

**ALTITUDE VARIATION ON FRUIT DEVELOPMENT AND QUALITY
ATTRIBUTES OF KIWIFRUIT (*ACTINIDIA DELICIOSA* CHEV.)
IN NORTH-WESTERN HIMALAYA**

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Abstract

Effects of climatic variability at different altitudes on the fruit development and quality attributes of kiwifruit in the North -Western Himalayas of India were investigated. The experiment was carried out at five altitudinal locations (1090, 1275, 1425, 1543, and 1924 m above mean sea level) and with two cultivars viz. Hayward and Allison. It was observed that fruit yield and quality varied according to altitude and cultivars. The Hayward cultivar performed better in terms of yield, graded portion, and fruit quality like titratable acidity and ascorbic acid at higher elevations whereas, the Allison cultivar performed better at lower elevations. Findings revealed that the elevation ranging from 1000 to 1450 m was appropriate for the Allison cultivar and the elevation ranging from 1500 to 1950 m was appropriate for the Hayward cultivation.

Introduction

Kiwifruit has been grown all over the world since it has health advantages like an increase in antioxidants, a decrease in blood lipids, and an improvement in gastrointestinal laxation. Kiwifruit was utilized as a treatment for a number of illnesses in ancient China, including dyspepsia, rheumatism, and digestive difficulties (Rana and Kumar 2021). The production of fruit only requires the four *Actinidia* species: *chinensis* (golden kiwifruit), *deliciosa* (fuzzy kiwifruit), *kolomikta*, and *arguta* (baby kiwifruit). The variety of kiwifruit that is grown most frequently is *A. deliciosa*. In New Zealand, the name Hayward was decided in 1925. The Hayward cultivar and its related male pollinator plants make up about half of all kiwifruit cultivated worldwide, and 90 to 95 per cent of all kiwifruit exported internationally are "Hayward" fruit (Tait *et al.* 2018). It produces up to 50 tonnes per hectare and has a large yield with good flavour and a long shelf life. Additionally, late spring frosts are avoided because it blooms later. This cultivar should only be used in areas with mild winters. Allison is also a prolific bearer. Allison, a chance seedling released in the early 1930s. The fruit has good preservation qualities and has gained popularity in India due to its high sugar and acid blend (Sharma *et al.* 2022).

Pome and stone fruits, are declining day by day due to the changing climatic scenario (Kundu *et al.* 2022). The finest substitute might be kiwifruit. Due to its high yield per area and excellent compatibility with the local ecological conditions, Nowadays, Kiwifruit has been grown under many ecological conditions, including various altitudes and directions all over the world. In India, kiwifruit cultivation has become more common particularly in the North Himalayan region. But more research is required on methods for cultivation, propagation, and the methods for boosting fruit yield and quality. Pollination, flowering period, irrigation, fertilizer scheduling, altitude or elevation, plant growth regulators, training, and pruning are orchard characteristics

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known to affect fruit quality and its variability in fruit output (Bennewitz *et al.* 2019). Thus, an experiment was carried out to identify the best optimal altitude(s) for kiwifruit production for two cultivars of Kiwifruit, *viz.* Hayward and Allison.

Materials and Methods

Field investigation was carried out at five locations *viz.*, Bajaura (1090 m), Nauni (1275 m), Kandaghat (1425 m), Seobagh (1543 m) and Phagli (1924 m) of Himachal Pradesh during 2019-20 and 2020-21. Different agro ecological zones of Himachal Pradesh were covered by these selected five different locations. A randomized complete block design was used with four replicates for each cultivar. Five fully matured vines of each cultivar namely were marked at each of selected sites for recording observations. The vines with uniform vigour and size was planted at a 4.0 m × 6.0 m spacing and trained on T-bar system. Uniform cultural practices were given to each vine to keep the plants healthy. The selected experimental sites are the potential kiwifruit growing areas with little variation in climatic conditions and the geographical details are presented in Table 1. The research was carried in kiwifruit orchards grown at different altitudes *viz.* 1090m, 1275m, 1425m, 1543m and 1924m altitude.

