar (22.66). The minimum pulp/stone ratio was observed in ‘Bur Alooche’ (14.26), ‘Ghermez’ (14.61) and ‘Baraghan’ (20.46).

Milatovic *et al.* (2011) studied seven plum cultivars *viz*., ‘Sorriso di’, ‘Primavera’, ‘Obilnaja’, ‘Strival’, Black Amber’, ‘T.C. Sun’, ‘Angeleno’ and ‘Autumn Giant’ according to the data reported, the 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. Compared to the standard cultivars Japanese plums had smaller stones and lower share of the stone in fruit weight *i.e.,* higher flesh percentage.

Thakur (2012) evaluated eight cultivars namely ‘Au-Rosa’, ‘Florida 1-2’, ‘Fortune’, ‘Frontier’, ‘Queen Rosa’, Red Beaut’, ‘Ruby Sweet’ and ‘Santa Rosa’. He observed that the cultivars ‘Frontier’ and ‘Red Beaut’ were free stone while all others were clingstone.

Nisar *et al.* (2015) carried out a study on sixteen plum genotypes according to which seed shape exhibited by plum genotypes had three shaped seeds *i.e.,* oval, round and elliptical. Six plum genotypes were oval shaped (37.50 %), five round shaped seeds (31.25 %) and remaining five were elliptical (31.25 %).

Kumar (2016) carried out a study on eight plum cultivars *viz*., 'Duarte', 'Black Amber', 'Friar', 'Shiro', 'Frontier', 'Santa Rosa', 'Red Beaut' and 'Mariposa'. He reported that the maximum pulp/stone ratio was recorded in 'Frontier' (48.31 %) while the minimum pulp to stone ratio was recorded in 'Shiro' (20.17 %).

Verma (2016) studied exotic plum germplasm in Kashmir conditions namely 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Black Amber', 'Burbank', 'Au-Cherry', 'Au-Rosa', 'Kanto 5', 'Kubio Plum', 'Red Plum', 'Krassivica Plum', 'Monarch' and 'Beauty'. He categorized that the adherence of stone to the fruit flesh as cling, semi cling and free stone types. The data revealed nine cultivars had cling stone, three cultivars were free stone and two cultivars were semi cling stone type.

Kishor *et al.* (2017) evaluated twelve variants of plums, further the study illustrated the highest pulp: stone ratio (25.63) and lowest stone weight (1.01 g) was recorded in 'Collection-3' whereas, lowest pulp: stone ratio (5.11) and highest stone weight (6.45 g) was recorded in 'Collection-12'.

Latifikhah *et al.* (2017) evaluated the performance of four different plum and prune genotypes namely 'Ghohrood', 'Dobahreh', 'Khansar' and 'Plum No.1 of Mobarakeh' in which they observed maximum stone weight was found in 'Ghohrood' (1.4 g), followed by 'Dobahreh' (0.9 g), 'Khansar' (1.1 g) and 'Plum No.1 of Mobarakeh' (1.3 g). Stone adhesion was found complete in 'Ghohrood', 'Dobahreh' and 'Plum No.1 of Mobarakeh' whereas, it was completely separate in 'Khansar'.

Kwon *et al.* (2018) evaluated sixty-three varieties and accessions from the plum germplasm collection. For adherence of stone to the pulp only seven varieties showed the non-adherent trait, whereas most of the varieties showed semi-adherent (28) and adherent (28) character. The lateral view of the stones helped classify the accessions into narrow elliptic (10), medium elliptic (39), circular (13) and broad ovate (1) shapes.

Sundouri *et al.* (2018) studied fourteen plum cultivars *viz*., 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Black Amber', 'Burbank', 'Au-Cherry', 'Au-Rosa', 'Kanto-5', 'Kubio Plum', 'Red Plum', 'Krassivica Plum', 'Monarch' and 'Beauty' in which maximum stone weight was found in 'Grand Duke' (1.86 g) and minimum stone weight was recorded in 'Au-Cherry' and 'Kubio Plum' (0.89 g).

Imrak *et al.* (2019) carried out a study on three Japanese plum cultivars namely 'Black Diamond', 'Angeleno' and 'Friar'. They observed that flesh/seed ranged between 35.72-35.89 per cent in 'Angeleno' and 34.1-34.7 per cent in 'Black Diamond'.

Majid *et al.* (2020) carried out a study on six cultivars of plum *viz.,* 'Burbank', 'Stanley', 'Friar', 'Wickson', 'Santa Rosa' and 'Satsuma'. Maximum stone weight was recorded in 'Stanley' (2.04 g) which was statistically highest amongst all the cultivars, followed by 'Burbank' (1.75 g), 'Santa Rosa' (1.46 g) and 'Wickson' (1.13 g). Minimum stone weight was recorded in cultivar 'Friar' (0.72 g) which was statistically at par with 'Satsuma' (0.74 g). The maximum pulp to stone ratio was recorded in the cultivar 'Friar' (68.61), followed by 'Satsuma' (51.71) both being superior to cultivar 'Wickson' (41.68), which in turn was statistically superior to 'Santa Rosa' (33.49). The minimum pulp to stone ratio was recorded in 'Stanley' (19.05) which was statistically at par with 'Burbank' (21.55). The cultivars 'Burbank', 'Wickson' and 'Santa Rosa' were clingstone while 'Satsuma' was semi-clingstone whereas, 'Stanley' and 'Friar' were found to be freestone in nature.

Bilal *et al.* (2021) carried out a study on four plum cultivars namely 'D-Agen', 'President', 'Blue Free' and 'Ruby Red' in which the maximum stone weight was recorded for variety 'President' (2.48 gm) and minimum stone weight was found in 'D-Agen' (1.11 gm).

2.7 BIOCHEMCIAL CHARACTERISTICS

Prakash (1993) carried out a study on ten plum cultivars *viz*., 'Alubukhara', 'Alucha Amritsari', 'Carinota', 'Dabba', 'Golden Lalri', 'Kala Amritsari', 'Kala Bahadurgarh', 'Kataroo Chak', 'Red Alubukhara' and 'Zardalu'. He reported maximum reducing sugars and total sugars in the cultivar 'Alubukhara' (6.87 and 9.55 %) whereas, the values were minimum in 'Carniota' (5.45 %) and 'Golden Lalri' (7.26 %), respectively.

Sharma (1999) evaluated ten cultivars *viz*., 'Au-Amber', 'Au-Rosa', 'Florida 1-2', 'Frontier', 'Kanto-5', 'Red Ace', 'Red Beaut', 'Santa Rosa', 'Sweet Early' and 'Tarrol'. It was reported that the total sugars content ranged from 6.61 per cent in 'Au-Amber' to 8.79 per cent in 'Frontier'. 'Frontier' showed significantly higher sugar content of total sugars than other cultivars.

Prakash *et al.* (2003) studied six plum cultivars namely 'Methley', 'Santa Rosa', 'Ramgarh Maynard', 'First Plum', 'New Plum' and 'Kabul Green Gage' under mid-hills of Uttaranchal in which they recorded that maximum TSS in 'Santa Rosa' (14.72 °B) and the minimum was recorded in 'New Plum' (9.82 °B). Maximum acid content was recorded in the fruits of 'New Plum' (2.12 %) and minimum in 'Methley' (1.23 %). Maximum total sugar content was found in the cultivar 'Santa Rosa' (9.58%) and minimum in 'New Plum' (5.84 %).

Suranyi and Erdos (2004) evaluated various cultivars of plum and recorded maximum total soluble solids in 'Laroda/C 449' (19.5 %) and minimum in 'Methley' (11.4 %). Acidity was found maximum in 'Purpurovaya' (1.76 %) and minimum in 'KS 9' (0.67 %).

Kang *et al.* (2005) conducted an experiment on thirty-four different plum accessions for quality parameters. Maximum total soluble solids were reported as 18.8 per cent and minimum was 11.3 per cent whereas, the maximum acidity was found to be 2.0 per cent and minimum 0.14 per cent.

Tandon (2006) evaluated 'Black Amber', 'Cherry Plum', 'Queen Rosa', 'Ruby Sweet', 'Satluj Purple' and 'Shiro'. Titratable acidity was reported maximum in 'Satluj Purple' (2.59 %) and minimum in 'Ruby Sweet' (1.12 %). Whereas, total sugars were maximum in 'Shiro' (8.95 %) and minimum in 'Queen Rosa' (6.07 %).

Blazek and Pistekova (2009) evaluated twenty-three cultivars of plum and observed that the maximum total soluble solids were found in cultivars 'Top 2000' (20.7 %), 'Toptaste' (20.5 %), 'Oneida' (20.1 %), 'Topfive' (19.7%), 'Elena' (19.6 %) and 'Gabrovska' (19.4 %), while 'Ruth Gerstetter' (13.6 %) and 'Topfirst' (14.2 %) had significantly minimum content of soluble solids.

Lozano *et al*. (2009) studied six Japanese plum cultivars namely 'Black Amber', 'Suplumeleven', 'Fortune', 'Larry Ann', 'Suplumsix' and 'Songold'. They observed that there was a significant difference in the TSS content with 'Larry Ann' and 'Suplumsix', the maximum values at 17.7 and 17.8 °Brix respectively, while the minimum was found in 'Fortune' 12.3 °Brix.

Ganji *et al.* (2011) evaluated eighteen plum cultivars according to which the maximum total soluble solids (TSS) were found in 'Blu Fre' (23.55 %) and minimum in 'Angelono' (12.1 %). The sugar: acid ratio was found maximum in 'Blu Fre' (19.14) and minimum in 'Black Amber' (5.97).

Mabrouk and Mejri (2011) evaluated two Japanese plum varieties 'Black Diamond' and 'Fortune'. 'Black Diamond' showed a rapid soluble solid concentration increase with values of 13.8 per cent two weeks before harvest and 15 per cent at harvest. 'Fortune' soluble solid concentration increase ranged between 14.6 per cent and 14.8 per cent during the same period. Harvest titratable acidity values were around 0.94 per cent malic acid for 'Black Diamond' and 1.24 per cent for 'Fortune'.

Thakur (2012) carried out a study on eight plum cultivars namely 'Au-Rosa', 'Florida 1-2', 'Fortune', 'Frontier', 'Queen Rosa', 'Red Beaut', 'Ruby Sweet' and 'Santa Rosa'. He observed that the maximum sugar acid ratio was recorded in cultivar 'Queen Rosa' (7.93), followed by 'Florida' 1-2 (7.35) whereas minimum sugar acid ratio was found in the cultivar 'Fortune' (4.29).

Bobrich *et al.* (2014) accessed two Japanese plum cultivars namely 'Queen Garnet' and 'Black Diamond' in which they observed that the anthocyanin content (sum of cyanidin-3-glucoside and cyanidin-3-rutinoside) was maximum in peel, flesh and whole fruit with 'Queen Garnet' having significantly higher levels than 'Black Diamond'. The relative anthocyanin content in 'Queen Garnet' flesh [% of total (whole fruit) content] was significantly higher than in 'Black Diamond' at all harvest dates.

Bozhkova (2014) evaluated twelve plum cultivars for total soluble solids content. It was recorded maximum in 'Topking' (22.19 °B) cultivar and minimum in 'Tuleu Timpuriu' (15.6 °B) cultivar. The total sugar content was maximum in 'Jojo' (12.31 %) and minimum in 'Tuleu Timpuriu' (6.96 %). Titratable acidity was found maximum in 'Pacific' (1.28 %) and minimum in 'Bellamira' (0.55 %).

Pirkhezri *et al.* (2014) carried out a study on eighteen plum cultivars and reported the maximum content of total soluble solids (TSS) in cultivar 'KP2' (21.8 %) and minimum was recorded in 'Early Golden' (12.1 %). Titratable acidity (TA) varied from 4.4 per cent in 'Friar' to 20.55 per cent in 'Oblenaja'.

Jun *et al.* (2015) studied Japanese plum cultivar 'Summer Fantasia' and its performance was compared to 'Oishiwase', 'Purple Queen', 'Santa Rosa', 'Soldam', and 'Taiyo'. They observed that the soluble sugar content of 'Summer Fantasia' (14.5 °Brix) was higher than that of the other cultivars whereas, fruit acidity (0.76 %) was found similar in all the cultivars.

Kumar (2016) studied eight plum cultivars *viz.*, 'Duarte', 'Black Amber', 'Friar', 'Shiro', 'Frontier', 'Santa Rosa', 'Red Beaut' and 'Mariposa'. The observations revealed maximum total sugar content in 'Black Amber' (8.19 %) and minimum in 'Santa Rosa' (7.49 %). Maximum reducing sugars was recorded in the cultivar 'Mariposa' (6.52 %) while, minimum reducing sugars was found in the cultivar 'Shiro' (5.18 %). The non-reducing sugars was found maximum in 'Shiro' (2.54 %) and minimum in 'Red Beaut' (1.16 %).

Verma (2016) studied fourteen exotic plum germplasm in Kashmir conditions *viz.*, 'Frontier', 'Red Beaut', 'Tarrol', 'Grand Duke', 'Black Amber', 'Burbank', 'Au-Cherry', 'Au-Rosa', 'Kanto 5', 'Kubio Plum', 'Red Plum', 'Krassivica Plum', 'Monarch' and 'Beauty'. Maximum total soluble solids (TSS) were recorded in cultivar 'Au-Rosa' (16.06 °B) while the minimum was recorded in the cultivar 'Krassivica Plum' (10.0 °B).

Kishor *et al.* (2017) evaluated twelve variants of plums for biochemical traits. The total soluble solids were recorded maximum in 'Collection-5' (15.60 °B) while, minimum in 'Collection-12' (10.50 °B). The maximum total sugars (4.16%) and reducing sugars (3.03%) were reported in 'Collection-2' while minimum total sugars (3.73%) and reducing sugars (2.13%) were recorded in the 'Collection-12' whereas, non-reducing sugars was found maximum in 'Collection-1' (1.65%) and minimum in 'Collection-5' (0.84%).

Latifikhah *et al.* (2017) evaluated the performance of four different plum and prune genotypes namely 'Ghohrood', 'Dobahreh', 'Khansar' and 'Plum No.1 of Mobarakeh' for total soluble solids and observed maximum value in 'Ghohrood' (22 %), followed by 'Khansar' (21 %), 'Dobahreh' (19 %) and minimum was recorded in 'Plum No.1 of Mobarakeh' (18 %).

Kumar *et al.* (2018) carried out a study on eight cultivars of plum namely 'Black Amber', 'Duarte', 'Friar', 'Shiro', 'Frontier', 'Mariposa', 'Red Beaut' and 'Santa Rosa'.

Maximum total soluble solids (TSS) were recorded in cultivar 'Black Amber' (15.16 °B) while, minimum total soluble solids were recorded in the cultivar 'Shiro' (12.92 °B) which was statistically at par with 'Red Beaut' (13.04 °B). The maximum acidity was recorded in 'Mariposa' (1.66 %) and minimum was docketed in 'Black Amber' (1.28 %). The maximum sugar to acid ratio was observed in 'Black Amber' (6.38) while, the minimum was reported in 'Mariposa' (4.87) which was statistically at par with 'Frontier' (5.05), 'Shiro' (5.12), 'Friar' (5.24) and 'Santa Rosa' (5.28).

Kwon *et al.* (2018) evaluated sixty-three varieties and accessions from the plum germplasm collection. The average soluble solid concentration (SSC) was 12.2 °Brix, ranging from 9.5 to 15.5 °Brix. Maximum soluble solid concentration (>14.0 °Brix) was found in 'Beniryozen', 'Honey Rosa', 'Methley', 'Starking Delicious' and 'Summer Fantasia' whereas, minimum (<10 °B) was recorded in 'Benikayama', 'Meilili' and Robusto. The titratable acidity values ranged from 0.42 to 1.66 g L^{-1} with an average of 0.90 g L^{-1}. Maximum acidity was reported in 'Benikayama', 'Kagayaki' and 'Underwood' (>1.5 g L^{-1}) whereas, minimum acidity was recorded in 'Akihime', 'Formosa', 'Honey Red', 'Kiyou', 'Riou' and 'Wonkyo Ma-15' (<0.5 g L^{-1}).

Butac *et al.* (2019) studied various European and Japanese plum cultivars in which they observed that the European plum cultivars with the maximum soluble solids content were 24.43 per cent in 'Agent', 23.10 per cent in 'Andreea' and 19.13 per cent in 'Carpatin'. The Japanese plum cultivars with the maximum soluble solids content were 16.96 per cent in 'Angeleno' followed by 16.13 per cent in 'Eldorado'.

Taiti *et al.* (2019) studied different plum cultivars *viz.,* 'Laroda', 'Black Diamond', 'Fortune', 'Golden Plum' and 'Angeleno' all of them belonging to (P. *salicina* Lindl.) and 'Settembrine' belonging to (P. *domestica* Lindl.). The maximum values for total soluble solids were detected in 'Settembrine' (15.90 °Brix) and 'Angeleno' (15.23 °Brix) while, the minimum was found in 'Black Diamond' (11.75 °Brix) followed by 'Laroda' (8.70 °Brix). The maximum value of titratable acidity was diarized in 'Golden Plum' and 'Black Diamond' while the minimum acidity values were observed in 'Settembrine' and 'Angeleno'. Maximum anthocyanin content was observed in plums with red pulp and red flesh such as 'Dof Giudy' and 'Black Diamond' (97.9±4.70 and 95.3±10.79 mg cyd-3-glu equivalents L^{-1}, respectively) while, yellow pulp varieties such as 'Fortune', 'Golden Plum', 'Angeleno' and 'Settembrine' had minimum anthocyanin content.

Bilal *et al.* (2021) carried out a study on four plum cultivars *viz.,* 'D-Agen', 'President', 'Blue Free' and 'Ruby Red' according to which maximum total soluble solids (TSS) were determined in variety 'D-Agen' (16.38 °B) and the minimum in 'Bluefre' (9.77 °B).

Abd Elaziz *et al.* (2022) conducted an experiment on mature plum trees of 'Pioneer' and 'Hollywood' plum. 'Hollywood' cultivar attained significantly the maximum percentage of total soluble solids ranged between 16.13 to 16.37 per cent in both the seasons. 'Pioneer' produced significantly the minimum range between 15.09 to 15.32 per cent in both seasons, respectively. Acidity in 'Pioneer' cultivar had maximum percentage from 1.63 per cent and 1.66 per cent whereas, 'Hollywood' plum cultivar resulted in minimum percentage of acidity from 1.51 per cent and 1.57 per cent in both the seasons, respectively.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled "**DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm**" was carried out in the field gene bank of National Bureau of Plant Genetics Resources (NBPGR), Regional Station Phagli, Shimla (Himachal Pradesh) during the year 2021-2022. The experimental area was located at an elevation of 1924 m amsl and the climate of the location was wet temperate.

The Japanese plum accessions undertaken for studies were:

1. EC-382826
2. EC-393740
3. EC-552696
4. EC-513684
5. Frontier
6. IC-555314
7. IC-555355
8. Kala Amritsari
9. EC-538999
10. IC-558067
11. Methley
12. Red Beaut
13. Shiro
14. EC-552693

Standard analytical procedures UPOV (Anonymous, 2002) and UPOV (Anonymous, 2011) test guidelines and DUS test guidelines were followed to characterize and evaluate the above listed varieties under study.

3. EXPERIMENTAL LAYOUT

The experiment was laid out in a Randomized Complete Block Design with three replications of each accession during the year 2021-2022. The data on various morphological and physico-chemical characters were recorded.

Number of treatments	:	14
Number of replications	:	3
Experimental Design	:	Randomized complete block design (RCBD)

3.1 TREE CHARACTERS

3.1.1 Tree height (m)

The height of the tree was measured with the help of calibrated staff from ground level to the tip of tallest branch of the tree and it was expressed in metres.

3.1.2 Shoot Colour

It was observed visually on the sunny side after removal of cuticle and observed according to UPOV (Anonymous, 2011) as under:

a) Greyish brown
b) Yellow brown
c) Brown
d) Reddish brown

3.1.3 Tree vigour

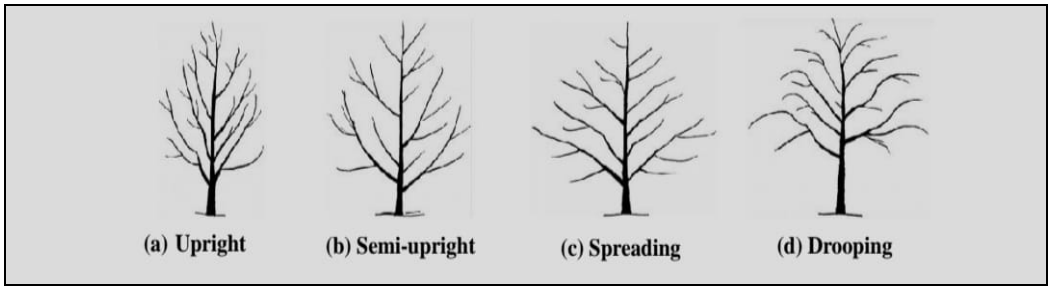
The vigour of the tree was observed as the overall abundance of vegetative growth and categorised as per UPOV descriptor (Anonymous, 2011) as under:

a) Weak
b) Medium
c) Strong

3.1.4 Tree Habit

Habit was the general appearance, growth form, or architecture of a tree which was observed visually and categorized as per UPOV descriptor (Anonymous, 2011) as under:

a) Upright
b) Semi-upright
c) Spreading
d) Drooping



3.1.5 Tree spread (m)

It was a measure of the footprint of the area of the crown of the tree, the observations were recorded in metres (m) with the help of a measuring tape and average of both the measurements was worked out.

a) North-South (N-S)

b) East-West (E-W)

3.1.6 Tree Girth (cm)

It was the measurement of the distance around the trunk of the tree measured perpendicular to the axis of the trunk. It was measured with the help of a measuring tape and was expressed in centimetres.

3.2 FOLIAGE CHARACTERS

Thirty leaves from the middle portion of the current growth were selected for recording observations as suggested by Beyers (1962).

3.2.1 Time of Bud Burst

The emergence of new leaves on a plant at the beginning of each growing season.

3.2.2 Leaf Blade Length (mm)

Leaf blade length was measured at the end of summer flush growth in late August with the help of Vernier Calliper from the tip of the apex to the base of leaf lamina and expressed in mm. This was calculated on the basis of average length of the leaves.

3.2.3 Leaf Blade Width (mm)

Leaf blade width was measured at the end of summer flush growth in late August with the help of Vernier Calliper from the broadest portion to work out the average width of the leaves and expressed in mm.

3.2.4 Leaf blade: length/width ratio

The length/width ratio of the leaves was calculated by dividing the leaf blade length by the leaf blade width.

3.2.5 Leaf area (mm^2)

Leaf area was measured with digital leaf area meter (LICOR - model 3100 A) and expressed in mm^2. Average area of ten leaves was considered as one replication and three such replications were made.

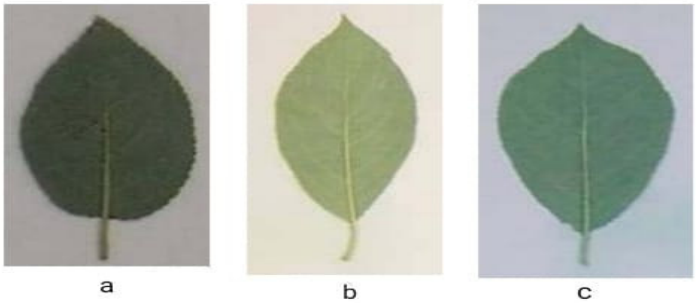
3.2.6 Leaf Blade Shape

Leaf blade shape was observed virtually and assigned as per UPOV descriptor (Anonymous, 2011) under the following categories:

a) Ovate

b) Elliptic

c) Obovate



3.2.7 Leaf blade: colour of upper side

Colour charts of the Royal Horticultural Society, London (Wilson, 1941) was used to determine the colour of the leaves.

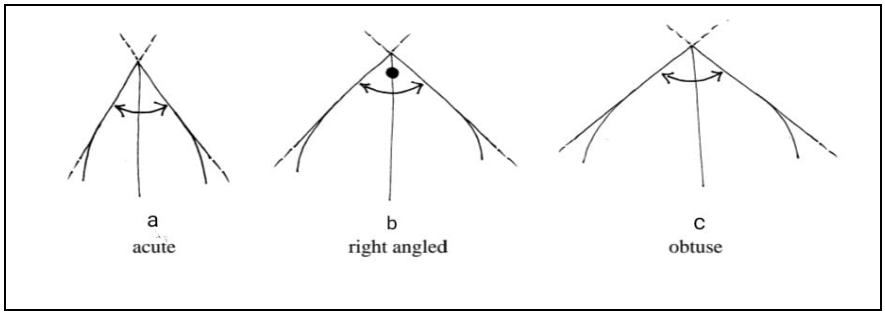
3.2.8 Leaf blade: angle of apex (excluding tip)

The apex angle was the angle between the lines that define the apex and was taken visually and assigned using the UPOV descriptor (Anonymous, 2011) under the following categories:

a) Acute

b) Right angled

c) Obtuse



3.2.9 Leaf: Glossiness on upper side

Glossiness on upper side of leaves observed visually as per UPOV descriptor (Anonymous, 2011) and classified under the following categories:

a) Weak

b) Medium

c) Strong

3.2.10 Leaf blade: density of pubescence of lower side

Density of pubescence of lower side on leaf blade was categorized as per UPOV descriptor (Anonymous, 2011). The observations were made visually under the following categories:

a) Sparse

b) Medium

c) Dense

3.2.11 Leaf blade: incisions of margin

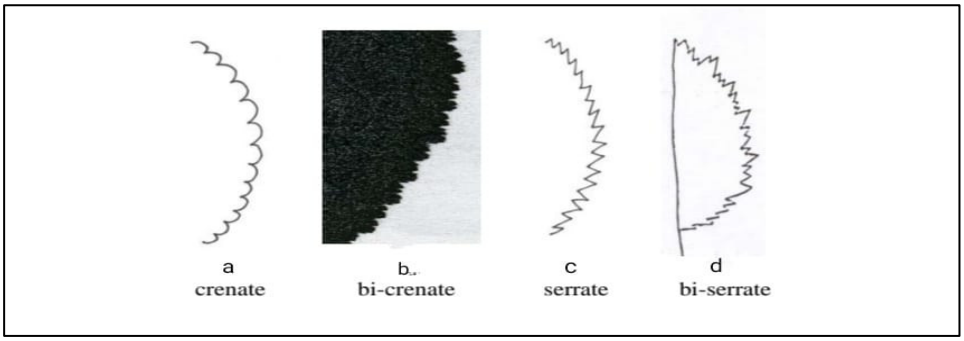
Incision of margin was observed visually as per UPOV descriptor (Anonymous, 2011) and assigned the following categories:

a) Crenate

b) Bi-crenate

c) Serrate

d) Bi-serrate



3.2.12 Petiole length (mm)

The petiole length was measured with the help of a Vernier Calliper (Model No. Digital 156, Zhart India) from the juncture of blade to the base of petiole and was expressed in mm. Average length of petiole of leaves per tree was worked out.

3.2.13 Leaf: position of nectaries

Position of nectaries was observed visually using the UPOV descriptor (Anonymous, 2011) and characterized as below:

a) Predominantly on base of leaf blade

b) Equally on base of leaf blade and on petiole

c) Predominantly on petiole

3.2.14 Leaf Fall

The natural separation and dropping of the leaf at the end of the growing season. The observations on leaf fall were recorded as the date on which there was 80-85 per cent of leaf fall.

3.3 FLOWER CHARACTERS

Time and duration of flowering

Four well distributed branches on different aspects of each tree of each replication were selected and tagged for recording the flowering data on different flowering aspects which were recorded as:

3.3.1 Date of opening of first flower

The date when 5-10 per cent flowers were found to be open was recorded as the date of opening of first flower.

3.3.2 Date of full bloom

The date on which about 75 per cent flowers had opened was recorded as the date of full bloom.

3.3.3 Date of opening of last flower

The date when last flower opened in each accession was considered as the date of opening of last flower.

3.3.4 Duration of flowering

The number of days from the date of opening of first flower to the date of opening of last flower in each accession was recommended as the duration of flowering.

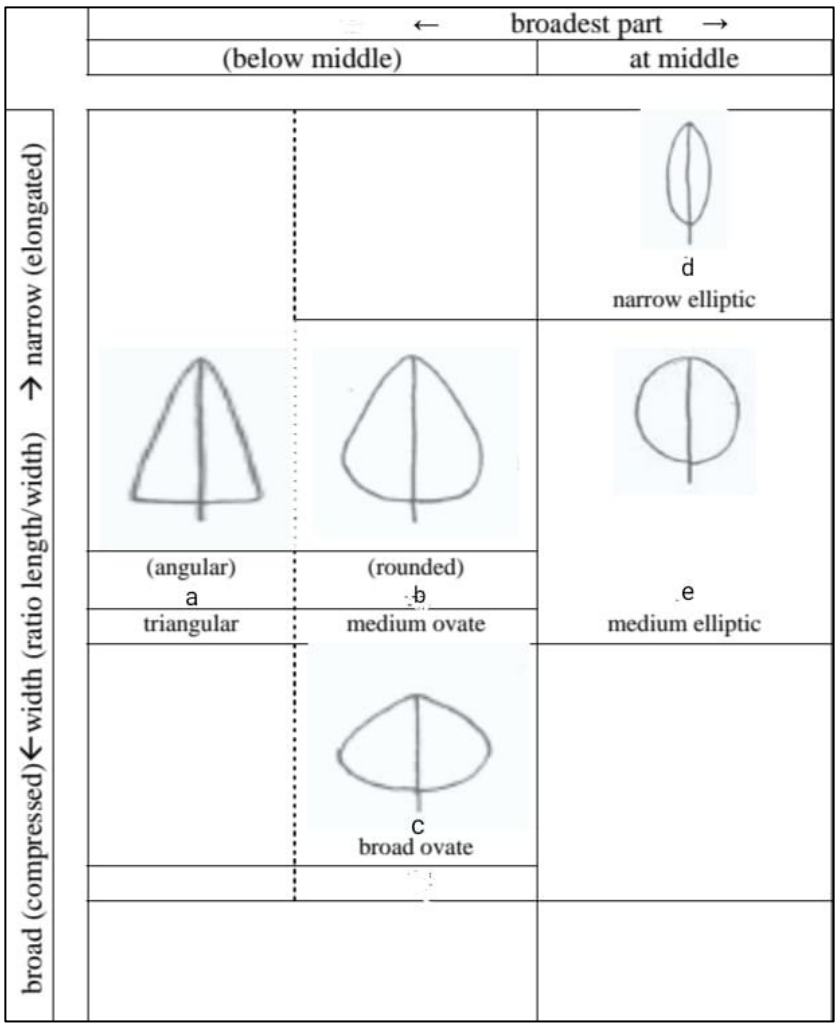
3.3.5 Flower diameter (mm)

The measurement on flower diameter was carried out on completely opened flowers with petals pressed into horizontal position and was measured with the help of Vernier Calliper (Model No. Digital 156, Zhart India) and expressed in mm.

3.3.6 Sepal shape

The sepal shape was observed visually as per UPOV guidelines (Anonymous, 2011) and was categorized under the following:

a) Triangular
b) Medium ovate
c) Broad ovate
d) Narrow elliptic
e) Medium elliptic



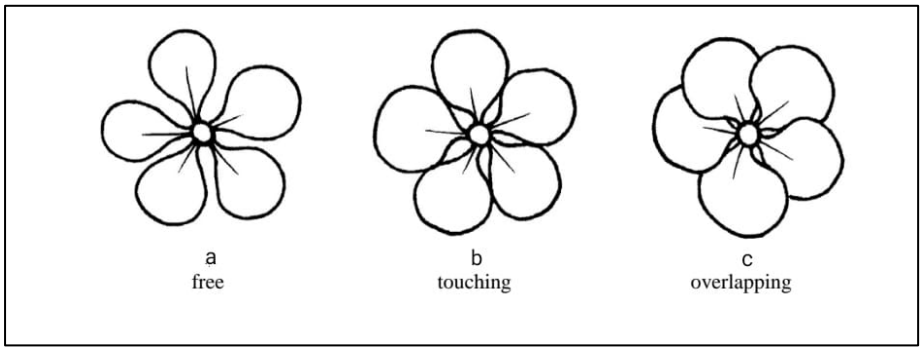
3.7.7 Petal length (mm)

Petal length was measured with the help of Vernier Calliper (Model No. Digital 156, Zhart India) and expressed in mm.

