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Evaluation of Phenological Traits of Pear Varieties in Warm Temperate Region of Nepal

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ABSTRACT

Phenological study of a fruit tree is important for timely and proper orchard management. This study was carried out in orchard located at Warm Temperate Horticulture Centre (WTHC), Kathmandu, Nepal from January to August, 2020 with the objective to identify the different timing of phenological stages in 18 different varieties of pear. Data on days from swollen bud to bud burst, swollen bud to green cluster, swollen bud to white bud, swollen bud to bloom, swollen bud to petal fall, swollen bud to fruit set, fruit length, and fruit diameter were recorded. The phenological and fruit traits were found highly significant. The shortest flowering period (days from swollen bud to petal fall) was observed in varieties Sinko and Yakumo (13.33 days) and the longest period was found in Pharping local (Green) (35.00 days) followed by Pharping local (Brown) (34.00 days). The longest fruit (58.80 mm) was recorded in Anjou followed by Bartlett (52.90 mm) and Yakumo (49.80 mm). Similarly, the highest fruit diameter (57.60 mm) was recorded in Anjou followed by Yakumo (55.80 mm) and Atago (51.60 mm). On the basis of total variability, pear varieties were grouped into five distinct clusters. Cluster 2 showed that Anjou had the highest fruit length and fruit diameter. Cluster 5 illustrated that the longest flowering period was observed in the Pharping local (Green) followed by Pharping local (Brown). Based on phenological traits Sinko and Yakumo and based on fruits traits Anjou were found potential varieties for cultivation under warm temperate region of Nepal.

Keywords: Cultivar, Growth stages, Pear, Phenology

1. INTRODUCTION

Pear (*Pyrus spp*.) is a temperate fruit, belongs to the family Rosaceae. Mainly two species of pear are commonly cultivated in the world, *Pyrus communis* (European type) and *Pyrus pyrifolia* L. (Asian type). European type of pear is mainly cultivated in Europe, South America, North America, and Australia and Asian type of pear are predominate in China, Japan and South-East Asia (Hancock, 2008). As pear fruit has its sweetness, crispness, characteristic fragrance and slight aroma, it is popular among the consumers (Chen, Wang, Wu, Wang, & Hu, 2007). The total area production of pear in the world are 1,381,923 ha and 23,733,772 tons respectively. Asia is the highest producer of pear (about 70%) in the world. In Nepal, the area under pear cultivation is 3,248 ha and total production is 30,827 tons (FAOSTAT, 2018). There is a great possibility of pear

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cultivation from 1200 to 2200 masl throughout the mid hills of Nepal (Atreya, 2018). Hybrid pear varieties (obtained from crosses between *Pyrus pyrifolia* and *Pyrus communis*) can be cultivated in subtropical climate having mild winters (Tecchio, Bettiol Neto, Barbosa, & Tucci, 2011). The varieties as well as rootstock influence the evolution dynamic of tree and the fruit formation gets affected by the type of the fruit structure and its foliar area which are important parameters to the phenological evolution (Petri, Hawerroth, Leite, Couto, & Francescatto, 2012). In pear tree, fruiting structures arises from the buds located on the branches and these buds may give rise to structures as spurs (vegetative or reproductive), brindles (vegetative or reproductive) and bourses (de Alcântara Barbosa et al., 2018).

