Int.J.Curr.Microbiol.App.Sci (2021) *10*(01): 686-692

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 10 Number 01 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1001.083

Altitudinal Wise Variations in Phenological Stages of Apple Crop in North-Western Himalayan Regions of Himachal Pradesh

Priyanka[1*], Bhardwaj[1] and Dinesh Thakur[2]

[1]Department of Environmental Sciences, College of Forestry, [2]Regional Horticulture Research and Training Station, Mashobra Shimla, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan 173230 H.P., India

**Corresponding author*

Keywords

Climatic conditions, Phenology, BBCH, GDD

Article Info

Accepted:
08 December 2020
Available Online:
10 January 2021

A B S T R A C T

Phenological observations are some of the most sensitive data for the identification of plant species growth in regional climatic conditions. Thus, an experiment was conducted during the year 2016 to 2017. The field experiment was laid out in Random Block Design (factorial) to characterize the phenological stages of apple grown in three agro-climatic zones at Kullu, Shimla and Kinnaur of Himachal Pradesh. The data on Phenological stages were recorded as per BBCH scale. The results revealed that apple cultivars exhibited variations for attaining phenophases from bud development to fruit maturity in the range of 130.3 to 138.6 days. The phenological stages accumulated highest GDD at lower altitude range 1500-2000 m amsl and lowest at higher altitude range 2500-3000 m amsl.

Introduction

Apple (*Malus* × *domestica* Borkh.) is one of the major fruit crop of temperate zone of the world and occupies an area of 47,11,533 hectares with the production of 70,29,212 metric tonnes. In India, apple is cultivated in an area of approximately 3,13,000 ha with total production of about 24,97,700 metric tonnes (FAO, 2014). However, the commercial production of apple in India is confined mainly to the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand in North-Western Himalayan region. Himachal Pradesh has varied climatic conduction due to this apple is commercially cultivated in the sub-temperate regions and has a significant economic value among fruits. The efficiency of agricultural production is largely associated with climatic conditions. The change in climate in the form of erratic precipitation, increase in temperature and lack of chilling hours have started affecting the horticulture-based production system. Apple productivity has declined in the elevations up to 1500 m amsl to the tune of 40-50 per cent due to lack of chilling requirement and advancement of flowering as an outcome of warmer climate during winter (Chadda and Sharma, 2009).

Phenological events are best quantifying the plants response to climatic conditions, that is climate changes (Walther *et al.,* 2002). The phenological events are highly responsive to temperature, such as low temperature is required to break dormancy and relatively high temperature is essential for flowering (Chuine *et al.,* 2016). These variation in phenological events due to climatic factors have important impact on crop production. Increasing temperature has caused various diseases in fruit trees and has induced impacts on normal production of fruits. The apple production in Himachal Pradesh has decreased by 0.4 tons/ha in the period of 1985-2009 (Sen *et al.,* 2015). The quality of apple also depends upon temperature; the concentration of malic acid is slowly being reduced in some apple cultivars (Stromberg, 2013). The apple orchards of Himachal Pradesh are highly affected due to variations in phenological stages. In lower regions, climate change has adversely affected flowering, fruit set, fruit quality and yield of apple due to which its cultivation is shifting towards higher areas of state. Kullu valley was once known for best quality apple but now this region of the state become uneconomical, non-viable and less profitable. While higher region like Lahual and Spiti and Kinnaur district were unfit for apple cultivation due to extreme weather conditions is now witnessing increase plantation of apple. Therefore, variation in phenology due to global warming are best quantifying the plants response to climatic conditions, this paper aims to studying the variations in phenophases in apple crop at different altitude, to highlight the changes occurred under current climatic conditions.

Materials and Methods

The present investigation was conducted in two growing period 2016-2017. Three altitudinal gradients in three districts of Himachal Pradesh dominated by apple cultivation i.e. lower altitude 1500-2000 m amsl (Kullu), mid altitude 2000-2500 m amsl (Shimla) and higher altitude 2500-3000 m amsl (Kinnaur)were selected. Four commercial growing varieties of apple namely Royal delicious, Golden Delicious, Red chief and Gale gala was selected. The six plants of each variety were selected to record the phenological stages as per BBCH scale (Merier,1994). The daily weather data on average maximum temperature, minimum temperature and rainfall was procured from agro-met observatory. The growing degree days accumulated for attaining phenological stage was calculated with base temperature 4°C.

$$GDD = \sum_{i=1}^{m} (Ti - Tbase)$$

Ti = (Tmax + Tmin)/2

Where, Ti = mean air temperature (°C) on the i^{th} day of the growing season.