3.7.8 Flower arrangement of petals

The arrangement of petals was observed visually as per UPOV guidelines (Anonymous, 2011) and was categorized under the following:

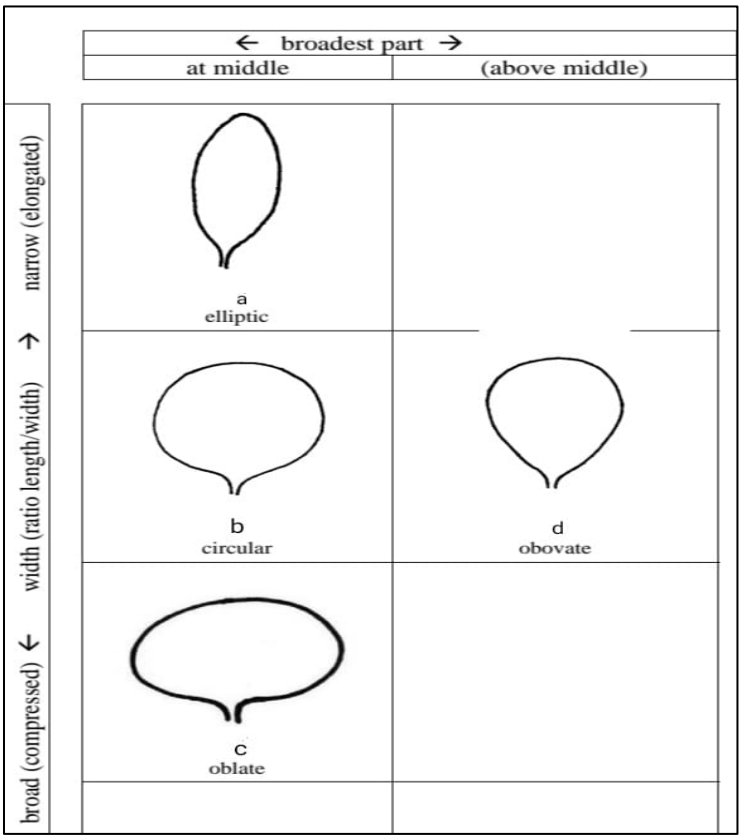
a) Free
b) Touching
c) Overlapping



3.7.9 Petal shape

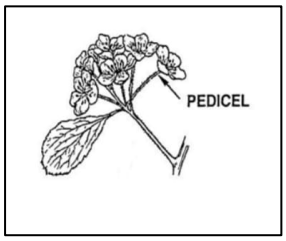
The shape of the petals was observed visually as per UPOV descriptor (Anonymous, 2011) and classified under the following categories:

a) Elliptic
b) Circular
c) Oblate
d) Obovate



3.3.10 Pedicel length (mm)

Pedicel length was measured with the help of Vernier Calliper (Model No. Digital 156, Zhart India) and measured in mm.



3.3.11 Stigma: position in relation to anthers

Stigma position in relation to anthers was observed visually following UPOV guidelines (Anonymous, 2011) and marked as:

a) Below

b) Same level

c) Above

3.3 POLLEN STUDIES

Flower buds at popcorn (balloon) stage were collected and the anthers were separated with the help of forceps. Separated anthers were kept in petri dish under partial shade for dehiscence. The pollen grains thus collected were put in pollen vials and hence, freshly dehisced pollen grains were used for pollen studies.

3.4.1 Pollen viability

3.4.1.1 Acetocarmine solution (2%) test

Pollen grains were stained in acetocarmine (2 %) solution prepared by dissolving 2 g of carmine powder in 45 ml of glacial acetic acid and making a final volume of 100 ml by adding distilled water. This solution was boiled for five minutes and filtered through Whatman No. 4 filter paper. The pollen grains were dusted on a clean glass slide and one or two drops of acetocarmine were put on these grains. After placing a cover slip over the stain, it was left for five minutes for proper staining of pollen grains. Slides were observed under microscope. Deeply stained and normal looking pollen grains were considered as viable whereas shrivelled, lightly stained or colourless pollen grains were counted as non-viable. Three microscopic fields were observed and number of viable and non-viable pollen grains

were counted in each field to work out the per cent pollen viability. Each microscopic field was considered as one replication.

3.4.1.2 Erythrosine B solution (0.1 %) test

Pollen grains were stained in 0.1 % per cent erythrosine B solution. The unstained pollen grains were considered viable in this method. Stain solution (0.1 %) was prepared by dissolving 100 mg of erythrosine B in distilled water to make a final solution of 100 ml. Staining procedure was same as done in acetocarmine test (Section 3.4.1.1).

3.4.2 *In vitro* pollen germination test

The freshly dehisced pollen grains were used for *in vitro* germination test. The different concentrations of sucrose *i.e.,* 10 and 15 per cent were prepared by dissolving 10 and 15 grams of sucrose in 100 ml of distilled water, respectively. Different sucrose solutions were placed in cavities of different microscopic slides and pollen grains were dusted over them. After placing cover slips their edges were smeared with vaseline and the slides were inverted instantly, leading to the formation of a hanging drop over the cover slips. These cavity slides were placed in petri dishes containing moist filter paper to ensure uniform and high relative humidity. Pollen tube growth was assessed under microscope after 24 hours. The pollen grains having pollen tube at least two times longer than pollen size were considered to be germinated and percentage of germinated pollen grains under three microscopic fields were worked out, which were treated as one replication.

3.5 FRUIT CHARACTERS

To study fruit characters, total five fruits were selected randomly from all directions in each replication and observations so recorded were averaged.

3.5.1 Date of Harvest

The date on which fruit was harvested from plants was considered as date of harvest.

3.5.2 Length of Stalk (mm)

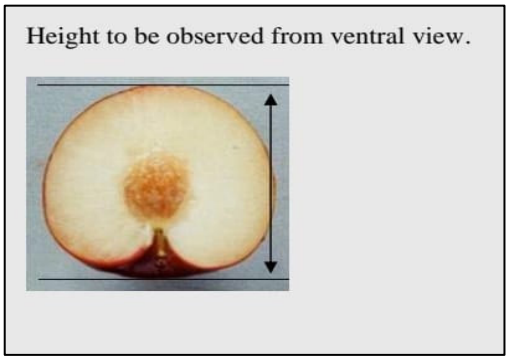
The length of fruit stalk was recorded with the help of digital Vernier Calliper (Model No. Digital 156, Zhart India) and measured in mm. Average length of fruit stalk of five fruits per tree was recorded.

3.5.3 Fruit Weight (g)

The weight of five fruits from each replication was recorded by weighing them on top pan electronic balance and the average weight per fruit was expressed in g.

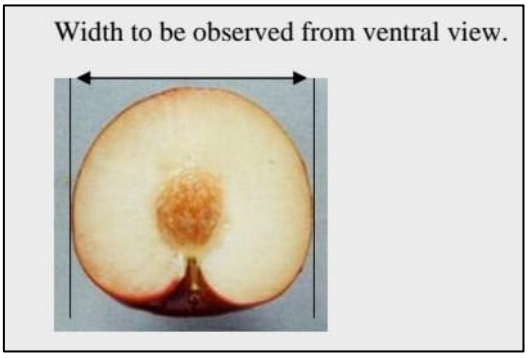
3.5.4 Fruit Height (mm)

The fruit length was measured with the help of digital Vernier Calliper (Model No. Digital 156, Zhart India) and expressed in mm.



3.5.5 Fruit Width (mm)

The fruit width was measured with the help of a digital Vernier Calliper (Model No. Digital 156, Zhart India) and expressed in mm.



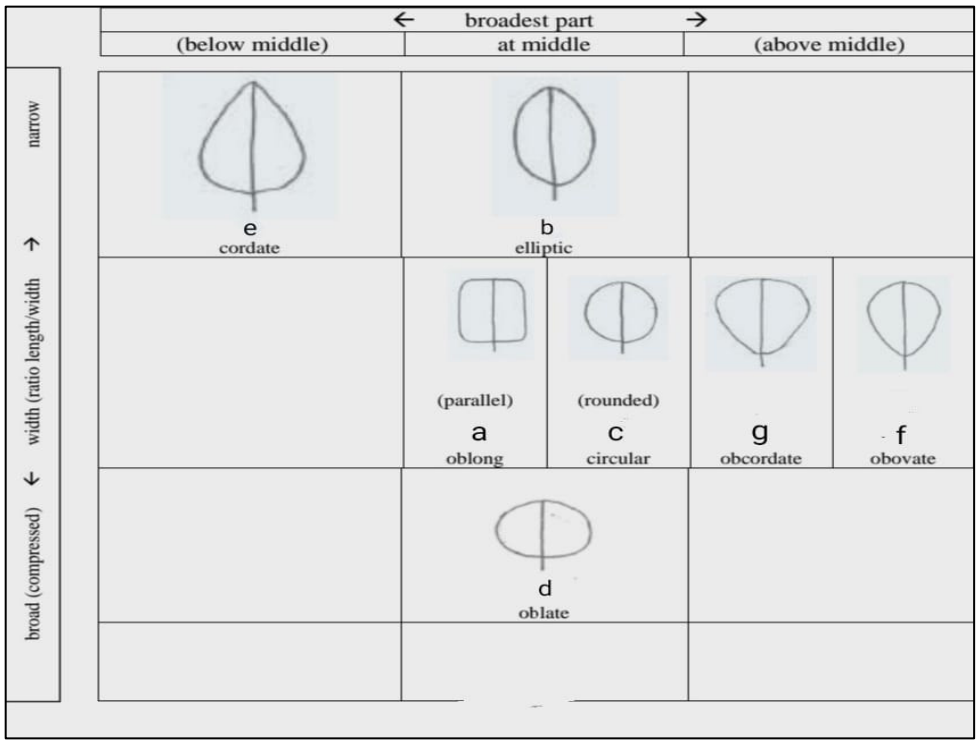
3.5.6 Fruit Volume (cm^3)

Fruit volume of fruits were recorded by water displacement method. A measuring cylinder was filled with water up to a certain graduation and fruits were immersed in the cylinder one by one. The reading was recorded before and after immersion. The difference between the two readings gave the measurement of the total volume and the results were expressed as volume in cubic centimetre per fruit.

3.5.7 Fruit Shape

The shape of fruit was observed visually and assigned as per UPOV guidelines (Anonymous, 2011) and categorized as below:

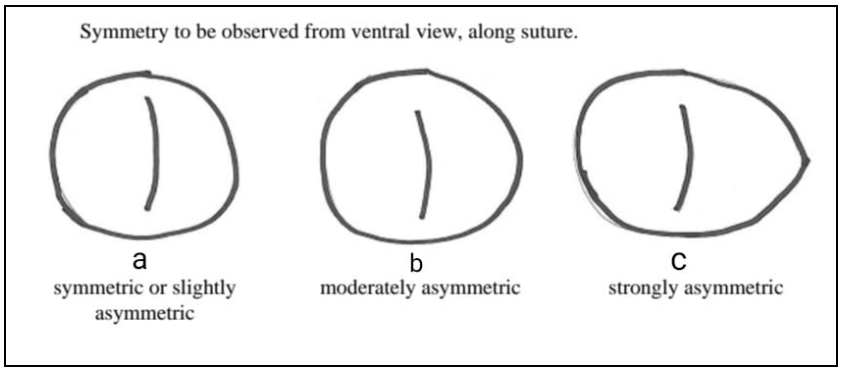
a) Oblong
b) Elliptic
c) Circular
d) Oblate
e) Cordate
f) Obovate
g) Obcordate



3.5.8 Fruit Symmetry

Fruit symmetry was observed visually according to UPOV descriptor (Anonymous, 2011) from ventral view, along suture and categorized under:

a) Symmetric or slightly asymmetric
b) Moderately asymmetric
c) Strongly asymmetric



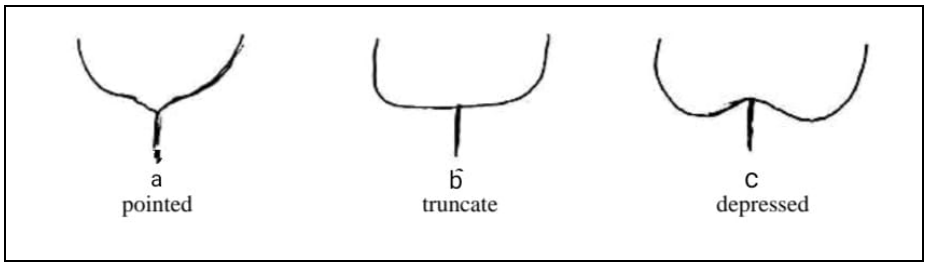
3.5.9 Fruit: Shape of Base

The shape of base of fruit was observed visually as per UPOV guidelines (Anonymous, 2011) and classified under the following:

a) Pointed

b) Truncate

c) Depressed



3.5.10 Fruit: Shape of Apex

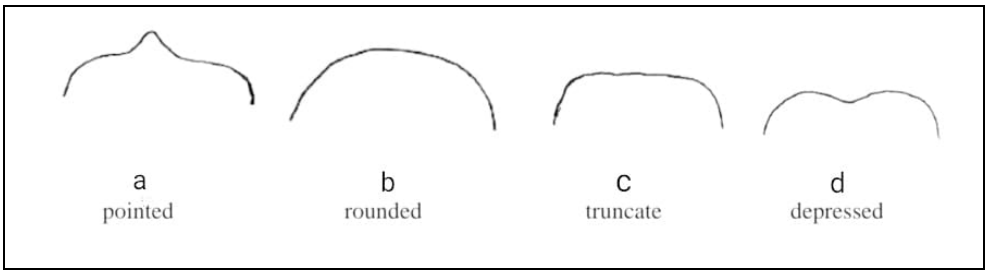
The shape of apex of fruit was observed visually as per UPOV guidelines (Anonymous, 2011) and described among the following categories:

a) Pointed

b) Rounded

c) Truncate

d) Depressed



3.5.11 Fruit: Depth of Stalk Cavity

Fruit should be cut through the central axis as accurately as possible and the depth of stalk cavity is observed visually and categorized as per UPOV descriptor (Anonymous, 2011) under the following categories:

a) Shallow

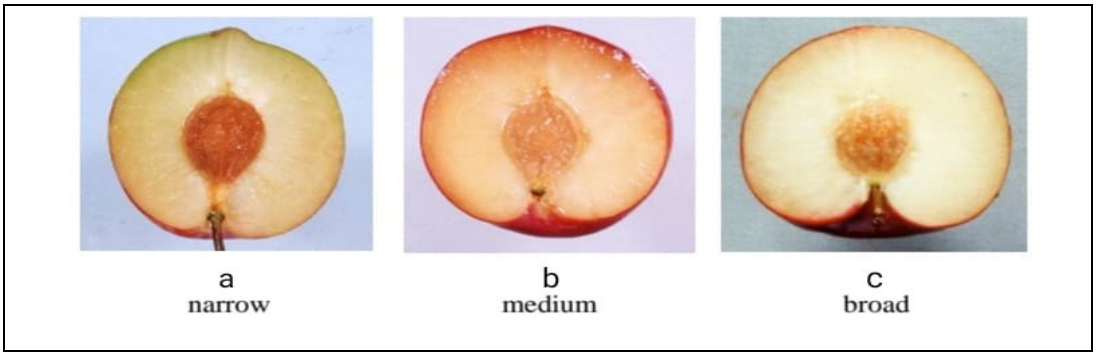
b) Medium

c) Deep

3.5.12 Fruit: Width of Stalk Cavity

Fruit was cut through the central axis as accurately as possible and the width of the stalk cavity was observed visually and classified according to UPOV descriptor (Anonymous, 2011) for following categories:

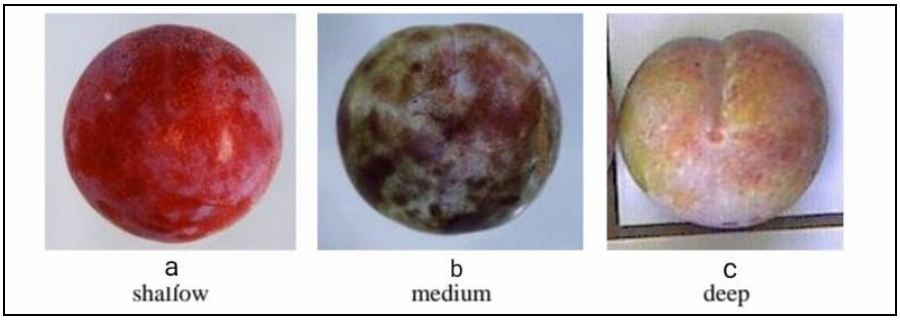
a) Narrow
b) Medium
c) Broad



3.5.13 Fruit: Depth of Suture

Depth of suture was observed visually in each genotype and assigned for UPOV descriptor (Anonymous, 2011) under the following categories:

a) Absent or very shallow
b) Shallow
c) Deep



3.5.14 Fruit: Colour of Peel

The flesh colour of the fruit was observed visually and assigned as per UPOV descriptor (Anonymous, 2011) under the following categories:

a) Yellowish green

b) Yellow

c) Orange yellow

d) Medium red

e) Dark red

f) Purple

g) Dark blue

3.5.15 Fruit: Pattern of Over Colour

Pattern of over colour was observed visually as per UPOV guidelines (Anonymous, 2011) and classified under the following:

a) Flecks only

b) Mottled

c) Solid flush only

3.5.16 Fruit: Bloom of Skin

Bloom of skin was observed visually and assigned as per UPOV descriptor (Anonymous, 2011) under the following categories:

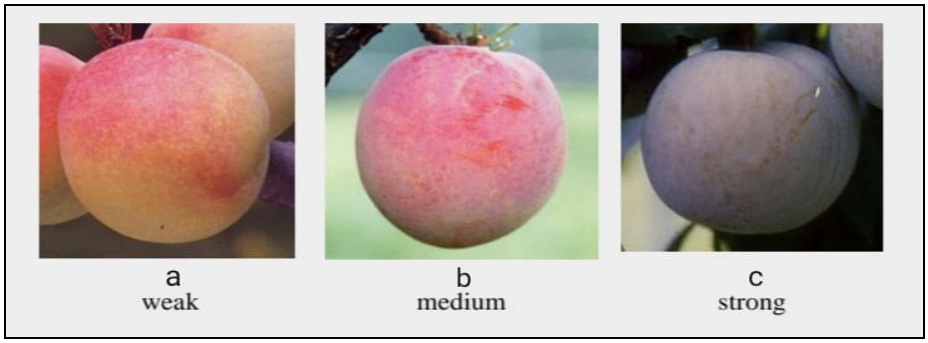
a) Very weak or absent

b) Weak

c) Medium

d) Strong

e) Very strong



3.5.17 Fruit: Number of Lenticels

Number of lenticles was observed visually and classified according to UPOV descriptor (Anonymous, 2011) under the following classes:

a) Few

b) Medium

c) Many

3.5.18 Fruit: Colour of Flesh

The flesh colour of the fruit was observed visually by comparing it with the colour charts of the Royal Horticultural Society, London (Wilson, 1941).

3.5.19 Fruit: Firmness (kg/cm^2)

Fruit firmness was measured with the help of penetrometer and expressed in (kg/cm^2) which recorded the necessary pressure for the plunger to penetrate the peeled flesh of plum fruits.

3.5.20 Fruit: Adherence of Stone to Flesh

It was observed visually as per UPOV descriptor (2011) and recorded under the following categories:

a) Non-adherent

b) Semi-adherent

c) Adherent

3.5.21 Fruit Set (%)

Four shoots of one meter length were selected randomly in all directions of the tree and were tagged for counting the flowers. The fruit set was recorded three weeks after petal fall and expressed as per cent fruit set as suggested by Westwood (1978).

3.5.22 Fruit drop (%)

For calculation of fruit drop, initial fruit set was recorded one week after petal fall stage and final fruit set was recorded three weeks later as per standard method by Westwood (1978) and results were expressed in per cent fruit drop. Fruit drop percentage was calculated by the following formula:

$$\text{Fruit drop (\%)} = \frac{\text{Initial Fruit Set} - \text{Final Fruit Set}}{\text{Initial Fruit Set}} \times 100$$

3.5.23 Fruit retention (%)

Fruit retention was recorded one month before harvesting in per cent (%) and calculated by using the formula suggested by Westwood (1978) as:

$$\text{Fruit retention (\%)} = \frac{\text{Number of fruit set} - \text{Final Fruit drop}}{\text{Number of fruit set}} \times 100$$

3.5.24 Number of days from full bloom to harvest

Duration from full bloom stage to harvest for each replication of each accession was recorded as days from full bloom to maturity.

3.5.25 Fruit yield (kg/tree)

Yield was recorded by weighing the total number of fruits at the time of harvesting and was expressed as kg per tree.

3.6 STONE CHARACTERS

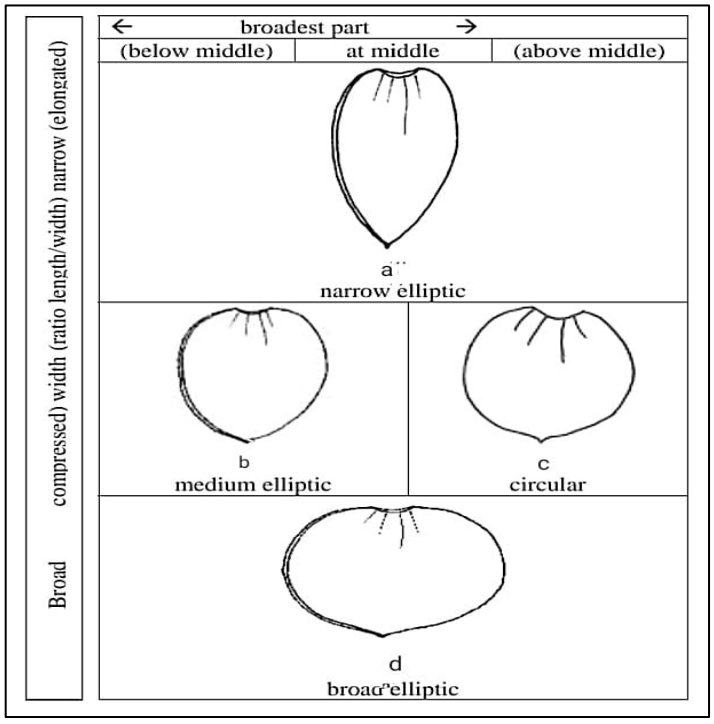
3.6.1 Stone weight (g)

Five stones from each replication were taken and weighed on electronic top pan balance. The average stone weight was expressed in gram.

3.6.2 Stone shape

The shape of the stone was determined visually as per UPOV descriptor (Anonymous, 2011) and described under the following classes:

a) Narrow elliptic
b) Medium elliptic
c) Circular
d) Broad ovate



3.6.3 Stone: Texture

Stone texture was observed visually according to UPOV descriptor (Anonymous, 2011) and assigned relevant categorizes given below:

a) Fine grained

b) Granular

c) Rough

d) Hammered

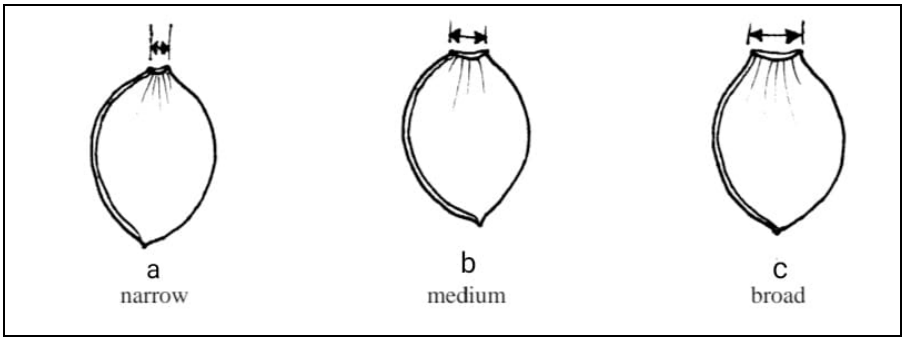
3.6.4 Stone: Width of Stalk-End

Width of stalk end was observed visually as per UPOV descriptor (Anonymous, 2011) and kept under the relevant categorizes:

a) Narrow

b) Medium

c) Broad



3.6.5 Pulp to stone ratio

Pulp to stone ratio was determined out by subtracting the weight of the fruit pulp (including the peel of the fruit) by the weight of the stone.

3.7 BIOCHEMICAL CHARACTERISTICS

Five fruits were randomly selected from each replication to determine the following biochemical characteristics as per the standard procedures given by Ranganna (1986).

3.7.1 Total Soluble Solids (^{o}B)

The total soluble solid content of fruits was determined with Erma Hand Refractometer (0-32^{o}B range). 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 total soluble solids present in the fruit in ºBrix were reflected on the screen.

3.7.2 Titratable Acidity (%)

The titratable acidity was determined as per standard method devised by Ranganna (1986) according to which 25 g of fruit pulp was crushed and the volume was made to 250 ml in a volumetric flask by adding distilled water. Out of it, 50 ml extract was taken for the estimation of acidity and the rest was used for determining the total sugars and reducing sugars. 10 ml of this juice extract was titrated against N/10 NaOH solution, using phenolphthalein as an indicator, to a light pink coloured end point. The titratable acidity was calculated in terms of malic acid on the basis of 1 ml of N/10 NaOH = 0.0067 g of anhydrous malic acid. Formula used for calculation of per cent acidity was:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value x Normality of NaOH x Volume made x Equivalent weight of acid}}{\text{Weight of sample taken x Volume of aliquot taken x 1000}} \text{ x } 100$$

3.7.3 Total Sugars (%)

Lane and Eynon's volumetric method (A.O.A.C., 1980) was employed for the estimation of sugars. The 200 ml of juice extract which was remaining after the estimation of acid was used. To this, 10 ml of saturated lead acetate was added. The contents of the flask were shaken and filtered into flask containing 10 ml of potassium oxalate to precipitate the excess of lead. The filtrate was shaken and again filtered after keeping it for few minutes. The 50 ml of the filtrate was taken in 250 ml volumetric flask and to it 5 ml concentrated HCl was added for hydrolysis. It was kept overnight at room temperature. The excess of hydrochloric acid was neutralised with saturated NaOH solution. The total sugars were then estimated by titrating against boiling mixture containing 5 ml each of Fehling A and Fehling B solution, using methylene blue as an indicator. The end point was indicated by the appearance of brick red colour. Total sugars content was expressed as percentage of fresh pulp weight as per the formula:

$$\text{Total sugars (\%)} = \frac{\text{*Factor x Dilution}}{\text{Titre value x Weight of sample taken x Volume of aliquot taken}} \text{ x } 100$$

*Factor = 0.05

3.7.4 Reducing Sugars (%)

For the estimation of reducing sugars, unhydrolyzed but lead free and clarified solution was titrated against boiling solution of 5 ml each of Fehling A and Fehling B using

methylene blue as an indicator (A.O.A.C., 1980). Reducing sugars content was expressed as percentage of fresh pulp weight as per the formula given below

$$\text{Reducing sugars (\%)} = \frac{\text{*Factor x Dilution}}{\text{Titre value x Weight of sample taken}} \text{ x } 100$$

***Factor = 0.05**

3.7.5 Non-reducing Sugars (%)

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

Non-reducing sugars (%) = (Total sugars – Reducing sugars) × 0.95

3.7.6 Sugar/Acid Ratio

Sugar/acid ratio was worked out by dividing per cent total sugars with per cent titratable acidity.

$$\text{Sugars/acid ratio} = \frac{\text{Total sugars (\%)}}{\text{Titratable acidity (\%)}}$$

3.7.7 Anthocyanin Content (A_{530})

Anthocyanin pigment in plum was determined by the method given by Harborne (1973). One gram of plum skin was macerated in a known quantity of methanol containing 1 per cent hydrochloric acid. The content was kept overnight at 0 °C temperature in a deep freezer. The absorbance of red coloured solution was recorded at 530 nm on Spectronic-20 colorimeter (NUKES). Anthocyanin content was expressed as absorption units at 530 nm per gram fresh plum skin.

Statistical analysis

The statistical analysis was carried out using MS-Excel and OPSTAT. The mean values of data were subjected to analysis of various traits as described by Gomez and Gomez (1984) for randomized complete block design. The following procedure and formula were adopted for estimation of different statistical parameters:

ANOVA for RCBD was as follows:

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F_{cal}
Treatments	(t-1)	S_t	$M_t = S_t / (t-1)$	M_t / M_e
Replications	(r-1)	S_r	$M_r = S_r / (r-1)$	M_r / M_e
Error	(r-1) (t-1)	S_e	$M_e = S_e / (r-1)(t-1)$	
Total	(rt-1)	S_T		

Where,

r = Number of replications

t = Number of treatments

S_r = Sum of squares due to replications

S_t = Sum of squares due to treatments

S_e = Sum of squares due to error

S_T = Total sum of squares

M_r = Mean sum of squares due to replications

M_t = Mean sum of squares due to treatments

M_e = Mean sum of squares due to error

The replication and treatment mean sum of square were tested against error mean squares by 'F' test at (r-1), (r-1) (t-1) and (t-1), (r-1) (t-1) degree of freedom for RCBD at 5% level of significance.

The calculated F-values were compared with tabulated F- value. When F- test was found significant, critical difference was calculated to find out the superiority of one treatment over the others.

The standard error and critical difference were calculated as follow:

$CD_{0.05}$ = S.E. (d) x $t_{(0.05)}$ (r-1) (t-1) df

SE ± (d) = $\sqrt{2\,Me/r}$

SE ± (m) = $\sqrt{Me/r}$

SE ± (m) = Standard error of mean

SE ± (d) = Standard error of difference

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

Chapter-4

RESULTS AND DISCUSSION

The study entitled, "**DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm"** was conducted during the years 2021 and 2022 at NBPGR, Phagli Shimla and the results were presented under suitable headings as follows:

4.1 Tree Characters
4.2 Foliage Characters
4.3 Flower Characters
4.4 Pollen Studies
4.5 Fruit Characters
4.6 Stone Characters
4.7 Biochemical Characteristics

4.1 TREE CHARACTERS

4.1.1 Tree Height (m)

Tree height was reported maximum in Kala Amritsari for both the years (4.22 m) in 2021 and (4.68 m) in 2022, respectively. While minimum was observed in IC-555314 (2.93 m) for the year 2021 and in IC-555314 (3.16 m) for the year 2022.

Pooled tree height (Table 4.1.1) was diarized maximum in Kala Amritsari (4.45 m) which was at par with Red Beaut (4.15 m) and EC-393740 (4.09 m) while, minimum was observed in IC-555314 (3.05 m).

4.1.2 Shoot Colour

Tree shoot colour was coincident for the years 2021 and 2022 (Table 4.1.1). Five accessions had reddish-brown shoot colour *viz.,* EC-382826, EC-393740, EC-552696, IC-555355 and EC-538999, three accessions had yellow-brown shoot colour *viz.,* EC-513684, Red Beaut and EC-552693 and remaining six had brown colour *viz.,* Frontier, IC-555314, Kala Amritsari, IC-558067, Methley and Shiro.

4.1.3 Tree Vigour

Tree vigour was recorded (Table 4.1.2) strong in seven genotypes namely EC-382826, EC-393740, Frontier, IC-555355, Kala Amritsari, Red Beaut and Shiro; although it was medium in four genotypes *viz.,* IC-555314, EC-538999, IC-558067 and Methley and remaining three genotypes had weak vigour namely EC-552696, EC-513684 and EC-552693 for both the years.