Phenology of a deciduous fruit tree is the periodical biological events from the dormant stage to the fruit development and which are closely regulated by climate and seasonal changes (Chen et al., 2007). The study of phenology of fruit tree is important for timing proper management practices such as training and pruning, irrigation, fertilization, pest and weed control etc. At the end of winter or early spring, the period of vegetative growth begins and finishes in autumn (Martínez Valero et al., 2001). For the first time, Fleckinfer defined 'phenological stages' with the combination of letters and numbers in 1945 (Fleckinger, 1948). Later on, Bleiholder, Kirfel, Langeluddeke, and Stauss (1991) proposed a uniform decimal code, known as the BBCH-scale (Biologishe Bundesanstalt, Bundessortenamt, Chemische Industrie). The extended BBCH scale was later proposed by Hack et al. (1992) and Hess et al. (1997). This study was also conducted on the basis of extended BBCH scale but important growth stages were only recorded. Chapman and Catlin (1976) also suggested eight important growth stages of pear. These eight growth stages of pear are dormant, swollen bud, budburst, green bud, white bud, bloom, petal fall and fruit set. In dormant stage, fruit buds are relatively inactive. Fruit buds starts to swell separating scales and exposes areas of lighter colored tissue. Then budburst takes place showing tips of blossom buds. After few days of budburst, green blossom buds appear in the cluster with lengthened stem and later on turns into white blossom buds. Finally, the blossom buds get opened (bloom) which will later on followed by petal fall and fruit set stage respectively. In early varieties of pear tree, the cell division stage lasts for 25-30 days after blooming and 45 days in late varieties (Jackson, 2003). The fruit enlargement stage takes place at the last one month or two before harvest and at that time pear fruit grow quickly. The pear fruit enlarge slowly during the period between cell division and fruit enlargement (Marsal, Rapoport, Manrique, & Girona, 2000).

Cluster analysis is frequently used to classify fruit genotypes and can be used by breeders and geneticists to identify subsets of accessions which have potential utility for specific breeding or genetic purposes (Rincon et al., 1996). The main aim of using a cluster technique in plant breeding

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trials is to group the varieties into several homogeneous groups such that those varieties within a group have a similar response pattern across the locations (Shrestha, 2016).

The objective of this study was to identify the different timing of phenological stages in 18 different varieties of pear (including both European and Asian type) in mid hills of Nepal.

2. MATERIALS AND METHODS

Experimental site:

The experiment was performed in the pear orchard located at Warm Temperate Horticulture Centre (WTHC), Kirtipur, Kathmandu. Warm temperate region in Nepal is the zone that covers the areas of upper part of mid hills running from east to west of the country and the mean annual temperature ranging from 15-17.5^{0}C (MPHD, 1990). The experimental site is situated at 27°4'N latitude and an altitude of 1320 masl. The climatic condition of the research site is warm temperate. The maximum temperature reaches up to 31^{0}C during summer and minimum temperature drops to 1^{0}C during winter and average annual precipitation is 1025mm. The experiment was carried out from January 2020 to August 2020.

Cultivar selection:

Eighteen varieties of pear (fifteen Asian, two European and one unidentified cultivar named as Kirtipur-1) were selected to conduct the phenological observations. The list of varieties used in the experiment was given in Table 1. Japanese and European varieties were brought from Japan during JICA project period while Pharping Local (white and brown) were collected from our local pear production area i.e., Pharping. Two plants from each cultivar were selected. The different varieties were tagged with the white colored tagging ribbon. All the plants from different varieties belongs to similar age group, approximately 26 years old. All the varieties were grafted plants and were cultivated under similar management practices like training and pruning, weed management, fertilization, disease and insect management etc. Trees were trained in open center system and top working of the tree was done whenever necessary. The spacing between plant to plant was 5 m.

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Table 1: The details of pear varieties used in the experiment

S.N.	Varieties	Source of origin	S. N.	Varieties	Source of origin
1	Hosui	Japan	10	Pharping Local (Brown)	Nepal
2	Kosui	Japan	11	Pharping Local (Green)	Nepal
3	Meigetsu	Japan	12	Nittaka	Japan
4	Yakumo	Japan	13	Hawana	Japan
5	Kikisui	Japan	14	Aatago	Japan
6	Waseka	Japan	15	Chojuro	Japan
7	Gold Nijisseiki	Japan	16	Kirtipur-1	Nepal
8	Okisankichi	Japan	17	Bartlett	Europe
9	Sinko	Japan	18	Anjou	Europe

Design of experiment:

The experiment was carried out in randomized complete block design (RCBD) with two replications. The eighteen varieties of pear were selected as treatments and replicated two times with two trees per treatment.

Data observations:

In each tree, four branches were selected for phenological study. The selection of branches was done in such a manner that each branch faces one direction i.e., north, south, east and west so that errors can be minimized. The observations were started from the dormant stage and were done on 2-3 days interval until fruit set. Visual observations were taken from the tagged branches. Data on days from swollen bud to bud burst, swollen bud to green cluster, swollen bud to white bud, swollen bud to bloom, swollen bud to petal fall, swollen bud to fruit set, fruit length, and fruit diameter were recorded.