The fruits were harvested at optimum harvest (TSS > 6.2°B). The dates of harvesting for both the cultivars at each altitude and sites were recorded. The yield of fruits were expressed in kilograms per tree (kg/vine). On the basis of weight, the harvested fruits were classified into three grades *viz.*, A (>80 g), B (60-80 g) and C (<60 g). The yields of different grade fruit were expressed in kg/vine. The size of the fruit was expressed in terms of length and diameter. The length and diameter of the fruits were measured with the help of Digital Vernier caliper and were expressed in millimetre. All fruits harvested in each altitude and replication were weighed on electronic top pan balance and average fruit weight was expressed as gram (g). Total soluble solid contents (TSS) in fruits at harvest and eating maturity stage were measured by Erma Hand Refractometer (0-32%). Total titratable acidity and vitamin C contents were following the standard method (AOAC 2016). Data from the analytical determinations were subjected to analysis of variance (ANOVA). All analyses were performed with SPSS software package (version 21.0).

Results and Discussion

The data recorded on the harvest maturity of kiwifruit cultivars during the years 2019-20 and 2020-21 are presented in Fig. 1. A perusal of data revealed that different altitudes and cultivars exerted a significant effects on the harvest maturity of kiwifruit during both the years of study. This event occurs when seeds mature, harden and change in colour from white to brown and the TSS reached at 6.2° Brix. The onset of Harvest Maturity was noticed between 12th Oct to 21st Nov during 2019-20 and 07th Oct to 12th Nov for Hayward cultivar during 2020-21 at different altitudes. The earliest harvest maturity was recorded at lower altitude (1090m) for Hayward cultivar on the 12th Oct in 2019-20 and 07th Oct during 2020-21. The latest harvest maturity stage was recorded at higher altitudes (1924 m) on 21st Nov during 2019-20 and 12th Nov during 2020-21. Similarly, the onset of harvest maturity in Allison cultivar was noticed from 02nd Oct to 16th Nov during 2019-20 and 29th Sept to 06th Nov during 2020-21. The harvest maturity trend with respect to experimental locations was almost similar as that of Hayward. The high temperature promotes the accumulation of photothermic heat due to which the rate of reaction might be enhanced. Generally, ambient air temperature during fruit development is known to be an important determinant of the growth and quality of many fruits. For example, In fruit crops, lower

air temperature increases fruit weight and size at harvest time, whereas higher air temperature accelerates fruit colouring and shortens the harvest period (Tait *et al.* 2018).

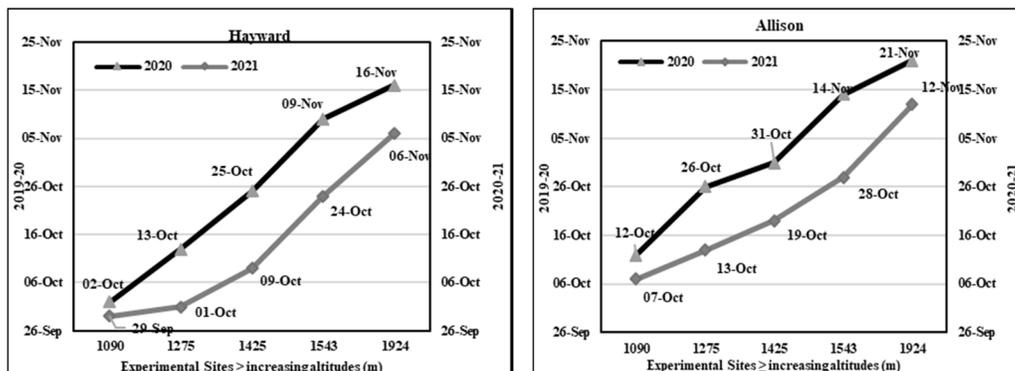


Fig. 1. Altitudinal Variation in harvest maturity of kiwifruit cvs. Hayward and Allison.