Table 4.1.1 Tree characters of different plum genotypes

Genotypes	Tree Height (m)			Shoot Colour	
	2021	2022	Pooled	2021	2022
EC-382826	3.56	3.78	3.67	Reddish-brown	Reddish-brown
EC-393740	3.95	4.2	4.09	Reddish-brown	Reddish-brown
EC-552696	3.20	3.44	3.32	Reddish-brown	Reddish-brown
EC-513684	3.32	3.51	3.41	Yellow-brown	Yellow-brown
Frontier	3.28	3.60	3.44	Brown	Brown
IC-555314	2.93	3.16	3.05	Brown	Brown
IC-555355	3.70	4.08	3.89	Reddish-brown	Reddish-brown
Kala Amritsari	4.22	4.68	4.45	Brown	Brown
EC-538999	3.32	3.64	3.48	Reddish-brown	Reddish-brown
IC-558067	3.36	3.57	3.46	Brown	Brown
Methley	3.77	4.00	3.88	Brown	Brown
Red Beaut	4.02	4.28	4.15	Yellow-brown	Yellow-brown
Shiro	3.48	3.73	3.60	Brown	Brown
EC-552693	3.46	3.65	3.55	Yellow-Brown	Yellow-brown
Mean	3.50	3.80	-	-	-
$CD_{0.05}$	0.64	0.61	0.60	-	-
SE ± (m)	0.22	0.20	0.20	-	-
SD	0.31	0.29	0.29	-	-

4.1.4 Tree Habit

Tree habit for the years 2021 and 2022 was homogeneous (Table 4.1.2); three genotypes had upright habit *viz.,* EC-513684, EC-538999 and Methley; five genotypes had semi-upright habit *viz.,* EC-382826, IC-555314, EC-552696, Red Beaut and EC-552693; six genotypes had spreading habit viz., EC-393740, Frontier, IC-555355, Kala Amritsari, IC-558067 and Shiro.

Table 4.1.2 Tree characters of different plum genotypes

Genotypes	Tree Vigour		Tree Habit	
	2021	2022	2021	2022
EC-382826	Strong	Strong	Semi-upright	Semi-Upright
EC-393740	Strong	Strong	Spreading	Spreading
EC-552696	Weak	Weak	Semi-upright	Semi-Upright
EC-513684	Weak	Weak	Upright	Upright
Frontier	Strong	Strong	Spreading	Spreading
IC-555314	Medium	Medium	Semi-upright	Semi-upright
IC-555355	Strong	Strong	Spreading	Spreading
Kala Amritsari	Strong	Strong	Spreading	Spreading
EC-538999	Medium	Medium	Upright	Upright
IC-558067	Medium	Medium	Spreading	Spreading
Methley	Medium	Medium	Upright	Upright
Red Beaut	Strong	Strong	Semi-upright	Semi-upright
Shiro	Strong	Strong	Spreading	Spreading
EC-552693	Weak	Weak	Semi-upright	Semi-upright

4.1.3 Tree Spread (m)

The maximum tree spread from North-South direction was observed in cultivar Shiro (4.14 m, 4.31 m), while the minimum was recorded in EC-513684 (2.29 m, 2.44 m) for the years 2021 and 2022, respectively. Tree spread from East to West direction was divulged maximum in cultivar Shiro (4.06 m, 4.32 m), while the minimum was recorded in accession EC-513684 (2.19 m, 2.36 m) for the years 2021 and 2022, respectively.

The pooled data in Table 4.1.3 showed that the cultivar Shiro had the maximum pooled tree spread from North to South (4.22 m) and East to West direction (4.19 m) respectively, which was at par with Kala Amritsari (4.19 m, 4.09 m), Red Beaut (4.12 m, 4.05 m), Methley (3.91 m, 4.09 m) and IC-555355 (4.11 m, 4.17 m). The minimum pooled tree spread from North-South direction was espied in accession EC-513684 (2.37 m) and minimum pooled tree spread from East-West direction was espied in EC-513684 (2.27 m).

4.1.4 Tree Girth (cm)

Girth of the plum trees was recorded maximum in Kala Amritsari for the years 2021 (51.14 cm) and 2022 (53.48 cm), respectively and minimum in IC-558067 for the years 2021 (32.99 cm) and 2022 (36.50 cm), respectively.

While according to the pooled data (Table 4.1.3) tree girth was found maximum in Kala Amritsari (52.37cm) and minimum in IC-558067 (34.74 cm).

Table 4.1.3 Tree characters of different plum genotypes

Genotypes	Tree Spread (m)						Tree Girth (cm)		
	(N-S)			(E-W)					
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
EC-382826	2.84	3.01	2.93	2.73	2.97	2.85	44.18	47.44	45.81
EC-393740	3.53	3.83	3.68	3.74	3.91	3.83	46.66	49.54	48.10
EC-552696	2.34	2.53	2.43	2.53	2.80	2.66	34.24	36.84	35.54
EC-513684	2.29	2.44	2.37	2.19	2.36	2.27	35.67	38.47	37.07
Frontier	3.25	3.51	3.38	3.57	3.84	3.70	38.67	42.65	40.66
IC-555314	2.46	2.87	2.65	2.55	2.87	2.71	36.84	39.14	37.99
IC-555355	4.03	4.19	4.11	4.08	4.26	4.17	48.62	51.48	50.05
Kala Amritsari	4.11	4.26	4.19	3.95	4.23	4.09	51.14	53.48	52.37
EC-538999	3.20	3.47	3.34	3.06	3.30	3.18	42.62	44.28	43.45
IC-558067	2.79	2.98	2.89	2.92	3.15	3.03	32.99	36.50	34.74
Methley	3.77	4.05	3.91	3.96	4.22	4.09	43.25	45.91	44.58
Red Beaut	4.00	4.25	4.12	3.95	4.16	4.05	47.55	51.99	49.77
Shiro	4.14	4.31	4.22	4.06	4.32	4.19	39.29	42.44	40.86
EC-552693	2.44	2.65	2.55	2.45	2.67	2.56	37.74	41.64	39.69
Mean	3.22	3.45	-	3.26	3.50	-	41.39	44.41	-
$CD_{0.05}$	0.43	0.33	0.33	0.43	0.52	0.44	1.73	1.95	1.67
SE ± (m)	0.14	0.11	0.11	0.14	0.17	0.15	0.59	0.66	0.57
SD	0.21	0.16	0.16	0.21	0.25	0.21	0.84	0.94	0.81

Tree growth characters such as tree vigour, habit and shoot colour were observed as per UPOV descriptor (Anonymous, 2011) test guidelines. These guidelines varied considerably amongst the Japanese plum accessions under study which fell into distinct classes over a span of two years. Out of fourteen cultivars three cultivars had upright habit, five cultivars had semi-upright habit and six cultivars had spreading habit. Nevertheless, Nisar *et al.* (2015) reported growth habit to be upright, extremely upright, semi-upright and spreading in different plum cultivars. Tree vigour was espied to be weak, medium and strong over the span of two years in the present study whereas, according to Jun *et al.* (2015), they compared the performance of Summer Fantasia to Oishiwase, Purple Queen, Santa Rosa, Soldam, and Taiyo and documented that the tree vigour was medium and strong.

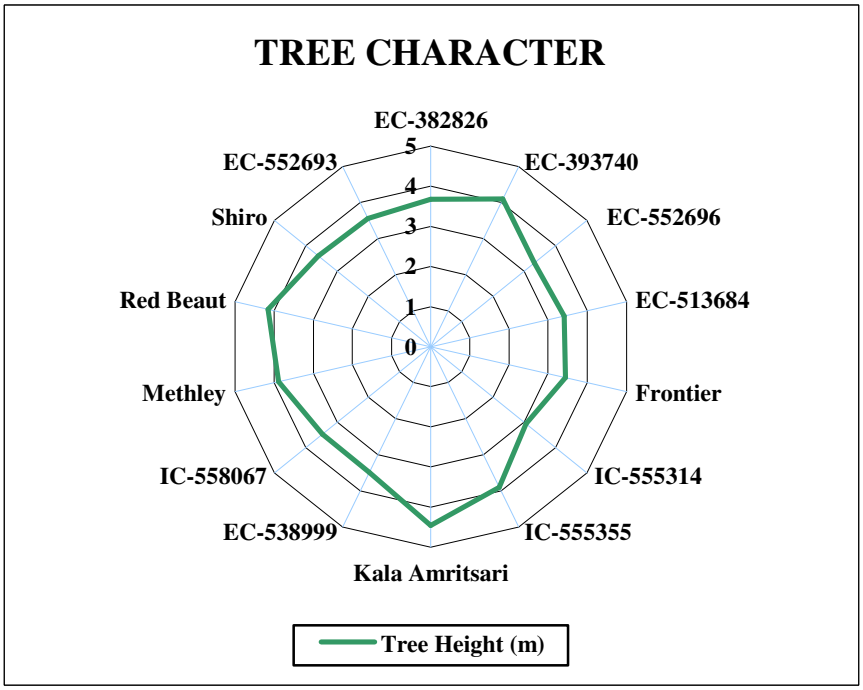


Figure 1: Extent of variation in tree height of different accessions

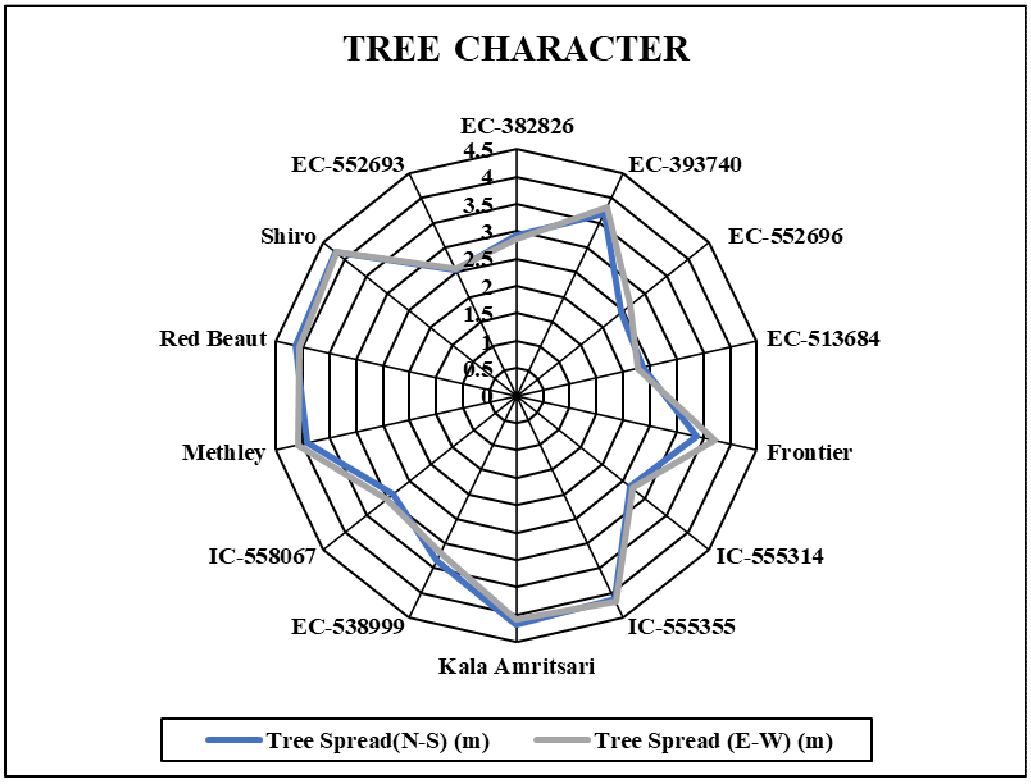


Figure 2: Extent of variation in tree spread from North to South and East to West of different accessions

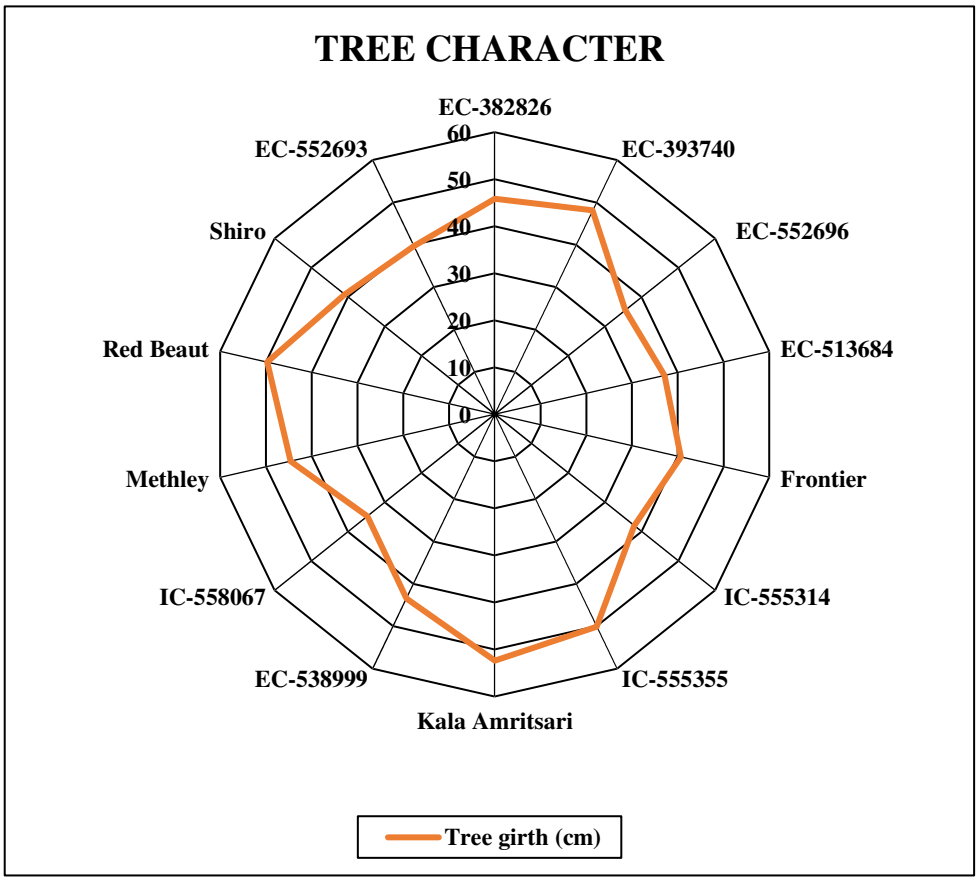


Figure 3: Extent of variation in tree girth of different plum accessions

Amongst all the evaluated accessions Shiro had the maximum tree spread from North-South and East-West direction whereas, EC-513684 had the minimum tree spread in both the directions. Sharma *et al.* (2018) also perceived that the maximum tree spread was in Shiro (2.14 m) and minimum in Friar (1.06 m) which was statistically at par with cultivars Black Amber and Duarte. The maximum pooled tree girth was chronicled in Kala Amritsari (67.37 cm) and minimum was documented in accession IC-558067 (24.74 cm). Though, Kumar *et al.* (2018) conducted a trial where the maximum trunk girth was inscribed in the cultivar Santa Rosa (20.46 cm) which was statistically at par with Red Beaut (20.16 cm), Frontier (19.86 cm) and Shiro (18.98 cm) whereas, the minimum girth was attained by the cultivar Friar (13.06 cm). Pooled tree height was maximum in Kala Amritsari (4.45 m) and minimum in IC-555314 (3.05 m). Prakash *et al.* (2003) studied six plum cultivars and observed maximum tree height in First Plum (10.76 m), followed by Ramgarh Maynard (10.40 m) while minimum tree height was recorded in New Plum (4.07 m). Tandon (2006) evaluated six cultivars and it was set forth Satluj Purple had maximum tree height (4.00 m) and trunk girth (45.90 cm) whereas, Black Amber had minimum plant height (2.50 m) and trunk girth (13.00 cm). However, Sestras *et al.* (2007) described that maximum tree height in Reine Claude d'Althan (5.96 m) and minimum was espied in Vinete de Italia (4.00 m).

4.2 FOLIAGE CHARACTERS

4.2.1 Time of Bud Burst

The time of bud burst was comparable during the years 2021 and 2022. The earliest was found in Red Beaut (9th February and 3rd February) and last to present time of bud burst was EC-552693 (12th March and 6th March) in the consecutive years, respectively.

4.2.2 Leaf Blade Length (mm)

Leaf blade length was recorded maximum in EC-393740 for both 2021 and 2022 (116.54 mm and 119.74 mm, respectively) while, leaf blade length for the year 2021 was recorded minimum in EC-552693 (83.53 mm) and for the year 2022 it was logged minimum in Shiro (84.25 mm).

The pooled data in Table 4.2.1 depicts that maximum leaf blade length was recorded in EC-393740 (118.14 mm) and minimum leaf blade length was recorded in EC-552693 (85.59 mm).

Table 4.2.1 Foliage characters of different plum genotypes

Genotypes	Time of Bud Burst		Leaf Blade Length (mm)		
	2021	2022	2021	2022	Pooled
EC-382826	4th March	26th February	105.94	109.02	107.31
EC-393740	8th March	1st March	116.54	119.74	118.14
EC-552696	24th February	19th February	95.34	93.53	94.43
EC-513684	6th March	1st March	108.74	105.22	106.96
Frontier	28th February	21st February	99.73	103.73	101.72
IC-555314	2nd March	25th February	107.54	104.10	105.78
IC-555355	15th February	11th February	102.44	105.78	103.89
Kala Amritsari	2[1st] February	17th February	101.72	105.25	103.48
EC-538999	11h March	6th March	89.46	91.01	90.23
IC-558067	1th March	24th February	106.56	106.65	106.60
Methley	19th February	15th February	92.85	95.33	94.08
Red Beaut	9th February	3rd February	111.92	115.81	113.85
Shiro	10th March	4th March	87.33	84.25	85.81
EC-552693	12th March	6th March	83.53	87.65	85.59
Mean	-	-	100.688	101.933	-
$CD_{0.05}$	-	-	0.261	0.343	0.114
SD	-	-	0.08	0.11	0.03
SE ± (m)	-	-	0.12	0.16	0.05

4.2.3 Leaf Blade Width (mm)

Leaf blade width was documented maximum in EC-393740 for both the years 2021 and 2022 (60.34 mm and 63.71 mm, respectively) while, leaf blade width for the year 2021 was documented minimum in EC-552693 (34.61 mm) and for the year 2022 it was recorded minimum in IC-555314 (33.43 mm).

The pooled data in Table 4.2.2 states that the maximum leaf blade width was documented in EC-393740 (62.02 mm) and minimum leaf blade width was noted in IC-555314 (35.19 mm).

4.2.4 Leaf blade: length/width ratio

Maximum leaf blade ratio for the year 2021 was proclaimed in EC-382826 (2.71) and minimum was documented in Methley (1.91). Considering, for the year 2022 it was recorded maximum for IC-555314 (3.11) and minimum for Methley (1.86).

According to the Table 4.2.2 the pooled length/width ratio was catalogued maximum in IC-555314 (3.01) and minimum was docketed in Methley (1.88).

Table 4.2.2 Foliage characters of different plum genotypes

Genotypes	Leaf Blade Width (mm)			Leaf blade: length/width ratio		
	2021	2022	Pooled	2021	2022	Pooled
EC-382826	38.96	40.58	39.77	2.71	2.68	2.70
EC-393740	60.34	63.71	62.02	1.92	1.87	1.90
EC-552696	44.65	42.96	43.80	2.19	2.17	2.18
EC-513684	45.64	41.73	43.69	2.38	2.54	2.46
Frontier	39.54	42.72	41.13	2.52	2.42	2.47
IC-555314	36.95	33.43	35.19	2.90	3.11	3.01
IC-555355	42.73	44.36	43.54	2.39	2.38	2.39
Kala Amritsari	40.23	43.15	41.69	2.52	2.43	2.48
EC-538999	37.85	40.56	39.21	2.36	2.24	2.30
IC-558067	46.38	47.12	46.75	2.29	2.26	2.27
Methley	48.45	51.23	49.84	1.91	1.86	1.88
Red Beaut	58.27	60.53	59.40	1.92	1.91	1.92
Shiro	38.64	35.94	37.29	2.26	2.34	2.30
EC-552693	34.61	37.72	36.16	2.41	2.32	2.36
Mean	43.80	44.69	-	2.33	2.32	-
$CD_{0.05}$	1.29	1.56	1.42	0.062	0.05	0.05
SE ± (m)	0.444	0.536	0.489	0.021	0.017	0.017
SD	0.627	0.759	0.691	0.030	0.025	0.025

4.2.5 Leaf area (mm^2)

The area of the leaf was found maximum in EC-393740 for both the consecutive years 2021 and 2022 (871.64 mm^2 and 909.53 mm^2, respectively) while, it was minimum in EC-552693 for the years 2021 and 2022 (611.76 mm^2 and 610.45 mm^2, respectively).

According to the Table 4.2.3 pooled leaf area was divulged maximum in EC-393740 (890.58 mm^2) and minimum in EC-552693 (611.10 mm^2).

4.2.6 Leaf Blade Shape

The shape of the leaf was found to be similar for both the years; nine cultivars had elliptic shape namely EC-382826, EC-552696, EC-513684, Frontier, IC-555314, Kala Amritsari, Methley, Shiro and EC-552693 and five had obovate shape *viz.*, EC-393740, IC-555355, EC-538999, IC-558067 and Red Beaut.

4.2.7 Leaf blade: colour of upper side

Colour on the upper side of the leaf blade was variable. EC-382826 had green group (139-A) whereas, EC-393740 had green group (138-A), EC-552696 fell in the green group (143-A), while EC-513684 and Kala Amritsari had yellow green colour (147-A), Frontier, IC-555355 and IC-558067 fell under the green group (137-A). However, IC-555314 and EC-552693 both fell in green group (137-C), EC-538999 in green group (137-B), Methley in green group (147-B), Red Beaut under green group (136-A) and Shiro under green group (141-A) for the years 2021 and 2022.

Table 4.2.3 Foliage characters of different plum genotypes

Genotypes	Leaf Blade Area (mm^2)			Leaf Blade Shape		Leaf blade: colour of upper side	
	2021	2022	Pooled	2021	2022	2021	2022
EC-382826	822.34	853.64	837.99	Elliptic	Elliptic	Green Group (139-A)	Green Group (139-A)
EC-393740	871.64	909.53	890.58	Obovate	Obovate	Green Group (138-A)	Green Group (138-A)
EC-552696	673.74	654.73	664.23	Elliptic	Elliptic	Green Group (143-A)	Green Group (143-A)
EC-513684	753.77	774.46	764.12	Elliptic	Elliptic	Yellow Green Group (147-A)	Yellow Green Group (147-A)
Frontier	789.75	865.64	827.69	Elliptic	Elliptic	Green Group (137-A)	Green Group (137-A)
IC-555314	621.43	647.75	634.59	Elliptic	Elliptic	Green Group (137-C)	Green Group (137-C)
IC-555355	666.35	728.44	697.40	Obovate	Obovate	Green Group (137-A)	Green Group (137-A)
Kala Amritsari	793.72	848.75	821.24	Elliptic	Elliptic	Yellow Green Group (147-A)	Yellow Green Group (147-A)
EC-538999	619.45	681.54	650.49	Obovate	Obovate	Green Group (137-B)	Green Group (137-B)
IC-558067	830.75	872.41	851.58	Obovate	Obovate	Green Group (137-A)	Green Group (137-A)
Methley	741.65	752.85	747.25	Elliptic	Elliptic	Yellow Green Group (147-B)	Yellow Green Group (147-B)
Red Beaut	869.75	887.61	878.68	Obovate	Obovate	Green Group (136-A)	Green Group (136-A)
Shiro	728.80	765.34	747.25	Elliptic	Elliptic	Green Group (141-A)	Green Group (141-A)
EC-552693	611.76	610.45	611.10	Elliptic	Elliptic	Green Group (137-C)	Green Group (137-C)
Mean	742.49	775.22	-	-	-	-	-
$CD_{0.05}$	5.25	0.79	2.41	-	-	-	-
SE ± (m)	1.79	0.27	0.82	-	-	-	-
SD	2.54	0.38	1.17	-	-	-	-

4.2.8 Leaf blade: angle of apex (excluding tip)

Angle of apex was similar for the years 2021 and 2022. It was right angled for three accessions (EC-382826, EC-552696 and EC-513684), obtuse for five accessions (EC-393740, IC-555355, Kala Amritsari, Methley and Red Beaut) and acute for remaining six accessions (Frontier, IC-555314, EC-538999, IC-558067, Shiro and EC-552693).

4.2.9 Leaf: Glossiness on upper side

For the years 2021 and 2022 glossiness of the leaf was inscribed to be strong for six genotypes *viz.,* EC-382826, EC-393740, EC-513684, IC-555314, IC-558067 and EC-552693; medium glossiness was recorded for EC-552696, Frontier, IC-555355, Kala Amritsari, EC-538999 and Red Beaut whereas, weak glossiness was diarized in Methley and Shiro.

4.2.10 Leaf blade: density of pubescence of lower side

Density of pubescence on the lower side of the leaf for the first and second-year was recorded dense for four accessions *viz.,* EC-393740, Kala Amritsari, EC-538999 and Shiro; medium for five accessions *viz.,* EC-382826, EC-513684, IC-555355, IC-558067 and Red Beaut and five accessions had sparse pubescence *viz.,* EC-552696, Frontier, IC-555314, Methley and EC-552693.

Table 4.2.4 Foliage characters of different plum genotypes

Genotypes	Leaf blade: angle of apex (excluding tip)		Leaf: Glossiness on upper side		Leaf blade: density of pubescence of lower side	
	2021	2022	2021	2022	2021	2022
EC-382826	Right angled	Right angled	Strong	Strong	Medium	Medium
EC-393740	Obtuse	Obtuse	Strong	Strong	Dense	Dense
EC-552696	Right angled	Right angled	Medium	Medium	Sparse	Sparse
EC-513684	Right angled	Right angled	Strong	Strong	Medium	Medium
Frontier	Acute	Acute	Medium	Medium	Sparse	Sparse
IC-555314	Acute	Acute	Strong	Strong	Sparse	Sparse
IC-555355	Obtuse	Obtuse	Medium	Medium	Medium	Medium
Kala Amritsari	Obtuse	Obtuse	Medium	Medium	Dense	Dense
EC-538999	Acute	Acute	Medium	Medium	Dense	Dense
IC-558067	Acute	Acute	Strong	Strong	Medium	Medium
Methley	Obtuse	Obtuse	Weak	Weak	Sparse	Sparse
Red Beaut	Obtuse	Obtuse	Medium	Medium	Medium	Medium
Shiro	Acute	Acute	Weak	Weak	Dense	Dense
EC-552693	Acute	Acute	Strong	Strong	Sparse	Sparse

4.2.11 Leaf blade: incision of margin

Incision of margin on leaf was catalogued to be similar for the years 2021 and 2022. It was recorded serrate for EC-382826, Frontier, EC-538999 and IC-558067; crenate in EC-393740, EC-552696, IC-555314, Kala Amritsari, Red Beaut, Shiro and EC-552693 and bi-crenate in EC-513684, IC-555355 and Methley.

4.2.12 Petiole length (mm)

Petiole length was taped to be maximum in Methley (16.81 mm) in the year 2021 and in EC-513684 (17.71 mm) in 2022. Petiole length was observed to be minimum for the years 2021 and 2022 in Shiro (10.76 mm, 10.03 mm, respectively).

According to the Table 4.2.5 pooled petiole length was reported maximum in EC-513684 (17.14 mm) which was at par with Methley (16.88 mm), EC-393740 (16.66 mm), IC-555314 (15.83 mm) and IC-558067 (15.56 mm) while, minimum leaf petiole length was observed in Shiro (10.39 mm).

Table 4.2.5 Foliage characters of different plum genotypes

Genotypes	Leaf blade: incisions of margin		Petiole length (mm)		
	2021	2022	2021	2022	Pooled
EC-382826	Serrate	Serrate	14.47	15.77	15.25
EC-393740	Crenate	Crenate	16.56	16.76	16.66
EC-552696	Crenate	Crenate	13.18	14.51	13.84
EC-513684	Bi-crenate	Bi-crenate	16.57	17.71	17.14
Frontier	Serrate	Serrate	14.03	14.00	14.05
IC-555314	Crenate	Crenate	15.92	15.68	15.83
IC-555355	Bi-serrate	Bi-serrate	12.45	12.51	12.48
Kala Amritsari	Crenate	Crenate	14.15	15.17	14.66
EC-538999	Serrate	Serrate	14.08	14.02	14.05
IC-558067	Serrate	Serrate	14.60	16.52	15.56
Methley	Bi-crenate	Bi-crenate	16.81	16.94	16.88
Red Beaut	Crenate	Crenate	11.06	11.72	11.39
Shiro	Crenate	Crenate	10.76	10.03	10.39
EC-552693	Crenate	Crenate	11.61	11.44	11.52
Mean	-	-	14.01	14.48	-
$CD_{0.05}$	-	-	3.38	1.75	1.69
SE ± (m)	-	-	1.15	0.60	0.58
SD	-	-	1.63	0.85	0.82

4.2.13 Leaf: position of nectaries

Position of nectaries on leaf was observed to be equally on the base of the leaf blade and petiole for five accessions *viz.,* EC-382826, EC-513684, Kala Amritsari, Methley and Shiro; nectaries predominantly on the base of the leaf blade in five accessions *viz.,* EC-393740, IC-555314, EC-538999, IC-558067 and Red Beaut; and nectaries predominantly on petiole in four accessions *viz.,* EC-552696, Frontier, IC-555355 and EC-552693.

4.2.14 Leaf Fall

Leaf fall in fourteen Japanese plum accessions was noted earliest in Red Beaut on 11th November, followed by IC-555355 on 14th November, Methley on 15th November, Kala Amritsari on 17th November, EC-552696 on 20th November, EC-538999 on 21st November, EC-382826 on 22nd November, IC-558067 on 24th November, IC-555314 on 26th November, EC-513684 on 29th November, EC-393740 1st December and last was Shiro on 2nd December.

Table 4.2.6 Foliage characters of different plum genotypes

Genotypes	Leaf: position of nectarines		Leaf Fall
	2021	2022	
EC-382826	Equally on the base of leaf blade and petiole	Equally on the base of leaf blade and petiole	22nd November
EC-393740	Predominantly on the base of leaf blade	Predominantly on the base of leaf blade	1st December
EC-552696	Predominantly on petiole	Predominantly on petiole	20th November
EC-513684	Equally on the base of leaf blade and petiole	Equally on the base of leaf blade and petiole	29th November
Frontier	Predominantly on petiole	Predominantly on petiole	19th November
IC-555314	Predominantly on the base of leaf blade	Predominantly on the base of leaf blade	26th November
IC-555355	Predominantly on petiole	Predominantly on petiole	14st November
Kala Amritsari	Equally on the base of leaf blade and petiole	Equally on the base of leaf blade and petiole	17th November
EC-538999	Predominantly on the base of leaf blade	Predominantly on the base of leaf blade	21st November
IC-558067	Predominantly on the base of leaf blade	Predominantly on the base of leaf blade	24th November
Methley	Equally on the base of leaf blade and petiole	Equally on the base of leaf blade and petiole	15th November
Red Beaut	Predominantly on the base of leaf blade	Predominantly on the base of leaf blade	11th November
Shiro	Equally on the base of leaf blade and petiole	Equally on the base of leaf blade and petiole	2nd December
EC-552693	Predominantly on petiole	Predominantly on petiole	30th November

Leaf characters are commonly used to distinguish and identify various fruit crop species and varieties. The present study promulgated huge variation in time of bud burst, leaf length, leaf width, leaf length/width ratio, leaf area, colour of leaf, leaf shape, angle of apex, shape of base, length of petiole, glossiness on upper side, leaf blade: density of pubescence of lower side, incision of margin, position of nectaries and time of leaf fall in both the years. The time of bud burst was observed between 9th February in Red Beaut to 12th March in EC-552693 in 2021 and 3rd February in Red Beaut to 6th March in EC-552693 in 2022. Time of bud emergence heed earliest in Satluj Purple on 25th January to 24th February in Shiro (Tandon, 2006). Thakur (2012) also witnessed that the time of bud burst extended from second week of February to the second week of March. Although, Kumar (2016) evaluated the time of bud burst was earliest in Red Beaut on 7th February and bud burst in Shiro was on 10th March. Aran *et al.* (2012) assessed thirty-five plum genotypes in which the maximum leaf length was 61.3 mm and minimum leaf length was 31.0 mm while, maximum leaf width was 34.5 mm and minimum leaf width was 7.8 mm. Verma (2016) studied that the maximum leaf length was diarized in Frontier (116.13 mm) and minimum was recorded in Red Beaut (99.33 mm), leaf breadth was maximum in Au-Rosa (49.66 mm) and minimum in Burbank (33.26 mm). Majid *et al.* (2020) endowed leaf length to be maximum in Santa Rosa (12 cm) and minimum in Stanley (6.80 cm). Leaf breadth was maximum in Santa Rosa (5.63 cm) and minimum in Burbank (3.90 cm). However, according to the present studies maximum pooled leaf length was recorded in EC-393740 (118.14 mm) and minimum in EC-552693 (85.59 mm**)** while maximum pooled leaf width was recorded in EC-393740 (62.02 mm) and minimum in IC-555314 (35.19 mm).

