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Research Paper

Influence of altitudinal variation on phenology and yield characteristics of apple in Kashmir valley under changing climatic scenario

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ABSTRACT

Apple is one of the important temperate crops cultivated worldwide. The phenological stages that are highly responsive to the changing climatic conditions have a significant impact on crop production. This study observed the variations in phenophases in apple crop at different altitudes along with the yield and quality response curves to highlight the changes occurred under current climatic conditions in the Jammu & Kashmir UT. Two districts under the study were Baramulla and Shopian with the elevations ranging 1612-2054 m amsl and 1630-2084 m amsl, respectively. Comparison of three commercial apple varieties (Red Delicious, Royal Delicious and Golden Delicious) at different altitudes revealed that flowering occurred earlier in lower elevations. Duration of flowering ranged from 13-17 days in district Baramulla and from 16-22 days in district Shopian. However, fruit set and yield were found highest at higher elevations than at lower elevations. Fruits from lower altitudes were heavier and larger in size compared to higher altitudes. The fruits from higher altitudes had higher fruit chemical characteristics viz. TSS, total sugar content and TSS/ acidity ratio. Between the two districts, fruits from Shopian have better fruit quality traits as compared to the fruits from Baramulla. The CO_2 concentration was recorded higher during winter months in both the districts. Overall, temperature showed slightly increasing trend (2.15 %) and rainfall showed decreasing trend (9.59 %) over the last four decades. Climate change seems to be inevitable, thus increase in atmospheric temperature have adverse effects on apple crop production which may result in shifting of apple cultivation belt to higher elevations in the valley. The correlation analysis revealed that temperature positively influenced RD and RYD yields, while rainfall had a negative effect and CO_2 exerted a moderate positive impact, indicating differential crop responses to environmental factors.

Key words: Altitudinal variation, apple, climate variability, phenology, yield efficiency

Apples being one of the most important temperate fruit crops cultivated worldwide has socio economic importance in the apple growing regions. The apple cultivation was originated in Central Asia and Europe and then spread throughout the world where climatic conditions are suitable for apple cultivation (Boudichevskaia *et al*., 2020). However, the commercial production of apple in India is confined to states/UT of Himachal Pradesh, Uttarakhand and Jammu & Kashmir. The mountain ecosystem is one of the most susceptible ecosystems affected by climate variability and its changes, which is already showing rampant impacts on the Himalayan ecosystem (Sahu *et al*., 2020). In the Northwest Himalayan region, it has increased by almost 1.6ºC (Bhutiyani *et al*., 2007). Recent studies indicate that surface temperature variation has amplified due to significant influence from topographic changes, which eventually lead to surface temperature evolution (Zhao *et al*., 2019), including the - Himalayan region (Shrestha & Aryal, 2011). The climatic factors, which determine the apple spatial and temporal distribution, have significantly changed with the increased climate change (Sharma *et al*., 2014; Sugiura *et al.,* 2005; Fang *et al.* 2015). In India evidence of climate change could be clearly depicted by changes like receding snowfall, increased temperature and shifting of temperate fruit belt upward, adversely affecting productivity of apple (Arundati & Bhagat, 2020). Climate change with warmer winter and spring temperatures pose a major challenge to apple fruit production. Especially warmer temperatures in spring disturb the tightly controlled timing of the alternating phases of winter dormancy, where buds are well protected by bud scales and can outlast strong frosts and the phase of plant growth and reproduction. As temperatures gradually rise in spring, bud break and flowering occur earlier, increasing the risk of flower damage and yield losses from late frost events. (Lempe *et al*., 2022; Chen *et al*., 2025).

The climatic variations in the Himalayan region of India had resulted in the reduction of available chilling requirement for flowering of various temperate crops such as apple (Kumar *et al.,* 2017; Rai *et al*., 2015; Vedwan & Rhoades, 2001) which adversely influence the fruit set quality and the yield. An increase in surface temperature during both summer and winter directly reduces the number of chilling hours, thereby greatly affecting apple production. (Basannagari & Kala, 2013; Khan *et al*., 2023). Studies have also confirmed that overall apple cultivation in Himachal Pradesh has shifted from lower altitude regions experiencing warmer temperatures such as Kullu valley, to higher altitude regions such as Lahaul and Spiti which used to be cold deserts in the past (Rana *et al*., 2012). Singh & Patel, (2017), reported a drastic shift in apple orchard zones towards higher altitudes in Himachal Pradesh during 2000-2013, while the shift was marginal during 1970-80. Khan *et al*. (2023) has reported an altitudinal shift in apple cultivation in Kalpa, Himachal Pradesh owing to the interlinked relation between local temperature change, snow cover area, precipitation trends. It has also been noted that for every one degree rise of temperature, apple cultivation shifts upward by about 984 feet (Dogra, 2009). There are reports stating that the texture and taste of fruits are changing due to the effects of global warming (Sugiura *et al*., 2013), especially apples, which is sensitive to increasing temperature, leading to low-quality apples due to short chilling period, becoming a burning issue in the past few decades for farmers. The phenological stages that are highly responsive to the changing climatic conditions have a significant impact on crop production (Chen et al., 2024; Chuine *et al*., 2016; Walther *et al*., 2002). This paper aims to assess the variations in phenophases in apple crop at different altitude, along with the yield and quality response curves to highlight the changes occurred under current climatic conditions in the Jammu & Kashmir UT which is the major contributor in terms of apple production in India.

MATERIALS AND METHODS

Study area: The present investigation was conducted in growing period 2018-2021. For determination of growth response of existing apple varieties, selection of orchards were made in two aspirational apple growing districts of Kashmir valley *viz*., Baramulla and Shopian (Fig. 1) Orchards were selected at five different altitudes between 1612-2054 m amsl for district Baramulla while for district Shopian it lies between 1630-2084 m (Table 1). From each selected orchard three apple cultivars *viz*. Red Delicious, Golden Delicious and Royal Delicious were selected and selection of similar type of apple trees from each orchard were made on the basis of age, tree health and vigour. Selected apple varieties were evaluated for their growth, phenological, yield and fruit quality characteristics.

