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Research Article

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Evaluation of Phenological and Pomological Characteristics of Plum Varieties (*Prunus* spp. L.) in Mustang, Nepal

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Abstract

Plum is a temperate stone fruit widely adapted and is by far the most diverse of all the '*Prunus*' species. However, fruit and flower phenology and pomological characteristics differ among varieties. Phenological and pomological characteristics of six plum varieties ('Soldam,' 'Mirabelle,' 'Quetsche,' 'Methley,' 'Santa Rosa,' and 'Local') during September 2021-August 2022 in the fruit orchard of Temperate Horticulture Development Center, Mustang, Nepal, were studied. The phenological study revealed the Local as early and Quetsche as late among the tested varieties. However, the average flowering duration was lowest in Methley (10.6 days) and highest in Soldam (15.2 days). Linear dimensions of the fruits were maximum in Soldam and minimum in Mirabelle. The fruit shape of all the varieties was round except for Quetsche, which was elliptic. The stone share was highest in Mirabelle (7.82%) and lowest in Soldam (1.86%). The ripening index was highest for Mirabelle (29.11) and lowest for Methley (7.20). The organoleptic evaluation revealed that Soldam was the most preferred while Quetsche was the least. In conclusion, our study showcased a significant diversity in plum varieties, with implications for orchard management and variety selection to cater to various preferences and needs in the local market and beyond.

Keywords : Phenological stages, plum, fruit characters, organoleptic evaluation, management practices.

Introduction:

Plum (*Prunus* spp. L.) is an essential temperate stone fruit successfully grown in different parts of the world under varied geography (Birwal et al., 2017; Ucar et al., 2022). Plum is listed as one of the minor fruits of Nepal and is grown in limited areas compared to other significant fruits such as banana, mango, and papaya (Karki et al., 2017). Due to the varied geography and climate, there is a high potential for increasing the area, production, and, subsequently, the trade of minor fruits in Nepal (Devkota, 2016). Locally, the plum is called 'Aaru Bakhada,' and it is cultivated commercially in almost 70% of districts in Nepal; the total area, production, and productivity of plums were 1585 ha, 10,284 MT, and 6.49 MT/ha during the fiscal year 2020/21 for Nepal (MoALD, 2022). The productivity of plums in the Mustang district is 7.9 MT/ha, which is higher than the global plum productivity (4.64 MT/ha) (FAO, 2020), unlocking the vast potentiality of commercial plum production.

Phenological stages of plum bud growth encompass the following steps: swollen bud, bud burst, green cluster, white bud, bloom, and petal fall (Chapman & Catlin, 1976; Murray, 2015). Significant differences in the occurrence of these stages were found among different varieties of plum (Majid et al., 2019). Similarly, the flowering phenology, the period between the initiation and end of flowering, is considered necessary to study the pollination behavior of the varieties (Koskela et al., 2008; Wadhwa & Sihag, 2019). The flowering duration among the varieties varied significantly (Comulescu et

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al., 2010); the duration varied within the same variety in different years (Liverani et al., 2008). In addition to this, the stages after the petal fall, viz., fruit set, marble-sized fruit, and fruit maturity are essential to studying fruit development duration (Kwon et al., 2018). All the phenological stages of plums among varieties, starting from the dormant bud and ending at mature fruit, are affected by a series of factors, including temperature and precipitation (Comulescu et al., 2010). Moreover, climate change also directly impacts the phenology of temperate fruits, including plums, which advance flowering and fruiting by a few days (Ramirez & Kallarackal, 2015; Atreya & Kafle, 2020).

The pomological characteristics of plums are significant for the post-harvest handling of mature fruits. Physical properties are essential for sorting, grading, processing, packing, and transportation of fruits (Ertekin et al., 2006); the sphericity index and aspect ratio relate to the shape of the fruit, reflecting its attractiveness (Mohsenin, 1970); chemical properties such as total soluble solids (TSS), titrable acidity (TA), and ripening index (RI) imply the acceptance of variety by consumers (Crisosto et al., 2007). Pomological characteristics vary significantly among the varieties within the same year, which provides the intimation to differentiate between them (Kwon et al., 2018).