Leaf area according to the present studies was perceived maximum in EC-393740 (890.58 mm^2) and minimum in EC-552693 (611.10 mm^2). Sharma (1999) also had significantly variable result according to which the maximum leaf area was logged in Red Beaut (17.51 cm²) whereas, minimum was espied in Au-Rosa (10.13 cm²). Nisar *et al.* (2015) taped the maximum leaf area in SY2 (26.37 cm^2) and minimum in DR2 (10.66 cm^2). However, Kumar *et al.* (2018) stated that the maximum leaf area was catalogued in Red Beaut (18.36 cm^2) while, minimum was noted in Black Amber (12.53 cm^2). Aran *et al.* (2012) evaluated thirty-five genotypes out of which, petiole length ranged from 7.5 mm to 17.9 mm which was also comparable to the present studies over the span of two years and ranged from 10.39 mm to 17.1 mm. Latifikhah *et al.* (2017) recorded maximum leaf length/leaf width ratio in Khansar (2.33) and minimum in Dobahreh (1.69) which was

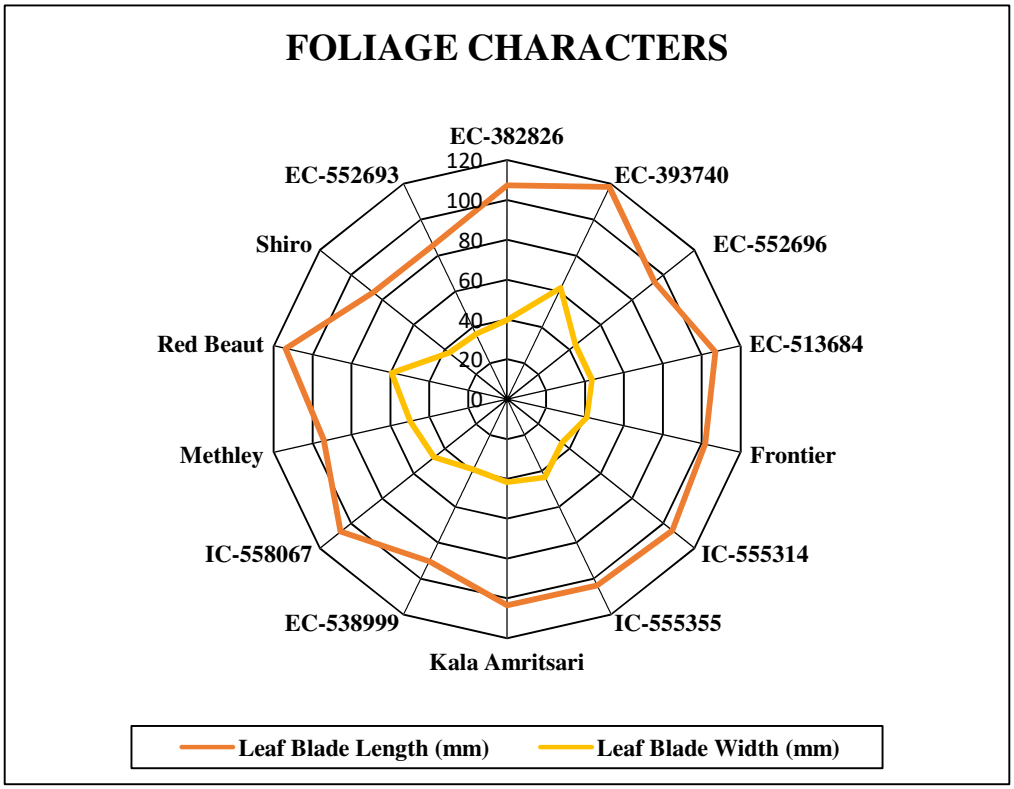


Figure 4: Extent of variation in leaf blade length and leaf blade width of different plum accessions

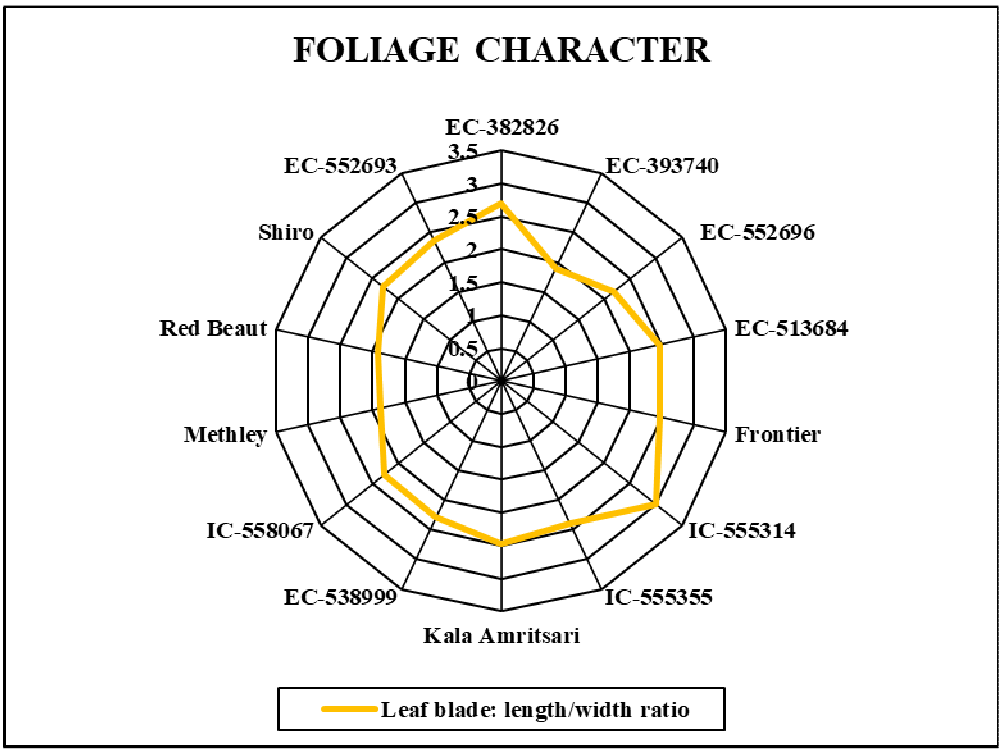


Figure 5: Extent of variation in leaf blade length/width ratio of different plum accessions

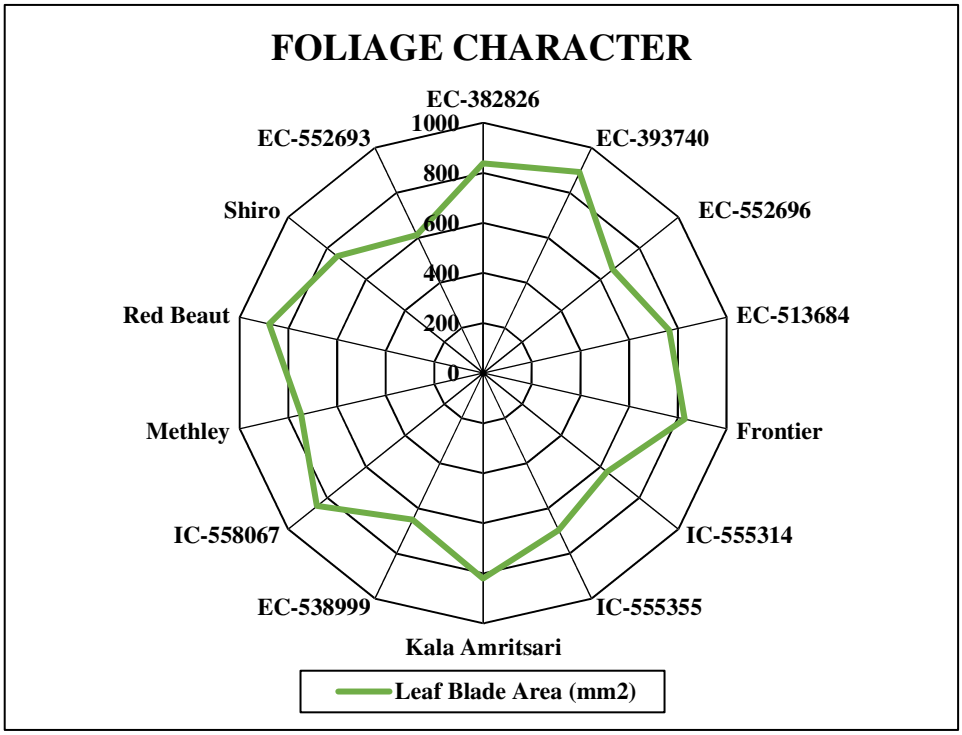


Figure 6: Extent of variation in leaf blade area of different plum accessions

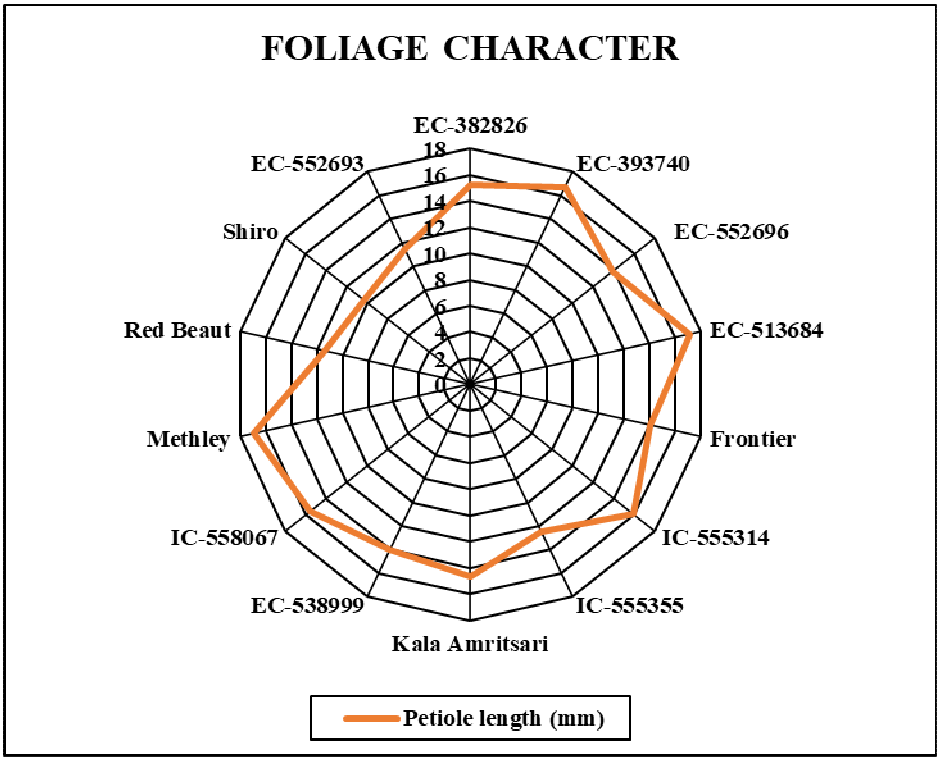


Figure 7: Extent of variation in petiole length of different plum accessions

statistically different than the present studies which ranged from 1.88 to 3.01. Holland *et al.* (2007) observed the blade margins were crenate whereas, in the fourteen accessions the incision of the margins was blazoned to be crenate, bi-crenate and serrate.

4.3 FLOWER CHARACTERS

4.3.1 Date of opening of first flower

The date of opening of the first flowering (Table 4.3.1) during the year 2021 was found earliest in Red Beaut on 16th February followed by IC-555355 (22th February) and Kala Amritsari (24th February) and the last to depict date of opening of first flower was accession EC-538999 and EC-552693 on 18th March. Opening of first flower in 2022 was observed earliest in Red Beaut on 11th February, followed by IC-555355 on 18th February and Kala Amritsari on 19th February while, the last to show opening of first flower was EC-552693 on 13th March succeeded by Shiro on 11th March.

4.3.2 Date of full bloom

Date of full bloom (Table 4.3.1) was noted earliest in Red Beaut for both the years 2021 and 2022 (26th February and 17th February), respectively. The last date of full bloom for 2021 and 2022 was observed in accession EC-538999 (30th March and 24th March), respectively which was coinciding with EC-552693 (28th March in 2021 and 23th March in 2022) and Shiro (27th March in 2021 and 20th March in 2022).

Table 4.3.1 Flower characters of different plum genotypes

Genotypes	Date of opening of first flower		Date of full bloom	
	2021	2022	2021	2022
EC-382826	12th March	6th March	22nd March	16th March
EC-393740	16th March	11th March	26th March	21st March
EC-552696	9th March	3rd March	11th March	08th March
EC-513684	14th March	6th March	25th March	13th March
Frontier	3rd March	28th February	08th March	4th March
IC-555314	10th March	5th March	18th March	11th March
IC-555355	22ndFebruary	18th February	3rd March	27th February
Kala Amritsari	24th February	19th February	5th March	27th February
EC-538999	18th March	12th March	30th March	24th March
IC-558067	9th March	2nd March	20th March	13rd March
Methley	26th February	21st February	6th March	28th February
Red Beaut	16h February	11th February	26th February	17th February
Shiro	17th March	11th March	27th March	20th March
EC-552693	18th March	13th March	28th March	23rd March

4.3.3 Date of opening of last flower

Date of opening of last flower (Table 4.3.2) was recorded earliest in Red Beaut for the years 2021 and 2022 (5th March and 22nd February), respectively whereas, the last genotype to show the date of opening of last flower was Shiro on (4th April 2021) followed by EC-552693 on (2nd April) whereas, in the year 2022 EC-393740 and EC-538999 displayed opening of last flowering on (28th March).

4.3.4 Duration of flowering

Duration of flowering was recorded maximum in EC-393740, EC-513684 and Shiro for 18 days in 2021 and in 2022, it was reported maximum in EC-393740 and Shiro for 17 days. The minimum duration of flowering was inscribed in EC-552696 and Frontier (10 days and 10 days) in the years 2021 and 2022, correspondingly. The mean days for duration of flowering was 15.35 in 2021 and 14.14 days for 2022.

Table 4.3.2 Flower characters of different plum genotypes

Genotypes	Date of opening of last flower		Duration of flowering (days)		Flower Diameter (mm)		
	2021	2022	2021	2022	2021	2022	Pooled
EC-382826	29th March	22nd March	17	16	18.51	21.46	19.98
EC-393740	3rdApril	28th March	18	17	21.85	25.34	23.59
EC-552696	19th March	14th March	10	11	15.81	18.75	17.28
EC-513684	1st April	20th March	18	16	16.55	15.43	15.99
Frontier	14th March	10th March	11	10	20.42	19.75	20.08
IC-555314	25th March	19th March	15	14	16.85	16.85	16.85
IC-555355	9th March	3rd March	15	14	17.84	17.63	17.74
Kala Amritsari	10th March	3rd March	14	13	19.38	20.82	20.10
EC-538999	4th April	28th March	17	16	16.25	16.10	16.17
IC-558067	25th March	19th March	16	15	18.65	20.23	19.44
Methley	15th March	7th March	14	14	19.36	17.64	18.50
Red Beaut	5th March	22nd February	17	11	21.01	23.61	22.31
Shiro	4th April	27th March	18	17	17.61	15.98	16.79
EC-552693	2nd April	27th March	15	14	17.34	17.56	17.45
Mean	-	-	15.35	14.14	18.38	19.08	-
$CD_{0.05}$	-	-	-	-	0.77	0.27	0.38
SE ± (m)	-	-	-	-	0.26	0.09	0.13
SD	-	-	-	-	0.37	0.13	0.18

4.3.5 Flower diameter (mm)

Flower diameter was recorded maximum in EC-393740 (21.85 mm and 25.34 mm) for the two consecutive years. While, it was recorded minimum in EC-552696 (15.81 mm) in 2021 and EC-513684 (15.43 mm) in 2022.

According to the Table 4.3.2 pooled flower diameter was logged maximum in EC-393740 (23.59 mm) and minimum in EC-513684 (15.99 mm).

4.3.6 Sepal shape

Sepal shape for the years 2021 and 2022 were identical (Table 4.3.3) in EC-382826, EC-552696, Kala Amritsari and Shiro were medium ovate in shape; EC-393740, Frontier and Methley were observed to be triangular in shape; EC-513684, IC-555355, IC-558067 and EC-552693 were broad ovate; IC-555314 was narrow elliptic while, EC-538999 and Red Beaut were medium elliptic.

Table 4.3.3 Flower characters of different plum genotypes

Genotypes	Sepal Shape		Petal Length (mm)			Flower arrangement of petals	
	2021	2022	2021	2022	Pooled	2021	2022
EC-382826	Medium ovate	Medium ovate	10.62	11.37	10.99	Touching	Touching
EC-393740	Triangular	Triangular	12.86	13.31	13.08	Touching	Touching
EC-552696	Medium ovate	Medium ovate	7.37	9.15	8.26	Free	Free
EC-513684	Broad Ovate	Broad Ovate	10.84	11.33	11.08	Free	Free
Frontier	Triangular	Triangular	11.14	12.55	11.85	Touching	Touching
IC-555314	Narrow elliptic	Narrow elliptic	9.67	9.40	9.53	Free	Free
IC-555355	Broad Ovate	Broad Ovate	10.72	10.36	10.54	Overlapping	Overlapping
Kala Amritsari	Medium ovate	Medium ovate	8.27	8.83	8.55	Free	Free
EC-538999	Medium Elliptic	Medium Elliptic	10.03	10.92	10.48	Overlapping	Overlapping
IC-558067	Broad Ovate	Broad Ovate	9.17	10.02	9.60	Overlapping	Overlapping
Methley	Triangular	Triangular	9.95	11.64	10.79	Overlapping	Overlapping
Red Beaut	Medium Elliptic	Medium Elliptic	7.54	8.26	7.90	Free	Free
Shiro	Medium ovate	Medium ovate	8.48	9.82	9.15	Overlapping	Overlapping
EC-552693	Broad Ovate	Broad Ovate	10.57	9.61	10.09	Free	Free
Mean	-	-	9.80	10.46	-	-	-
$CD_{0.05}$	-	-	0.19	0.24	0.14	-	-
SE ± (m)	-	-	0.06	0.084	0.04	-	-
SD	-	-	0.09	0.11	0.06		

4.3.7 Petal length (mm)

Length of the petal was maximum in EC-393740 (12.86 mm, 13.31 mm) for both the consecutive years and minimum in EC-552696 (7.37 mm) in 2021 and Red Beaut (8.26 mm) in 2022.

The pooled data in Table 4.3.3 indicates the maximum pooled petal length in EC-393740 (13.08 mm) and minimum in Red Beaut (7.90 mm).

4.3.8 Flower arrangement of petals

Flower arrangement of petals for the years 2021 and 2022 was found to be comparable. Three varieties had touching flower arrangement *viz.,* EC-382826, EC-393740 and Frontier; six varieties had free flower arrangement *viz.,* EC-552696, EC-513684, IC-555314, Kala Amritsari, Red Beaut and EC-552693 and five cultivars had overlapping arrangement *viz.,* IC-555355, EC-538999, IC-558067, Methley and Shiro.

4.3.9 Petal shape

Petal shape for five accessions was contemplated obovate *viz.,* EC-382826, IC-555314, IC-555355, EC-538999 and Red Beaut; two accessions had oblate shape *viz.,* EC-393740 and Shiro; three were circular *viz.,* EC-552696, Frontier and Methley whereas, four were elliptic in shape *viz.,* EC-513684, Kala Amritsari, IC-558067 and EC-552693 genotypes.

4.3.10 Pedicel length (mm)

The length of the pedicel was recorded maximum in Methley (17.14 mm) for 2021 and in Kala Amritsari (19.79 mm) for 2022. The length of the pedicel was chronicled minimum in EC-513684 (10.22 mm) in 2021 and (9.67 mm) for 2022.

According to Table 4.3.4 pooled pedicel length was catalogued maximum in Kala Amritsari (18.34 mm) and minimum in EC-513684 (9.94 mm).

4.3.11 Stigma: position in relation to anthers

Position of stigma in relation to anthers was found similar in the years 2021 and 2022. The stigma was noted below the anthers in six accessions *viz.,* EC-382826, EC-552696, EC-513684, Frontier, Kala Amritsari and EC-552693; three accessions had stigma above the

anthers *viz.,* EC-393740, IC-558067 and Shiro and five accessions *viz.,* IC-555314, IC-555355, EC-538999, Methley and Red Beaut had position of stigma on the same level as the anthers.

Blazek and Pistekova (2009) carried out research in the Czech Republic. The first flowers appeared in the cultivars Topfirst and Topstar Plus (14th April) but the last flowering was espied in cultivars Katinka and Ruth Gerstetter (1st May). Son (2010) scrutinized the mean Days from Full Bloom (DOFB) was earliest in Black Diamond, Black Beauty and Oblinaja than the other cultivars. The last flowering cultivars were President, October Sun and T.C. Sun whereas, according to the present studies, days from full bloom was earliest in cultivar Red Beaut, followed by IC-555355 and Kala Amritsari while, last to flower were EC-538999, EC-552693 and Shiro. Kumar (2016) also inscribed that flowering initiated from February and continued till mid-March. Red Beaut (13th February) was the first to flower whereas, Friar (12th March) was the last to flower. Whereas, Kour (2018) studied the commencement of flowering at different times, Kala Noki (3rd February) was the earliest to flower whereas, Alu Bokhara Amritsari (23rd February) was the last to flower.

Table 4.3.4 Flower characters of different plum genotypes

Genotypes	Petal Shape		Pedicel Length (mm)			Stigma: position in relation to anthers	
	2021	2022	2021	2022	Pooled	2021	2022
EC-382826	Obovate	Obovate	14.89	13.48	14.18	Below	Below
EC-393740	Oblate	Oblate	13.72	15.27	14.50	Above	Above
EC-552696	Circular	Circular	14.98	12.85	13.19	Below	Below
EC-513684	Elliptic	Elliptic	10.22	9.67	9.94	Below	Below
Frontier	Circular	Circular	12.19	14.56	13.37	Below	Below
IC-555314	Obovate	Obovate	13.85	12.72	13.28	Same level	Same level
IC-555355	Obovate	Obovate	15.54	16.72	16.13	Same level	Same level
Kala Amritsari	Elliptic	Elliptic	16.89	19.79	18.34	Below	Below
EC-538999	Obovate	Obovate	12.49	11.88	12.18	Same level	Same level
IC-558067	Elliptic	Elliptic	13.19	15.77	14.48	Above	Above
Methley	Circular	Circular	17.14	18.53	17.83	Same level	Same level
Red Beaut	Obovate	Obovate	11.73	11.39	11.56	Same level	Same level
Shiro	Oblate	Oblate	13.33	13.58	13.45	Above	Above
EC-552693	Elliptic	Elliptic	15.93	17.45	16.69	Below	Below
Mean	-	-	14.00	14.54	-	-	-
$CD_{0.05}$	-	-	0.12	0.20	0.11	-	-
SE ± (m)	-	-	0.04	0.07	0.04	-	-
SD	-	-	0.06	0.09	0.05	-	-

The mean duration of flowering days was 15.35 days in 2021 and 14.14 days in 2022, the maximum and minimum duration observed were 10-18 days in 2021 and 10-17 days in 2022, subsequently. Thakur (2012) and Verma (2016) observed homogeneous results where the maximum duration of flowering was 15.37 and 15 days, correspondingly.

Kwon *et al.* (2018) studied three types of flower petal arrangement but with different accessions which was similar to this study *i.e.,* free, touching and overlapping. They also studied different petal shapes *viz.,* elliptic, circular, oblate and obovate which were indistinguishable with the present evaluation conducted. Sharma (1999) illustrated the maximum breadth of sepals in Frontier (0.44 cm) and minimum in Kanto-5 (0.23 cm). In the present study the maximum flower diameter was diarized in EC-393740 (13.08 mm) and minimum in Red Beaut (7.90 mm). Ganji *et al.* (2011) and Kown (2018) observed the position of the stigma in relation to the anthers was found to be: on the same level, above and below which was alike to the present evaluation but the accessions used for the studies were variable.

4.4 POLLEN STUDIES

4.4.1 Pollen viability

Pollen viability recorded in different Japanese plum genotypes are presented in the Table 4.4.1.

4.4.1.1 Acetocarmine solution (2%) test

The maximum pollen viability with acetocarmine solution was recorded in EC-382826 (98.97 %) which was at par with Frontier (98.94 %), IC-558067 (98.09 %), Methley (97.63 %), Red Beaut (98.18 %) and EC-552693 (97.79 %). The minimum pollen viability was found in EC-538999 (91.11 %). The mean pollen viability was 95.55 per cent.

4.4.1.2 Erythrosine B solution (0.1 %) test

According to Erythrosine B (0.1 %) solution test the maximum pollen viability was counted in accession IC-558067 (71.46 %) which was at par with EC-382826 (71.37 %) and Red Beaut (71.18 %) whereas, minimum pollen viability was chronicled in EC-513684 (33.47 %). The mean pollen viability was recorded 59.10 per cent.

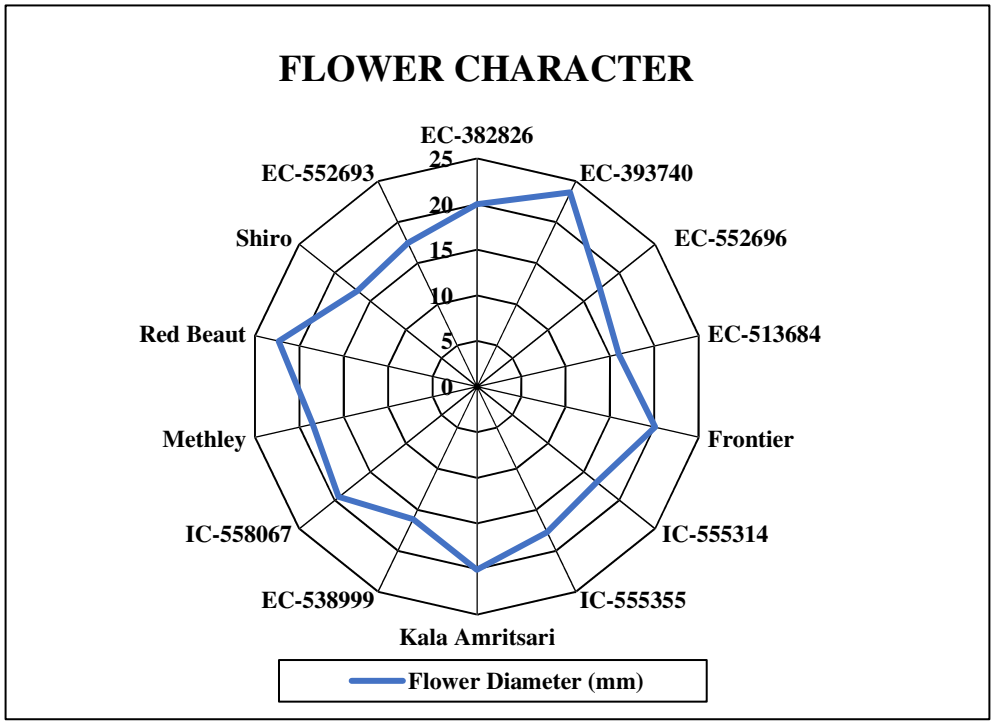


Figure 8: Extent of variation in flower diameter of different plum accessions

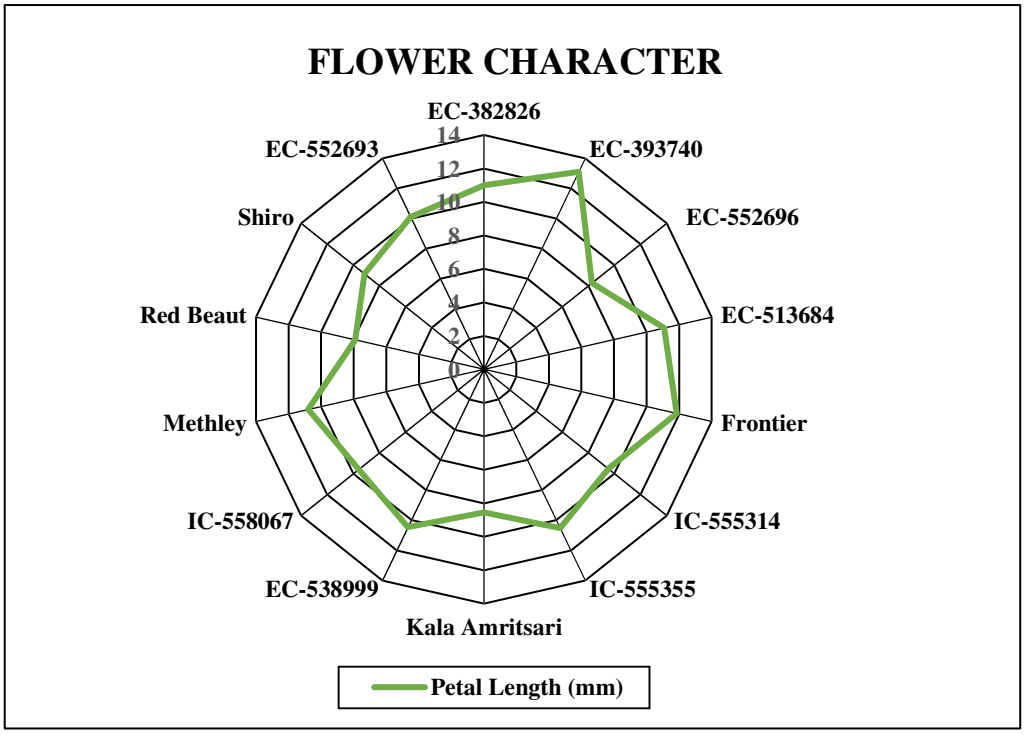


Figure 9: Extent of variation in petal length of different plum accessions

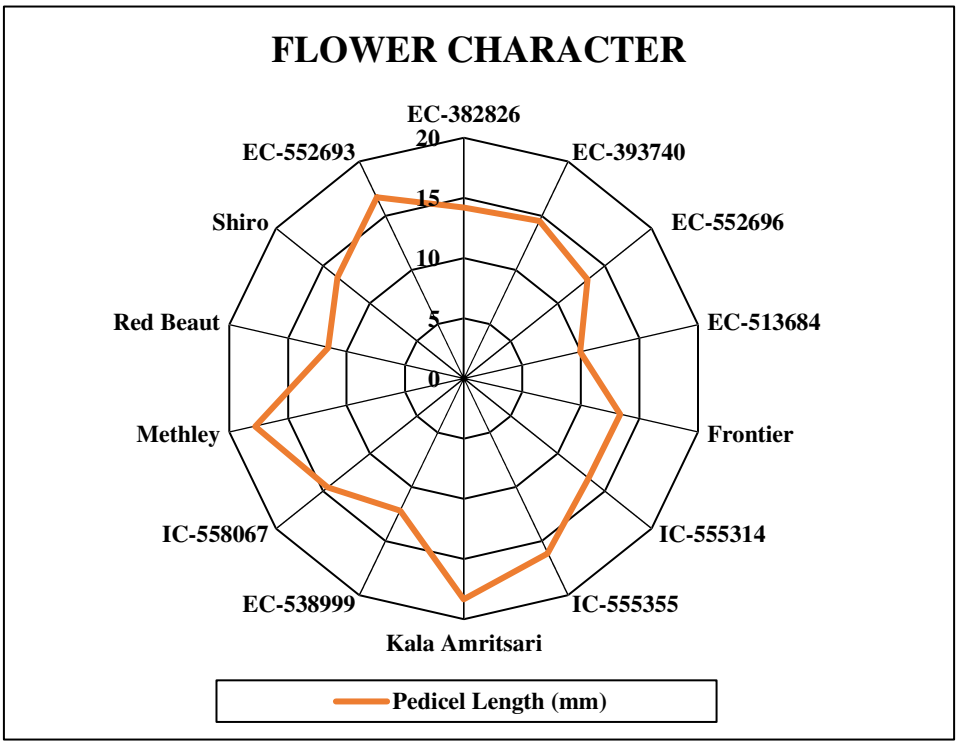


Figure 10: Extent of variation in pedicel length of different plum accessions

4.4.2 *In vitro* pollen germination test

In vitro pollen germination test with 10 per cent sucrose solution was found maximum in EC-382826 (81.69 %) which was at par with Red Beaut (80.84 %). The minimum pollen germination was recorded in IC-555314 (26.06 %). The average pollen germinability with 10 per cent sucrose solution was 58.96 per cent. Pollen germination with 15 per cent sucrose solution was recorded maximum in Frontier (90.53 %) and minimum in EC-513684 (29.11 %) whereas, mean germinability was 60.11 per cent.