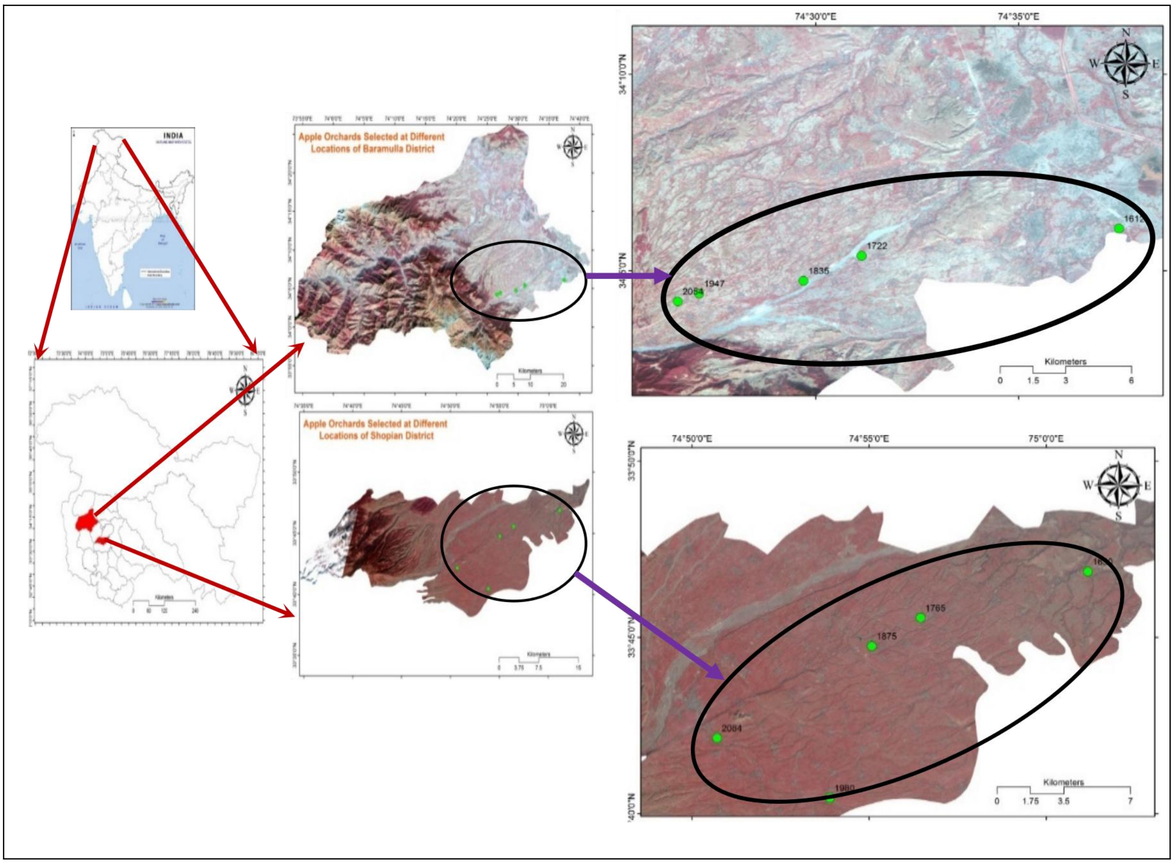

Fig. 1: Study area- District Baramulla and Shopian of Jammu &Kashmir UT

Sampling, processing & analysis: The data on the effect of altitudes on flowering, yield, quality and growth parameters was recorded as per standard procedures for parameters *viz.* annual shoot extension growth (cm), date of pink bud, date of initial bloom (about 10 % flowering), date of full bloom (above 80 % flowering), duration of flowering, date of Petal fall (80%), fruit set (%), yield (kg/tree), yield efficiency (kg/cm^2), fruit physico-chemical characteristics such as fruit length and breadth (mm), fruit weight (g). The fruit firmness (kg/cm^2) was recorded using a penetrometer (Pocharski, *et al.*, 2000) and total soluble solids (^{0}B) using a hand refractometer.

Table 1. Sampling locations of the study

District Baramulla (33º 55″00′N to 34º25″05′N latitude and 73º55″00′E to 74º40″00′E longitude)		**District Shopian** (33º 37″54′ N to 33º49″18′ N latitude and 75º04″40′E to 74º33″50′E longitude)	
Location	**Altitude**	**Location**	**Altitude**
L_1 (Mazhama)	1612 m	L1 (Babapora)	1630 m
L_2 (Takiya Batpora)	1722 m	L2 (Nagbal)	1765 m
L_3 (Gokhama)	1835 m	L3 (Imam Sahib)	1875 m
L_4 (Druroo)	1947 m	L4 (Wangam)	1980 m
L_5 (Chanapora)	2054 m	L5 (Memender)	2084 m.

The titrable acidity (%), TSS/Acidity ratio, total sugars content (%) were recorded by the method described in AOAC, 1990. The data obtained was subjected to generate the yield and quality response curves by fitting them in linear regression models using R studio software (V. 4.1.2). The adequacy of the fitted models was ascertained using the coefficient of determination (R^2) and the significance of the fitted models was ascertained from the model P values. The CO_2 concentrations at the study sites were measured using the CO_2 monitor, model: CDM 901 and the weather data was obtained from Division of Agro-meteorology, SKUAST- Kashmir.

RESULTS AND DISCUSSION

Phenophasic variations: Altitudinal difference exhibited a significant influence on date of pink bud, initial bloom, full bloom, and petal fall of apple cultivars *viz*., Red Delicious, Royal Delicious, and Golden Delicious. With the increase in altitude (lowest to highest) date of pink bud, initial bloom, full bloom, and date of petal fall were delayed by 14-16 days, 16 days, 13-19 days and 17 – 21 days in both the districts. On the other hand, duration of flowering ranged from 13-17 days in Baramulla and 16-22 days in Shopian district (Fig. 2) Rana, (2020) observed the phenophasic developmental stages correlating with change in weather and altitudinal gradients and reported an advancement of phenophases by 7-13 days in apple crop in low altitude regions.