Fruit trees undergo a series of growth stages, and synchronization of management practices with these stages is a must for the profitability of production (Chapman & Catlin, 1976). The phenological study of plums, which would reveal these stages and their timings (Keller, 2015), has never been carried out in the Mustang district. However, plums have been cultivated in Mustang, specifically at Temperate Horticulture Development Center (THDC), Marpha, for over 30 years (THDC, 2022). This research was carried out as a rigorous study to evaluate the phenology and pomology of different varieties of plum in Mustang.

Materials and Methods:

Six varieties of plum -'Soldam,' 'Mirabelle,' 'Quetsche,' 'Methley,' 'Santa Rosa,' and Local -were laid out in a randomized complete block design in five replications with a single tree per variety. A total of 30 randomly selected trees were used for the study. The varieties' Soldam', 'Methley,' and 'Santa Rosa' were Japanese, whereas 'Mirabelle' and 'Quetsche' were European. Selected plants were uniform, and similar management practices were applied during the study. The study was carried out from September 2021 to August 2022 in the orchard of THDC, Marpha of Mustang district. The soil of the study area is alkaline, and the soil type is sandy loam (THDC, 2022). Due to its higher elevation, the air temperature of THDC Marpha was relatively low and sometimes reached a freezing temperature. The temperate climate, along with fast-blowing wind, is a typical climatic feature of the research area. The temperature was higher during June-September, while maximum precipitation was recorded in May (Fig. No. 1).

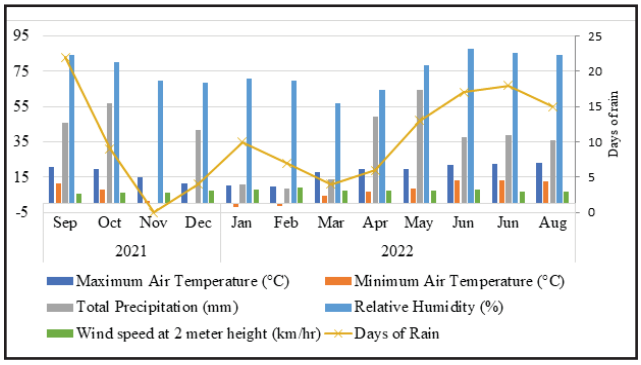

Fig. No. 1: Climatic Condition of THDC, Marpha during the year 2021/22

(Source: DHM, 2022)

Phenological stages:

The phenological stages of plums were determined according to the International Union for the Protection of New Varieties of Plants ('UPOV') guidelines (UPOV, 2002, 2021). The blooming stage was recorded as an initiation of flowering: 10% open flowers; full bloom: 80% open; and end of flowering: 90% petal fall (Wertheim, 1995). Open flowers were considered when the floral buds had ruptured, and the anthers or stigma were visible without touching (Gillespie et al., 2016). The total number of days from the initiation to the end of flowering (petal fall) is represented by flowering duration. The harvest date was confirmed when some hanging fruits reached eating maturity (Lateur et al., 2013). The interval between the date of full bloom and the date of fruit maturity or harvesting was considered the fruit development period (days) (Kwon et al., 2018). The experimental field was observed at intervals of 2 days. The dates of different phenological stages were taken accurately and converted to Days After the Reference Date (DARD), an arbitrary date of February 1. The number of stamens per flower and pistil length (mm) were recorded to determine the flower morphology. Fully opened flowers (n = 5) from different directions of the tree were randomly selected. Pistil length was measured using a vernier caliper. A ratio of stamens per flower to pistil length (relative stamen number per mm) was also calculated (Suranyi 2006, 2013, 2019).

Physical and chemical properties:

Different physical and chemical properties of fruit were determined using the 'UPOV' guidelines and ECPGR protocols (UPOV 2002, 2021; Lateur et al., 2013). Twenty fully matured fruit samples from each replication were harvested separately to study the fruit character. The linear dimensions of fruit, viz., length (L), width (W), and thickness(T), of all sampled fruits were taken by a vernier caliper of 0.01mm accuracy. Similarly, the mass of each sampled fruit and its stones were measured by an electronic balance of 0.01gram sensitivity.