Table 4.4.1 Pollen viability and *In vitro* pollen germination of different plum genotypes

Genotypes	Pollen viability (%)		Pollen germination (%)	
	Acetocarmine solution (2 %) test*	Erythrosine B solution (0.1 %) test**	Sucrose (10 %) **	Sucrose (15 %) **
EC-382826	98.97 (9.99)	71.37 (57.65)	81.69 (64.67)	87.51 (69.31)
EC-393740	93.20 (9.70)	64.49 (53.41)	64.79 (53.58)	74.47 (59.63)
EC-552696	95.59 (9.82)	55.46 (48.11)	34.94 (36.20)	48.85 (44.32)
EC-513684	90.82 (9.58)	33.47 (35.33)	43.15 (41.04)	29.11 (32.64)
Frontier	98.94 (9.99)	51.86 (46.04)	76.31 (60.87)	90.53 (72.06)
IC-555314	94.36 (9.76)	58.17 (49.68)	26.06 (30.66)	55.62 (48.21)
IC-555355	96.59 (9.87)	67.45 (55.19)	68.13 (55.61)	41.31 (39.98)
Kala Amritsari	93.48 (9.72)	57.99 (49.58)	57.40 (49.24)	64.87 (53.63)
EC-538999	91.11 (9.59)	63.40 (52.75)	47.97 (43.80)	40.65 (39.59)
IC-558067	98.09 (9.95)	71.46 (57.75)	77.80 (61.86)	68.50 (55.83)
Methley	97.63 (9.93)	54.72 (47.69)	51.58 (45.88)	45.75 (42.54)
Red Beaut	98.18 (9.95)	71.18 (57.51)	80.84 (55.86)	82.95 (65.58)
Shiro	93.93 (9.74)	65.23 (53.85)	68.54 (55.86)	75.24 (60.13)
EC-552693	97.79 (9.88)	41.12 (39.85)	46.29 (42.85)	36.27 (37.01)
Mean	95.55 (09.82)	59.10 (50.31)	58.96 (50.44)	60.11 (51.46)
$CD_{0.05}$	1.76 (0.09)	3.21 (1.91)	3.05 (1.92)	2.55 (1.67)
SE ± (m)	0.60 (0.03)	1.10 (0.65)	1.04 (0.65)	0.87 (0.57)
SD	0.85 (0.04)	1.55 (0.92)	1.47 (0.93)	1.23 (0.80)

Figures in parathesis are square root (*) and arc sign (**) transformed

Mohapatra (1994) concluded that the pollen viability in Black Chamba was 79.01 per cent and Alu Bokhara was 94.92 per cent with the acetocarmine stain test. Thakur (2012) reported that the pollen viability in acetocarmine (1 %) solution ranged from 72.60 per cent to 84.60 per cent. Dongariyal *et al.* (2020) delineated the cultivar Satluj Purple exhibited high pollen viability (90.45 %) as compared to Kala Amritsari (81.32 %). However, in the present

study the acetocarmine solution (1 %) test viability ranged from 91.11 to 98.97 per cent while, in the erythrosine B solution (0.1 %) test viability diverged between 33.47 to 71.46 per cent.

Tandon (2006) conducted a study and observed the *in vitro* pollen germination was maximum in Satluj Purple (76.20 %) and minimum in Black Amber (64.85 %). Sharafi (2011) conducted an experiment in which highest pollen germination (96.30 %) was recorded in Pl_3 and the least pollen germination (48.90 %) was observed in Pl_4. Sharafi *et al.* (2013) evaluated ten cultivars of plum, the highest pollen germination was counted in Gojah soltan (97.10 %) and the least in Shalyl alcha (55.80 %).

Thakur *et al.* (2014) observed that the highest pollen germination in Santa Rosa (66.57 %). Kwon *et al.* (2017) studied that the pollen germination percentage ranged between 4.99 per cent and 18.74 per cent in 2014 and between 0.88 per cent and 14.12 per cent in 2016. In the concurrent study, *in vitro* pollen germination ranged between 26.06 to 81.69 per cent with 10 per cent sucrose solution while, with 15 per cent sucrose solution it ranged between 29.11 to 90.53 per cent. The variation in pollen germination percentage so observed may be attributed due to genotypic constitution of the pollen in different accessions.

4.5 FRUIT CHARACTERS

4.5.1 Date of Harvest

Date of harvest (Table 4.5.1) was recorded earliest in Red Beaut (6th June), ensued by IC-555355 (9th June) and Kala Amritsari (10th June), the last accession to harvest was EC-538999 (7th July) ensued by EC-513684 (4th July), EC-393740 and IC-558067 on (3rd July) and Shiro on (2nd July) in the year 2021. Whereas, for the year 2022 the earliest cultivar to harvest was Kala Amritsari on (22nd May), ensued by Red Beaut (26th May). The last accession to harvest was EC-538999 (30th June) followed by EC-393740 (27th June), Shiro (24th June) and EC-552693 (23th June).

4.5.2 Length of Stalk (mm)

Stalk length was recorded maximum in IC-555355 (13.71 mm) and (14.23 mm) in two consecutive years. The minimum was inscribed in EC-552696 (6.39 mm) in 2021 and IC-558067 (6.69 mm) in 2022.

The pooled length of stalk (Table 4.5.1) was logged maximum in IC-555355 (13.97 mm) which was at par with Shiro (12.44 mm) and minimum in EC-552696 (6.75 mm).

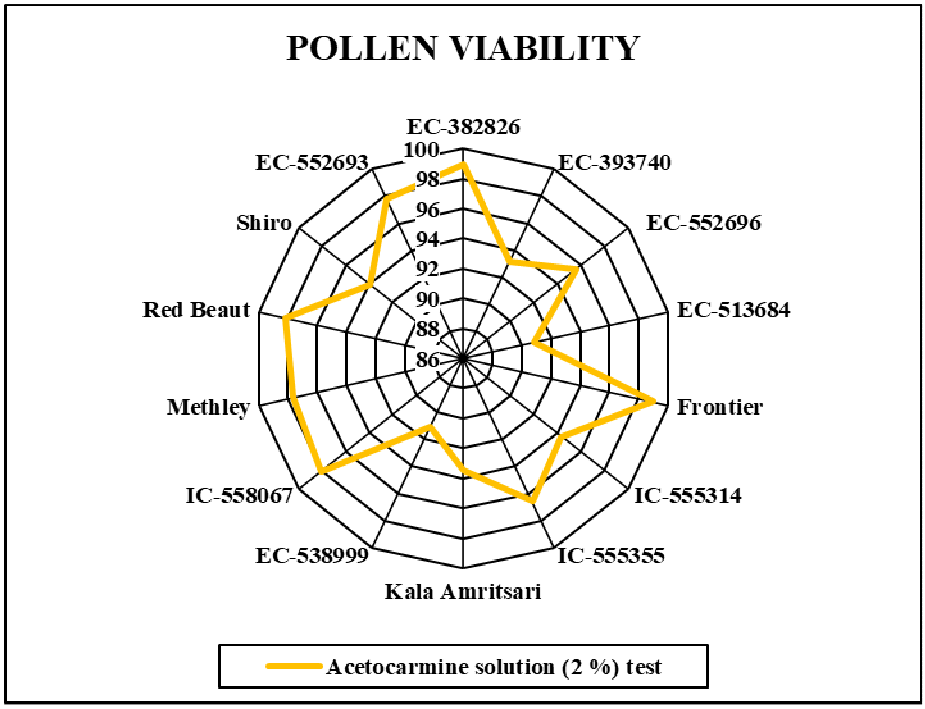


Figure 11: Extent of variation in pollen viability of different plum accessions

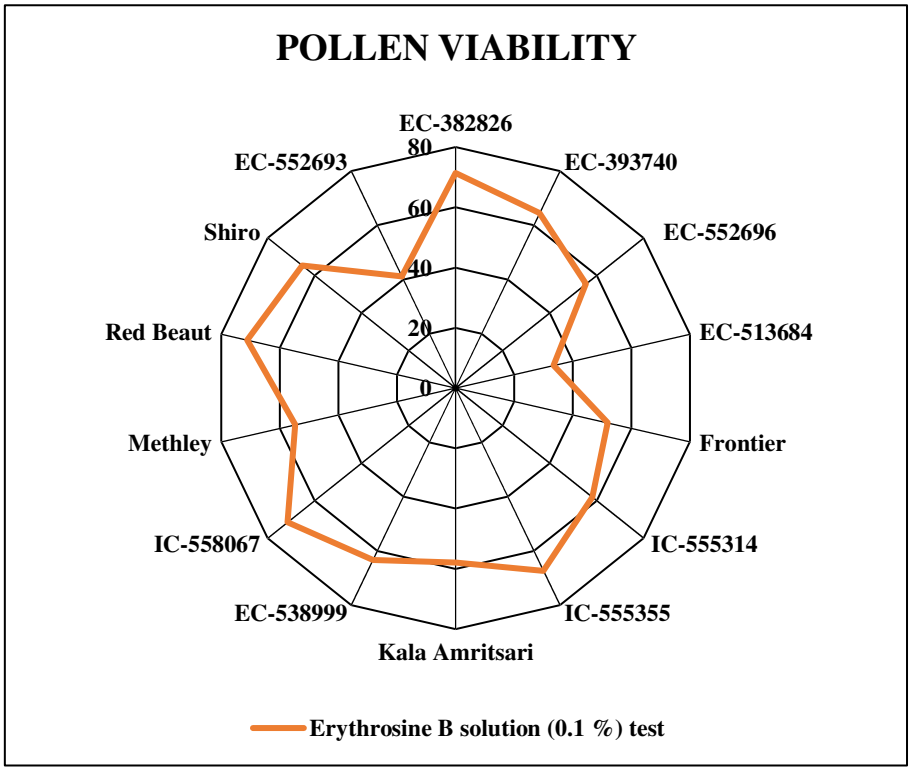


Figure 12: Extent of variation in pollen viability of different plum accessions

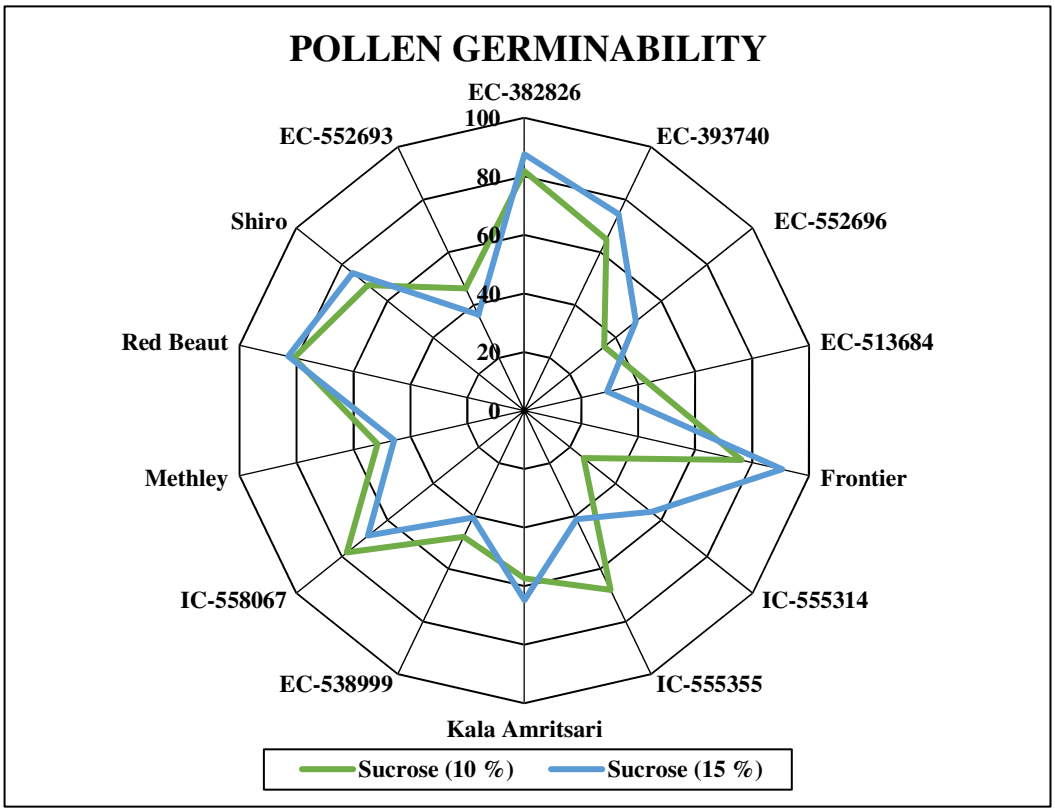
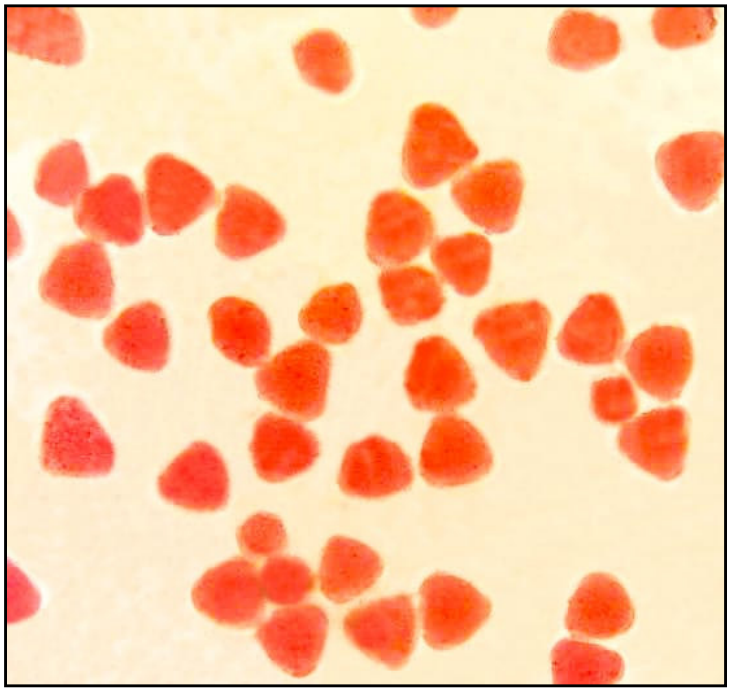
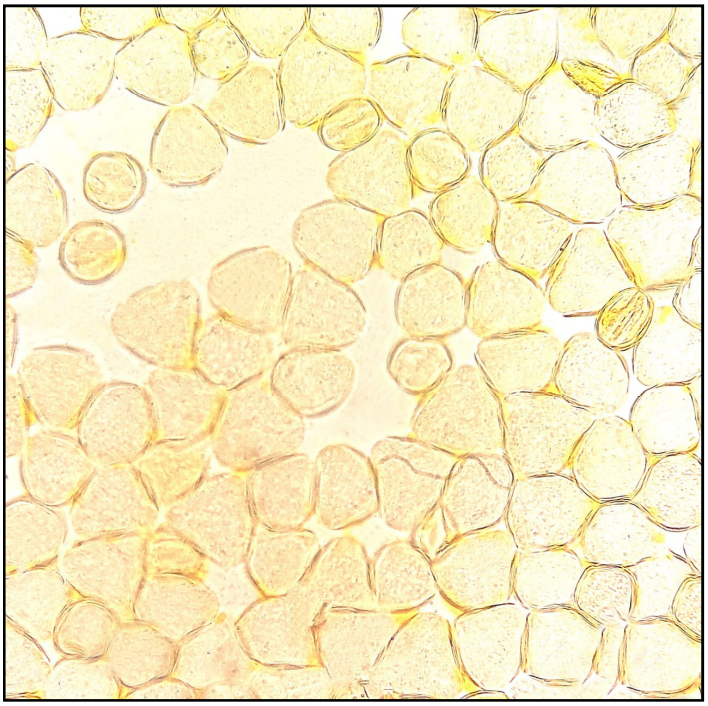


Figure 13: Extent of variation in pollen germination of different plum accessions



Acetocarmine solution (2 %) test



Erythrosine B solution (0.1 %) test

Staining test for pollen viability

Plate 1 (a): Pollen viability in Japanese plum accessions

In vitro pollen germination

Plate 1 (b): Pollen germinability in Japanese plum accessions

Table 4.5.1 Fruit characters of different plum genotypes

Genotypes	Date of Harvest		Length of Stalk (mm)		
	2021	2022	2021	2022	Pooled
EC-382826	26th June	18th June	9.97	9.51	9.74
EC-393740	3rd July	27th June	8.64	7.58	8.11
EC-552696	27th June	22nd June	6.39	7.11	6.75
EC-513684	4th July	20th June	8.28	9.61	8.95
Frontier	22nd June	14th June	7.64	8.51	8.08
IC-555314	30th June	20th June	10.22	9.79	10.01
IC-555355	9th June	2nd June	13.71	14.23	13.97
Kala Amritsari	10th June	22nd May	12.67	11.88	12.27
EC-538999	7th July	30th June	8.38	8.88	8.63
IC-558067	3rd July	21st June	6.95	6.69	6.82
Methley	13th June	04th June	11.62	11.51	11.57
Red Beaut	6th June	26th May	8.69	8.05	8.37
Shiro	2nd July	24th June	12.93	11.95	12.44
EC-552693	29thJune	23rd June	9.01	9.60	9.30
Mean	-	-	9.65	9.63	-
$CD_{0.05}$	-	-	2.020	1.63	1.60
SE ± (m)	-	-	0.691	0.56	0.54
SD	-	-	0.977	0.79	0.77

4.5.3 Fruit Weight (g)

The maximum fruit weight was recorded in Red Beaut (65.83 g and 65.43 g) in the two consecutive years. The minimum fruit weight was obtained in Kala Amritsari (15.98 g and 15.25 g) in 2021 and 2022.

In the Table 4.5.2 pooled fruit weight was found maximum in Red Beaut (65.18 g) which was at par with EC-393740 (63.76 g) and minimum was obtained in Kala Amritsari (15.62 g).

4.5.4 Fruit Height (mm)

The maximum fruit height was catalogued in EC-538999 (51.58 mm and 53.13 mm) in the two successive years. The minimum fruit height was taped in Kala Amritsari (27.79 mm and 27.61 mm) for the years 2021 and 2022.

The maximum pooled fruit height was charted in EC-538999 (52.35 mm) and the minimum was documented in Kala Amritsari (27.70 mm).

Table 4.5.2 Fruit characters of different plum genotypes

Genotypes	Fruit Weight (g)			Fruit Height (mm)		
	2021	2022	Pooled	2021	2022	Pooled
EC-382826	56.60	58.66	57.63	45.45	46.50	45.97
EC-393740	65.53	62.00	63.76	49.55	48.50	49.02
EC-552696	60.33	57.59	58.96	42.49	40.50	41.49
EC-513684	40.90	42.62	41.76	45.09	46.17	45.63
Frontier	61.06	58.20	59.63	42.77	40.52	41.64
IC-555314	41.42	43.68	42.55	39.10	40.57	39.83
IC-555355	17.33	19.61	18.47	28.38	29.02	28.70
Kala Amritsari	15.98	15.25	15.62	27.79	27.61	27.70
EC-538999	59.16	63.54	61.35	51.58	53.13	52.35
IC-558067	51.26	53.36	52.31	40.89	42.47	41.68
Methley	22.01	25.14	23.57	31.49	33.50	32.49
Red Beaut	65.83	64.53	65.18	48.57	47.61	48.09
Shiro	39.80	41.88	40.84	38.43	40.87	39.65
EC-552693	49.43	48.87	49.15	39.68	38.81	39.25
Mean	46.18	46.78	-	40.80	41.12	-
$CD_{0.05}$	5.12	1.93	2.65	2.01	1.68	1.42
SE ± (m)	1.75	0.66	0.90	0.68	0.57	0.48
SD	2.47	0.93	1.28	0.97	0.81	0.69

4.5.5 Fruit Width (mm)

For both the years 2021 and 2022 maximum fruit width was chronicled in Red Beaut (54.65 mm, 51.53 mm), correspondingly. However, minimum fruit width was documented in IC-555355 (28.11 mm and 28.70 mm) in the years 2021 and 2022, subsequently.

Maximum pooled fruit width was recorded in Red Beaut (53.09 mm) and minimum in IC-555355 (28.40 mm).

4.5.6 Fruit Volume (cm^3)

The fruit volume was found maximum in Red Beaut (68.95 cm^3 and 67.30 cm^3) in the years 2021 and 2022, subsequently. The minimum fruit volume was chronicled in Kala Amritsari (18.63 cm^3) in 2021 and (17.74 cm^3) in 2022, correspondingly.

Red Beaut had the maximum pooled fruit volume (68.12 cm^3) which was at par with EC-393740 (66.60 cm^3) and the minimum was recorded in Kala Amritsari (18.19 cm^3).

4.5.7 Fruit Shape

The shape of different plum fruits was found identical in both the years. One assession was obovate in shape *i.e.,* EC-552693; five germplasms were circular in shape *viz..,* EC-382826, IC-555355, Kala Amritsari, Methley and Shiro; three accessions were oblate *viz.,* EC-393740, Frontier and IC-558067; two accessions had obcordate shape *viz.,* EC-538999 and Red Beaut; two were elliptic *viz.,* EC-513684 and EC-555314 and one accession was oblong *viz.,* EC-552696.

Table 4.5.3 Fruit characters of different plum genotypes

Genotypes	Fruit Width (mm)			Fruit Volume (cm³)			Fruit Shape	
	2021	2022	Pooled	2021	2022	Pooled	2021	2022
EC-382826	46.30	48.25	47.27	57.76	60.44	59.10	Circular	Circular
EC-393740	52.87	51.10	51.98	67.65	65.55	66.60	Oblate	Oblate
EC-552696	50.07	48.52	49.29	62.74	59.30	61.02	Oblong	Oblong
EC-513684	37.34	40.65	38.99	41.32	44.81	43.06	Elliptic	Elliptic
Frontier	47.48	46.67	47.07	63.04	61.50	62.27	Oblate	Oblate
IC-555314	34.70	35.39	35.05	43.57	46.60	45.08	Elliptic	Elliptic
IC-555355	28.11	28.70	28.40	19.13	21.69	20.41	Circular	Circular
Kala Amritsari	30.09	31.39	30.74	18.63	17.74	18.19	Circular	Circular
EC-538999	48.50	50.67	49.59	61.91	64.91	63.41	Obcordate	Obcordate
IC-558067	45.62	49.71	47.66	52.01	55.68	53.84	Oblate	Oblate
Methley	29.55	31.53	30.54	25.84	27.17	26.50	Circular	Circular
Red Beaut	54.65	51.53	53.09	68.95	67.30	68.12	Obcordate	Obcordate
Shiro	35.47	37.61	36.54	41.91	44.36	43.13	Circular	Circular
EC-552693	43.42	41.58	42.50	50.84	51.45	51.14	Obovate	Obovate
Mean	41.72	42.37	-	48.23	49.17	-	-	-
$CD_{0.05}$	2.03	1.96	1.36	5.75	1.83	3.00	-	-
SE ± (m)	0.69	0.67	0.46	1.96	0.62	1.02	-	-
SD	0.98	0.95	0.65	2.78	0.88	1.45	-	-

4.5.8 Fruit Symmetry

The symmetry of the fruit was strongly asymmetric for EC-552696 and Red Beaut; moderately asymmetric for EC-393740, IC-555314, Frontier and IC-558067; symmetric or slightly asymmetric in EC-513684, EC-538999 and EC-552693 and symmetric in EC-382826, IC-555355, Kala Amritsari, Methley and Shiro for the years 2021 and 2022.

4.5.9 Fruit: Shape of Base

The fruit shape of base was homogeneous for both the years. The shape of base was pointed for EC-538999, Red Beaut And EC-552693; truncate shape of base for ten cultivars *viz.,* EC-382826, Frontier, EC-552696, EC-513684, IC-555314, IC-555355, Kala Amritsari, IC-558067, Methley and Shiro whereas, depressed for EC-393740.

4.5.10 Fruit: Shape of Apex

The shape of apex for different plum fruits was depressed, round and truncate. Seven genotypes had depressed shape of apex *viz.,* EC-382826, EC-393740, EC-552696, EC-513684, Frontier, IC-555314 and EC-552693; three were round *viz.,* EC-538999, Red Beaut and Shiro whereas, four plums had truncate shape *viz.,* IC-555355, Kala Amritsari, IC-558067 and Methley for both the consecutive years.

Table 4.5.4 Fruit characters of different plum genotypes

Genotypes	Fruit Symmetry		Fruit: Shape of Base		Fruit: Shape of Apex	
	2021	2022	2021	2022	2021	2022
EC-382826	Symmetric	Symmetric	Truncate	Truncate	Depressed	Depressed
EC-393740	Moderately asymmetric	Moderately asymmetric	Depressed	Depressed	Depressed	Depressed
EC-552696	Strongly asymmetric	Strongly asymmetric	Truncate	Truncate	Depressed	Depressed
EC-513684	Symmetric or slightly asymmetric	Symmetric or slightly asymmetric	Truncate	Truncate	Depressed	Depressed
Frontier	Moderately asymmetric	Moderately asymmetric	Truncate	Truncate	Depressed	Depressed
IC-555314	Moderately asymmetric	Moderately asymmetric	Truncate	Truncate	Depressed	Depressed
IC-555355	Symmetric	Symmetric	Truncate	Truncate	Truncate	Truncate
Kala Amritsari	Symmetric	Symmetric	Truncate	Truncate	Truncate	Truncate
EC-538999	Symmetric or slightly asymmetric	Symmetric or slightly asymmetric	Pointed	Pointed	Rounded	Rounded
IC-558067	Moderately asymmetric	Moderately asymmetric	Truncate	Truncate	Truncate	Truncate
Methley	Symmetric	Symmetric	Truncate	Truncate	Truncate	Truncate
Red Beaut	Strongly asymmetric	Strongly asymmetric	Pointed	Pointed	Rounded	Rounded
Shiro	Symmetric	Symmetric	Truncate	Truncate	Rounded	Rounded
EC-552693	Symmetric or slightly asymmetric	Symmetric or slightly asymmetric	Pointed	Pointed	Depressed	Depressed

4.5.11 Fruit: Depth of Stalk Cavity

Depth of stalk cavity in different plum genotypes over the span of two years was found indistinguishable. EC-393740, EC-513684 and EC-55269 had deep stalk cavity whereas, EC-382826, EC-552696, Frontier, IC-558067 and Red Beaut possessed medium stalk cavity and IC-555314, IC-555355, Kala Amritsari, Methley, EC-538999 and Shiro endured shallow depth of stalk cavity.

4.5.12 Fruit: Width of Stalk Cavity

Width of stalk cavity for 2021 and 2022 was espied broad in six accessions *viz.,* EC-382826, EC-393740, EC-552696, Frontier, IC-558067 and Red Beaut; two accessions possessed medium width of stalk cavity EC-513684 and EC-552693 and six had narrow width of stalk cavity *viz.,* IC-555314, IC-555355, Kala Amritsari, EC-538999, Methley and Shiro.

4.5.13 Fruit: Depth of Suture

Fruit depth of suture for 2021 and 2022 were procured to be homogeneous. Four accessions attained deep suture *viz.,* EC-382826, Frontier, EC-538999 and IC-558067; medium suture was possessed by EC-393740, EC-552696, EC-513684, IC-555314, Red Beaut and EC-552693 while, it was absent in IC-555355, Kala Amritsari, Methley and Shiro.

Table 4.5.5 Fruit characters of different plum genotypes

Genotypes	Fruit: Depth of Stalk Cavity		Fruit: Width of Stalk Cavity		Fruit: Depth of Suture	
	2021	2022	2021	2022	2021	2022
EC-382826	Medium	Medium	Broad	Broad	Deep	Deep
EC-393740	Deep	Deep	Broad	Broad	Medium	Medium
EC-552696	Medium	Medium	Broad	Broad	Medium	Medium
EC-513684	Deep	Deep	Medium	Medium	Medium	Medium
Frontier	Medium	Medium	Broad	Broad	Deep	Deep
IC-555314	Shallow	Shallow	Narrow	Narrow	Medium	Medium
IC-555355	Shallow	Shallow	Narrow	Narrow	Absent	Absent
Kala Amritsari	Shallow	Shallow	Narrow	Narrow	Absent	Absent
EC-538999	Shallow	Shallow	Narrow	Narrow	Deep	Deep
IC-558067	Medium	Medium	Broad	Broad	Deep	Deep
Methley	Shallow	Shallow	Narrow	Narrow	Absent	Absent
Red Beaut	Medium	Medium	Broad	Broad	Medium	Medium
Shiro	Shallow	Shallow	Narrow	Narrow	Absent	Absent
EC-552693	Deep	Deep	Medium	Medium	Medium	Medium

4.5.14 Fruit: Colour of Peel

The colour of peel for the years 2021 and 2022 were comparable. The accessions EC-382826, EC-513684, Frontier, IC-555314, IC-558067, Methley and Red Beaut were perceived to be dark red in colour; EC-393740, EC-552696, Kala Amritsari, EC-538999 and EC-552693 were medium red, IC-555355 was purple in colour and Shiro was yellowish green.

4.5.15 Fruit: Pattern of Over Colour

Pattern of over colour in different plum fruits were found as flecks only in three genotypes *viz.,* EC-382826, Frontier and EC-552693; mottled pattern in three genotypes *viz.,* EC-393740, EC-552696 and EC-538999 and solid flesh was found in the remaining eight accessions *viz.,* EC-513684, IC-555314*,* IC-555355, Kala Amritsari, IC-558067, Methley, Red Beaut and Shiro in the consecutive years of evaluation.

4.5.16 Fruit: Bloom of Skin

The bloom of skin on fruits were observed identical for the years 2021 and 2022, respectively. It was observed very strong for IC-558067 and Methley; strong in EC-382826, EC-513684, IC-555355; medium in Frontier, IC-555314, Kala Amritsari, EC-538999, Red Beaut and Shiro; weak bloom in EC-393740 and EC-552696 whereas, very weak or absent in EC-552693.