Statistical analysis:

The data were entered in Microsoft excel 2016 and analysis was done by using STAR 2.0.1 (Statistical Tool for Agricultural Research) and Cluster analysis by Minitab 17.

3. RESULTS AND DISCUSSION

The phenology of pear was studied with reference to BBCH (Biologische Bundesanstalt, Bundessortenamt and CHemical industry) scale. Eight stages were recorded for 18 pear varieties. The major eight stages are dormant, swollen bud, bud burst, green cluster, white bud, bloom, petal fall and fruit set (Chapman & Catlin, 1976). Among 18 varieties, 'Pharping Local (Green)' showed earlier bud burst on 14th February followed by 'Pharping Local (Brown)' which showed bud burst on 22nd February and Waseaka showed bud burst at the last on 24th March. Varieties; 'Hawana' and 'Aatago' showed earlier bud burst on 5th March among Asian varieties. Anjou showed earlier bud burst on 27th February among European varieties. The seasonal timing and duration of different

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phenological stages of fruit trees depends on local climatic conditions and fluctuate from year to year (Cordero, Bocanegra, García-Galavís, Santamaría, & Camacho, 2013). The phenology mainly depends on the genetic characteristics of different varieties. Different varieties show same stage of growth in different time period. Most of the temperate deciduous fruit trees undergo dormancy and requires certain amount of chilling for release (Lang, 1996). The growth cycle that takes place between late summer and budburst is considered as dormancy period (Faust, Erez, Rowland, Wang, & Norman, 1997). The development of inflorescence is initiated in the summer and autumn of the previous season of the bloom and flower continues to develop in the spring after a month of pollen meiosis and anthesis starts at the end of April or the beginning of May (Staritsky, 1970).

The mean number of days required from swollen bud to bud brust, green cluster, white bud, bloom, petal fall and fruit set were influenced by the varieties due to the variation in genetic makeup. The number of days required from swollen bud to bud burst was found highly significant different among the varieties (Table 2). The highest no of days required from swollen bud to bud burst in Hosui (7 days) followed by Aatago, Chojuro and Nittaka (6 days) while the lowest no of days recorded in Sinko (2 days). Similarly, swollen bud to green cluster, swollen bud to white bud, swollen bud to bloom, swollen bud to petal fall, swollen bud to fruit set were recorded and is shown in Table 2.

Table 2: No of days require for different phenological stages of pear varieties

Pear varieties	No of days					
	Swollen bud to bud burst	**Swollen bud to green cluster**	**Swollen bud to white bud**	**Swollen bud to bloom**	**Swollen bud to petal fall**	**Swollen bud to fruit set**
Aatago	6 b	10 a	16 a	19.33 a	25.33 b	30.67 abc
Anjou	4 d	5.67 bcd	10.67 bc	11.67 bcd	20.67 bc	24.33 abcde
Bartlett	3 e	6 bcd	7.67 cde	10.67 cd	17.33 cde	19.67 cde
Chojuro	6 b	6 bcd	11.33 b	12.33 bcd	17.33 cde	24.33 abcde
Gloden Nijisseiki	4 d	6.67 bcd	9.33 bcde	14 bc	20 bcd	25.33 abcde
Hawana	4 d	7.67 abc	9 b cde	12 bcd	21.67 bc	25 abcde
Hosui	7 a	7.67 abc	9.67 bcd	11.67 bcd	14.67 de	20.33 cde
Kikisui	5 c	5.33 cd	11.67 b	16.33 ab	18 cde	20.67 cde
Kirtipur 1	5 c	9.33 a	11.33 b	14 bc	20.67 bc	30 abc
Kosui	5 c	5.33 cd	10.67 bc	13.67 bcd	16 cde	21.67 cde
Meigetsu	2.33 ef	6 bcd	8.67 bcde	11.33 bcd	18 cde	23.33 bcde
Nittaka	6 b	8 ab	11.67 b	15 abc	21.33 bc	28.67 abcd
Okisankichi	3 e	5 d	7 de	11 cd	14.33 de	17.67 de
Pharping Local (Brown)	4 d	6.67 bcd	7.33 de	8.67 d	34 a	34.33 ab
Pharping Local (Green)	4 d	5.67 bcd	7.67 cde	11.67 bcd	35 a	34.67 a