The size of the fruit can be represented in terms of arithmetic mean diameter (D_a) and geometric mean diameter (D_g) and expressed in mm. According to Arshad et al. (2014), Mohsenin (1986),

$$D_a = \frac{L+W+T}{3}$$

Where:

D_a: Arithmetic Mean Diameter, mm

L: Fruit Length, mm

W: Fruit Width, mm

T: Fruit Thickness, mm

The geometric mean diameter (Dg) of the fruit was determined by using the formula given by Kibar & Ozturk (2008), Mohsenin (1986);

$$D_g = \sqrt[3]{L*W*T}$$

Where:

Dg: Geometric Mean Diameter, mm

The shape of the fruit is expressed in terms of the sphericity index and aspect ratio (Mohsenin, 1970). The sphericity index (Ø) of the fruit can be calculated by using the following equation given by Mohsenin (1986), Sitkei (1987), Omobuwajo et al. (1999):

$$Ø = \frac{D_g}{L} \times 100$$

Where:

Ø: Fruit Sphericity Index, %

L: longest Diameter of the Fruit, mm

The aspect ratio (Ra) of the fruit was calculated by using the following equation (Omobuwajo et al., 1999):

$$R_a = \frac{W}{L}$$

Where:

Ra: Fruit Aspect Ratio

The surface area (A) of the fruit was determined by the equation (Mohsenin, 1970);

$$A = \pi * D_g^2$$

Where:

A: Surface Area of fruit, mm^2

The volume and density of the fruit were measured by the water displacement method. Plum produces medium-sized fruit: the xylometric/water displacement method could be used instead of the toluene displacement method to calculate the individual fruit volume (V). Water cannot be compressed, so as long as the fruit absorbs a tiny amount of water, the change in water height should provide a close approximation of the fruit volume (Moreda et al., 2009)

The true solid density of fruit (ρt) of fruit was calculated as (Mohsenin, 1986);

$$\rho_t = \frac{W_f}{V}$$

Where:

ρ_t: True Solid Density of Fruit, gm/cm3

W_f : Individual Fruit Weight, gm

V: Individual Fruit Volume, ml or cm3

Mass and volume relationships were used to determine the fruit's bulk density (ρb) by filling an empty plastic container of known volume and weight with fruit from a height of 15 cm, striking the top (Fraser et al., 1978). The ratio of the weight of the fruit to the volume of the container gives the bulk density of the fruit as follows:

$$\rho_b = \frac{m}{v}$$

Where:

ρ_b: Bulk Density of Fruit, gm/cm3

m: Weight of Fruit to fill the Container, gm

v: Volume of the Container, cm3

The porosity of fruit (ε) was calculated by using the equation given by Mohsenin (1970);

$$\varepsilon = \left[1 - \frac{\rho_b}{\rho_t}\right] \times 100$$

Where:

ε: Porosity of fruit, %

After de-pulping and cleaning the stone, individual stone weight (Ws) was measured. The stone share (%) is the share of stone in the weight of fruit expressed in %. It was determined by using the following equation (Milatovic, 2016):

$$\text{Stone share \%} = \frac{W_s}{W_f} * 100$$

Where:

Ws: Individual Stone Weight, gm

The fruit's Total Soluble Solids (TSS) were measured using an ATC-1E automatic hand-held refractometer (Atago, Tokyo, Japan) with a 0-32° Brix scale at 20°C. The results were expressed in °Brix. The fruit's titrable acidity (TA) was determined as per the general procedures prescribed by Paul et al. (2010). The dilute fruit juice was titrated with 0.1 N NaOH until the color changed, as indicated by the phenolphthalein indicator. The TA

was expressed as the TA%, or percentage of dominant organic acid, or gram of dominant organic acid per 100 ml of fruit juice). The dominant organic acid found in the plum is malic acid, and hence the TA% was expressed as % malic acid (gm malic acid/100 ml of juice) (Wills et al., 1983; Milosevic & Milosevic, 2012; Ionica et al., 2013). The TA of the fruit can be calculated as (Paul et al., 2010);

$$TA\ \% = \frac{V_b * N * M_{eq}}{V_a} * 100$$

Where:

TA%: Titrable Acidity% or gm malic acid/100ml of juice

Vb: Volume of NaOH consumed in the reaction, ml

N: Normality of NaOH used (0.1N)

Meq: Milliequivalent of malic acid (0.067 for malic acid)

Va: Volume of fruit juice used, ml (10 ml)

Rather than relying individually on TSS or TA, the ripening index was calculated to know the actual taste of fruits. The ripening index/maturity index was determined by using the equation (Milosevic & Milosevic, 2012; Kwon et al., 2018);

$$RI = \frac{TSS}{TA}$$

Where:

RI: Ripening Index.