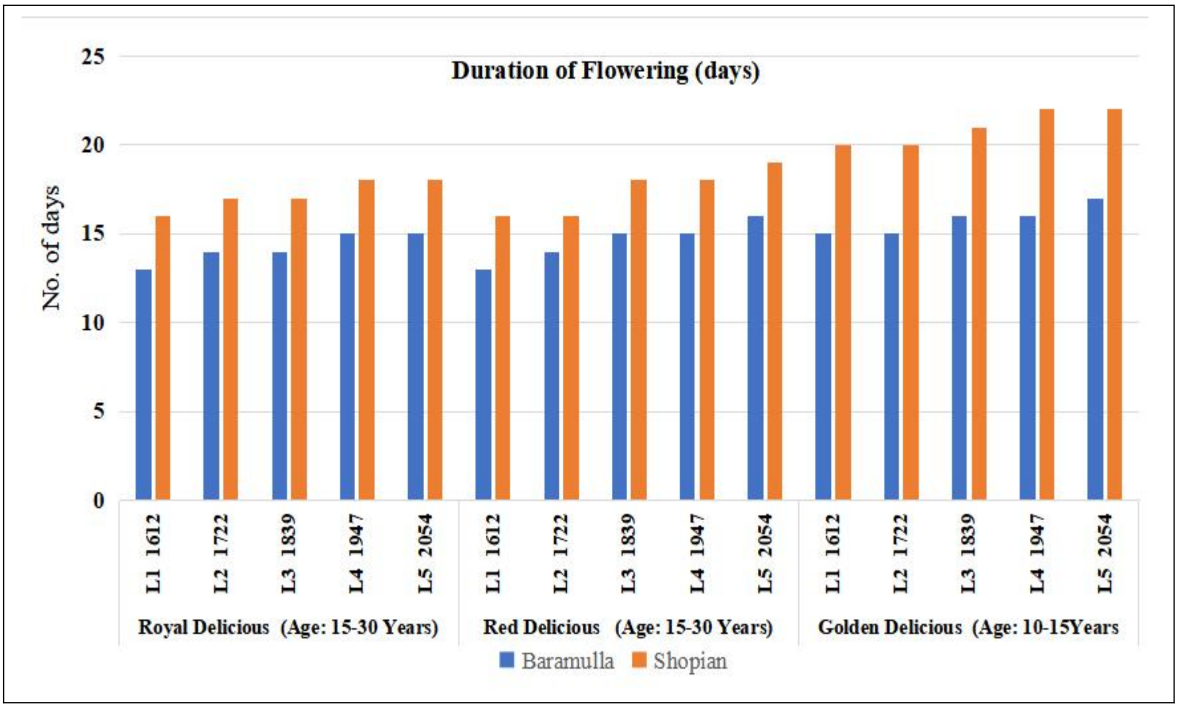

Fig. 2: Effect of altitudes on duration of flowering of apple cultivars

Growth and yield characteristics: Annual shoot extension growth showed a significant variation across different altitudes. In the cultivar Golden Delicious, the highest mean annual shoot extension growth in district Baramulla ranged from 63.7 cm to 56.37 cm. In comparison, the same cultivar in district Shopian exhibited a slightly lower range, varying from 62.64 cm to 53.35 cm. With the increase in altitude, mean initial and final fruit set increased in both the districts. Highest initial (70.02%) and final fruit set (60.80%) was observed at higher altitude (2054 amsl) in Golden Delicious in district Baramulla. While as in district Shopian the mean highest initial (83.94 %) and final fruit set (70.74 %) was recorded in Red Delicious variety at highest altitude (Fig. 3) (a)(b).
Fruit yield increased with increase in altitudes in both the districts.

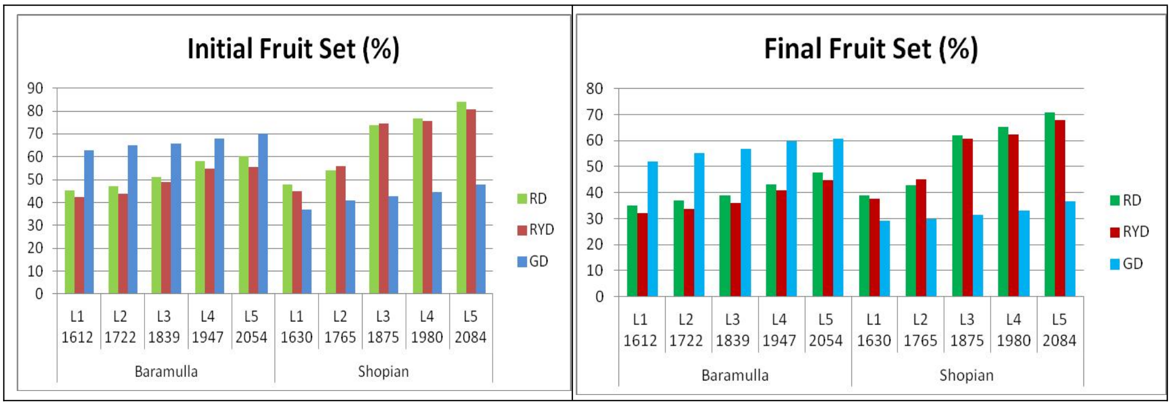

Fig. 3: Effect of altitude on (a) initial fruit set (b) final fruit set of apple cultivars

Maximum mean fruit yield of 139.64 kg tree^{-1} was recorded in Red Delicious in district Shopian. While it was 128.27 kg tree^{-1} in the same variety in district Baramulla (Fig. 4) Yield efficiency increased with altitudes in both the districts and it ranged from 0.17 to 0.89 kg tree^{-2} in district Baramulla while in district Shopian it ranged from 0.17 to 0.79 kg tree^{-2}. The maximum yield efficiency was recorded in Golden Delicious (0.89 kg tree^{-2}) in district Baramulla and in Royal Delicious (0.79 kg tree^{-2}) in district Shopian (Table 2).