Tmax = maximum temperature (°C)

Tmin = minimum temperature (°C)

Tbase = base/threshold temperature(°C)

Results and Discussion

The apple crop growing at different altitudinal range i.e. 1500-2000 m amsl (Kullu), 2000-2500 m amsl (Shimla) and 2500-3000 m amsl (Kinnaur) of Himachal Pradesh show significant variation to attain phenological events(Table 1, 2 and 3).The analysis of data indicated that earliest break of dormancy occurred at an altitude range 1500-2000 m amsl for the cultivar Gale gala (45.7 days) followed by Red chief (52.5 days), Golden delicious (53.6 days) and Royal delicious (57 days). The variation was lowest in case of Gale gala, whereas it was highest in Royal delicious, respectively. Significantly lower

Julian days of 77.2 were taken by Gale gala cultivars where as higher were taken by Royal delicious (81.4) at altitudinal range 2000-2500 m amsl.

Table.1 Phenological development of apple cultivars at 1500-2000 m amsl (Kullu) with respect to Julian days

Phenological stage	Royal delicious			Golden delicious			Red Chief			Gale Gala		
	2016	2017	mean	2016	2017	mean	2016	2017	mean	2016	2017	mean
Bud development	56.3	57.7	**57.0**	52.8	54.3	**53.6**	53.0	52.0	**52.5**	44.5	47.0	**45.8**
Leaf development	70.8	73.5	**72.2**	67.4	69.8	**68.6**	65.3	68.0	**66.7**	63.8	65.0	**64.4**
Shoot development	83.1	83.5	**83.3**	79.5	80.2	**79.9**	77.5	78.5	**78.0**	76.0	76.5	**76.3**
Inflorescence emergence	85.2	86.5	**85.9**	82.1	82.7	**82.4**	80.4	81.8	**81.1**	78.2	78.5	**78.4**
Flowering	102.8	105.6	**104.2**	99.5	101.9	**100.7**	96.5	98.9	**97.7**	95.1	97.0	**96.1**
Fruit development	119.5	121.4	**120.5**	116.5	117.6	**117.1**	114.5	116.3	**115.4**	112.5	113.4	**112.9**
Maturity	129.2	130.5	**129.9**	125.1	126.2	**125.7**	122.5	124.3	**123.4**	121.1	122.3	**121.7**

Table.2 Phenological development of apple cultivars at 2000-2500 m amsl (Shimla) with respect to Julian days

Phenological stage	Royal delicious			Golden delicious			Red Chief			Gale Gala		
	2016	2017	mean	2016	2017	mean	2016	2017	mean	2016	2017	mean
Bud development	81.0	81.8	**81.4**	78.8	80.5	**79.7**	78.0	79.6	**78.8**	76.0	78.3	**77.2**
Leaf development	86.0	88.3	**87.2**	83.2	85.0	**84.1**	80.5	82.0	**81.3**	79.0	80.0	**79.5**
Shoot development	96.4	98.3	**97.4**	93.2	94.1	**93.7**	91.4	92.4	**91.9**	90.2	90.0	**90.1**
Inflorescence emergence	99.8	99.5	**99.7**	94.8	95.5	**95.2**	94.5	95.9	**95.2**	92.2	90.5	**91.4**
Flowering	117.0	119.8	**118.4**	114.0	115.6	**114.8**	111.5	113.1	**112.3**	110.1	111.6	**110.9**
Fruit development	134.9	136.3	**135.6**	131.9	132.5	**132.2**	129.8	131.6	**130.7**	127.9	128.3	**128.1**
Maturity	143.4	145.5	**144.5**	140.9	141.5	**141.2**	137.8	139.6	**138.7**	135.5	137.6	**136.6**

Table.3 Phenological development of apple cultivars at 2500-3000 m amsl (Kinnaur) with respect to Julian days