Organoleptic Evaluation (Panel Test):

Organoleptic evaluation of the fruit was grouped into exterior/commercial aspects (shape, size, skin color) and pulp/sensory traits (mouthfeel, juiciness, sweetness, acidity). Three panelists (males between 25 and 40 years old) who were well-experienced government officials working at THDC Marpha evaluated two typical fruits of each plum variety. The evaluation was done by filling out a questionnaire provided to each panelist with parameters such as shape, size, skin color, mouthfeel, juiciness, sweetness, and acidity. Individual scoring for each character of each plum variety was done on a hedonic scale ranging from 1 to 9, where 1 indicated the minimum score, and 9 indicated the maximum for each trait. From each questionnaire, the total score was calculated for each variety. Finally, a general score was calculated for each variety by an average of three panelists (Butac et al., 2015; Milatovic, 2016; Shamsolshoara et al., 2021).

Meteorological data:

The meteorological data were obtained from the automatic weather station (Meteorological Station, Thakmarpha (Index No. 0604), Mustang) in 'Block C' of THDC, Marpha. It is under the supervision of the government of Nepal (Ministry of Energy, Water Resources, and Irrigation, Department of Hydrology and Meteorology).

Statistical analysis:

All the data were subjected to a one-way ANOVA with varieties as the treatment. The differences between mean values were determined using Duncan's multiple range test at a 5% significance level (Dafaallah, 2019). All the statistical analyses were performed using R packages (version 4.2.1).

Result and Discussion:

Phenological Characters

The timing of the phenological stages of the studied plum varieties is represented in Table No. 1. Mirabelle took the most prolonged period to reach the dormant bud (24.6 DARD) and swollen bud (33.4 DARD) stages. In comparison, Local was the earliest variety to reach these stages (18.4 DARD and 25.4 DARD). Similarly, the Local plum was the first to get budburst (30.4 DARD), green cluster (36.8 DARD), and white bud (43.6 DARD) stages, while Mirabelle took the maximum number of days to reach these stages (43.40 DARD, 51.6 DARD, and 59.6 DARD). The initiation of flowering in different plum varieties ranged from 48.60 DARD in Local to 63.60 DARD in Mirabelle. In comparison, the end of flowering went from 61.40 DARD in Local to 75.20 DARD in Mirabelle. The present findings align with the study of Majid et al. (2019), who investigated six varieties of plum in Kashmir, India. Similar variations in phenological stages were also observed by Sundouri et al. (2017), Celik & Cuba (2018), and Shamsolshoara et al. (2021) in different plum varieties.

An average flowering duration of 12.27 days was observed in the different plum varieties (Table No. 1). Soldam flowered for the most prolonged duration (15.20 days), followed by Local (12.80 days), which was statistically at par with Santa Rosa (12.00 days), while Methley had the shortest duration (10.60 days). Methley (53.20 DARD) and Soldam (53.40 DARD) showed synchrony for the initiation of flowering, and Quetsche (68.20 DARD) and Mirabelle (68.40 DARD) showed synchrony for full flowering. In contrast, Santa Rosa (64.20 and 69.60 DARD) and Soldam (64.40 and 68.60 DARD) showed synchrony for full flowering and petal fall, respectively. Milosevic et al. (2010) and Milatovic et al. (2016) suggested a similar variation in the flowering phenology of different plum varieties. The flowering duration is a factor of meteorological conditions and genetic composition and varies between 6 and 12 days among the cultivars (Cosmulescu et al., 2010). Synchrony in flowering within Japanese and European cultivars was also explained by Suranyi (2013) and Jun et al. (2015), which implies the feasibility of varieties for pollination activities after further experiments (Wadhwa & Sihag, 2019).

Fruit set and marble-sized fruit stages were found earlier in Local (70.60 DARD and 83.40 DARD), while Quetsche (89.60 DARD and 109.80 DARD) took the

Table No. 1 : Phenological stages of different plum varieties from dormant bud to matured fruit at THDC, Mustang (2022)