Table. 2: Fruit yield and Yield efficiency of three apple varieties at different altitudes in district Baramulla and Shopian

	Fruit yield (Kg tree^{-1})			Yield efficiency (Kg cm^{-2})		
Altitude (amsl)	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**
B L1 (1612)	94.40	86.40	67.76	0.18	0.17	0.24
B L2 (1722)	105.81	91.69	69.49	0.22	0.18	0.44
B L3 (1839)	116.68	98.22	80.61	0.33	0.31	0.57
B L4 (1947)	120.36	106.34	82.12	0.45	0.42	0.74
B L5 (2054)	128.28	110.48	88.64	0.61	0.54	0.89
CD	**3.893**	**3.473**	**2.357**	**0.016**	**0.013**	**0.017**
S L1 (1630)	97.53	88.61	36.53	0.18	0.17	0.2
S L2 (1765)	113.78	95.68	40.79	0.25	0.22	0.26
S L3 (1875)	125.41	108.22	42.79	0.29	0.26	0.3
S L4 (1980)	136.24	116.38	44.10	0.59	0.47	0.33
S L5 (2084)	139.64	125.50	47.61	0.78	0.79	0.45
CD	**5.292**	**3.430**	**1.395**	**0.021**	**1.315**	**0.016**

[B- district Baramulla; S- district Shopian; RD- Red Delicious; RYD- Royal Delicious; GD- Golden Delicious]

Mean fruit length, breadth and weight decreased with increase in altitude in both the districts and were recorded maximum in Red Delicious variety at lower altitudes (Table 3). Maximum fruit length of 73.12 mm was recorded in district Baramulla and 76.21 mm in district Shopian, breadth was 75.21mm in district Baramulla and 78.24 mm in district Shopian and weight was 188.71g in district Baramulla and 194.56 g in district Shopian. Mean fruit firmness was recorded highest in Red Delicious and increased from 8.24 to 8.53 kg/cm^2 with increase in altitude in district Baramulla. However, in district Shopian the value increased from 8.35 to 8.67 kg/cm^2 with increase in altitude (Table 3). With the increase in altitude, the fruit chemical characteristics (Table 4) *viz.* TSS (12.75 to 14.09 ^{o}B and 12.83 to 14.06 ^{0}B), total sugars (9.56 to 10.41 and 9.69 to 10.59%) and TSS/acidity ratio (49.6 to 65.1 and 53.5 to 70.1) increased and were highest in Red Delicious in district Baramulla and Shopian, respectively at higher altitudes. However, titrable acidity was highest in Golden Delicious at lower altitudes in both the districts. Kumar *et al.* (2019) also observed that the TSS, total sugars, titratable acidity, minerals and phenolic contents were significantly influenced by the altitude and cultivars. The apples grown at higher elevations were firmer and of superior quality compared to the lower altitude produce.

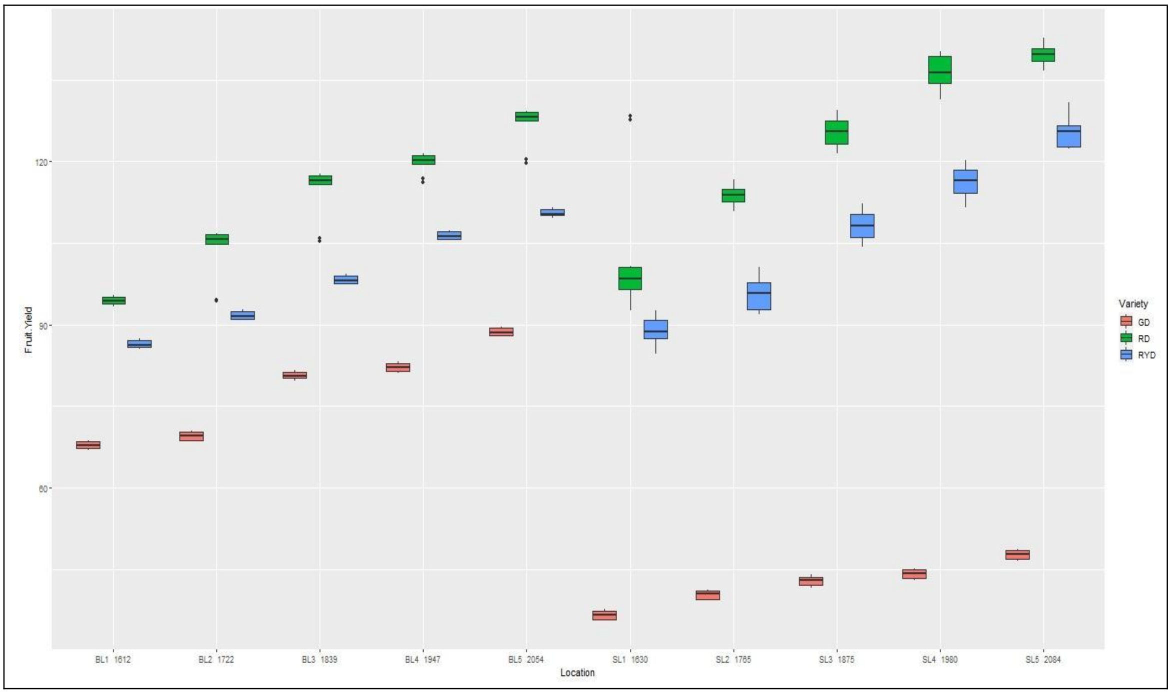

Fig. 4: Box-Whisker plot analysis of fruit yield of three apple varieties along various altitudes in district Baramulla and Shopian (pooled)