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Sinko	2 ^{f}	4.33 ^{d}	6.33 ^{e}	11.33 ^{bcd}	13.33 ^{e}	16 ^{e}
Waseaka	4 ^{d}	5.67 ^{bcd}	8.67 ^{bcde}	12.33 ^{bcd}	17.67 ^{cde}	23.33 ^{bcde}
Yakumo	3 ^{e}	5 ^{d}	8 ^{cde}	10.67 ^{cd}	13.33 ^{e}	16 ^{e}
Mean	4.30	6.44	9.59	12.65	19.93	24.22
SEM	0.0741	0.5882	1.1329	2.6492	3.6002	13.3039
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CV (%)	6.33	11.90	11.10	12.87	9.52	15.06
HSD at 5%	0.8369	2.3584	3.2729	5.0049	5.8345	11.2157

HSD: Tukey's Honest Significant. Difference, SEM: Standard error of mean, CV: Coefficient of variation. For each parameter, different lowercase letters in the same column indicates significant differences ($p < 0.05$) among pear varieties according to Tukey's test.

Pharping Local (Green), required the longest interval (34.67 days) between swollen bud to fruit set and is followed by Pharping Local (Brown) (34.33 days), Aatago (30.67 days) while the shortest interval was recorded in Sinko & Yakumo (16 days), followed by Okisankichi (17.67 days). An experiment conducted in Czech Republic, significant difference was not found in the flowering dates of different varieties of pear (Nicas et al., 2020), which is in contrast to our findings. Number of chilling hours and temperature required for breaking of dormancy vary from varieties to varieties. It was reported by Asano and Okuno (1990), cultivar 'Kosui' required temperature below 10^0C and cumulative chilling hours required was 600 hours for breaking dormancy of bud. But in case of 'Nijisseiki' 10^0C was effective to break bud (Tamura, Tanabe, & Ikeda, 1993). Varieties 'Hosui' and 'Kosui' were earlier than other varieties of both Asian and European type. Among these two varieties 'Hosui' and 'Kosui' breaking of dormancy takes place earlier in 'Hosui' as 'Kosui' requires more hours of chilling than 'Hosui' (Asano & Okuno, 1990). Flower differentiation occurs after the cessation of shoot elongation and formation of 12 bud scales in the early to mid-summer season due to increase in the cell division (Ito et al., 1999). Date of full bloom varies between varieties and some varieties in which bud burst took place earlier also showed full bloom date later than others. For example, in cultivar 'Kikisui', 'Gold nijisseki' and 'Kosui' bud burst took place on same date, 11th march but the date of full bloom varies among them i.e., 27th, 25th and 19th March respectively. Different hybrid varieties of pear required average of 41-69 days from first flower to full bloom and required about 99-120 days for harvesting (De Alcantara Barbosa et al., 2018). The Asian varieties 'Hosui' and 'Kosui' required 25 days and 30 days respectively from budburst until the onset of fruit growth (Lopes et al., 2013). Most of the Asian varieties of pear requires about 94-112 days from dormant bud to full bloom stage (Necas et al., 2020). Gotame, Subedi, Dhakal, and Khatiwada (2015) reported that cultivar 'Pharping Local' takes about 130 to 150 days from bud burst to full bloom whereas other Asian varieties ranges from 112 to 150 days. Petal fall stage was recorded after 1-2 weeks of full bloom in all Asian and

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European varieties whereas it took about 1 month for petal fall from full bloom in varieties 'Pharping Local (Brown)' and 'Pharping Local (Green)'. Fruit set stage occurred after about 1 weeks of petal fall in all varieties and harvesting was done about 4-5 months after fruit set in all varieties. First harvesting was done in cultivar 'Kosui' followed bycultivar 'Hosui'

The mean fruit length and diameter of different varieties of pear was found highly significant (Table 3). The longest fruit was recorded in Anjou (58.80 mm), followed by Bartlett (52.90 mm) and Yakumo (49.80 mm), while the shortest fruit was recorded in Nittaka (32.50 mm) followed by Kirtipur 1 (35.0 mm) and Pharping Local (Brown) (37.50 mm). Similarly, the highest fruit diameter was recorded in Anjou (57.60 mm) followed by Yakumo (55.80 mm) and Waseaka (50.80 mm) while the lowest fruit diameter was found in Nittaka (32.50 mm) followed by Kirtipur-1 (35.0 mm) and Sinko (40.10 mm).