Varieties	Before Flowering (DARD)					Flowering (DARD)				Fruit Development (DARD)			
	DB	SB	Bb	GC	WB	IoF	FF	EoF	FD (days)	FS	MsF	FM	FDP (days)
Soldam	23.20b	31.20b	36.60c	41.60d	49.20d	53.40d	64.40b	68.60c	15.20a	84.80c	99.40c	177.60c	113.20c
Mirabelle	24.60a	33.40a	43.40a	51.60a	59.60a	63.60a	68.40a	75.20a	11.60cd	87.80b	104.60b	191.60b	123.20b
Quetsche	24.00ab	30.60b	40.60b	49.60b	57.40b	62.20b	68.20a	73.60b	11.40cd	89.60a	109.80a	204.60a	136.40a
Methley	23.20b	29.20c	33.60d	40.80e	48.80d	53.20d	58.60c	63.80d	10.60d	78.80d	92.80e	156.20e	97.60e
Santa Rosa	22.00c	29.60c	36.60c	46.40c	54.80c	57.60c	64.20b	69.60c	12.00bc	84.80c	97.60d	172.40d	108.20d
Local	18.40d	25.40d	30.40e	36.80f	43.60e	48.60e	54.00d	61.40e	12.80b	70.60e	83.40f	149.60f	95.60f
LSD (0.05)	1.07	0.69	0.59	0.63	0.71	0.74	0.87	1.57	1.01	1.09	1.45	1.77	1.37
SEm (±)	0.15	0.10	0.08	0.09	0.10	0.10	0.12	0.17	0.14	0.15	0.20	0.24	0.19
CV, %	3.59	1.76	1.22	1.08	1.03	0.99	1.05	1.33	6.23	1.00	1.12	0.76	0.93
Grand Mean	22.57	29.90	36.87	44.47	52.23	56.43	62.97	68.70	12.27	82.73	97.93	175.33	112.37

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level. DB: Dormant Bud; SB: Swollen Bud; Bb: Budburst; GC: Green Cluster; WB: White Bud; IoF: Initiation of Flowering; FF: Full Flowering; EoF: End of Flowering; FD: Flowering Duration; FS: Fruit Set; MsF: Marble-sized Fruit; FM: Fruit Maturity; FDP: Fruit Development Period.

most prolonged period to reach these stages (Table No. 1). Soldam was statistically at par with Santa Rosa (84.80 DARD) to get the fruit set stage. All the varieties under study varied significantly in their fruit development and harvesting time. The earliest harvest was done on July 1 (149.60 DARD) in Local, followed by July 6 (156.20 DARD) in Methley, and lately on August 25 (204.60 DARD) in Quetsche. The fruit development period was the longest in Quetsche (136.40 days) and the shortest in Local (95.60 days). The findings are at par with the results of Milosevic et al. (2010), Suranyi (2013), Jun et al. (2015), and Kwon et al. (2018) after studying hundreds of varieties and clones of plums. The fruit development duration generally depends on the chilling requirement of the cultivar and the temperature from full bloom to the maturity stage (Majid et al., 2020).

Table No. 2 : Morphological traits of flowers of different plum varieties at THDC, Mustang (2022)

Varieties	Stamen no. per Flower, no.	Pistil Length, mm	Stamen Number/Pistil Length, no./ mm
Soldam	31.40a	9.66d	3.26b
Mirabelle	25.40d	10.90c	2.33c
Quetsche	26.64c	11.70b	2.28c
Methley	30.16b	8.66e	3.49a
Santa Rosa	25.93cd	8.18f	3.17b
Local	25.80cd	12.50a	2.07d
LSD (0.05)	0.98	0.45	0.17
SEm (±)	0.14	0.06	0.02
CV, %	2.70	3.23	4.63
Grand Mean	27.56	10.27	2.77

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

Morphological traits of flowers

The morphological characteristics of the flowers of different plum varieties are given in Table No. 2. The highest stamen number per flower (no.) was observed in Soldam (31.40) and the lowest in Mirabelle (25.40), which was statistically at par with Local (25.80) and Santa Rosa (25.93). The pistil length ranged from 8.18 mm in Santa Rosa to 12.50mm in Local, with an average of 10.27 mm. However, Methley (3.49) was found to have the highest stamen number per pistil length (no./ mm), while the lowest was recorded in Local (2.07). Suranyi (2006) and Hovarth et al. (2011) concluded similar findings for the flower morphological traits of different plum varieties.

Pomological Characters

Fruit Physical Properties

Fruit Linear Dimensions: Data on fruit linear dimensions of different plum varieties are represented in Table No. 3. The fruit length was highest in Soldam (48.37 mm), lowest (26.26 mm) in Mirabelle, and intermediate in Methley and Local. The width of the fruit also varied between 24.34 mm (Mirabelle) to 44.84 mm (Soldam) and 24.34 mm (Mirabelle); the same variation was observed for fruit thickness. Similarly, the arithmetic and geometric mean diameters were recorded as the highest for the fruit of Soldam (45.63mm and 45.57mm) and the lowest for Mirabelle (24.29mm and 24.20 mm).