Nautiyal *et al.* (2020) have also reported the impact of climate change on apple phenology and adaptability of Anna variety (Low chilling cultivar) in lower hills of Uttarakhand. The regression model of yield and elevation was significant at 5% level of significance with an R square of 29.31% and 27.13% for the districts Baramulla and Shopian respectively. The models revealed an increase in the fruit yield (kg/tree) with an increase in the elevation in the study districts. Similarly, the regression model of fruit Length and elevation with an R square of 19.34% and 26.90% respectively for the districts Baramulla and Shopian revealed a decrease in the fruit length with an increase in the elevation in the study districts. Table 5 shows that the regression model of fruit breadth and elevation was significant, with R^2 values of 21.27% and 23.73% for the districts of Baramulla and Shopian, respectively, revealing a decrease in fruit breadth with increasing elevation in the study districts. Also, the regression model of fruit weight was significant with an R square of 39.99% and 45.94%, revealing a decrease in the fruit weight with an increase in the elevation in the study districts. The regression model of Fruit firmness and elevation was significant with an R square of 39.88% and 31.67% for the districts Baramulla and Shopian respectively. The models revealed an increase in the fruit firmness with an increase in the elevation in the study districts. Likewise, the regression model of TSS was also significant with an R square of 29.66% and 41.90% respectively for the districts Baramulla and Shopian respectively. The models revealed an increase in the TSS with an increase in the elevation in the study districts. The regression model of Total Sugar and elevation was significant with an R square of 45.47% and 48.71% for the districts Baramulla and Shopian respectively. The models revealed an increase in the total sugars with an increase in the elevation in the study districts. Similarly, the regression model of titrable acidity was significant with an R square of 6.21% and 7.02% respectively for these two districts respectively.

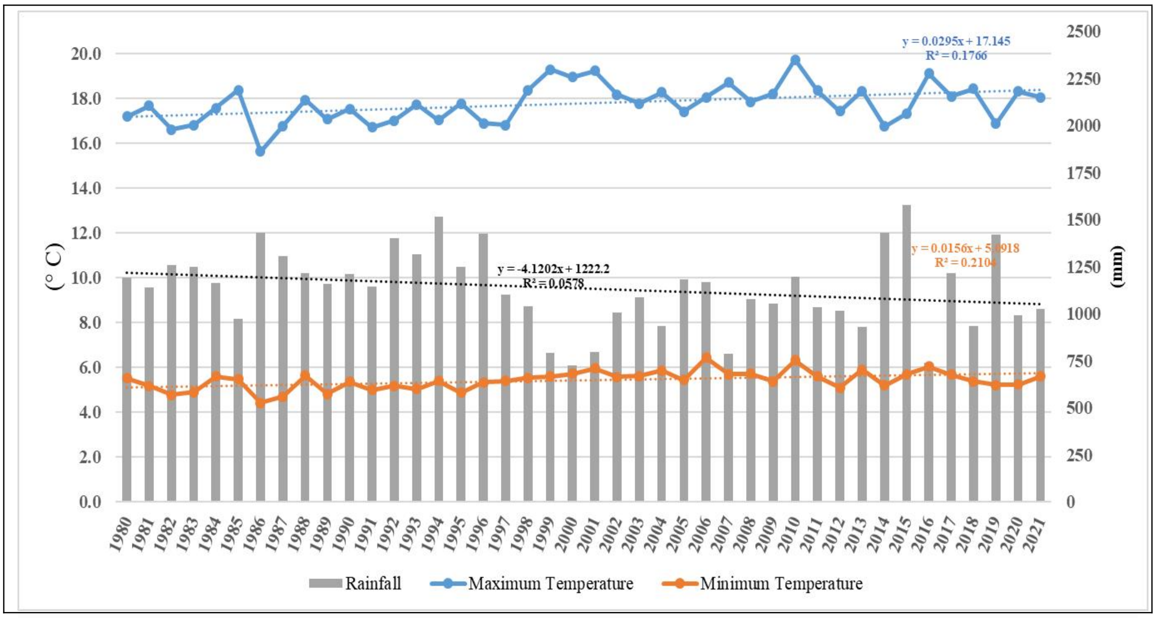

Fig. 5: Trend of temperature (minimum and maximum) and rainfall observed in Kashmir valley from 1980 to 2021