Table 4.5.6 Fruit characters of different plum genotypes

Genotypes	Fruit: Colour of Peel		Fruit: Pattern of Over Colour		Fruit: Bloom of Skin	
	2021	2022	2021	2022	2021	2022
EC-382826	Dark red	Dark red	Flecks only	Flecks only	Strong	Strong
EC-393740	Medium red	Medium red	Mottled	Mottled	Weak	Weak
EC-552696	Medium red	Medium red	Mottled	Mottled	Weak	Weak
EC-513684	Dark red	Dark red	Solid flesh only	Solid flesh only	Strong	Strong
Frontier	Dark red	Dark red	Flecks only	Flecks only	Medium	Medium
IC-555314	Dark red	Dark red	Solid flesh only	Solid flesh only	Medium	Medium
IC-555355	Purple	Purple	Solid flesh only	Solid flesh only	Strong	Strong
Kala Amritsari	Medium red	Medium red	Solid flesh only	Solid flesh only	Medium	Medium
EC-538999	Medium red	Medium red	Mottled	Mottled	Medium	Medium
IC-558067	Dark red	Dark red	Solid flesh only	Solid flesh only	Very Strong	Very Strong
Methley	Dark red	Dark red	Solid flesh only	Solid flesh only	Very Strong	Very Strong
Red Beaut	Dark red	Dark red	Solid flesh only	Solid flesh only	Medium	Medium
Shiro	Yellowish green	Yellowish green	Solid flesh only	Solid flesh only	Medium	Medium
EC-552693	Medium red	Medium red	Flecks only	Flecks only	Very weak or absent	Very weak or absent

4.5.17 Fruit: Number of Lenticels

The number of lenticels (Table 4.5.7) were many in EC-393740, EC-552696, Frontier EC-538999 and EC-552693; medium in EC-382826, EC-513684, IC-555314 and IC-558067 whilst, few in IC-555355, Kala Amritsari, Methley, Red Beaut and Shiro for the years 2021 and 2022.

Table 4.5.7 Fruit characters of different plum genotypes

Genotypes	Fruit: Number of Lenticles		Fruit: Colour of Flesh		Fruit: Firmness (kg/cm^2)		
	2021	2022	2021	2022	2021	2022	Pooled
EC-382826	Medium	Medium	Red group (43-A)	Red group (43-A)	2.31	2.33	2.32
EC-393740	Many	Many	Yellow group (8-A)	Yellow group (8-A)	2.10	2.14	2.12
EC-552696	Many	Many	Yellow group (11-A)	Yellow group (11-A)	2.36	2.39	2.37
EC-513684	Medium	Medium	Red group (43-A)	Red group (43-A)	2.26	2.23	2.25
Frontier	Many	Many	Red group (41-B)	Red group (41-B)	2.08	2.04	2.06
IC-555314	Medium	Medium	Red group (43-A)	Red group (43-A)	2.03	2.03	2.03
IC-555355	Few	Few	Red group (47-A)	Red group (47-A)	1.83	1.84	1.83
Kala Amritsari	Few	Few	Yellow orange group (15-C)	Yellow orange group (15-C)	1.73	1.76	1.75
EC-538999	Many	Many	Yellow group (2-C)	Yellow group (2-C)	2.15	2.15	2.15
IC-558067	Medium	Medium	Red group (46-A)	Red group (46-A)	2.26	2.28	2.27
Methley	Few	Few	Orange group (34-C)	Orange group (34-C)	1.79	1.77	1.78
Red Beaut	Few	Few	Yellow group (10-A)	Yellow group (10-A)	2.11	2.13	2.12
Shiro	Few	Few	Yellow green group (145-C)	Yellow green group (145-C)	2.10	2.08	2.09
EC-552693	Many	Many	Red group (45-A)	Red group (45-A)	2.29	2.27	2.28
Mean	-	-	-	-	2.10	2.10	-
$CD_{0.05}$	-	-	-	-	0.17	0.17	0.13
SE ± (m)	-	-	-	-	0.05	0.05	0.04
SD	-	-	-	-	0.08	0.08	0.06

4.5.18 Fruit: Colour of Flesh

The colour of flesh over the span of two years was cognate. The accessions EC-382826, EC-513684 and IC-555314 had red colour of flesh (43-A), EC-393740 allied into yellow group (8-A), EC-552696 had yellow group (11-A), Frontier allied into red group (41-B), IC-555355 belonged to red group (47-A), Kala Amritsari into yellow orange group (15-C), EC-538999 belonged to yellow group (2-C), IC-558067 came under the group red (46-A), Methley into orange group (34-C), Red Beaut came under yellow group (10-A), Shiro under yellow green group (145-C) and EC-552693 under red group (45-A).

4.5.19 Fruit: Firmness

Fruit firmness was maximum in EC-552696 (2.36 kg/cm^2 and 2.39 kg/cm^2) in 2021 and 2022, subsequently. The minimum fruit firmness was docketed in Kala Amritsari (1.73 kg/cm^2 and 1.76 kg/cm^2) in the two consecutive years.

According to the pooled data in Table 4.5.7 maximum fruit firmness was inscribed in EC-552696 (2.37 kg/cm^2) which was at par with EC-382826 (2.32 kg/cm^2) and EC-552693 (2.28 kg/cm^2) and minimum was recorded in Kala Amritsari (1.75 kg/cm^2).

4.5.20 Fruit: Adherence of Stone to Flesh

The adherence of stone to the flesh was found adherent in four genotypes *viz.,* EC-552696, IC-555355, Kala Amritsari and Red Beaut; semi-adherent in six genotypes *viz.,* EC-393740, IC-555314, EC-538999, IC-558067, Shiro and EC-552693 and non-adherent for four cultivars *viz.,* EC-382826, EC-513684, Frontier and Methley for 2021 and 2022, respectively.

4.5.21 Fruit Set (%)

Fruit set was found maximum in Shiro (56.32 % and 55.80 %) in the years 2021 and 2022, respectively whereas, it was perceived minimum in EC-382826 and EC-552696 (40.23 % and 40.54 %) in the two subsequent years.

Maximum pooled fruit set was transcribed in Shiro (56.06 %) and minimum was logged in EC-552696 (41.38 %).

Table 4.5.8 Fruit characters of different plum genotypes

Genotypes	Fruit: Adherence of Stone to Flesh		Fruit Set (%)		
	2021	2022	2021	2022	Pooled
EC-382826	Non-adherent	Non-adherent	40.23	42.61	41.42
EC-393740	Semi-adherent	Semi-adherent	44.02	45.36	44.69
EC-552696	Adherent	Adherent	42.21	40.54	41.38
EC-513684	Non-adherent	Non-adherent	47.78	50.58	49.18
Frontier	Non-Adherent	Non-Adherent	45.62	43.69	44.65
IC-555314	Semi-adherent	Semi-adherent	46.27	48.43	47.35
IC-555355	Adherent	Adherent	51.95	52.52	52.23
Kala Amritsari	Adherent	Adherent	53.73	50.53	52.13
EC-538999	Semi-adherent	Semi-adherent	48.89	49.55	49.22
IC-558067	Semi-adherent	Semi-adherent	42.75	41.01	41.88
Methley	Non-adherent	Non-adherent	50.57	50.86	50.71
Red Beaut	Adherent	Adherent	45.78	47.52	46.65
Shiro	Semi-adherent	Semi-adherent	56.32	55.80	56.06
EC-552693	Semi-adherent	Semi-adherent	40.69	43.18	41.93
Mean	-	-	46.91	47.29	-
$CD_{0.05}$	-	-	3.77	2.31	2.33
SE ± (m)	-	-	1.29	0.79	0.80
SD	-	-	1.8	1.11	1.13

4.5.22 Fruit drop (%)

The fruit drop per cent in the year 2021 was recorded maximum in EC-552693 (48.76 %) and minimum in Shiro (31.57 %). The maximum fruit drop in 2022 was recorded in EC-552696 (46.65 %) and minimum in Shiro (32.23 %).

According to the pooled data (Table 4.5.9) maximum fruit drop was observed maximum in EC-552693 (46.49 %) which was at par with the accession EC-552696 (46.02 %) and minimum was remarked in Shiro (31.60 %).

4.5.23 Fruit retention (%)

The retention of the fruits was found maximum in Shiro (68.34 % and 67.50 %) for the years 2021 and 2022, respectively. Minimum fruit retention was noted in EC-552693 (51.15 %) in 2021 and EC-552696 (53.25 %) in 2022, subsequently.

According to the Table 4.5.9 maximum pooled fruit retention was inscribed in Shiro (67.92 %) and minimum pooled retention was taped in EC-552693 (53.13 %).

Table 4.5.9 Fruit characters of different plum genotypes

Genotypes	Fruit drop (%)			Fruit retention (%)		
	2021	2022	Pooled	2021	2022	Pooled
EC-382826	45.92	42.37	43.58	54.04	57.41	55.72
EC-393740	40.63	39.59	39.80	59.20	60.33	59.77
EC-552696	45.27	46.65	46.02	54.63	53.25	53.94
EC-513684	37.66	35.30	36.42	62.26	64.49	63.37
Frontier	42.62	44.96	43.76	57.37	55.01	56.19
IC-555314	45.75	42.43	43.34	54.17	57.56	55.87
IC-555355	33.37	35.81	34.75	66.47	64.10	65.29
Kala Amritsari	35.60	38.62	37.15	64.36	61.29	62.82
EC-538999	42.95	41.67	41.88	57.01	58.23	57.62
IC-558067	40.58	41.14	40.77	59.37	58.82	59.10
Methley	37.32	38.42	37.95	62.53	61.43	61.98
Red Beaut	41.40	39.31	39.86	58.51	60.46	59.48
Shiro	31.57	32.23	31.60	68.34	67.50	67.92
EC-552693	48.76	44.77	46.49	51.15	55.11	53.13
Mean	40.67	40.23	-	59.24	59.64	-
$CD_{0.05}$	1.62	1.60	1.36	1.80	1.78	1.30
SE ± (m)	0.55	0.54	0.46	0.61	0.61	0.44
SD	0.78	0.77	0.66	0.87	0.86	0.62

4.5.24 Number of days from full bloom to harvest

Number of days from full bloom to harvest was catalogued between 93 days in EC-552693 to 108 days in EC-552696 in the year 2021. The mean number of days in 2021 was recorded 99.85 days. Whilst, in the year 2022 the number of days from full bloom to harvest was recorded between 92 days in EC-552693 to 106 days in EC-552696. The mean days in 2022 was calculated as 97.07 days.

4.5.25 Fruit yield/kg

The yield of the fruit was maximum in Shiro (51.54 kg/tree and 50.73 kg/tree) for both the years of evaluation, respectively. The yield was espied minimum in EC-552696 (23.58 kg/tree and 21.84 kg/tree) for both the years 2021 and 2022.

According to the Table 4.5.10 maximum pooled yield was observed in Shiro (51.13 kg/tree) while minimum was filed in EC-552696 (22.71 kg/tree).

Table 4.5.10 Fruit characters of different plum genotypes

Genotypes	Number of days from full bloom to harvest		Fruit yield (kg/tree)		
	2021	2022	2021	2022	Pooled
EC-382826	96 days	94 days	41.44	43.51	42.47
EC-393740	99 days	98 days	46.38	46.70	46.54
EC-552696	108 days	106 days	23.58	21.84	22.71
EC-513684	101 days	99 days	39.73	42.61	41.17
Frontier	106 days	102 days	46.82	45.65	46.23
IC-555314	104 days	101 days	24.88	28.67	26.77
IC-555355	98 days	95 days	30.54	30.61	30.57
Kala Amritsari	97 days	84 days	26.47	24.61	25.54
EC-538999	99 days	98 days	28.50	32.73	30.61
IC-558067	101 days	100 days	44.26	44.36	44.31
Methley	99 days	96 days	32.52	29.91	31.22
Red Beaut	100 days	98 days	42.70	45.79	44.25
Shiro	97 days	96 days	51.54	50.73	51.13
EC-552693	93 days	92 days	25.50	30.59	28.05
Mean	99.85 days	97.07 days	36.06	37.02	-
$CD_{0.05}$	-	-	3.31	1.70	1.69
SE ± (m)	-	-	1.13	0.58	0.57
SD	-	-	1.60	0.82	0.81

Prakash *et al.* (2003) recorded the maximum fruit weight in Santa Rosa (25.74 g) and minimum in Kabul Green Gage (7.17 g) which was contrary to the contemporary evaluation conducted, where the fruit weight was maximum in Red Beaut (65.18 g) and minimum in Kala Amritsari (15.62 g). Nisar *et al.* (2015) evoked results, where the maximum weight of flesh was recorded in LY1 (64.00 g) and the minimum in SY3 (3.93 g). Latifikhah *et al.* (2017) studied the maximum fruit length in Plum No.1 (56 mm) and minimum in Dobahreh (31 mm). The fruit width was maximum in Ghohrood (45 mm) and minimum in Dobahreh (33 mm) while, according to the study administered fruit height was maximum in accession EC-538999 (52.35 mm) and minimum in Kala Amritsari (27.70 mm) and the maximum fruit width was taped in Red Beaut (53.09 mm) and minimum in IC-555355 (28.40 mm). Red Beaut observed the maximum fruit volume (68.19 cm^3) and the minimum fruit volume was logged in Kala Amritsari (18.19 cm^3). Kumar *et al.* (2018) inscribed the maximum fruit volume in Frontier (61.70 cm^3) and minimum in Shiro (25.38 cm^3). Bilal *et al.* (2021) observed the maximum fruit volume in President (62.44 ml) and minimum in D-Agen (31.22 ml).

Matta *et al*. (1996) diarized the harvest date from May 27th to June 28th which was comparable to the present study while, Latifikhah *et al.* (2017) observed the time of fruit ripening between 28th July to 12th October. Nisar *et al.* (2015) reported the maximum fruit set in RB1 (42 %) and minimum in RB4 (15 %). Kumar (2016) also noted that the fruit drop was maximum in Red Beaut (80.47 %) and minimum in Shiro (61.05 %), he further added that Shiro had maximum fruit retention (34.89 %) while it was minimum in Santa Rosa (11.63 %). The fruit firmness ranged between 1.75 kg/cm^2 in Kala Amritsari to 2.37 kg/cm^2 in EC-552696 whereas, the findings of Sharma (1999) states that the fruit firmness varied from 0.83 kg/cm² in Red Ace to 2.49 kg/cm² in Frontier and Red Beaut. According to the evaluation directed the shape of the fruit was obovate (1), circular (5), oblate (3), obcordate (2), elliptic (2) and oblate (1) to which Kang *et al.* (2005) promogulated the fruit shape was predominantly of four types – cordate, round, flattened round and oblong. Kang *et al.* (2005) also reported that the accessions on fruit colour can be grouped into yellow or greenish yellow, orange, orange red, greyed orange, purple, purple brown, red purple, dark brown. Most of the germplasms showed the presence of fruit suture. Verma (2016) adumbrated that the cultivars possessed red purple colour, red colour, grey purple colour and yellow colour whilst, in the present evaluation the accessions possessed dark red (7), medium red (5), purple (1) and yellowish green (1).

Prakash (1993) observed that the yield/tree was maximum in cultivar Carniota (57.88 kg) whereas, it was negligible in Alucha Amritsari (3.63 kg). Szabo and Nyeki (2001) also divulged the fruit yield to be maximum in Methley (48 kg/tree) and minimum in Santa Rosa (12 kg/tree). Abd Elaziz *et al.* (2022) docketed the total yield in Pioneer and Hollywood cultivar as 52.69 and 13.57 kg/tree in the first season and 49.32 and 12.94 kg/tree in the next season. However, in instant the pooled yield ranged between 22.71 kg/tree to 51.13 kg/tree.

4.6 STONE CHARACTERS

4.6.1 Stone weight

The weight of the stone was attained maximum in EC-513684 (1.21 g) in 2021 and minimum in IC-555355 (0.50 g). Whereas, in the year 2022 it was found maximum in EC-513684 (1.24 g) and minimum in Kala Amritsari (0.73 g).

According to the Table 4.6.1 pooled stone weight was taped maximum in EC-513684 (1.22 g) which was at par with EC-393740 (1.17 g), Frontier, EC-552693 (1.14 g) and EC-382826 (1.13 g) and minimum was logged in IC-555335 (0.65 g).

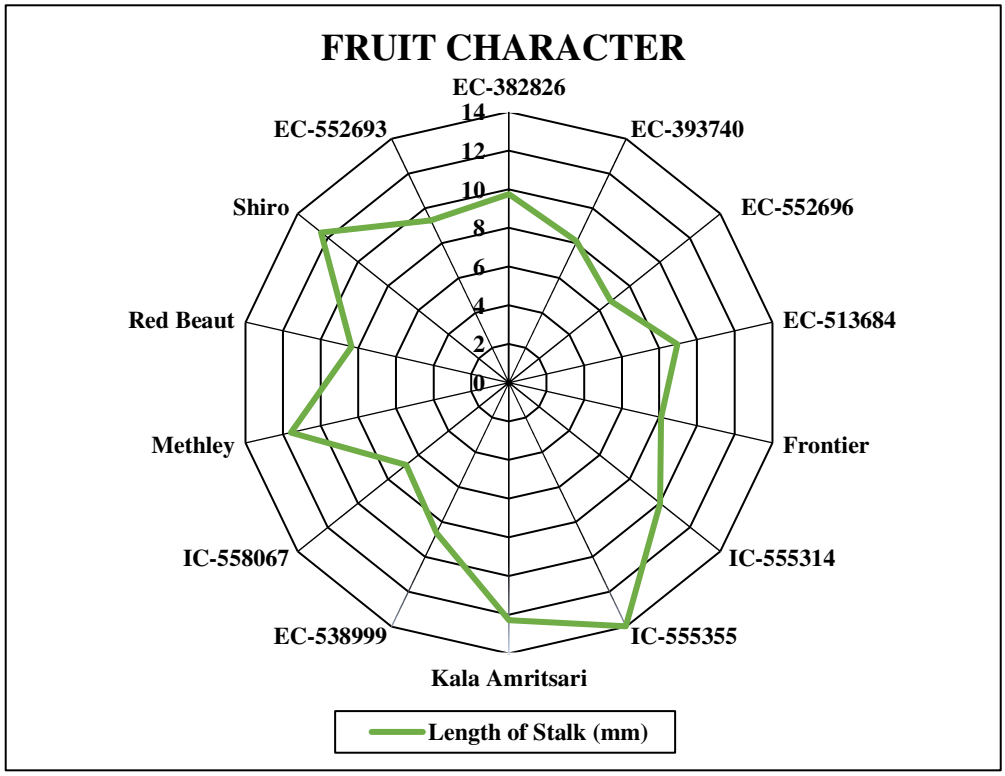


Figure 14: Extent of variation in length of stalk of different plum accessions

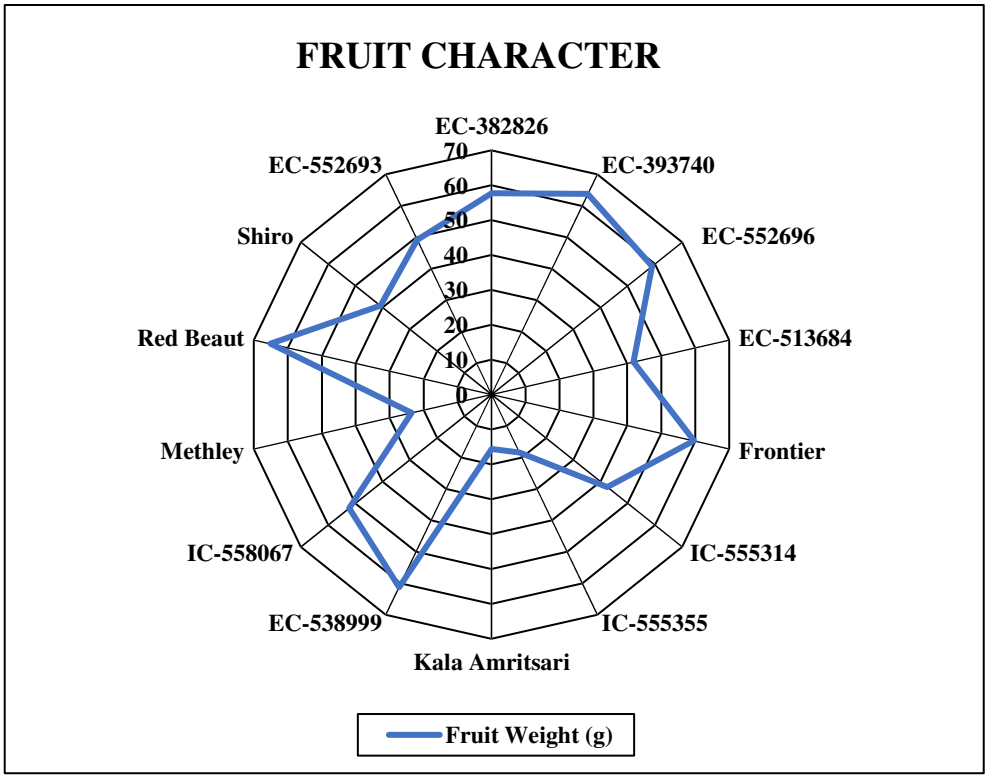


Figure 15: Extent of variation in fruit weight of different plum accessions

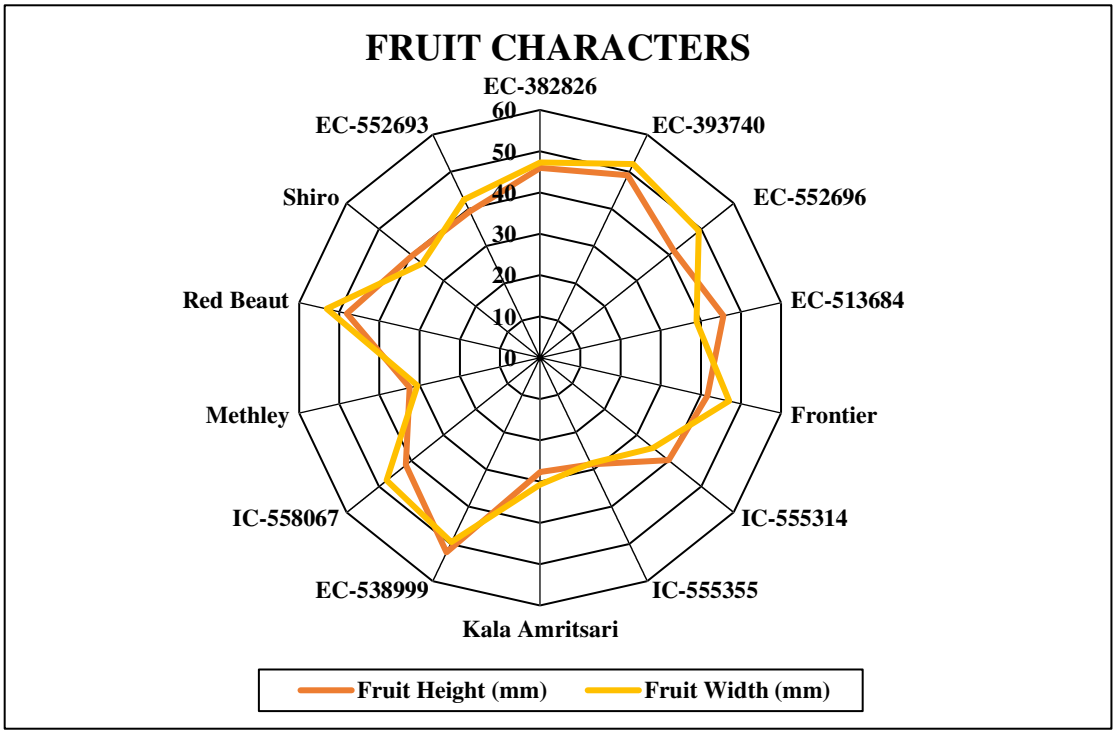


Figure 16: Extent of variation in fruit height and fruit width of different plum accessions

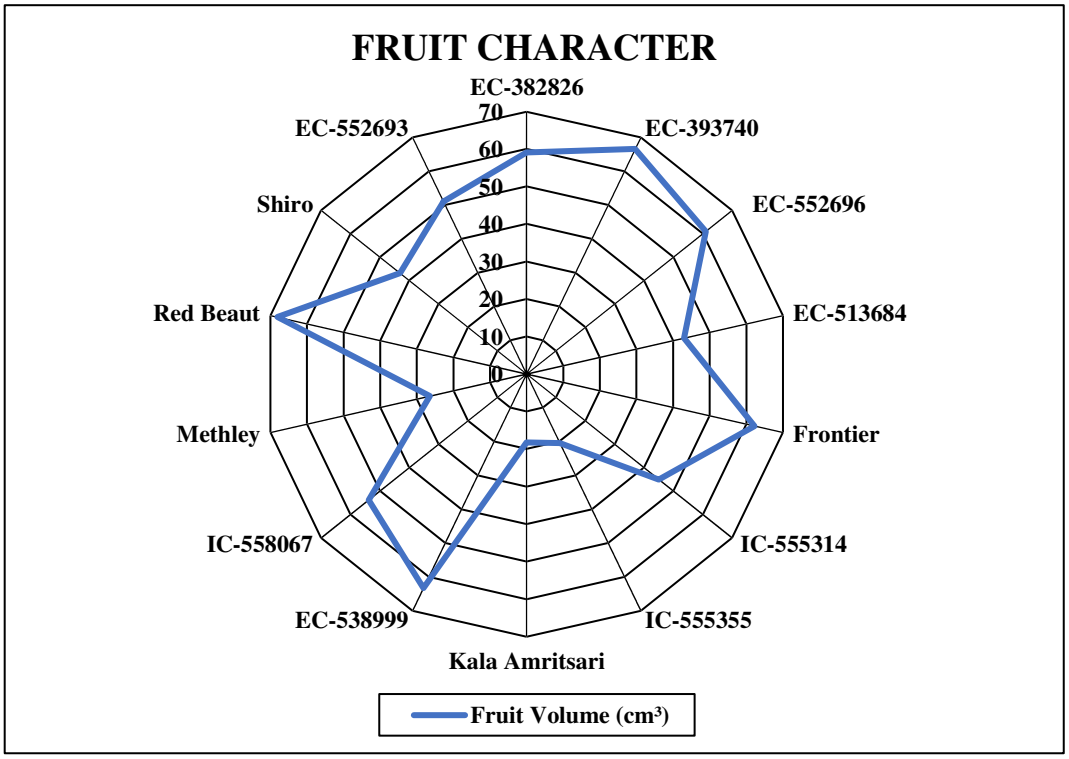


Figure 17: Extent of variation in fruit volume of different plum accessions

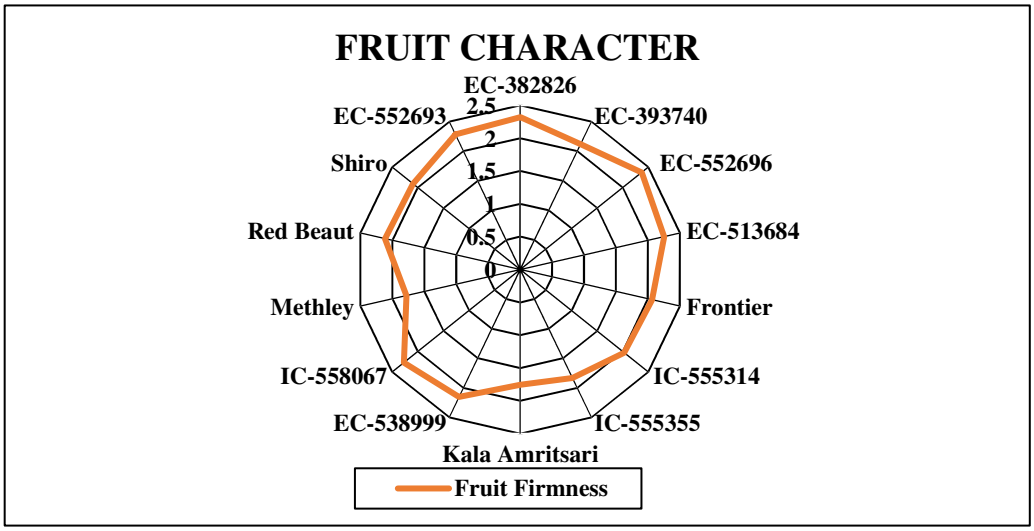


Figure 18: Extent of variation in fruit firmness of different plum accessions

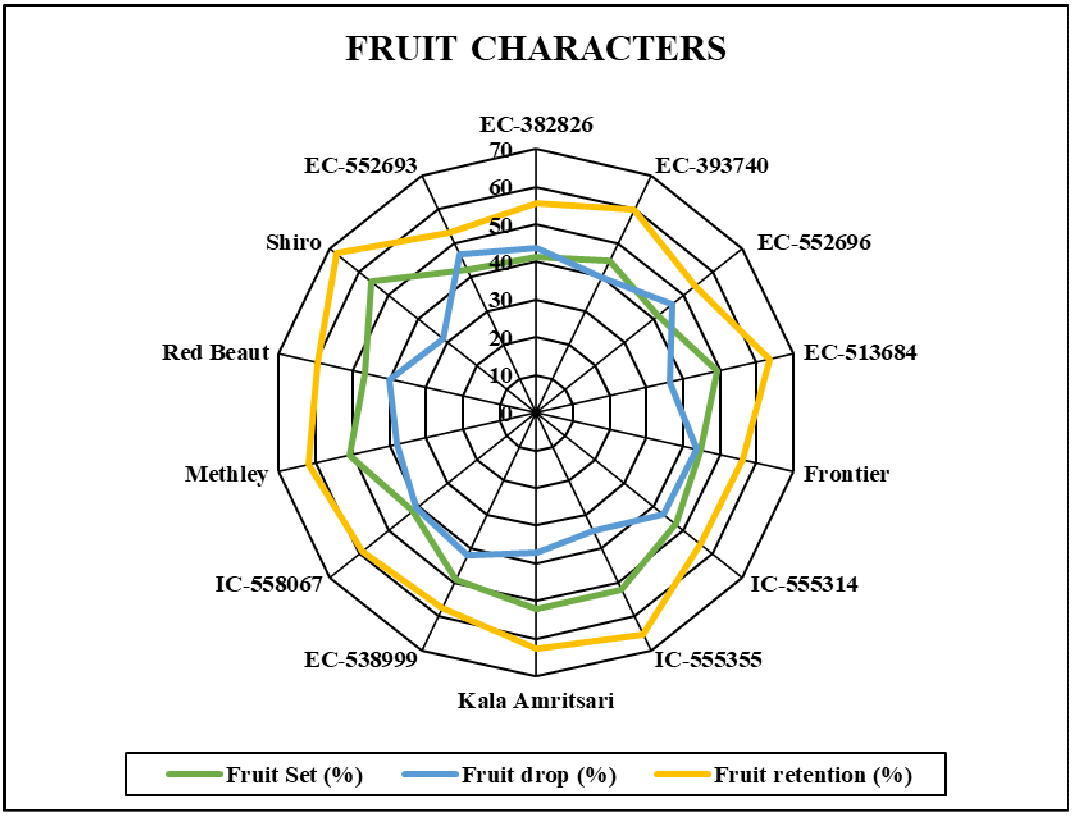


Figure 19: Extent of variation in fruit set, fruit drop and fruit retention of different plum accessions