Table No. 3 : Linear dimensions of the fruit of different plum varieties available at THDC, Mustang (2022)

Varieties	Length(mm)	Width(mm)	Thickness(mm)	Arithmetic Mean Diameter (mm)	Geometric Mean Diameter (mm)
Soldam	48.37a	44.84a	43.67a	45.63a	45.57a
Mirabelle	26.26e	24.34e	22.28e	24.29d	24.20d
Quetsche	35.10c	26.72d	25.62d	29.15c	28.85c
Methley	31.95d	30.54c	29.85c	30.78c	30.77c
Santa Rosa	40.26b	38.86b	38.24b	39.12b	39.11b
Local	30.95d	28.57cd	27.43cd	28.98c	28.94c
LSD (0.05)	2.94	2.15	2.87	2.44	2.47
SEm (±)	0.41	0.30	0.40	0.34	0.34
CV, %	6.28	5.04	6.98	5.60	5.68
Grand Mean	35.48	32.31	31.18	32.99	32.91

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

At the same time, both parameters were found to be statistically similar for the fruit of Quetsche, Santa Rosa, and Local. Kwon et al. (2018) and Kumar et al. (2018b) found a similar observation for fruit linear dimension while studying different plum cultivars. The arithmetic and geometric mean diameters are closely related to the major dimensions of the fruit: length, width, and thickness (Mohsenin, 1986). Moreover, fruit size varies depending on its location in the plum tree (Meland, 2005).

Shape Indices and Surface Area: The sphericity index and aspect ratio are measures of the shape of the fruit [18]. The aspect ratio value near one represents a round shape, while near zero represents the elliptic or oblong shape of the fruit (Omobuwajo et al., 1999). A statistically similar sphericity index (%) was observed in the fruit of Santa Rosa (97.17%) and Methley (96.30%), which was significantly higher than that of Mirabelle (92.25%) and Quetsche (82.20%) (Table No. 4). Similarly, a statistically similar aspect ratio was observed for all the varieties except Quetsche. This implies a more circular fruit shape for the Japanese and an elongated to oval shape for the European varieties (specifically for Quetsche). The findings are in line with the results of different researchers in the past, including Milosevic et al. (2010), Jun et al. (2015), and Gasi et al. (2020). Moreover, the surface area was recorded between 6542.11 mm2 (Soldam) and 1844.79 mm2 (Mirabelle) among the varieties. The shape indices and surface area are closely related to the fruit's linear dimension and are derivatives of them (Mohsenin, 1970). As the linear dimensions of fruits differ, the shape indices and surface area change accordingly.

Table No. 4 : Shape indices and surface area of fruits as influenced by different plum varieties available at THDC, Mustang (2022)

Varieties	Shape Indices		Surface Area(mm2)
	Sphericity Index (%)	Aspect Ratio	
Soldam	94.45ab	0.93a	6542.11a
Mirabelle	92.25b	0.93a	1844.79d
Quetsche	82.20c	0.76b	2623.46c
Methley	96.30a	0.96a	2981.66c
Santa Rosa	97.17a	0.97a	4817.61b
Local	93.53ab	0.92a	2643.23c
LSD (0.05)	3.67	0.04	558.11
SEm (±)	0.51	0.01	77.24
CV, %	3.01	3.65	11.83
Grand Mean	93.71	0.91	3575.48

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

Average Fruit Weight, Volume, Densities, and Porosity: Data on average weight, volume, true solid density, bulk density, and porosity characteristics of different plum varieties are shown in Table No. 5. Except for Methley and Quetsche, the average fruit weight showed highly significant variations ranging from 16.14 gm in Local to 69.99 gm in Soldam among the studied varieties. The same variations were observed in terms of fruit volume. When the average fruit weight of different varieties from this study was compared with other research in the past, they were found to be around the normal limits (Horvath et al., 2011; Kumar et al., 2018b; Drogoudi & Pantelidis, 2022); however, the variation in fruit weight and volume in different cultivars might be the effect of environmental and soil conditions during the fruit growth and development stages as well as genetic characteristics (Kumar et al., 2018a).