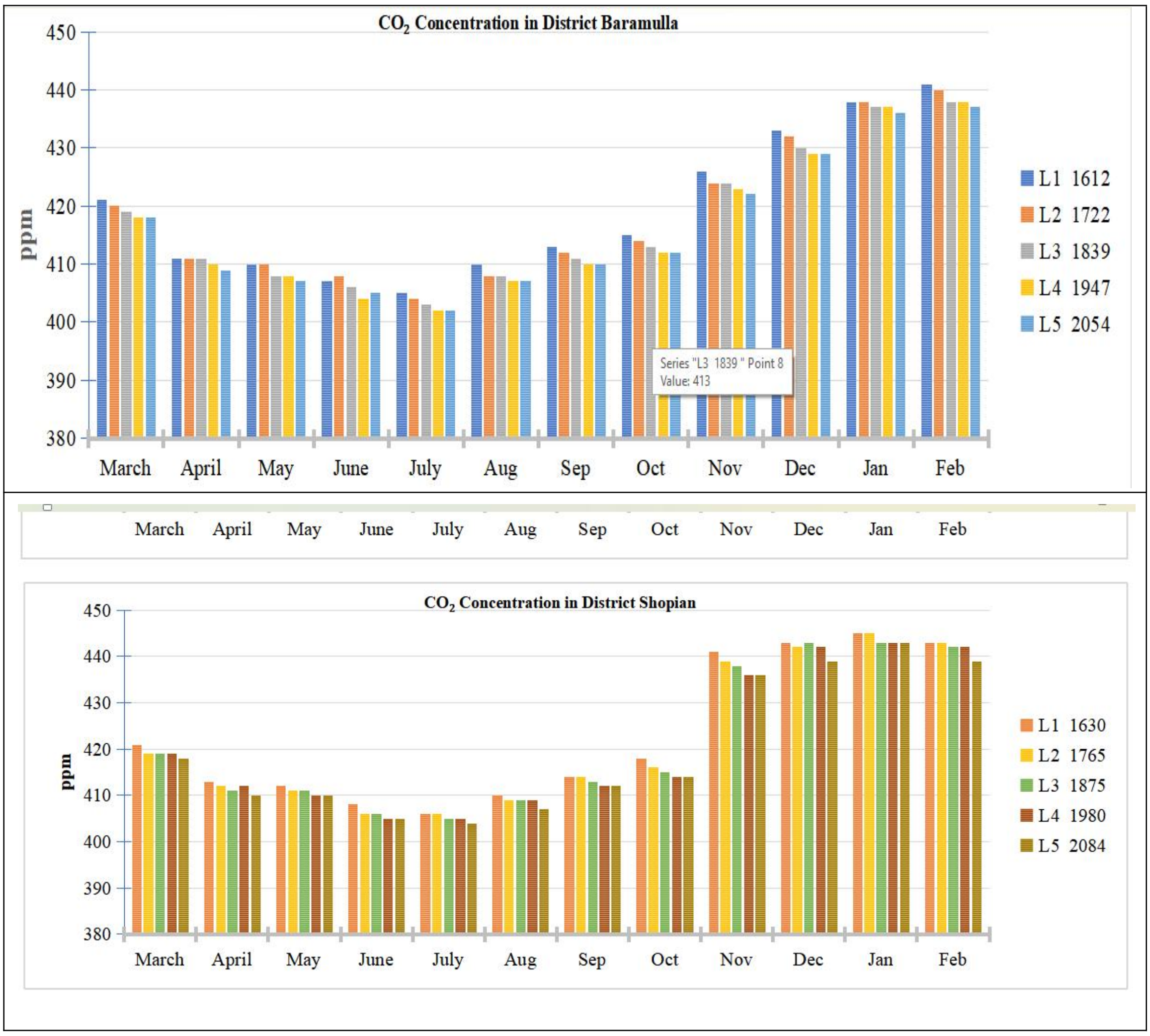

Fig. 6: CO_2 concentration observed in the study area during 2019-2020

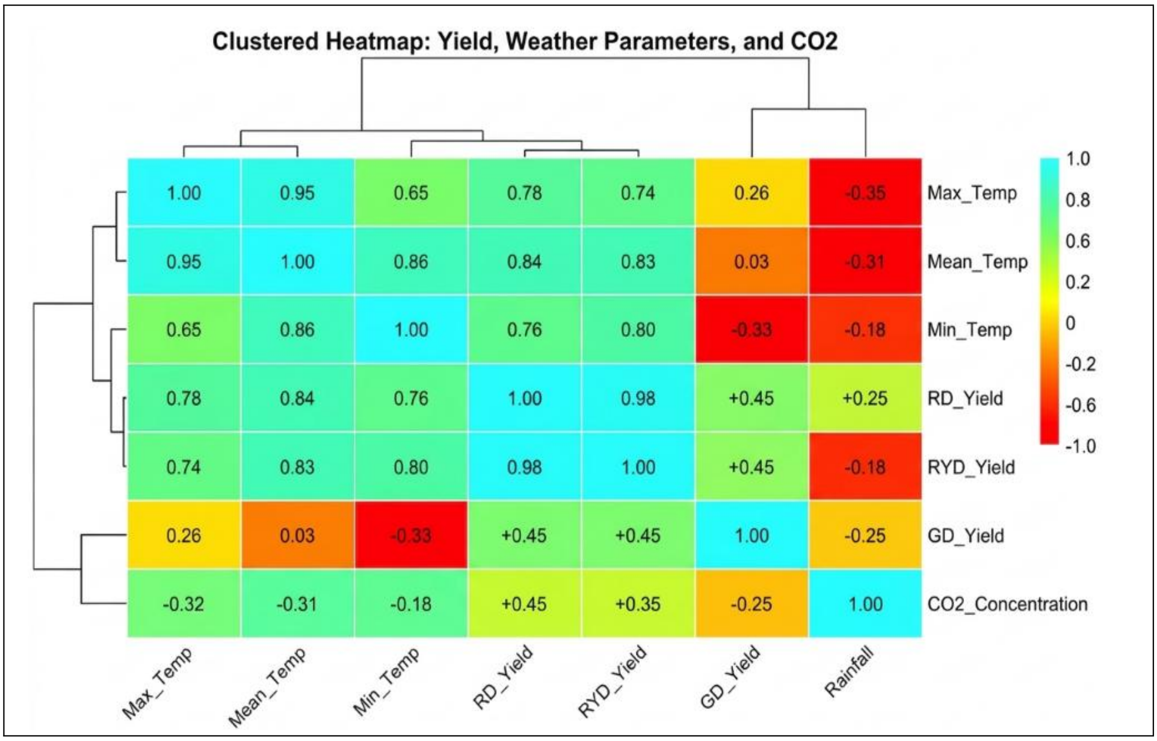

Fig.7: Correlation Heatmap between Yield, Weather parameters and C

The models revealed an increase in the titrable acidity of the apple cultivars with an increase in the elevation in the study districts and the regression model of TSS/Acid ratio was also significant with an R square of 12.21% and 11.60% for the districts Baramulla and Shopian respectively. The models revealed that the ratio increased with elevation in the study districts (Table 5). It is also pertinent to mention that lower mean temperature during flowering and fruit development resulted in increased duration of flowering and fruit TSS and total sugars in district Shopian than district Baramulla. However, higher temperature at lower elevations resulted in earlier flowering with higher fruit weight in studied cultivars.

Pearson Correlation Analysis of Apple yield, Fruit Quality and Morphological parameters: The heatmap (Fig .7) shows that temperature variables (max, mean, min) are strongly correlated and positively influence RD Yield and RYD Yield, which are themselves highly correlated (0.98), indicating similar crop responses. GD Yield behaves differently, showing weak or negative correlation with temperature but moderate positive association with RD and RYD yields. Rainfall generally has a negative relationship with both temperature and yields, suggesting possible adverse effects of excess rain. CO_2 concentration has a moderate positive effect on RD and RYD yields but a negative or weak relationship with temperature and GD Yield. Overall, two clusters emerge: (1) temperature with RD/RYD yields and (2) GD Yield with rainfall and CO_2, indicating distinct environmental influences. The heatmap was generated using the Corr plot package in R.

Climate variability in the study area: The vital climatic variables including long term daily minimum, maximum temperature and precipitation from 1980-2021 were collected from the Agrometeorological unit of the Division of Agronomy, SKUAST-K, Shalimar. These climatic variables were analysed for annual, decadal and extreme fluctuations.