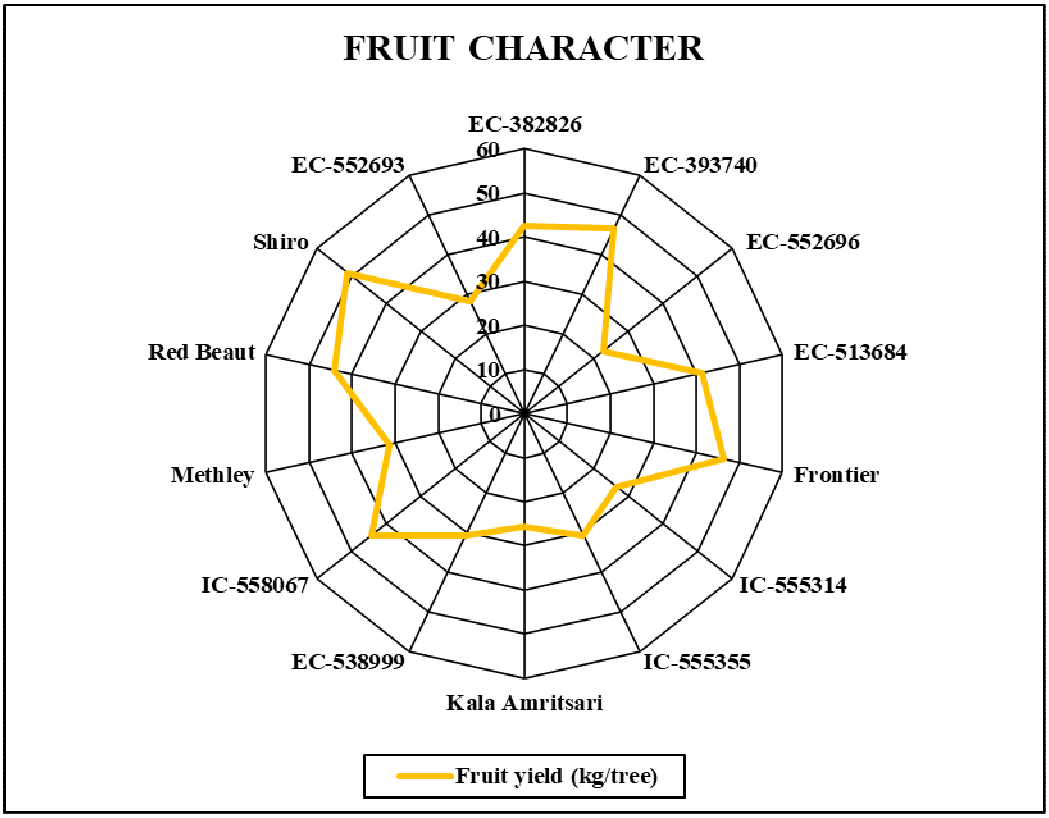


Figure 20: Extent of variation in fruit yield of different plum accessions

EC-382826

EC-393740

EC-552696

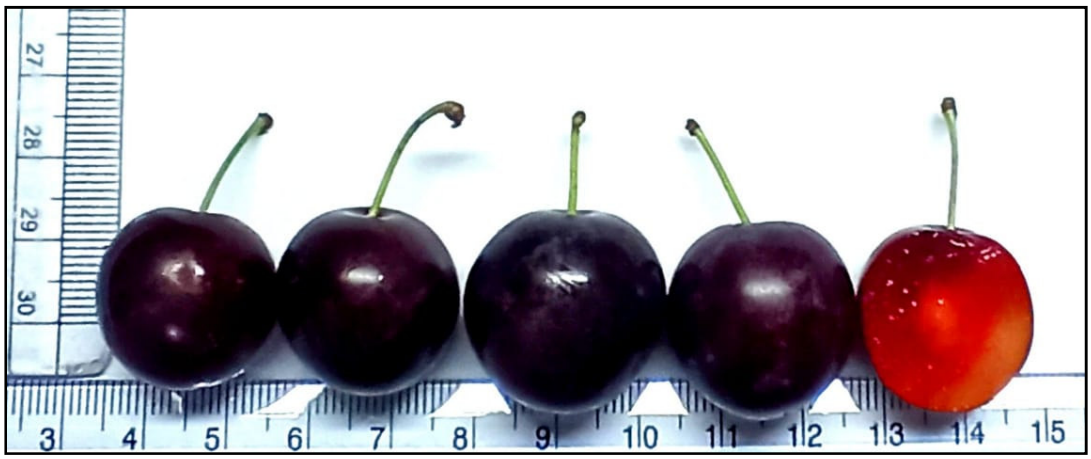
Plate 2 (a): Fruits of some Japanese plum accessions

EC-513684

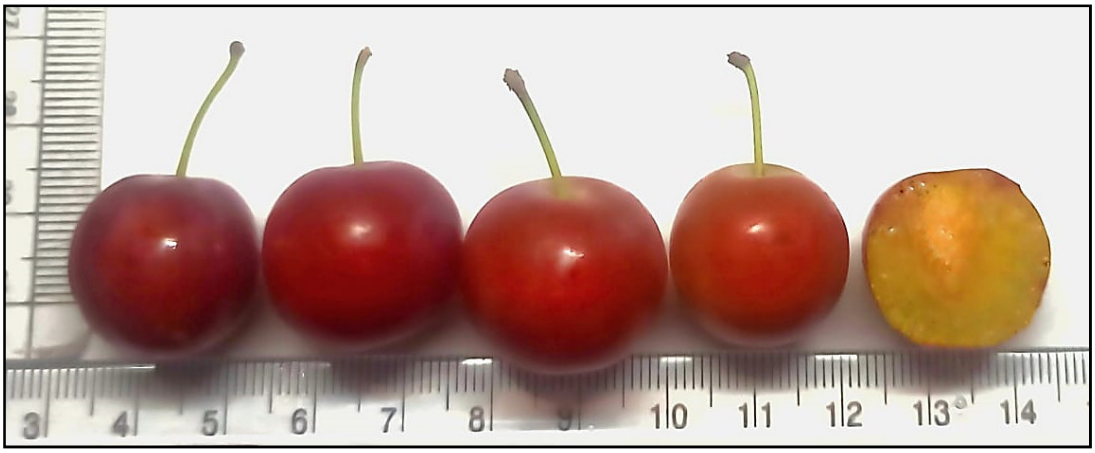
Frontier

IC-555314

Plate 2 (b): Fruits of some Japanese plum accessions



IC-555355



Kala Amritsari

EC-538999

Plate 2 (c): Fruits of some Japanese plum accessions

IC-558067

Methley

Red Beaut

Plate 2 (d): Fruits of some Japanese plum accessions

Shiro

EC-552693

Plate 2 (e): Fruits of some Japanese plum accessions

4.6.2 Stone Shape

The shape of the stone in lateral view was observed broad ovate in EC-382826, EC-513684 and EC-552693; medium elliptic in EC-393740, EC-552696, Frontier, IC-555314, IC-558067 and Shiro; narrow elliptic in IC-555355 and circular in Kala Amritsari, EC-538999, Methley and Red Beaut for both the years of evaluation.

Table 4.6.1 Stone characters of different plum genotypes

Genotypes	Stone Weight (g)			Stone Shape	
	2021	2022	Pooled	2021	2022
EC-382826	1.15	1.12	1.13	Broad ovate	Broad ovate
EC-393740	1.17	1.18	1.17	Medium elliptic	Medium elliptic
EC-552696	1.07	0.97	1.02	Medium elliptic	Medium elliptic
EC-513684	1.21	1.24	1.22	Broad ovate	Broad ovate
Frontier	1.13	1.16	1.14	Medium elliptic	Medium elliptic
IC-555314	1.03	1.05	1.04	Medium elliptic	Medium elliptic
IC-555355	0.50	0.80	0.65	Narrow elliptic	Narrow elliptic
Kala Amritsari	0.72	0.73	0.72	Circular	Circular
EC-538999	1.09	1.12	1.10	Circular	Circular
IC-558067	1.11	1.08	1.09	Medium elliptic	Medium elliptic
Methley	0.94	1.05	1.00	Circular	Circular
Red Beaut	1.08	1.12	1.10	Circular	Circular
Shiro	1.05	0.97	1.01	Medium elliptic	Medium elliptic
EC-552693	1.16	1.11	1.14	Broad ovate	Broad ovate
Mean	1.02	1.05	-	-	-
$CD_{0.05}$	0.14	0.15	0.11	-	-
SE ± (m)	0.05	0.05	0.03	-	-
SD	0.07	0.07	0.05	-	-

4.6.3 Stone: Texture

The texture of lateral surface of stone was found rough in three accessions *viz.,* EC-382826, EC-393740 and EC-538999; granular in five accessions *viz.,* EC-552696, EC-513684, Frontier, IC-555314 and Red Beaut and fine grained in the remaining six accessions *viz.,* IC-555355, Kala Amritsari, IC-558067, Methley, Shiro and EC-552693 in the years 2021 and 2022.

4.6.4 Stone: Width of Stalk-End

The width of the stalk occurred to be identical in both the years. It was remarked broad in EC-393740, EC-513684, Kala Amritsari, EC-538999, IC-558067, Red Beaut and

EC-552693; medium in Frontier and Shiro; narrow width of stalk end was observed in EC-382826, EC-552696, IC-555314, IC-555355 and Methley.

4.6.5 Pulp to stone ratio

Pulp to stone ratio was recorded maximum in Red Beaut (60.78) in the year 2021 and EC-552696 (60.18) in 2022 whereas, minimum pulp to stone ratio was logged in Kala Amritsari (22.37 and 20.93) in the years 2021 and 2022.

According to the Table 4.6.2 maximum pooled pulp to stone ratio was documented in Red Beaut (59.19) which was at par with EC-552696 (58.24) while minimum was reported in Kala Amritsari (21.65).

Table 4.6.2 Stone characters of different plum genotypes

Genotypes	Stone: Texture		Stone: Width of Stalk-End		Pulp to stone ratio		
	2021	2022	2021	2022	2021	2022	Pooled
EC-382826	Rough	Rough	Narrow	Narrow	49.11	52.27	50.69
EC-393740	Rough	Rough	Broad	Broad	56.35	52.54	54.45
EC-552696	Granular	Granular	Narrow	Narrow	56.31	60.18	58.24
EC-513684	Granular	Granular	Broad	Broad	33.85	34.43	34.14
Frontier	Granular	Granular	Medium	Medium	53.92	50.04	51.98
IC-555314	Granular	Granular	Narrow	Narrow	41.33	41.47	41.40
IC-555355	Fine grained	Fine grained	Narrow	Narrow	35.47	24.55	30.01
Kala Amritsari	Fine grained	Fine grained	Broad	Broad	22.37	20.93	21.65
EC-538999	Rough	Rough	Broad	Broad	53.99	56.84	55.42
IC-558067	Fine grained	Fine grained	Broad	Broad	46.35	49.41	47.88
Methley	Fine grained	Fine grained	Narrow	Narrow	22.89	24.24	23.57
Red Beaut	Granular	Granular	Broad	Broad	60.78	57.60	59.19
Shiro	Fine grained	Fine grained	Medium	Medium	37.73	43.27	40.50
EC-552693	Fine grained	Fine grained	Broad	Broad	42.54	43.82	43.18
Mean	-	-	-	-	43.78	43.68	-
$CD_{0.05}$	-	-	-	-	8.46	5.78	4.30
SE ± (m)	-	-	-	-	2.89	1.97	1.47
SD	-	-	-	-	4.09	2.79	2.08

Milatovic *et al.* (2011) inscribed stone weight ranging between 0.83 to 1.47 g. Sundouri *et al.* (2018) also proclaimed the maximum stone weight in Grand Duke (1.86 g) and minimum stone weight in Au-Cherry and Kubio Plum (0.89 g), comparable to this study

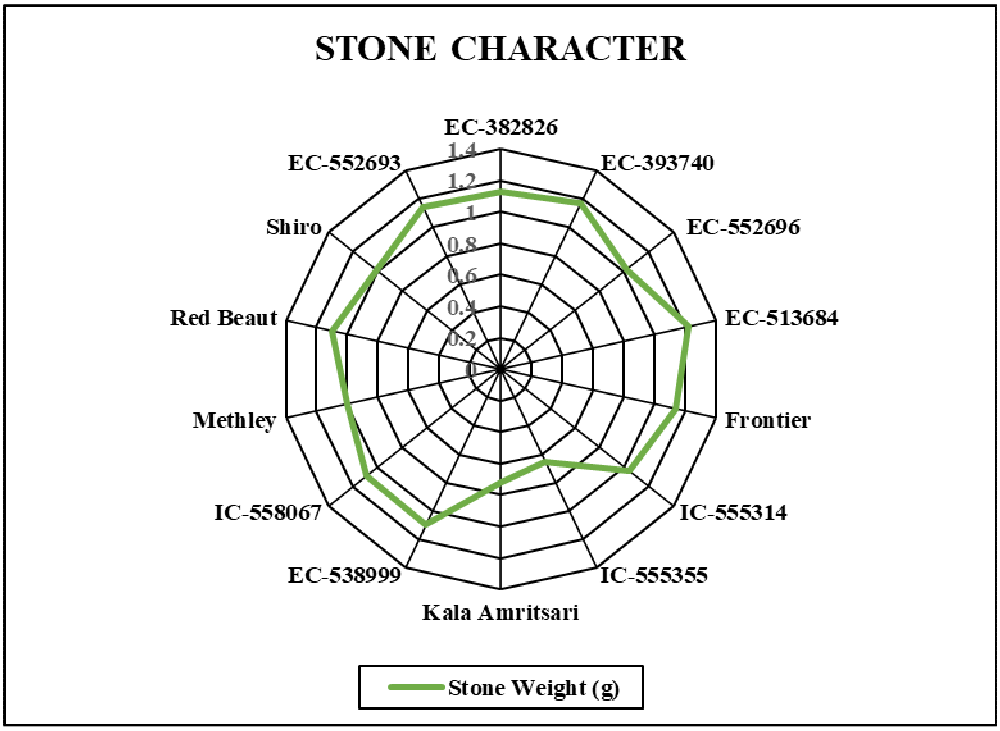


Figure 21: Extent of variation in stone weight of different plum accessions

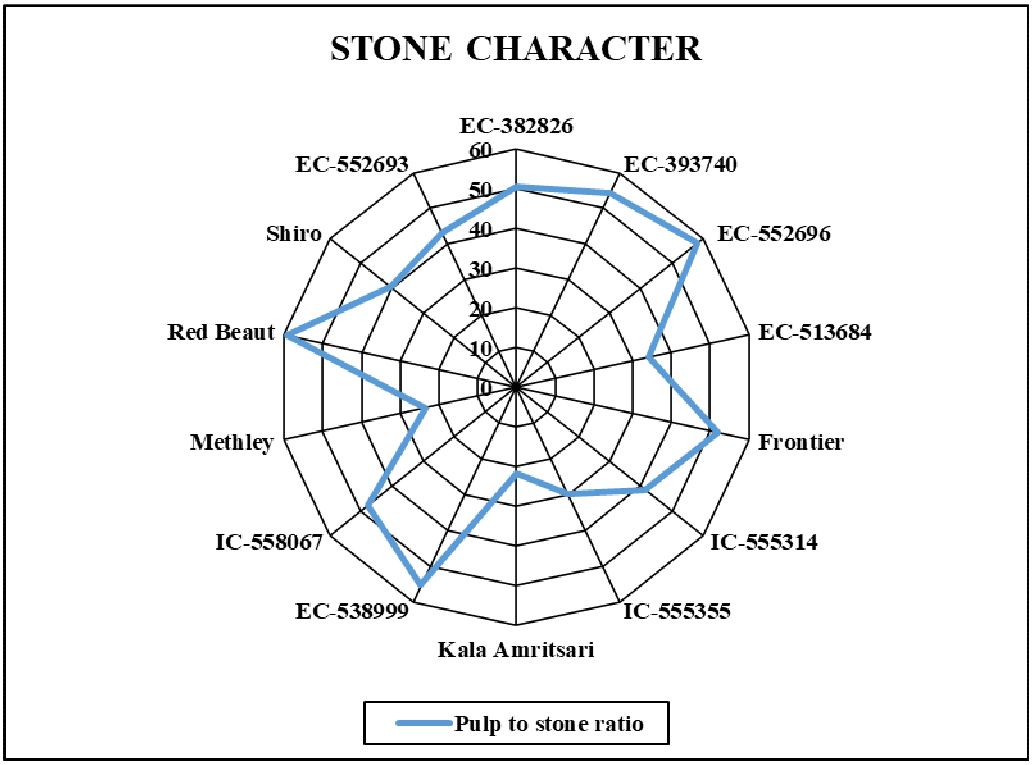


Figure 22: Extent of variation in pulp to stone ratio of different plum accessions

the maximum stone weight was in EC-513684 (1.22 g) and minimum in IC-555355 (0.65 g). Nisar *et al.* (2015) recorded the stone shape as oval, round and elliptical. Kwon *et al.* (2018) also observed the stone shape in lateral view: narrow elliptic, medium elliptic, circular and broad ovate were the evident shapes while, shape of the stone was catalogued as broad ovate in two genotypes, medium elliptic in six genotypes, narrow elliptic in two genotypes and circular in three accessions in the study conducted.

Sedaghathoor *et al.* (2009) reported the maximum pulp/stone ratio in Ghandi (29.32) whereas, the minimum was observed in Bur Alooche (14.26). Kumar (2016) diarized the maximum pulp/stone ratio in Frontier (48.31) while, minimum was noted in Shiro (20.17). The maximum pulp to stone ratio was transcribed in the cultivar Friar (68.61) and the minimum pulp to stone ratio in cultivar Stanley (19.05) (Majid *et al.*, 2020). In the evaluation conducted, the maximum pulp to stone ratio was docketed in Red Beaut (59.19) and minimum in Kala Amritsari (21.65).

4.7 BIOCHEMICAL CHARACTERISTICS

4.7.1 Total Soluble Solids (°B)

The total soluble solids in 2021 was chronicled maximum in Frontier (15.29 °B) and the minimum was in EC-538999 (11.67 °B) whereas, in the year 2022 the maximum was recorded in Methley (15.36 °B**)** and the minimum was taped in Shiro (11.89 °B).

The maximum pooled total soluble solids were in Frontier (15.20 °B) which was at par with Methley (15.14 °B), IC-558067 (14.88 °B) and EC-393740 (14.61 °B) and the minimum was taped in Shiro (11.69 °B).

4.7.2 Titratable Acidity (%)

The titratable acidity per cent was recorded maximum in IC-555314 (1.55 %) in 2021 and Shiro (1.58 %) in the year 2022 whereas, the minimum was logged in EC-552693 (1.26 %) in 2021 and Methley (1.23 %) in the year 2022.

According to the Table 4.7.1 maximum pooled titratable acidity was catalogued in Shiro (1.56 %) which was at par with IC-555314 (01.53 %), EC-552696 (1.50 %), EC-382826 (1.43 %) while, the minimum pooled acidity was reported in Methley (1.25 %).

Table 4.7.1 Biochemical Characteristics of different plum genotypes

Genotypes	Total Soluble Solids (°B)			Titratable Acidity (%)		
	2021	2022	Pooled	2021	2022	Pooled
EC-382826	13.10	12.93	13.01	1.45	1.42	1.43
EC-393740	14.76	14.46	14.61	1.27	1.30	1.28
EC-552696	12.19	12.32	12.25	1.48	1.51	1.50
EC-513684	13.69	13.98	13.84	1.40	1.44	1.42
Frontier	15.29	15.11	15.20	1.34	1.28	1.31
IC-555314	11.83	12.05	11.94	1.55	1.52	1.53
IC-555355	15.00	14.88	14.94	1.31	1.35	1.33
Kala Amritsari	12.63	12.25	13.41	1.34	1.32	1.33
EC-538999	11.67	11.79	11.73	1.41	1.43	1.42
IC-558067	14.95	14.81	14.88	1.30	1.35	1.33
Methley	14.91	15.36	15.14	1.28	1.23	1.25
Red Beaut	13.07	13.45	13.26	1.38	1.35	1.36
Shiro	11.50	11.89	11.69	1.54	1.58	1.56
EC-552693	12.85	12.92	12.89	1.26	1.29	1.28
Mean	13.38	13.44	-	1.37	1.38	-
$CD_{0.05}$	1.09	0.88	0.72	0.17	0.20	0.14
SE ± (m)	0.37	0.30	0.24	0.06	0.07	0.04
SD	0.52	0.42	0.35	0.08	0.10	0.06

4.7.3 Total Sugars (%)

The total sugars were maximum in Frontier (8.21 %) in 2021 and minimum in Shiro (7.45 %) while, in the year 2022 total sugars was recorded maximum in Methley (8.20 %) and minimum in IC-555314 (7.45 %).

The pooled data according to the Table 4.7.2 suggests that the maximum total sugars were docketed in the cultivar Frontier (08.20 %) which was at par with Methley (8.19 %), IC-558067 (8.13 %), EC-393740 (8.07 %) and IC-555355 (8.07 %) whilst, minimum was diarized in IC-555314 (7.46 %).

4.7.4 Reducing Sugars (%)

Reducing sugars were recorded maximum in Frontier (6.61 % and 6.62 %) in both the years of evaluation. The minimum was inscribed in Shiro (5.53 %) in 2021 and EC-538999 (5.58 %) in 2022.

According to the Table 4.7.2 maximum pooled reducing sugars were documented in Frontier (6.62 %) which was at par with Methley (6.57 %) and IC-558067 (6.50 %) and minimum was filed in Shiro (5.56 %).

Table 4.7.2 Biochemical Characteristics of different plum genotypes

Genotypes	Total Sugar (%)			Reducing Sugars (%)		
	2021	2022	Pooled	2021	2022	Pooled
EC-382826	7.67	7.61	7.64	6.27	6.23	6.25
EC-393740	8.05	8.09	8.07	6.32	6.32	6.32
EC-552696	7.54	7.58	7.56	6.12	6.22	6.17
EC-513684	7.61	7.64	7.63	5.71	5.67	5.69
Frontier	8.21	8.19	8.20	6.61	6.62	6.62
IC-555314	7.48	7.45	7.46	5.87	5.82	5.85
IC-555355	8.04	8.10	8.07	6.35	6.38	6.36
Kala Amritsari	7.84	7.81	7.83	6.29	6.27	6.28
EC-538999	7.49	7.52	7.50	5.55	5.54	5.54
IC-558067	8.11	8.15	8.13	6.46	6.54	6.50
Methley	8.17	8.20	8.19	6.55	6.59	6.57
Red Beaut	7.83	7.79	7.81	6.24	6.21	6.22
Shiro	7.45	7.51	7.48	5.53	5.59	5.56
EC-552693	7.91	7.94	7.92	6.31	6.33	6.32
Mean	7.81	7.82	-	6.15	6.16	-
$CD_{0.05}$	0.16	0.21	0.12	0.20	0.33	0.18
SE ± (m)	0.05	0.07	0.05	0.07	0.11	0.06
SD	0.07	0.10	0.08	0.10	0.16	0.09

4.7.5 Non-reducing Sugars (%)

The non-reducing sugars in the year 2021 was recorded maximum in EC-538999 (1.94 %) and minimum in EC-382826 (1.40 %) while, in the year 2022 maximum non-reducing sugars were logged in EC-538999 (1.98 %) and minimum in EC-552696 (1.36 %).

According to the Table 4.7.3 maximum pooled non-reducing sugars were inscribed in EC-538999 (1.96 %) which was at par with EC-513684 (1.93 %) and Shiro (1.91 %) whereas, minimum was chronicled in EC-382826 and EC-552696 (1.38 %).

4.7.6 Sugar/Acid Ratio

Maximum sugar/acid ratio in the year 2021 was catalogued in EC-393740 (6.38) and minimum in IC-555314 (4.83). Consequently, in the year 2022 it was logged maximum in Methley (6.72) and minimum in Shiro (4.73).

According to the Table 4.7.3 maximum pooled sugar/acid ratio was observed in Methley (6.54) which was at par with EC-393740 (6.33), Frontier (6.25), EC-552693 (6.19), IC-558067 (6.13) and IC-555355 (6.09) while, the minimum value was contemplated in Shiro (4.79).

4.7.7 Anthocyanin Content (mg/100g)

Maximum anthocyanin content was taped in IC-555355 (0.91 A_{530} in 2021 and 0.93 A_{530} in 2022) and minimum was noted in Shiro (0.066 A_{530} in 2021 and 0.069 A_{530} in 2022).

According to the Table 4.7.3 maximum pooled anthocyanin content was diarized in IC-555355 (0.92 A_{530}) which was at par with IC-558067 (0.86 A_{530}), IC-555314 (0.85 A_{530}) and Methley (0.83 A_{530}) while, the minimum was logged in Shiro (0.06 A_{530}).

Table 4.7.3 Biochemical Characteristics of different plum genotypes

Genotypes	Non-reducing Sugars (%)			Sugar/Acid Ratio			Anthocyanin Content (A_{530})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
EC-382826	1.40	1.37	1.38	5.30	5.37	5.34	0.65	0.69	0.67
EC-393740	1.72	1.76	1.74	6.38	6.28	6.33	0.47	0.45	0.46
EC-552696	1.41	1.36	1.38	5.07	5.01	5.04	0.68	0.64	0.66
EC-513684	1.90	1.97	1.93	5.47	5.32	5.40	0.59	0.54	0.56
Frontier	1.59	1.57	1.58	6.11	6.38	6.25	0.63	0.66	0.64
IC-555314	1.61	1.62	1.61	4.83	4.90	4.87	0.84	0.87	0.85
IC-555355	1.68	1.72	1.70	6.16	6.02	6.09	0.91	0.93	0.92
Kala Amritsari	1.55	1.54	1.54	5.85	5.95	5.90	0.54	0.51	0.52
EC-538999	1.94	1.98	1.96	5.35	5.31	5.33	0.42	0.44	0.43
IC-558067	1.65	1.62	1.63	6.21	6.06	6.13	0.85	0.87	0.86
Methley	1.62	1.60	1.61	6.36	6.72	6.54	0.84	0.83	0.83
Red Beaut	1.59	1.58	1.58	5.68	5.78	5.73	0.77	0.79	0.78
Shiro	1.91	1.91	1.91	4.85	4.73	4.79	0.066	0.069	0.06
EC-552693	1.60	1.60	1.60	6.25	6.13	6.19	0.59	0.60	0.59
Mean	1.65	1.65	-	5.70	5.71	-	0.63	0.64	-
$CD_{0.05}$	0.29	0.36	0.20	0.73	0.87	0.55	0.14	0.16	0.11
SE ± (m)	0.10	0.12	0.07	0.25	0.29	0.19	0.04	0.05	0.03
SD	0.14	0.17	0.09	0.35	0.42	0.26	0.06	0.07	0.05

The observations of the present study regarding titratable acidity are in accordance with Tandon (2006) where the titratable acidity was maximum in Satluj Purple (2.59 %) and

minimum in Ruby Sweet (1.12 %). Kumar *et al.* (2018) adumbrated the maximum acidity in Mariposa (1.66 %) whereas, the minimum acidity in Black Amber (1.28 %). The total pooled sugars content in the present study varied from 7.46 per cent to 8.20 per cent. Bozhkova (2014) had contradicting results according to which the total sugars content was maximum in Jojo (12.31 %) and minimum in Tuleu Timpuriu (6.96 %) whilst, Kumar (2016) inscribed maximum total sugars content in Black Amber (8.19 %) and minimum was obtained in Santa Rosa (7.49 %). Kishor *et al.* (2017) evaluated the maximum total sugars was 4.16 per cent and minimum was 3.73 per cent. Reducing sugars ranged from 5.54 to 6.62 per cent which was similar to the research conducted by Prakash (1993), where he promulgated the maximum reducing sugars content in Alubukhara (6.87 %) whereas, the minimum was reported in Carniota (5.45 %). Kishor *et al.* (2017) stated maximum non-reducing sugars in Collection-1 (1.65 %) whilst, minimum in Collection-5 (0.84 %) which was comparable in accordance to present study ranging between 1.38 to 1.96 per cent.

The soluble solids content in the present study was perceived between 11.69 °B to 15.20 °B and the similar results were evaluated by Kang *et al.* (2005), where the values ranged between 11.3 - 18.8 per cent. Verma (2016) also rooted out the total soluble solids value ranging between 10.0 °B to 16.06 °B. Kumar *et al.* (2018) documented the maximum soluble solid content in Black Amber (15.16 °B) and minimum in Shiro (12.92 °B). Ganji *et al.* (2011) logged the maximum sugar/acid ratio in Blu Fre (19.14) and minimum in Black Amber (5.97), which was contradicting to the present study ranging between 4.79 - 6.54. Although, Kumar *et al.* (2018) had similar findings, where the maximum sugar to acid ratio was observed in Black Amber (6.38) and minimum was divulged for Mariposa (4.87). The maximum anthocyanin content was remarked in plums with red pulp and red flesh such as Dof Giudy and Black Diamond (97.9 ± 4.70 and 95.3 ± 10.79 mg cyd-3-glu equivalents L^{-1}), respectively while yellow pulp varieties such as Fortune, Golden Plum, Angeleno and Settembrine had minimum anthocyanin content (Taiti *et al.*, 2019). The anthocyanin content ranged between 0.06 A_{530} to 0.92 A_{530} according to the propound evaluation.