True density, bulk density, and porosity are significant for separating fruit through hydrodynamic means (Owolarafe & Shotonde, 2004). There were significant differences among each variety (Table No. 5). True solid density ranged from 0.96 g/cm3 in Mirabelle to 1.08 g/cm3 in Quetsche values. At the same time, bulk density stood statistically similar between Local, Mirabelle, Santa Rosa, and Soldam, with an average of 0.60 g/cm3. Likewise, the porosity ranged from 30.99% in Methley

Table No. 5 : Average fruit weight, volume, densities, and porosity as influenced by different plum varieties available at THDC, Mustang (2022)

Varieties	Average Fruit Weight(gm)	Fruit Volume (ml or cm^3)	Density (gm/cm^3)		Porosity (%)
			True Solid Density(gm/cm3)	Bulk Density(gm/cm^3)	
Soldam	69.99a	67.23a	1.04d	0.53c	48.91b
Mirabelle	13.01d	13.51d	0.96f	0.64b	33.12d
Quetsche	16.21cd	14.99cd	1.08a	0.50d	54.08a
Methley	18.76c	17.69c	1.06b	0.73a	30.99d
Santa Rosa	48.39b	47.94b	1.01e	0.54c	46.97b
Local	16.14cd	15.34cd	1.05c	0.66b	37.65c
LSD (0.05)	3.27	3.07	0.01	0.03	2.90
SEm (±)	0.45	0.43	0.000690411	0.00407431	0.40
CV, %	8.14	7.90	0.37	3.72	5.23
Grand Mean	30.42	29.45	1.04	0.60	41.95

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

Table No. 6 : Stone characteristics of different plum varieties available at THDC, Mustang (2022)

Varieties	Stone Weight(gm)	Stone Share (%)
Soldam	1.30b	1.86d
Mirabelle	1.01cd	7.82a
Quetsche	1.16bc	7.44a
Methley	1.24b	6.70ab
Santa Rosa	1.56a	3.24c
Local	0.93d	5.82b
LSD (0.05)	0.15	1.33
SEm (±)	0.02	0.18
CV, %	9.42	18.38
Grand Mean	1.20	5.48

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

to 54.08% in Quetsche. These findings align with and firmly fit within the range of the literature values (Calisir et al., 2005; Celik & Kuba, 2018).

Stone Characteristics: Stone weight and percentage of stone shares were significantly influenced by plum varieties under the study (Table No. 6). The stone weight was measured between 0.93 g (Local) and 1.56 g (Santa Rosa); however, the stone share percentage was calculated to be highest in Mirabelle (7.82%) and lowest in Soldam (1.86%). These findings were found to be in line with the research done in the past on different plum varieties (Horvath et al., 2011; Kumar et al., 2018a; Majid et al., 2020).

Fruit Chemical Properties

Significant differences were observed among the varieties for fruit TSS except for Local, and Santa Rosa

Table No. 7 : TSS, TA, and ripening index as influenced by different plum varieties available at THDC, Mustang (2022)

Varieties	Total Soluble Solids/ TSS (°Brix)	Titrable Acidity (%)	Ripening Index/RI
Soldam	15.60c	0.91c	17.07c
Mirabelle	22.30a	0.77e	29.11a
Quetsche	17.20b	0.87d	19.87b
Methley	11.55e	1.61a	7.20f
Santa Rosa	12.80d	1.43b	8.95e
Local	13.10d	0.85d	15.49d
LSD (0.05)	1.18	0.04	1.55
SEm (±)	0.16	0.005385165	0.21
CV, %	5.79	2.75	7.21
Grand Mean	15.43	1.07	16.28

Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

(Table No. 7). The fruit TSS ranged from 11.55°Brix in Methley to 22.30°Brix in Mirabelle (22.30). In contrast, the maximum and minimum TA were recorded in Methley (1.61%) and Mirabelle (0.77%). On calculating the ripening index from the TSS and TA, the maximum and minimum were observed for Mirabelle (29.11) and Methley (7.20), respectively, and all of the varieties varied significantly. It is tacit that the Japanese varieties - Santa Rosa, Methley, and Soldam -are found to have lower TSS, TA, and ripening index than the European varieties - Mirabelle and Quetsche. Similar findings were inferred by different researchers in the past, including Dragoyski et al. (2008), Hartmann & Neumuller (2009), and Drogoudi & Pantelidis (2022), which strongly supports our study of fruit chemical properties.