Trends in Temperature: The weather data of Kashmir valley from 1980-2021 show that maximum annual temperatures averages around 17.78 °C while the average minimum temperature as per the historical data is 5.42 °C (Fig. 5). In the last 40 years (1980-2021) the average temperature in Kashmir valley has remained 13.14°C. Overall, the average temperature from 1981-2000 has been observed as 13°C and from 2000-2021 as 13.28°C showing an increase of 0.28°C

(2.15%) in the last 20 years. The lower altitude (1000-1200 m amsl) apple growing regions has now become a vulnerable for its production due to the rise in temperatures (Rana, 2020). The total annual average rainfall (1980-2021) is 1133.58 mm for Kashmir valley, while the average rainfall has shown a declining trend in the past 40 years (1190.7 mm from 1980-2000 to 1076.5 mm from 2001-2021) showing a decrease of 9.59 % in the last 20 years.

Trends in CO_2 concentrations: The value of CO_2 measured during the study period ranges between 400 to 446 ppm between various altitudes of the selected sites in both the districts. The concentration of CO_2 in both the districts was higher during winter months (November to February). Moreover, the mean annual values at different sites in district Baramulla ranged from 417-419 ppm whereas in district Shopian the values were slightly higher and ranged from 420-422 ppm as shown in Fig. 6.

CONCLUSION

Apple trees are experiencing advances in flowering date as a consequence of increasing annual mean temperatures. The beginning of apple growing season is getting earlier due to increasing temperature. In general, climatic change is affecting apple fruit trees differently according to the cultivar and area selected. Comparison of three commercial apple varieties (Red Delicious, Royal Delicious and Golden Delicious) at different altitudes revealed that flowering occurred earlier in lower elevations (i.e. about 15-22 days earlier) as compared to higher altitudes. However, fruit set, yield and yield efficiency were found highest at higher elevations than lower elevations. Extra fruit yield of 11-42 kg/tree was reported in apple cultivars at higher altitude than at lower altitude. Fruits from lower altitudes were heavier and larger in size compared to higher altitudes. However, fruits quality from higher altitudes was found better as they had higher fruit chemical characteristics viz. TSS, total sugar content and TSS/ acidity ratio. Among the two districts, fruits from district Shopian have better fruit quality traits as compared to the fruits from district Baramulla. Temperature variables exhibit a positive association with RD and RYD yields, which are strongly interrelated, whereas GD Yield demonstrates a comparatively weaker or negative relationship with temperature. Rainfall generally shows a negative influence on yields, while CO_2 concentration exhibits a moderate positive effect on RD and RYD yields, indicating differential crop responses to environmental factors. The higher elevations have the favorable climatic conditions for better apple production, thus better performance than the lower altitude cultivation. Also, the CO_2 concentration was recorded higher during winter months in both the districts. Overall temperature trend showed slightly increasing trend (2.15 %) and rainfall showed decreasing trend (9.59 %) over the last four decades. Climate change seems to be inevitable, thus increase in atmospheric temperature have adverse effects on apple crop production which may result in shifting of apple cultivation belt to higher elevations in the valley.

CONFLICT OF INTEREST

All the authors affirm that there is no conflict of interest among them. All research activities comply with relevant legal, institutional and ethical standards.

AUTHOR CONTRIBUTION

All the authors contributed equally in this research article.

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Table 3: Fruit physical characteristics of three apple varieties at different altitudes in district Baramulla and Shopian

	Fruit length (mm)			Fruit breadth (mm)			Fruit weight (g)			Fruit Firmness (Kg cm^{-2})		
Altitude (amsl)	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**
B L1 (1612)	73.12	69.88	64.61	75.21	71.35	66.83	188.71	186.44	178.22	8.24	8.11	8.08
B L2 (1722)	72.62	67.35	62.93	74.35	69.41	65.03	185.53	183.51	176.45	8.35	8.19	8.15
B L3 (1839)	70.15	66.71	62.49	71.66	68.63	64.35	183.23	181.44	174.66	8.43	8.22	8.25
B L4 (1947)	69.40	65.79	61.96	71.51	67.33	63.66	180.39	178.64	172.63	8.45	8.39	8.31
B L5 (2054)	67.17	64.93	61.74	68.87	66.84	63.41	179.28	176.78	172.55	8.53	8.47	8.40
CD	**2.319**	**2.147**	**1.953**	**2.471**	**2.346**	**2.495**	**5.877**	**1.315**	**6.643**	**0.269**	**0.356**	**0.343**
S L1 (1630)	76.21	71.61	67.71	78.24	73.35	68.77	194.57	190.63	181.37	8.36	8.26	8.18
S L2 (1765)	74.43	69.69	65.82	76.13	67.42	64.84	189.39	185.54	178.48	8.51	8.34	8.30
S L3 (1875)	73.34	68.80	64.79	75.12	70.22	65.85	186.30	184.73	177.66	8.54	8.36	8.30
S L4 (1980)	71.40	67.49	63.81	73.14	69.24	64.77	184.46	181.75	174.76	8.56	8.45	8.36
S L5 (2084)	68.71	66.89	62.59	70.52	68.74	63.46	180.28	177.83	173.84	8.67	8.52	8.47
CD	**2.263**	**2.361**	**1.826**	**2.155**	**2.316**	**2.015**	**6.463**	**8.336**	**6.136**	**0.236**	**0.256**	**0.323**

Table 4: Fruit chemical characteristics of three apple varieties at different altitudes in district Baramulla and Shopian