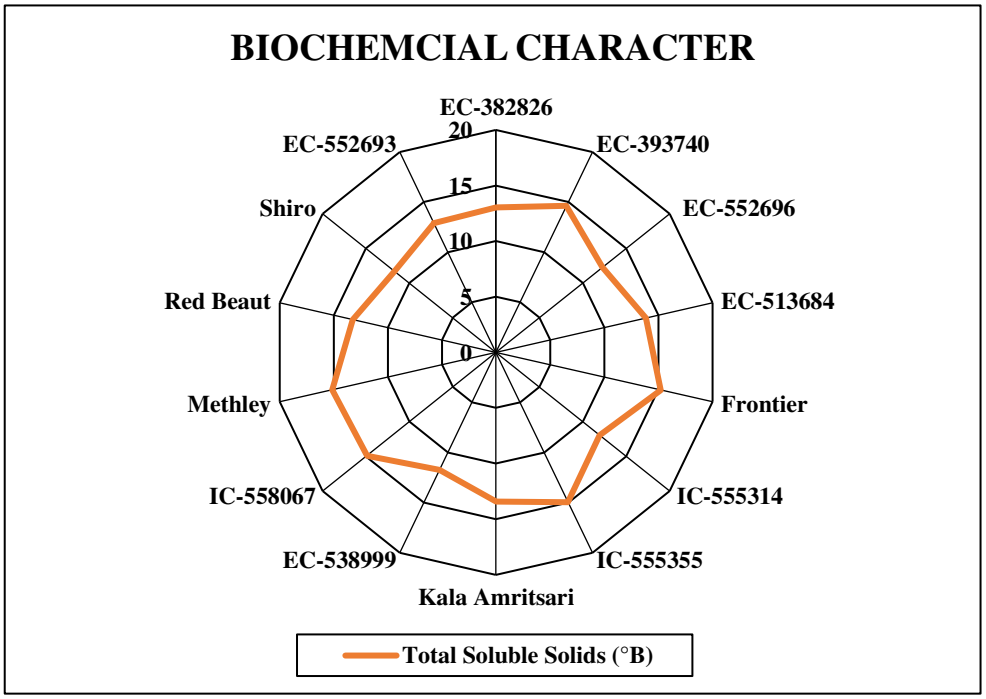


Figure 23: Extent of variation in total soluble solids of different plum accessions

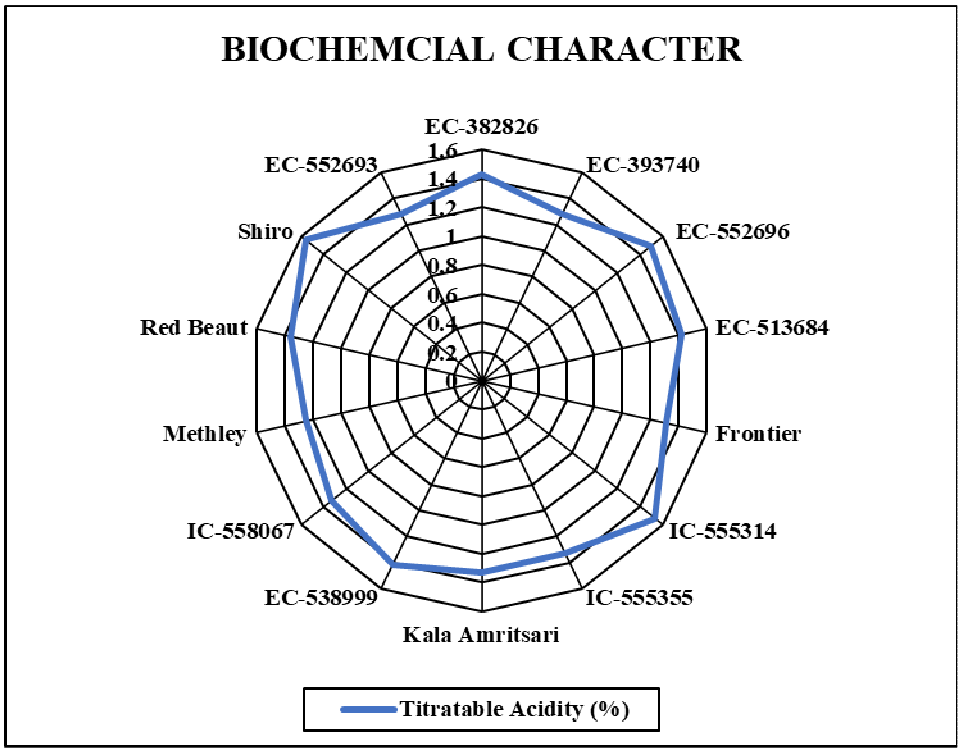


Figure 24: Extent of variation in titratable acidity of different plum accessions

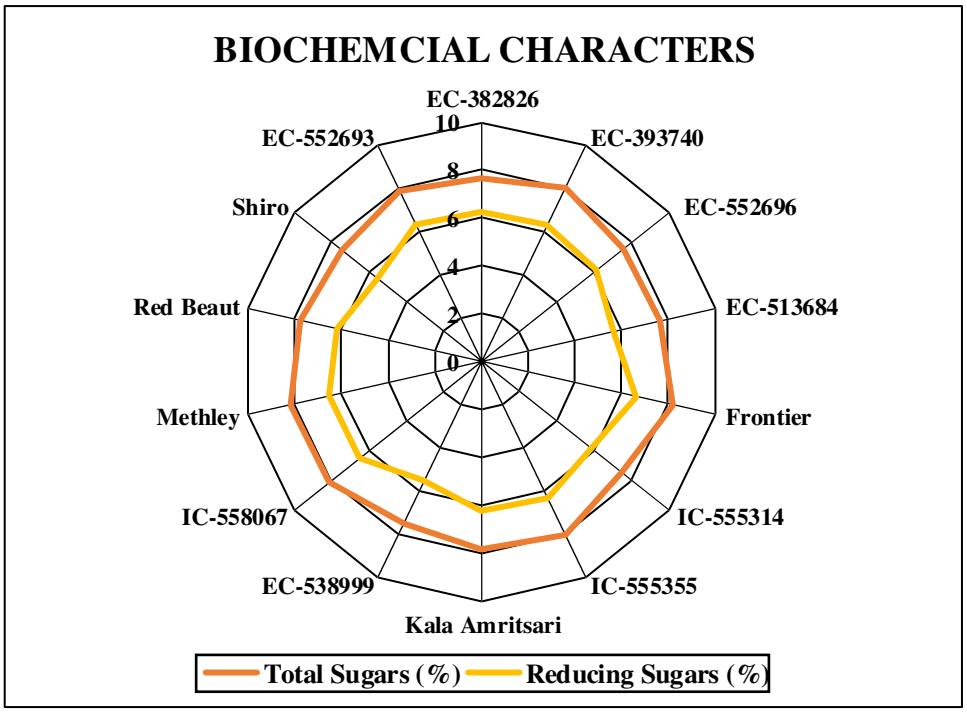


Figure 25: Extent of variation in total sugars and reducing sugars of different plum accessions

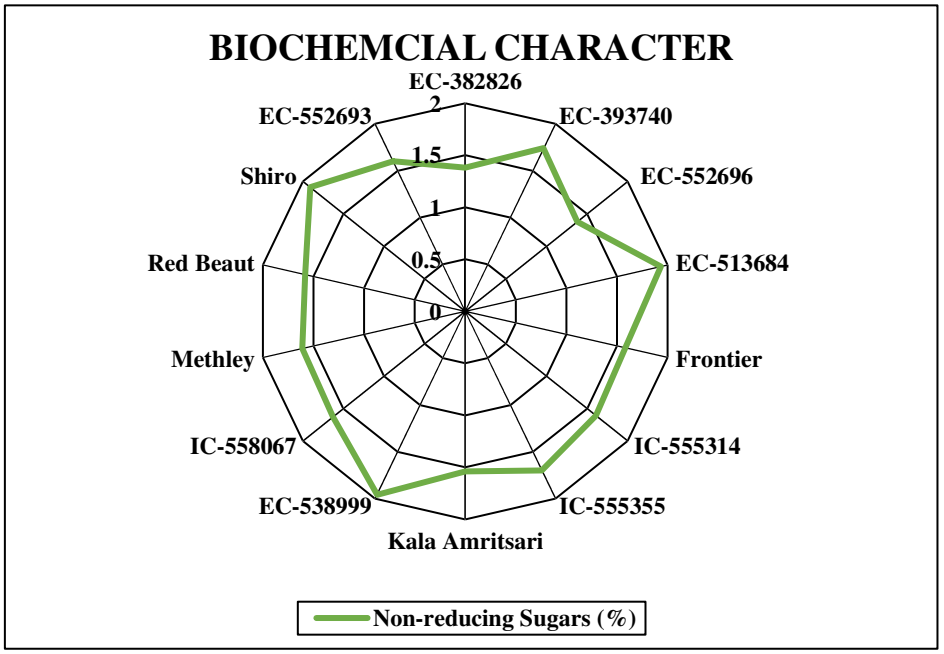


Figure 26: Extent of variation in non-reducing sugars of different plum accessions

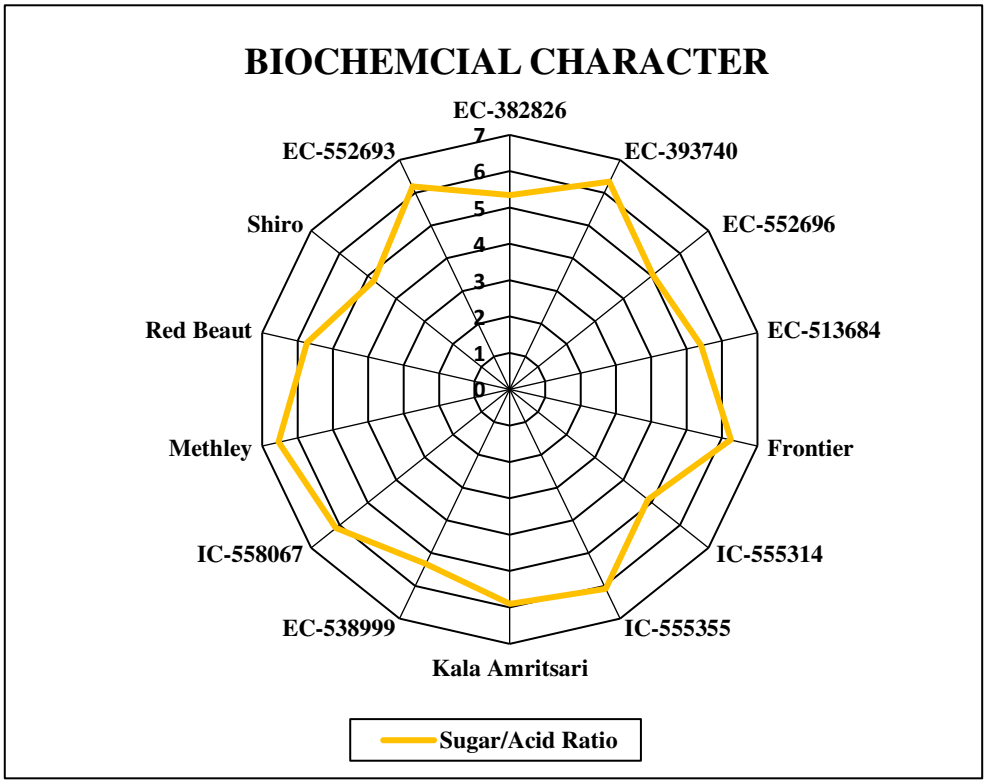


Figure 27: Extent of variation in sugar/acid ratio of different plum accessions

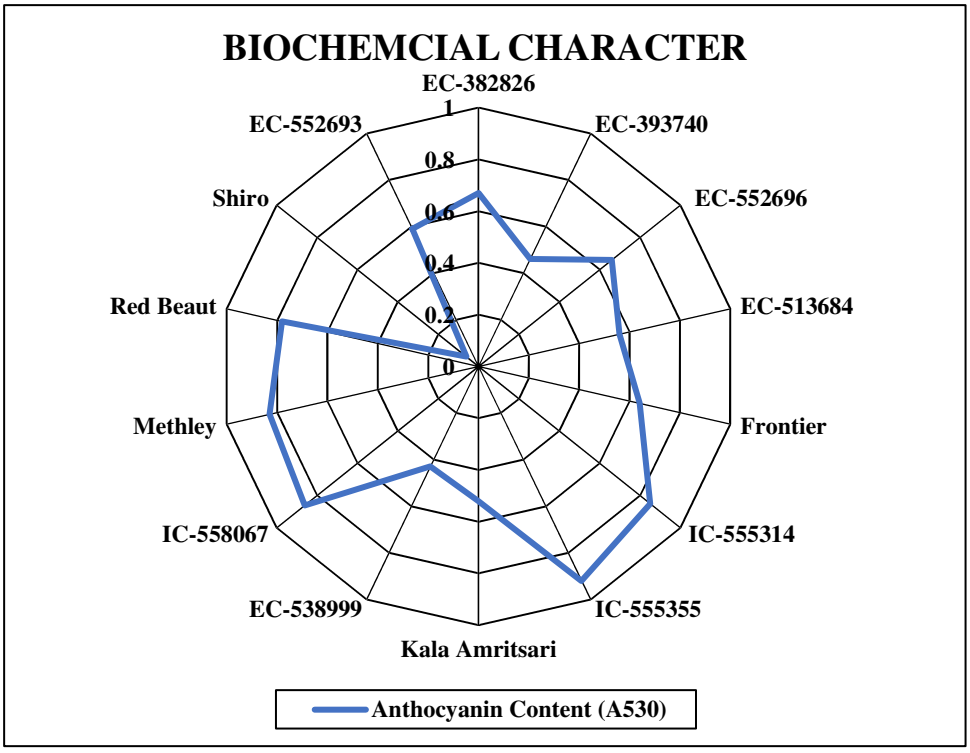


Figure 28: Extent of variation in anthocyanin content of different plum accessions

Chapter-5

SUMMARY AND CONCLUSION

The profound study entitled "**DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm**" was carried out in the field gene bank of National Bureau of Plant Genetics Resources (NBPGR), Regional Station Phagli, Shimla (Himachal Pradesh) during the year 2021-2022. The salient results of the studies are summarized and concluded as under:

SUMMARY

5.1 Tree height was maximum for Kala Amritsari (4.45 m) while, minimum was observed in IC-555314 (3.05 m).

5.2 The cultivar Shiro had the maximum pooled tree spread from North to South (4.22 m) and East to West direction (4.19 m), respectively. The minimum tree spread from North-South direction was espied in accession EC-513684 (2.37 m) and minimum spread from East-West direction was espied in EC-513684 (2.27 m).

5.3 Tree girth was found maximum in Kala Amritsari (52.37cm) and minimum in IC-558067 (34.74 cm).

5.4 The earliest bud burst was found in Red Beaut (9^{th} February and 3^{rd} February) whereas, last was found in EC-552693 (12^{th} March and 6^{th} March) in the consecutive years, respectively.

5.5 Leaf blade length was recorded maximum in EC-393740 (118.14 mm) and minimum was recorded in EC-552693 (85.59 mm).

5.6 The maximum leaf blade width was documented in EC-393740 (62.02 mm) and minimum was noted in IC-555314 (35.19 mm).

5.7 Leaf area was divulged maximum in EC-393740 (890.58 mm^2) and minimum in EC-552693 (611.10 mm^2).

5.8 Leaf fall out of all the fourteen Japanese plum accessions was observed earliest in Red Beaut on 11^{th} November and last was recorded in Shiro on 2^{nd} December.

5.9 The date of opening of the first flowering was found earliest in Red Beaut on (16^{th} February and 11^{th} February) in the years 2021 and 2022. The last to show opening of

first flower was accession EC-538999 and EC-552693 on 18th March in the year 2021 and EC-552693 (13th March) in the year 2022.

5.10 Date of full bloom was noted earliest in Red Beaut for both the years 2021 and 2022 (26th February and 17th February), respectively. The last date of full bloom for 2021 and 2022 was observed in accession EC-552693 (28th March and 23th March), respectively.

5.11 Duration of flowering was recorded maximum in EC-393740, EC-513684 and Shiro for 18 days in 2021 and in 2022 it was reported maximum in EC-393740 and Shiro for 17 days. The minimum duration of flowering was inscribed in EC-552696 and Frontier (11 days and 10 days) in the years 2021 and 2022 correspondingly.

5.12 Pedicel length was catalogued maximum in Kala Amritsari (18.34 mm) and minimum in EC-513684 (9.94 mm).

5.13 Petal shape for five accessions was contemplated obovate *viz.,* EC-382826, IC-555314, IC-555355, EC-538999 and Red Beaut; two accessions had oblate shape *viz.,* EC-393740 and Shiro; three were circular *viz.,* EC-552696, Frontier and Methley and four were elliptic in shape *viz.,* EC-513684, Kala Amritsari, IC-558067 and EC-552693.

5.14 Flower arrangement of petals was touching in EC-382826, EC-393740 and Frontier; free in EC-552696, EC-513684, IC 555314, Kala Amritsari, Red Beaut and EC-552693 and overlapping arrangement in *viz.,* IC 555355, EC-538999, IC-558067, Methley and Shiro.

5.15 The maximum pollen viability with acetocarmine solution was recorded in EC-382826 (98.97 %) and the minimum pollen viability was found in EC-538999 (91.11 %).

5.16 According to the Erythrosine B (0.1 %) solution test, the maximum pollen viability was counted in accession IC-558067 (71.46 %) whereas, the minimum pollen viability was chronicled in EC-513684 (33.47 %).

5.17 *In vitro* pollen germination test with 10 per cent sucrose solution was found maximum in EC-382826 (81.69 %). The minimum pollen germination was recorded in IC-555314 (26.06 %). Pollen germination with 15 per cent sucrose solution was recorded maximum in Frontier (90.53 %) and minimum in EC-513684 (29.11 %).

5.18 Date of harvest was recorded earliest on Red Beaut and Kala Amritsari (6th June and 22nd May), correspondingly in the two consecutive years. The last accession to harvest was EC-538999 (7th July and 30th June) for the years 2021 and 2022.

5.19 Fruit weight was found maximum in Red Beaut (65.18 g) and minimum was obtained in Kala Amritsari (15.62 g).

5.20 The maximum fruit height was charted in EC-538999 (52.35 mm) and the minimum in Kala Amritsari (27.70 mm).

5.21 Fruit width was recorded maximum in Red Beaut (53.09 mm) and minimum in IC-555355 (28.40 mm).

5.22 Red Beaut had the maximum fruit volume (68.12 cm^3) and the minimum was recorded in Kala Amritsari (18.19 cm^3).

5.23 Length of stalk was logged maximum in IC-555355 (13.97 mm) and minimum in EC-552696 (6.75 mm).

5.24 Colour of peel was dark red in EC-382826, EC-513684, Frontier, IC-555314, IC-558067, Methley and Red Beaut; medium red in EC-393740, EC-552696, Kala Amritsari, EC-538999 and EC-552693, purple was perceived in IC-555355 and yellowish green in Shiro.

5.25 The symmetry of the fruit was strongly asymmetric for EC-552696 and Red Beaut; moderately asymmetric for EC-393740, IC-555314, Frontier and IC-558067; symmetric or slightly asymmetric in EC-513684, EC-538999 and EC-552693 and symmetric in EC-382826, IC-555355, Kala Amritsari, Methley and Shiro.

5.26 The bloom of skin on fruit was observed very strong for IC-558067 and Methley; strong in EC-382826, EC-513684, IC-555355; medium in Frontier, IC-555314, Kala Amritsari, EC-538999, Red Beaut and Shiro; weak bloom in EC-393740 and EC-552696 whereas, very weak or absent in EC-552693.

5.27 The fruit firmness was inscribed in EC-552696 (2.37 kg/cm^2) and minimum was recorded in Kala Amritsari (1.75 kg/cm^2).

5.28 Maximum fruit set was transcribed in Shiro (56.06 %) and minimum in EC-552696 (41.38 %).

5.29 Fruit drop was observed maximum in EC-552693 (46.49 %) and minimum was remarked in Shiro (31.60 %).

5.30 Maximum fruit retention was inscribed in Shiro (67.92 %) and minimum in EC-552693 (53.13 %).

5.31 Number of days from full bloom to harvest was catalogued between 93 days in EC-552693 to 108 days in EC-552696 in the year 2021. Whilst, in the year 2022 the number of days from full bloom to harvest was recorded between 92 days in EC-552693 to 106 days in EC-552696.

5.32 Maximum yield was observed in Shiro (51.13 kg/tree) while, minimum in EC-552696 (22.71 kg/tree).

5.33 The stone weight was taped maximum in EC-513684 (1.22 g) and minimum in IC-555335 (0.65 g).

5.34 The pulp to stone ratio was documented maximum in Red Beaut (59.19) which was at par with EC-552696 (58.24) while minimum in Kala Amritsari (21.65).

5.35 The maximum pooled total soluble solids were inscribed in Frontier (15.20 °B) and the minimum in Shiro (11.69 °B).

5.36 The maximum titratable acidity was catalogued in Shiro (1.56 %) while, the minimum was reported in Methley (1.25 %).

5.37 The maximum total sugars were docketed in the cultivar Frontier (8.20 %) whilst, minimum was diarized in IC-555314 (7.46 %).

5.38 The maximum reducing sugars were documented in Frontier (6.62 %) and minimum was filed in Shiro (5.56 %).

5.39 The sugar/acid ratio was observed maximum in Methley (6.54) and the minimum value was contemplated in Shiro (4.79).

5.40 The anthocyanin content was diarized maximum in IC-555355 (0.92 A_{530}) while, the minimum in Shiro (0.06 A_{530}).

CONCLUSION

From the former colloquy, it is clinched that the results obtained are preliminary and there is further need to evaluate these accessions in the subsequent years. However, the present studies specifies that some of these germplasms do possess one or more horticulturally desirable characteristics and thus can be used to broaden the genetic base from the pre-existing cultivars. Some of which are mentioned below:

1. The tree size was found comparable in EC-393740 along with strong tree vigour.
2. Leaf length, width and area were maximum compared to others in EC-393740.

3. Along with Red Beaut and Kala Amritsari, IC-555355 was the earliest to flower and fruit.
4. The flower diameter and petal length of accession EC-393740 was diarized maximum.
5. Fruit size was great in Red Beaut which could be compared by EC-393740 and EC-538999, Frontier and EC-552696.
6. The accessions to harvest the earliest were Red Beaut, Kala Amritsari along with IC-555355 whilst, the last accessions to harvest were EC-538999, EC-513684, EC-393740 and IC-558067.
7. Pulp/Stone ratio along with Red Beaut was impressively high in EC-552696.
8. Methley was amongst the maximum recorded total souble solids and sugars.
9. Sugar/Acid ratio was efficient in EC-393740 and Methley.
10. IC-555355 accession had the maximum anthocyanin content.

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APPENDIX-I

ANOVA for tree characters of Japanese plum accessions

Tree Height (m)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.422	0.211		0.842	0.421		0.598	0.299	
Treatment	13	4.907	0.377	2.579	6.192	0.476	3.629	5.495	0.423	3.305
Error	26	3.806	0.146		3.412	0.131		3.325	0.128	
Total	41	9.135			10.447			9.418		

Tree Spread (North-South) (m)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.232	0.116		0.071	0.035		0.133	0.066	
Treatment	13	19.381	1.491	22.487	19.111	1.470	37.476	19.203	1.477	38.678
Error	26	1.724	0.066		1.020	0.039		0.993	0.038	
Total	41	21.337			20.202			20.329		

Tree Spread (East-West) (m)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.239	0.119		0.105	0.0525		0.165	0.082	
Treatment	13	19.097	1.469	22.265	19.026	1.464	15.306	19.043	1.465	20.953
Error	26	1.715	0.066		2.486	0.096		1.818	0.070	
Total	41	21.052			21.617			21.026		

Tree Girth (cm)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	2.706	1.353		1.694	0.847		2.014	1.007	
Treatment	13	1,278.189	98.322	92.603	1,281.668	98.590	73.439	1,274.653	98.050	99.486
Error	26	27.606	1.062		34.904	1.342		25.625	0.986	
Total	41	1,308.501			1,318.266			1,302.291		

ANOVA for foliage characters of Japanese plum accessions

Leaf blade length (mm)		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	0.141	0.0705		0.135	0.0675		-0.099	-0.0495	
Treatment	13	3,732.291	287.099	11,964.14	4,130.771	317.752	7,679.765	3,833.575	294.890	64,975.959
Error	26	0.624	0.024		1.076	0.041		0.118	0.005	
Total	41	3,733.056			4,131.982			3,833.594		

Leaf Blade Width (mm		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	**2**	1.082	0.541		1.975	0.987		1.479	0.739	
Treatment	**13**	2,292.372	176.336	298.830	2,894.964	222.690	257.988	2,524.441	194.188	271.137
Error	**26**	15.342	0.590		22.443	0.863		18.621	0.716	
Total	**41**	2,308.797			2,919.382			2,544.541		

Leaf blade length/width ratio		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	0.006	0.003		0.003	0.0015		0.005	0.0025	
Treatment	13	3.281	0.252	188.907	4.322	0.332	365.716	3.710	0.285	316.865
Error	26	0.035	0.001		0.024	0.001		0.023	0.001	
Total	41	3.322			4.349			3.739		

Leaf Blade Area (mm^2)		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	15.208	7.604		25,076.464	12538.232		13.220	6.61	
Treatment	13	328,870.387	25,297.722	2,609.887	619,277.404	47,636.723	3.790	351,751.771	27,057.829	13,166.464
Error	26	252.019	9.693		326,752.510	12,567.404		53.431	2.055	
Total	41	329,137.614			971,106.378			351,818.423		

Petiole Length (mm)		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	16.527	8.263		4.141	2.0705		1.035	0.517	
Treatment	13	160.961	12.382	3.084	211.345	16.257	14.985	180.782	13.906	13.732
Error	26	104.380	4.015		28.208	1.085		26.331	1.013	
Total	41	281.868			243.695			208.148		

ANOVA for floral characters of Japanese plum accessions

Flower Diameter (mm)		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	0.447	0.223		0.447	0.223		0.117	0.0585	
Treatment	13	131.931	10.149	47.676	131.931	10.149	47.676	205.042	15.772	297.627
Error	26	5.535	0.213		5.535	0.213		1.378	0.053	
Total	41	137.913			137.913			206.537		

Pedicel Length (mm)		2021			2022			Pooled		
Source of Variation	df	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	0.001	0.0005		0.131	0.0655		0.031	0.0655	
Treatment	13	156.820	12.063	2,073.354	323.223	24.863	1,706.843	215.058	16.543	3,492.087
Error	26	0.151	0.006		0.379	0.015		0.123	0.005	
Total	41	156.972			323.733			215.212		

Petal Length (mm)		2021			2022			Pooled		
Source of Variation	DF	SS	MS	F	SS	MS	F	SS	MS	F
Replication	2	0.005	0.0025		0.002	0.001		0.002	0.001	
Treatment	13	89.774	6.906	520.089	81.956	6.304	296.218	79.852	6.142	851.872
Error	26	0.345	0.013		0.553	0.021		0.187	0.007	
Total	41	90.124			82.511			80.042		

ANOVA for pollen viability and in vitro pollen germination of Japanese plum accessions

Pollen Viability (%)		Acetocarmine (1%) solution test			Erythrosine (0.1 %) solution test		
Source of Variation	df	SS	MS	F	SS	MS	F
Replication	2	2.419	1.2095		12.854	6.427	
Treatment	13	298.273	22.944	21.068	5,012.924	385.610	105.964
Error	26	28.316	1.089		94.616	3.639	
Total	41	329.008			5,120.394		

Pollen Germination (%)		Sucrose (10 %) solution			Sucrose (15 %) solution		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	13.152	6.576		0.769	0.3845	
Treatment	13	12,330.263	948.482	289.596	16,019.645	1,232.280	539.796
Error	26	85.155	3.275		59.354	2.283	
Total	41	12,428.571			16,079.769		

ANOVA for fruit characters of Japanese plum accessions

Length of Stalk (mm)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.378	0.189		1.970	0.985		0.910	0.455	
Treatment	13	205.499	15.808	11.035	176.091	13.545	14.396	185.162	14.243	15.780
Error	26	37.246	1.433		24.464	0.941		23.469	0.903	
Total	41	243.124			202.524			209.541		

Fruit Weight (g)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	6.817	3.4085		2.132	1.066		4.131	2.0655	
Treatment	13	11,746.453	903.573	98.076	10,545.459	811.189	615.939	11,085.204	852.708	345.934
Error	26	239.537	9.213		34.242	1.317		64.088	2.465	
Total	41	11,992.808			10,581.832			11,153.423		

Fruit Height (mm)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	4.087	2.0435		0.742	0.371		0.376	0.188	
Treatment	13	2,159.643	166.126	117.119	2,072.548	159.427	160.662	2,093.451	161.035	224.551
Error	26	36.880	1.418		25.800	0.992		18.646	0.717	
Total	41	2,200.609			2,099.090			2,112.472		

Fruit Width (mm)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	4.432	2.216		3.811	1.9055		1.886	0.943	
Treatment	13	3,165.976	243.537	167.098	2,620.452	201.573	148.646	2,847.847	219.065	336.334
Error	26	37.894	1.457		35.258	1.356		16.935	0.651	
Total	41	3,208.302			2,659.520			2,866.668		

Fruit Volume (cm^3)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	27.420	13.71		0.846	0.423		4.596	2.298	
Treatment	13	11,606.400	892.800	76.746	10,649.130	819.164	696.794	11,071.202	851.631	268.617
Error	26	302.462	11.633		30.566	1.176		82.431	3.170	
Total	41	11,936.282			10,680.543			11,158.229		

Fruit Firmness (kg/cm^2)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.089	0.0445		0.057	0.0285		0.056	0.028	
Treatment	13	1.538	0.118	11.315	1.569	0.121	11.443	1.548	0.119	19.216
Error	26	0.272	0.010		0.274	0.011		0.161	0.006	
Total	41	1.899			1.900			1.765		

Fruit Set (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	39.076	19.538		4.914	2.457		13.591	6.7955	
Treatment	13	938.715	72.209	14.472	841.796	64.754	34.487	854.239	65.711	34.206
Error	26	129.727	4.990		48.818	1.878		49.947	1.921	
Total	41	1,107.517			895.528			917.777		

Fruit Drop (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	11.405	5.7025		4.622			0.736		
Treatment	13	994.537	76.503	82.793	634.906	48.839	54.261	730.042	56.157	85.417
Error	26	24.025	0.924		23.402	0.900		17.094	0.657	
Total	41	1,029.967			662.930			747.872		

Fruit Retention (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	2.133	1.0665		2.320	1.16		1.964	0.982	
Treatment	13	989.121	76.086	66.677	620.700	47.746	42.590	750.448	57.727	97.182
Error	26	29.669	1.141		29.148	1.121		15.444	0.594	
Total	41	1,020.924			652.168			767.856		

Fruit Yield (kg/tree)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	4.927	2.4635		2.652	1.326		3.569	1.7845	
Treatment	13	3,599.930	276.918	71.848	3,497.303	269.023	264.048	3,486.451	268.189	267.306
Error	26	100.209	3.854		26.490	1.019		26.086	1.003	
Total	41	3,705.066			3,526.445			3,516.106		

ANOVA for stone characters of Japanese plum accessions

Stone Weight (g)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.021	0.0105		0.025	0.0125		0.011	0.0055	
Treatment	13	1.494	0.115	14.766	0.770	0.059	7.412	1.037	0.080	18.890
Error	26	0.202	0.008		0.208	0.008		0.110	0.004	
Total	41	1.717			1.003			1.158		

Pulp to stone ratio		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	56.592	28.296		28.951	14.4755		22.260	11.13	
Treatment	13	5,857.956	450.612	17.927	6,651.338	511.641	43.531	6,076.197	467.400	71.739
Error	26	653.536	25.136		305.588	11.753		169.397	6.515	
Total	41	6,568.084			6,985.877			6,267.853		

ANOVA for biochemical characters of Japanese plum accessions

TSS (°B)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.159	0.0795		1.528	0.764		0.356	0.178	
Treatment	13	73.117	5.624	13.374	65.874	5.067	19.255	65.731	5.056	27.166
Error	26	10.934	0.421		6.842	0.263		4.839	0.186	
Total	41	84.209			74.244			70.926		

Titratable Acidity (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.040	0.02		0.005	0.0025		0.016	0.008	
Treatment	13	0.360	0.028	2.517	0.416	0.032	2.143	0.374	0.029	4.021
Error	26	0.286	0.011		0.388	0.015		0.186	0.007	
Total	41	0.687			0.810			0.576		

Total Sugars (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.041	0.0205		0.001	0.0005		0.012	0.0006	
Treatment	13	2.932	0.226	24.688	3.060	0.235	14.647	2.978	0.229	41.255
Error	26	0.238	0.009		0.418	0.016		0.144	0.006	
Total	41	3.211			3.479			3.135		

Reducing Sugars (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.007	0.0035		0.012	0.006		0.007	0.0035	
Treatment	13	4.875	0.375	24.826	5.159	0.397	9.986	4.996	0.384	31.498
Error	26	0.393	0.015		1.033	0.040		0.317	0.012	
Total	41	5.275			6.204			5.321		

Non-Reducing Sugars (%)		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.018	0.009		0.003	0.0015		0.006	0.003	
Treatment	13	1.084	0.083	2.756	1.461	0.112	2.455	1.260	0.097	6.530
Error	26	0.787	0.030		1.190	0.046		0.386	0.015	
Total	41	1.888			2.654			1.652		

Sugar/Acid Ratio		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.425	0.2125		0.095	0.0475		0.148	0.074	
Treatment	13	12.174	0.936	5.000	14.291	1.099	4.110	12.980	0.998	9.179
Error	26	4.869	0.187		6.954	0.267		2.828	0.109	
Total	41	17.468			21.341			15.956		

Anthocyanin Content (A_{530})		2021			2022			Pooled		
Source of Variation	**df**	**SS**	**MS**	**F**	**SS**	**MS**	**F**	**SS**	**MS**	**F**
Replication	2	0.118	0.059		0.001	0.0005		0.034	0.017	
Treatment	13	1.951	0.150	21.564	2.065	0.159	17.463	2.001	0.154	33.135
Error	26	0.181	0.007		0.237	0.009		0.121	0.005	
Total	41	2.251			2.303			2.156		

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Title of Thesis	**:**	**'DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) Germplasm'**
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Minor Field (s)	**:**	Genetics and Plant Breeding
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Major Advisor	**:**	Dr RK Dogra

ABSTRACT

The present investigation entitled **''DUS Characterization of Japanese Plum (*Prunus salicina* Lindl.) germplasm"** was executed in the field gene bank of National Bureau of Plant Genetics Resources (NBPGR), Regional Station Phagli, Shimla (Himachal Pradesh) during the year 2021-2022. The experimental material consisted of fourteen germplasm accessions, laid out in randomized complete block design with three replications. The observations were diarized to characterize and evaluate Japanese plum germplasm for growth, floral and fruit characters during the course of investigation. The results of the investigation of different plum genotypes revealed that the maximum tree height and tree girth were diarized in Kala Amritsari (4.45 m and 52.37 cm), respectively. The maximum spread was docketed in Shiro. EC-393740 inscribed the maximum leaf blade length and leaf blade width. Date of full bloom was noted earliest in Red Beaut. The maximum pollen viability with acetocarmine solution and Erythrosine B (0.1 %) test was recorded in EC-382826 (98.97 %) and IC-558067 (71.46 %), subsequently. *In vitro* pollen germination with 10 and 15 per cent sucrose solution was catalogued maximum in EC-382826 (81.69 %) and Frontier (90.53 %), respectively. Fruit weight was obtained maximum in Red Beaut (65.18 g). Maximum fruit drop was chronicled in EC-552693 (46.49 %) and maximum fruit retention was documented in Shiro (67.92 %). Pulp to stone ratio was documented maximum in Red Beaut. Total soluble solids were logged maximum in Frontier (15.20 °B) whilst, the maximum titratable acidity was documented in Shiro (1.56 %). The maximum total sugars, reducing sugars and non-reducing sugars were recorded in Frontier (8.20 %), Frontier (6.62 %) and EC-538999 (1.96 %), respectively. The present study specified that some of these germplasms do possess one or more horticulturally desirable characteristics and thus can be used to broaden the genetic base from the pre-existing cultivars.

Signature of the Student	**Signature of the Major Advisor**
Name: Gauri Sood	**Name: Dr RK Dogra**
Date:	**Date:**

Head of the Department

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