Phenological stage	Royal delicious			Golden delicious			Red Chief			Gale Gala		
	2016	2017	mean	2016	2017	mean	2016	2017	mean	2016	2017	mean
Bud development	82.6	87.3	**84.9**	80.8	83.5	**82.2**	79.3	82.3	**80.8**	77.2	81.3	**79.3**
Leaf development	88.5	88.3	**88.4**	85.1	85.0	**85.1**	82.6	82.0	**82.3**	81.5	80.0	**80.8**
Shoot development	98.5	100.9	**99.7**	95.1	96.7	**95.9**	94.1	94.8	**94.5**	91.8	92.8	**92.3**
Inflorescence emergence	103.0	102.8	**102.9**	97.0	98.4	**97.7**	97.3	98.7	**98.0**	95.8	94.8	**95.3**
Flowering	121.5	123.8	**122.7**	117.9	120.2	**119.1**	114.7	117.5	**116.1**	113.9	116.5	**115.2**
Fruit development	137.8	140.3	**139.1**	134.5	136.6	**135.6**	132.5	135.3	**133.9**	130.5	132.3	**131.4**
Maturity	146.8	151.3	**149.1**	142.0	145.2	**143.6**	140.5	143.3	**141.9**	138.7	141.3	**140.0**

Table.4 Effect of altitudinal wise weather variations on GDD for phenological stages in different cultivars of apple fruit crop

1500-2000 m amsl																		
Phenological Stages	**Leaf development**			**Shoot development**			**Inflorescence emergence**			**Flowering**			**Fruit development**			**Maturity**		
	2016	**2017**	**mean**	**2016**	**2017**	**mean**	**2016**	**2017**	**mean**	**2016**	**2017**	**mean**	**2016**	**2017**	**mean**	**2016**	**2017**	**mean**
Royal delicious	251.7	213.9	232.8	276.2	344.6	270.3	359.1	426.2	392.6	705.2	703.2	704.2	1162.6	1280.6	1221.6	1648.0	1508.7	1578.4
Golden delicious	210.0	203.4	206.7	233.4	303.0	259.7	344.2	403.0	373.6	647.3	663.2	655.2	1055.0	1089.4	1072.2	1580.5	1596.9	1588.7
Red Chief	199.8	194.0	196.9	212.9	296.5	239.3	312.6	362.9	337.7	563.0	567.7	565.3	1026.4	1075.0	1050.7	1451.5	1499.0	1475.3
Gale gala	168.6	136.5	152.5	196.6	208.0	180.9	303.0	346.2	324.6	500.9	502.3	501.6	1007.3	1018.4	1012.8	1215	1266.1	1240.6
CV (%)	**14.3**	**16.9**	**14.9**	**17.4**	**17.3**	**15.0**	**7.0**	**8.2**	**7.6**	**13.1**	**13.3**	**13.2**	**5.7**	**8.9**	**7.3**	**12.9**	**9.6**	**11.0**
2000-2500 m amsl																		
Royal delicious	210.7	213.7	212.2	265.0	270.2	267.6	350.6	358.0	354.3	695.3	700.1	697.7	1140.6	1145.6	1143.1	1548.8	1499.9	1524.4
Golden delicious	198.5	204.0	201.3	224.5	229.5	227.0	335.2	341.2	338.2	679.1	684.1	681.6	1045.8	1059.0	1052.4	1463.4	1425.0	1444.2
Red Chief	158.9	172.9	165.9	213.5	216.7	215.1	335.4	349.9	342.6	557.3	571.3	564.3	948.6	970.3	959.5	1246.4	1295.6	1271.0
Gale gala	115.0	123.8	119.4	186.3	194.3	190.3	294.1	302.1	298.1	497.4	505.4	501.4	907.4	915.6	911.5	1195.6	1200.5	1198.1
CV (%)	**25.3**	**22.7**	**23.9**	**14.7**	**14.0**	**14.3**	**7.4**	**7.3**	**7.3**	**15.8**	**15.1**	**15.4**	**10.3**	**9.9**	**10.1**	**12.4**	**9.8**	**11.1**
2500-3000 m amsl																		
Royal delicious	108.9	122.9	115.9	209.6	194.3	201.9	235.4	249.3	242.4	498.3	510.8	504.5	915.9	938.6	927.3	1433.3	1485.2	1459.3
Golden delicious	165.4	169.9	167.6	254.8	260.5	257.6	250.6	255.5	253.1	609.2	615.1	612.2	1095.5	1130.4	1112.9	1246.4	1330.6	1288.5
Red Chief	147.9	153.8	150.8	204.5	212.1	208.3	246.5	253.3	249.9	597.4	603.7	600.5	932.8	1001.6	967.2	1363.4	1395.6	1379.5
Gale gala	88.2	96.3	92.3	166.8	176.6	171.7	279.5	289.5	284.5	412.9	422.1	417.5	888.1	895.3	891.7	1080.6	1152.0	1116.3
CV (%)	**27.7**	**24.1**	**25.8**	**17.3**	**17.1**	**17.0**	**7.4**	**7.1**	**7.2**	**17.4**	**16.8**	**17.1**	**9.8**	**10.3**	**10.0**	**12.0**	**10.5**	**11.2**