Table 3: Fruit length and diameter of different pear varieties

Pear varieties	Fruit length (mm)	Fruit diameter (mm)
Aatago	48 ^{bcd}	51.60 ^{abc}
Anjou	58.80 ^{a}	57.60 ^{a}
Bartlett	52.90 ^{ab}	45 ^{cde}
Chojuro	41.50 ^{defg}	48.80 ^{bcd}
Gloden Nijisseiki	44.50 ^{cdef}	46.70 ^{cde}
Hawana	44 ^{cdef}	47.20 ^{bcde}
Hosui	45.60 ^{bcdef}	49.30 ^{abcd}
Kikisui	44.20 ^{cdef}	49.60 ^{abcd}
Kirtipur 1	35 ^{gh}	35 ^{fg}
Kosui	43.90 ^{cdef}	50.10 ^{abcd}
Meigetsu	47 ^{bcd}	46.60 ^{cde}
Nittaka	32.50 ^{h}	32.50 ^{g}
Okisankichi	44.20 ^{cdef}	48.30 ^{bcde}
Pharping Local (Brown)	37.50 ^{fgh}	42.40 ^{efg}
Pharping Local (Green)	43.20 ^{cdef}	44.5^{cde}
Sinko	37.90 ^{efgh}	40.10 ^{efg}
Waseaka	46 ^{bcde}	50.80 ^{abcd}
Yakumo	49.80 ^{bc}	55.80 ^{ab}
Mean	44.25	46.77
SEM	26.7526	30.0072
P value	0.0000	0.0000
CV (%)	11.67	11.68
HSD at 5%	8.1381	8.6189

HSD: Tukey's Honest Significant. Difference, SEM: Standard error of mean, CV: Coefficient of variation. For each parameter, different lowercase letters in the same column indicates significant differences ($p < 0.05$) among pear varieties according to Tukey's test.

Harvesting duration of all 18 varieties lasts for about two months (Table 4). Early harvesting was done in cultivar Kosui on 4th week of July and late harvesting was done in cultivar

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Okisankichi on 4th week of September. The period of ripening and maturity is affected by some of the factors like flowering dates and temperature during the period from flowering to the ripening. Among different varieties of Asian pear, the period from dormant bud to maturity of the fruit varied from about 223 days to 276 days (Nicas et al., 2020).

Table 4: Different timing of harvest of 18 varieties of pear.

Varieties	**Date of harvest**	**Varieties**	**Date of harvest**
Hosui	1st week of August	Pharping Local (Brown)	2nd week of September
Kosui	4th week of July	Pharping Local (Green)	2nd week of August
Meigetsu	4th week of August	Nittaka	1st week of September
Yakumo	2nd week of August	Hawana	3rd week of August
Kikisui	2nd week of August	Aatago	3rd week of September
Waseka	3rd week of August	Chojuro	3rd week of August
Gold Nijiseiki	4th week of August	Kirtipur-1	4th week of August
Okisankichi	4th week of September	Bartlett	4th week of August
Sinko	3rd week of August	Anjou	3rd week of August

The 18 pear varieties were grouped into five clusters (Figure 1 and Table 5). The pear variety grouped into cluster 1 showed the highest value for swollen bud to bud burst (6.00 days), swollen bud to white bud (16.00 days) and swollen bud to bloom (19.33 days). The variety belonged to cluster 2 showed the highest value for fruit length (58.80 days) and fruit diameter (57.60 days). Similarly, the varieties belongs to cluster 4 showed the highest value for swollen bud to green cluster (8.67 days), and cluster 5 showed the highest value for swollen bud to petal fall (Table 6). Clustering into natural groups is represented by a dendrogram, which gradually divides interventions into smaller and smaller groups (KC, 2001).