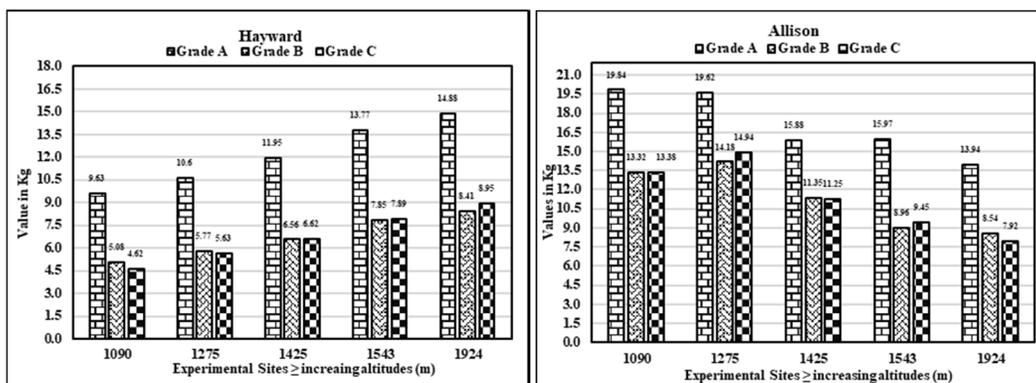


Fig. 2. Variation in average graded yield of kiwifruit cvs. Hayward and Allison at different altitudes.

Data related to the fruit yield per vine as influenced by the different altitudes and cultivars during the years 2020 and 2021 are presented in Table 1 which revealed significant effects of altitudes, cultivars and their interaction during both the years of study. The highest average fruit yield (32.25 kg/vine) of Hayward kiwifruit was recorded at higher altitude (1924m) and the lowest fruit (19.33 kg/vine) yield was recorded at lower altitude. During, 2021, the lower fruit yields were reduced at all the location as compared to 2020. The highest average fruit yield per vine was recorded during 2020. Among interactions, the fruit yield was found at higher altitude (1924 m) in 2020. In contrary, Allison cultivar, the highest average fruit yield (48.74 kg/vine) was recorded at lower altitude and lowest yield (30.41 kg/vine) was recorded at higher altitude (1924 m). Data on graded yield exhibited a significant effect on the proportion of grade ‘A’ ‘B’ and ‘C’ fruits in Hayward. The highest average grade A portion was recorded at higher altitude (1924m) and lowest ‘A’ grade fruits of Hayward were recorded at lower altitude (1275m) during both year of the study. Figure 2 showed that highest average grade A portion was recorded at lower altitude

and decrease with the increase of altitude. Likewise, the proportion of grade B was also highest at higher altitude (1924m) which was followed in similar trend. However, the grade B of Hayward cultivar was found to be lowest at lower altitude. In Allison cultivar, the highest grade B portion of total yield was recorded at lower altitude ranging from 1090 m to 1275 m and decrease with the increase the altitude. Data related to grade C as influenced by the different locations indicated that highest grade C proportion of grade C per vine was also recorded at higher altitude and the of grade C was recorded with lower altitude. The highest grade C portion of yield was also recorded at lower altitude. However, In Hayward cultivar showed increasing trend in fruit and graded proportion with the increase of the altitude on the contrary, Allison yield and portion yield were increased with decrease of altitude.

Table 1. General information of the kiwifruit orchards at different altitudes.

Location	Altitude (m)	Latitude	Longitude	Spacing (R × P)	No of vines/ha
A ₁	1090	30.50°N	77.00°E	4m×6m	416 (376♀)
A ₂	1275	30.80°N	77.16°E	4m×6m	416 (376♀)
A ₃	1425	30.90°N	77.10°E	4m×6m	416 (376♀)
A ₄	1543	31.90°N	77.13°E	4m×6m	416 (376♀)
A ₅	1924	31.50 °N	77.50 °E	4m×6m	416 (376♀)

Climate plays an important role in fruit yield of different kiwifruit cultivars. In the present investigation, the Hayward yielded lower than Allison cultivar at lower mid-hills conditions. Relative performance in respect of total fruit yield of cultivar Allison and Hayward is due to differences in chilling requirement. In the present study, Allison performed better at lower elevation whereas, Hayward cultivar performed better at higher altitudes. It was reported that altitude plays an important in performance of any cultivar (Sharma *et al.* 2022). With the increase in elevation, plants tend to remain shorter with decreased biomass decreased, leaf area reduced and increased the stomatal density, leaf nitrogen content, photosynthetic process (Gong *et al.* 2015).