The highest number of days for bud breaking was observed at altitude 2500-3000 m amsl where cultivar Royal delicious took (84 days) followed by Golden delicious (82.2 days), Red chief (80.8 days) and Gale gala (79.3 days). Indicating there by Julian days taken to attain bud development increased significantly with increase elevation above mean sea level. The leaf development stage was earliest at an altitude range 1500-2000 m amsl where apple crop took 68.0 julian days to attain the stage. The delayed leaf development stage (84.1 days) was at 2500-3000 m amsl. The minimum number of days (80.8) was taken by cultivar Gale gala and highest number of days (88.4) were taken by Royal delicious at an altitude range 2500-3000 m amsl. Shoot development appeared earliest at altitude range 1500-2000 m amsl with 79.4 julian days however, this stage was seen much delayed at altitude range 2500-3000 m amsl with 95.6 julian days. Among the cultivars the maximum number of days was taken by cultivar Royal delicious (99.7 days) and minimum number of days (92.3 days) were taken by cultivar Gale gala at an altitude range 2500-3000 m amsl. Further perusal of data showed that Gale gala took minimum number of 76.3 days followed by Red chief (78.0 days), Golden delicious (79.9 days) and Royal delicious (83.3 days) at 1500-2000 m amsl. Similar trend was observed at altitude range 2000-2500 m amsl in order of 90.1, 91.9, 93.7 and 97.4 by Gale gala, Red chief, Golden delicious and Royal delicious. The inflorescence emergence stage (pink bud stage) indicated that mean minimum days (82.0) were required at 1500-2000 m amsl followed by 2000-2500 (95.4) and 2500-3000 m amsl (98.5), respectively. Irrespective of altitudes, the cultivar Gale gala took minimum 78.4 (1500-2000 m amsl), 91.4 (2000-2500 m amsl)& 95.3(2500-3000 m amsl) followed by Red chief {81.1 (1500-2000 m amsl), 95.2 (2000-2500 m amsl) & 98.0 (2500-3000 m amsl)} which was at par with Golden delicious{82.4 (1500-2000 m amsl), 95.2 (2000-2500 m amsl)& 97.7 (2500-3000 m amsl)} and Royal delicious {85.9 (1500-2000 m amsl), 99.7 (2000-2500 m amsl)& 102.9 (2500-3000 m amsl)}.

The flowering was significantly affected by different altitude range. The delayed flowering was recorded at an altitude range of 2500-3000 m amsl where crop took 118.3 days and it was earliest at 1500-2000 m amsl with 99.7 days. The cultivar Gale gala took minimum (96.1 days) number at an altitude 1500 -2000 m amslwhich was statistically at par with cultivar Red chief (97.7 days). The highest number were recorded in cultivar Royal delicious (104.2 days) followed by Golden delicious (100.7 days). There was a significant variation in terms of julian days at an altitude 2000-2500 m amslwith respect to an altitude 1500-2000 m amsl for the attainment of flowering. The shortest duration to attain flowering was recorded in Gale gala (111 days) followed by Red chief (112.3 days) and highest duration were recorded in Royal delicious (118.4 days) followed by Golden delicious (114.8 days). However, the highest number of days for flowering at an altitude 2500-3000 m amsl were recorded in cultivar Royal delicious (122.7 days) followed by Golden delicious (119.1 days). The minimum number of days were recorded in Gale gala (115.0 days) followed by Red chief (116.1 days).

The fruit was developed in 116.5 days at an altitude range 1500-2000 m amsl and 135.0 days at altitude range 2500-3000 m amsl, respectively. Among cultivars the the Gale gala took minimum 113, 128.0 and 131.0 days to attain the stage however, Royal delicious took maximum 120.5, 135.6 and 139.1 days at all the selected altitudes. On an average crop took 125.3 days to attain maturity at 1500-2000 m amsl, 140.2 days and 143.6 days at an altitude 2000-2500 m

amsl and 2500-3000 m amsl, respectively. This variation was at par among all the cultivars for attaining the maturity at different altitudes. In two seasons Gale gala took minimum days (122) for attaining maturity at 1500-2000 m amsl as compare to other cultivars. Whereas, it was highest in case of Royal delicious (149.1 days) at 2500-3000 m amsl.