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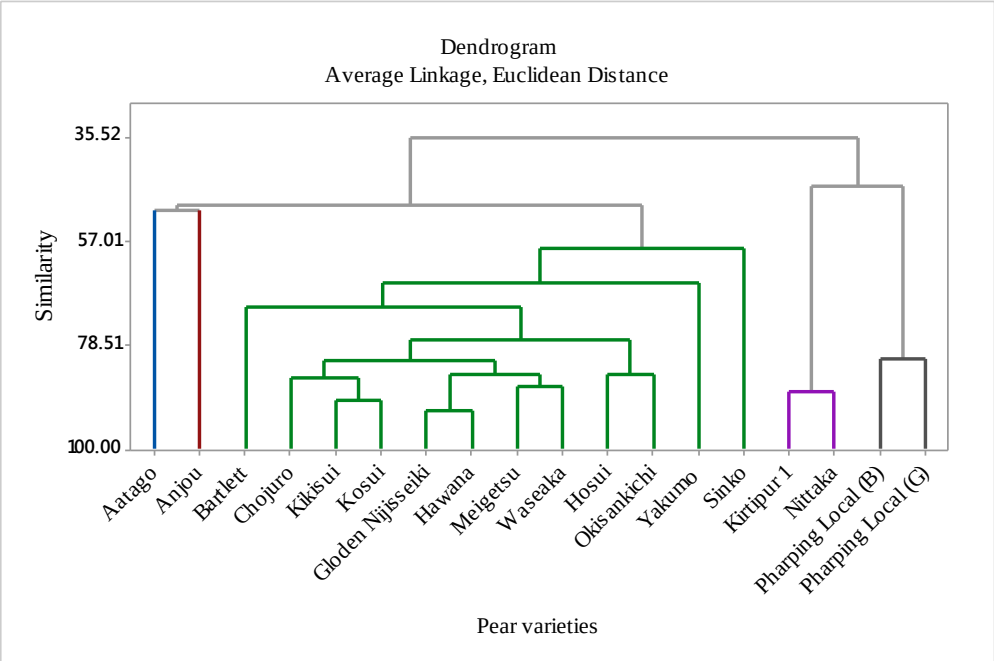

Figure 1: Cluster analysis of 18 pear varieties evaluated for flowering traits under at Warm Temperate Horticulture Centre, Kirtipur, Kathmandu, 2020 [In Pharping Local 'B' indicate brown and 'G' indicate green]

Table 5: Grouping of 18 pear varieties into five clusters based on flowering traits

Cluster1	Cluster 2	Cluster3	Cluster4	Cluster5
Aatago	Anjou	Bartlett, Chojuro, Gloden Nijisseiki, Hawana, Hosui, Kikisui, Kosui, Meigetsu, Okisankichi, Sinko, Waseaka, Yakumo	Kirtipur-1, Nittaka	Pharping Local (Brown), Pharping Local (Green)

Table 6: Flowering traits of 18 pear varieties within and among five clusters

Variable	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	centroid
Fruit length (mm)	48.00	58.80	45.13	33.75	40.35	44.25
Fruit diameter (mm)	51.60	57.60	48.19	33.75	43.45	46.77
Swollen bud to bud burst (days)	6.00	4.00	3.47	5.50	4.00	3.92
Swollen bud to green cluster (days)	0.42	5.67	5.89	8.67	6.17	5.91
Swollen bud to white bud (days)	16.00	10.67	9.00	11.50	7.50	9.59
Swollen bud to bloom (days)	19.33	11.67	12.28	14.50	10.17	12.65
Swollen bud to petal fall (days)	25.33	20.67	16.81	21.00	34.50	19.93
Swollen bud to fruit set (days)	30.67	24.33	21.11	29.34	34.50	24.22

4. CONCLUSION

In this study, 18 pear varieties have been evaluated with respect to the phenological and fruit traits. From the observation, significant variation for these traits was found in pear varieties.

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The shortest flowering period was observed in Sinko and Yakumo. The longest fruit and the highest fruit diameter were found in Anjou. Based on fruits traits Anjou and based on phenological traits Sinko and Yakumo were found potential varieties for cultivation under warm temperate region of Nepal.

Conflicts of Interest

The authors declare no conflict of interest.

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