Data on the fruit weight as influenced by different locations and cultivars during the years 2019-20 and 2020-21 showed that the altitudes and cultivars had significant effects on the fruit weight during both the year but interaction effect was non-significant (Table 1). The highest average fruit weight was recorded at lower attitude Bajaura (1090 m). However, the average fruit weight of Hayward cultivar was found to be lowest at higher altitude. While comparing different years, the highest fruit weight was noticed in 2021 as compared to 2020. However, the interaction effect was found to be non-significant. In Allison cultivar, the average fruit weight was found to be highest at higher altitude (1924 m) whereas, the lowest fruit weight was recorded at Bajaura location with significant variations in case of interaction effects. In the resent investigation, it was observed that the location which recorded higher yield result in lower proportion and average fruit weight irrespective cultivars under study. Bostan and Gunay (2014) reported that weight of cv. 'Hayward' varied with altitude and directions and that the highest yield was obtained at high

altitude. The fruit weight depends on the number of fruits per plant and if the plant have higher number of fruits per vine then there is reduction of average but increase in overall yield. This might be due to the availability of more photo-assimilates to the crop and distribution is more due to which the average fruit weight increased.

An analysis of the data revealed that significantly higher fruit length for Hayward cultivar was recorded at lower altitude 1090 m (Table 2). However, the fruit length was found to be lowest at higher altitude *i.e.* 1924 m. The interaction effect was also found to be significant. The highest fruit length was found in the 2021 at lower altitude (1090m) and lowest was found at higher altitude during 2020. In Allison cultivar, the highest average fruit length was recorded at higher altitude (1924 m). The lowest fruit length was recorded at lower elevation 1090 m. Among years, the highest fruit length was noticed for Allison in 2020. The interaction effect was also found to be significant and the highest fruit length was found at higher altitude *i.e.* (1924 m) in 2021. In Hayward, significantly higher fruit diameter was recorded at lower altitude and the lowest value of fruit diameter was found at higher altitude. In 2021 the higher fruit diameter was found as compared to 2020. The interaction effect was also found to be significant. The highest fruit diameter was found in the 2021 at lower elevation and lowest was found at higher location during 2020. Highest average fruit diameter was recorded in the Allison cultivar at higher altitude. The lowest fruit diameter was recorded at lower altitude (1090m). During the different year, the highest fruit diameter was recorded during 2021.

Climate also affected the size of kiwifruit at different locations. Among kiwifruit cultivars, the Hayward exhibited better performance at the higher altitude conditions as compared to lower altitudes. This might be due to high chill requirement of the Hayward cultivar as compared to the Allison. On the contrary, the performance of kiwifruit was found better at lower elevation. Like fruit weight fruit also showed negative correlation with the total yield which is obvious bearing leads to reduction in average fruit size in terms of length and diameter. In general, thinning, climate and altitude play an important role in fruit production of better grade. Lower altitude gave high production of Allison cultivar fruits and Hayward gave in higher altitudes. Higher number of the fruits present into vine affect the yield and fruit size. Fruit weight and size were found to improve significantly with the decreasing number of fruits per vine due to more distribution of carbohydrates per fruit. These results are in conformity with results reported by Zhao *et al.* (2017) and Milech *et al.* (2018).

Total soluble salt (TSS) is an Important quality attribute of kiwifruit. Total soluble solids (TSS) of kiwifruit as influenced by different and cultivars during both the years (Table 3). The data revealed that the altitude, cultivars and their interaction had significant effects on the TSS content of kiwifruit during both the years. In both the cultivars, significantly higher fruit TSS was recorded at the lower elevation. However, the lowest value of fruit TSS was found at higher altitude. The variation in total soluble solids among altitude and cultivars may be due differences in climatic conditions especially, the temperature which lead to breakdown of complex carbohydrates into simple sugars. The sugars constitute the major proportion of TSS. Another source of variation is translocation of carbohydrates into fruits as a sink which exhibited valuable among cultivars and locations. Temperature has been reported to have significant effects on kiwifruit maturation and the starch turned into sugars at high temperatures. Mean daily temperature decreased with increase in altitude and consequently effected fruit quality (Tait *et al.* 2018).