Taste is one of the crucial factors governing fruit quality. However, the fruit preference varies from customer to customer and country to country. People of South Europe and Asia prefer sweet fruit (high TSS), while people from the rest of the world prefer a good balance of sugar and acid in the fruit (TSS: TA) (Hartmann & Neumuller, 2009). A survey conducted by Vangdal (1980) revealed that most customers did not prefer the plum fruit with less than 12.5°Brix TSS. Contrary to this, Crisosto et al. (2007) insisted that the ripening index (TSS: TA) was a perfect indicator of consumer variety acceptance. Crisosto et al. (2004), from an in-store consumer test, suggested that consumer acceptance of the variety was closely related to the ripening index only when the TSS was less than 12°Brix, while the ripening index was not necessitated for acceptance of the variety when the TSS was greater than 14°Brix; consumer acceptance was shallow (11.1%) when the TSS was between 10 and 11.9°Brix and TA was more significant than 1%.

Table No. 8: Organoleptic evaluation of different plum varieties available at THDC, Mustang (2022)

Varieties	Exterior/Commercial Aspects			Pulp/Sensory Traits			
	Shape	Size	Skin Color	Mouthfeel	Juiciness	Sweetness	Acidity
Soldam	6.17c	8.17a	7.83a	6.83b	8.17a	6.17bc	4.50c
Mirabelle	5.50d	4.67d	5.83c	5.83c	4.67e	8.33a	3.83d
Quetsche	4.50e	5.33c	5.67c	5.00d	4.17f	6.50b	4.00d
Methley	6.50c	6.67b	7.33ab	7.83a	5.67d	4.50e	6.67a
Santa Rosa	7.33b	7.67a	6.50bc	5.83c	7.17b	5.33d	5.83b
Local	8.17a	6.33b	6.33bc	6.83b	6.17c	5.67cd	4.00d
LSD (0.05)	0.57	0.57	1.04	0.66	0.47	0.74	0.49
SEm (±)	0.07	0.07	0.13	0.09	0.06	0.10	0.06
CV, %	4.90	4.82	8.66	5.68	4.30	6.71	5.59
Grand Mean	6.36	6.47	6.58	6.36	6.00	6.08	4.81

*Hedonic scale ranging from 1 to 9, where 1 indicates the minimum, and 9 indicates the maximum score for each trait.

** Means in the same column followed by the same letter(s) are not significantly different by DMRT at a 5% significance level.

Organoleptic Evaluation

A panel test was conducted among fruits of different plum varieties to determine their commercial aspects and pulp traits (Table No. 8). On a hedonic scale ranging from 1 to 9, Local (8.17) and Quetsche (4.50) scored the highest and lowest scores for fruit shape, respectively. Soldam (8.17) scored the highest for size traits, and Mirabelle (4.67) scored the lowest. Soldam and Santa Rosa were found to be statistically similar in fruit size. Similarly, Soldam (7.83) scored the highest, while Quetsche (5.67) scored the lowest for skin color. No significant difference was found between Soldam and Methley and between Quetsche and Mirabelle for skin color. Significant differences were also observed in the sensory traits of fruits of different plum varieties. Methley (7.83) and Soldam (8.17) scored the highest, and Quetsche (5.00 and 4.17) scored the lowest for mouthfeel and juiciness traits, respectively. Similarly, Mirabelle was observed to score the highest sweetness (8.33) and lowest acidity (3.83), while Methley scored the lowest sweetness (4.50) and highest acidity (6.67). After averaging the scores, the three panelists gave, the general score was calculated for each variety. The available score was found in the following order: Soldam (47.83), Santa Rosa (45.67), Methley (45.17), Local (43.50), Mirabelle (38.67), and Quetsche (35.17).

Conclusion:

The present study on the phenological stages concluded that Local was the earliest and Quetsche was the latest among the studied plum varieties. The flowering duration varied between 10.60 and 15.20 days, with synchronization within studied Japanese and European varieties. Significant differences were found among the studied varieties for the fruit development period, with an average of 112.37 days. The fruit of Soldam was found to have the largest size and highest weight, while it was the smallest and lightest in the case of Mirabelle. The ripening index was highest in Mirabelle and lowest in Methley. Organoleptic evaluation of different plum varieties concluded that Soldam was the most preferred among all varieties under consumer study.

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The authors declare no conflicts of interest regarding the publication of this manuscript.

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