	TSS (^{o}B)			Total Sugars (%)			Titrable acidity (%)			TSS/ Acidity ratio		
Altitude (amsl)	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**	**RD**	**RYD**	**GD**
B L1 (1612)	12.75	12.46	11.91	9.57	9.37	9.16	0.26	0.26	0.40	49.66	47.29	29.78
B L2 (1722)	12.88	12.59	12.03	9.68	9.46	9.27	0.24	0.25	0.39	52.94	49.67	31.10
B L3 (1839)	13.05	12.77	12.35	10.20	9.69	9.34	0.24	0.24	0.37	55.13	53.19	33.07
B L4 (1947)	13.61	13.60	12.51	10.27	9.90	9.57	0.22	0.23	0.35	61.00	58.28	36.09
B L5 (2054)	14.09	13.99	12.71	10.42	10.16	9.70	0.22	0.22	0.33	65.05	63.61	38.91
CD	**0.508**	**0.412**	**0.386**	**0.331**	**0.352**	**0.354**	**0.011**	**1.074**	**0.013**	**1.708**	**1.704**	**1.089**
S L1 (1630)	12.83	12.53	11.98	9.69	9.61	9.27	0.24	0.25	0.38	53.51	50.16	31.54
S L2 (1765)	12.90	12.68	12.14	9.78	9.70	9.41	0.23	0.24	0.36	56.33	53.04	33.78
S L3 (1875)	13.04	12.88	12.38	10.29	9.89	9.49	0.22	0.23	0.34	59.34	56.06	36.43
S L4 (1980)	13.56	13.00	12.63	10.41	10.20	9.71	0.21	0.22	0.32	64.65	59.16	39.49
S L5 (2084)	14.01	13.47	12.86	10.59	10.27	9.90	0.20	0.21	0.30	70.15	64.22	42.89
CD	**0.488**	**0.325**	**0.379**	**0.280**	**0.312**	**0.342**	**1.314**	**0.009**	**1.315**	**2.177**	**1.630**	**1.278**

Tab 5: Regression models of different fruit parameters on location with R^2 and p values

Parameter	District	Regression Models	R^2	p-value
Fruit Yield	Baramulla	*Fruit Yield = 82.85 + 0.0 Location_BL1 + 6.15 Location_BL2 + 15.65 Location_BL3 + 20.09 Location_BL4 + 26.28 Location_BL5*	29.31%	0.0001
	Shopian	*Fruit Yield = 74.23 + 0.0 Location_SL1 + 9.03 Location_SL2 + 17.92 Location_SL3 + 24.62 Location_SL4 + 30.04 Location_SL5*	8.55%	0.0001
Fruit Length	Baramulla	*Fruit Length = 69.203 + 0.0 Location_BL1 - 1.570 Location_BL2 - 2.753 Location_BL3 - 3.487 Location_BL4 - 4.590 Location_BL5*	19.34%	0.0001
	Shopian	*Fruit Length = 71.843 + 0.0 Location_SL1 - 1.863 Location_SL2 - 2.867 Location_SL3 - 4.277 Location_SL4 - 5.780 Location_SL5*	26.90%	0.0001
Fruit Breadth	Baramulla	*Fruit Breadth = 71.130 + 0.0 Location_BL1 - 1.533 Location_BL2 - 2.917 Location_BL3 - 3.630 Location_BL4 - 4.757 Location_BL5*	21.27%	0.0001
	Shopian	*Fruit Breadth = 73.457 + 0.0 Location_SL1 - 2.79 Location_SL2 - 3.64 Location_SL3 - 4.57 Location_SL4 - 6.36 Location_SL5*	23.73%	0.0001
Fruit Weight	Baramulla	*Fruit Weight = 184.458 + 0.0 Location_BL1 - 2.63 Location_BL2 - 4.68 Location_BL3 - 7.24 Location_BL4 - 8.25 Location_BL5*	39.99%	0.0001
	Shopian	*Fruit Weight = 188.853 + 0.0 Location_SL1 - 4.39 Location_SL2 - 5.96 Location_SL3 - 8.53 Location_SL4 - 11.54 Location_SL5*	45.94%	0.0001
Fruit Firmness	Baramulla	*Fruit Firmness = 8.1444 + 0.0 Location_BL1 + 0.0867 Location_BL2 + 0.1567 Location_BL3 + 0.2400 Location_BL4 + 0.3256 Location_BL5*	39.88%	0.0001
	Shopian	*Fruit Firmness = 8.2633 + 0.0 Location_SL1 + 0.0656 Location_SL2 + 0.1422 Location_SL3 + 0.2122 Location_SL4 + 0.2933 Location_SL5*	31.67%	0.0001
TSS	Baramulla	*TSS = 12.373 + 0.0 Location_BL1 + 0.127 Location_BL2 + 0.350Location_BL3 + 0.870 Location_BL4 + 1.227 Location_BL5*	29.66%	0.0001
	Shopian	*TSS = 12.4500 + 0.0 Location_SL1 + 0.127 Location_SL2 + 0.320 Location_SL3 + 0.617 Location_SL4 + 1.000 Location_SL5*	41.90%	0.0001
Total Sugars	Baramulla	*Total Sugars = 9.3633 + 0.0 Location_BL1 + 0.1033 Location_BL2 + 0.3767 Location_BL3 + 0.5467 Location_BL4 + 0.7267 Location_BL5*	45.47%	0.0001
	Shopian	*Total Sugars = 9.5267 + 0.0 Location_SL1 + 0.1067 Location_SL2 + 0.3667 Location_SL3 + 0.5833 Location_SL4 + 0.7300 Location_SL5*	48.71%	0.0001
Titrable Acidity	Baramulla	*Tritable Acidity = 0.3067 + 0.0 Location_BL1 - 0.0122 Location_BL2 - 0.0233 Location_BL3 - 0.0389 Location_BL4 - 0.0519 Location_BL5*	6.21%	0.0001
	Shopian	*Tritable Acidity = 0.2900 + 0.0 Location_SL1 - 0.0133 Location_SL2 - 0.0267 Location_SL3 - 0.0400 Location_SL4 - 0.0530 Location_SL5*	7.02%	0.049
TSS/Acidity Ratio	Baramulla	*TSS/Acidity Ratio = 43.18 + 0.0 Location_BL1 + 1.85 Location_BL2 + 4.96 Location_BL3 + 10.78 Location_BL4 + 13.91 Location_BL5*	12.21%	0.0001
	Shopian	*TSS/Acidity Ratio = 46.38 + 0.0 Location_SL1 + 2.01 Location_SL2 + 5.45 Location_SL3 + 10.61 Location_SL4 + 14.92 Location_SL5*	11.60%	0.004

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