Accumulated Growing degree days for apple crop

The altitude wise GDD accumulation ranged from 1116.3 to 1240 which decreased with increasing altitude range. The altitude wise order of GDD accumulation was 1116.3 at 2500-3000 m amsl > 1198.1 at 2000-2500 m amsl > 1240 at 1500-2000 m amsl, respectively (Table 4).

The finding of study indicated that apple cultivars exhibited variations in days for attaining phenophases from bud brust to fruit maturity. All the selected cultivars of apple took significantly higher numbers of Julian days with increase in altitude range. This may be attributed to the altitude wise variations in air temperature. The data further revealed the 3-4 ºC rise in temperature at 1500-2000 m amsl has induced 10-15 days advancement in attainment of phenophases as compared to higher altitude range (2500-3000 m amsl). The results are supported with the finding of Jackson (2003) stated that the growth rate is determined by temperature hence higher the temperature speed up the rate of growth.

In conclusion among the common cultivars of apple being growing in different altitude of Himachal Pradesh the newly introduced cultivars namely Gale gala took minimum days to attain various phenological stages as compared to standard cultivars hence Royal delicious. At 1500-2000 m amsl (Kullu), 2000-2500 m amsl (Shimla) and 2500-3000 m amsl (Kinnaur) elevations the newly introduced varieties took 122, 137.0 & 140.0 days to mature as compare to standard varieties. These variations were also associated to the growing degree days (GDD). The higher thermal amplitude the higher the sum of GDD.

Acknowledgment

Author is thankful to the Professor and Head, Department of Environmental Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H. P.), India for providing necessary facilities.

References

Chadda KL and Sharma NK. 2009. Climate change impacts on production of horticulture crops. In: Impact of climate change on fruit crops (W S Dhillon and P S Aulakh Eds), Delhi:Narendra Publishing House. Pp. 3-9.

ChuineI, Bonhomme M, Legave JM, García De Cortazar-Atauri I, CharrierG, Lacointe A, and Ameglio T. 2016. Can phenological models predict tree phenology accurately in the future? The unrevealed hurdle of endodormancy break. *Global Change Biology, 22*(10): 3444-3460.

Jackson JE. 2003. *The biology of apples and pears*. New York, USA: Cambridge University Press. 488 pp.

Meier UH, Garf H, Hack M, Hess W, Kennel R, Klose D, Mappes D, Seipp R, Stauss D, Streif and T. van den Boom 1994. Phänologische Entwicklungsstadien der Kernobstes (*Malusdomestica* Borkh. and *Pyrus communis* L.), des Steinobstes (*Prunus*-Arten), der Johannisbeere (*Ribes*-Arten) und der Erdbeere (*Fragaria* x *ananassa* Duch.).

Codierung und Beschrei bung nach der Erweiterten BBCH-Skala, mit Abbildungen, Nachrichtenbl. *Deut.Pfl anzenschutzd*., 46: 141-153.

Sen V, Rana RS, Chauhan RC and Aditya. 201. Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh. *Indian Journal of Horticulture*, 72 (1): 14-20.

Strömberg CAE. 2011. Evolution of grasses and grassland ecosystems. *Annual Review of Earth and Planetary Sciences* 39: 517– 544.

Walther G., Post E., Convey P., Menzel A., Parmesan C.Beebee T.J.C. et al. (2002) Ecological responses to recent climate change. Nature,416, 389–395

Wertheim S and Schmidt H. 2005. Flowering, Pollination and fruit set. In Webster, A. D., Wertheim, S.J. and Tromp, J (eds) *Fundamentals of temperate tree fruit production, pp.* 216-239. Leiden, The Netherlands: Backhuys.

How to cite this article:

Priyanka, Bhardwaj and Dinesh Thakur. 2021. Altitudinal Wise Variations in Phenological Stages of Apple Crop in North-Western Himalayan Regions of Himachal Pradesh. *Int.J.Curr.Microbiol.App.Sci.* 10(01): 686-692. doi: https://doi.org/10.20546/ijcmas.2021.1001.083