Titrateable acidity of kiwifruit as influenced by different altitude and cultivars in the years 2020 and 2021 showed a significant impact (Table 3). In Hayward, significantly higher titrateable acidity was recorded at 1924m representing higher elevation and the lowest value of titrateable acidity was recorded at lower elevation (1090m). However, during 2020 the highest titrateable

acidity was found as compared to 2021. In Allison cultivar, the average titratable acidity was recorded to be higher at 1924m and the lowest titratable acidity was recorded at 1090m. Temperature also plays an important role in development of acid contents in fruits. At high altitudes, the degradation of acid is slower compared to lower elevation. Richardson *et al.* (2004) reported that the Titratable acidity is more at higher altitudes as compared to lower altitude kiwifruit that both malate and citrate are concentrations increased during fruit development if temperature is low and the accumulation of malate was reduced during the high temperature during starch accumulation and fruit maturation. Data pertaining to the effects of altitude and cultivar differences on the TSS: acid ratio of fruits during the years 2019-20 and 2020-21 are presented in Table 3. It is evident that Hayward cultivar exhibited significantly higher TSS: acid ratio at lower altitude. However, the lowest ratio of TSS: acid was found at higher altitudes (1924 m). In Allison cultivar, the trend was almost similar as followed in the Hayward cultivar. The highest TSS: acid ratio was recorded at lower altitudes (1090m) and lowest value of TSS: acid ratio was found at higher altitudes (1924 m). The higher TSS content coupled with low acid contents at variable locations and cultivar is responsible for variation in TSS:acid ratio. These results are in conformity with finding of Bostan and Gunay (2014) and Zenginbal *et al.* (2018) in kiwifruit cv. 'Hayward' at harvest maturity.

Data recorded on the total sugars content of kiwifruit as influenced by the different locations and cultivars during the years 2020 and 2021 are presented in Table 3 which revealed that highest total sugars content was recorded at lower altitude (1090m) in both the cultivars namely; Hayward and Allison cultivars of kiwifruit recorded. However, the lowest total sugars was noticed at higher altitude (1924 m). In 2021 highest fruit total sugars was recorded as compared to 2020. The interaction effect was also found to be significant. The highest fruit total sugar was found in the 2021 at an height of 1090m and lowest was found at higher altitude during 2021. Results showed that the sugars content might be increased with decrease an altitude. Sugars are the main constituent of TSS. Temperature plays an important role in TSS; acidity and TSS acid ratio content of kiwifruit. Temperature has been reported to have significant effects on kiwifruit maturation and the starch turned into sugars at high temperatures (Sharma *et al.* 2022; Rana and Kumar, 2021). This leads to accumulation of more sugars formation at low altitude due to the high temperature. Table 4 represent collected data on the sugars acid ratio composition of kiwifruit as impacted by various regions and cultivars over the years 2020 and 2021. Data showed that the Hayward and Allison cultivar in at lower altitude (1090m) had a substantially higher sugars acid ratio. However, an altitude of 1924m had the lowest sugars acid ratio value. Significant results were also reported for the interaction effect. The highest sugars acid ratio was found in 2021 at the lower altitude, and the lowest was reported in 2020 at the higher altitude location. The sugars acid blend contribute palatability of the kiwifruit. Result showed that the Allison cultivar had more sugars acid blend than the Hayward variety. The temperature plays an important role in sugar acid ratio content of kiwifruit performance as the sugars content are directly proportional to the sugar acid ratio. Temperature has been reported to have significant effects on kiwifruit maturation and the starch turned into sugars at high temperatures. The higher altitude have more acidity due to photosensitive nature of acid due to which less sugar acid ratio were found at high altitude. This lead to accumulation of more sugars formation in low altitude due to the high temperature.

Table 4. Variation in sugar acid ratio and ascorbic acid content (Vitamin C) of kiwifruit at different altitudes.

Code	Experiment location	Sugars Acid Ratio									Ascorbic acid (mg per 100g)								
		Hayward			Allison			Hayward			Allison			Hayward			Allison		
		2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
A ₁	1090m	10.16	11.68	10.92	11.82	13.37	12.60	80.68	78.01	79.35	81.43	78.76	80.10						
A ₂	1275m	9.10	10.34	9.72	10.95	12.55	11.75	84.03	83.38	83.71	84.78	84.13	84.46						
A ₃	1425m	8.35	9.33	8.84	9.95	11.14	10.55	85.03	83.97	84.50	85.78	84.72	85.25						
A ₄	1543m	7.54	8.56	8.05	8.84	10.17	9.50	85.84	84.97	85.40	86.59	85.72	86.15						
A ₅	1924m	6.96	7.76	7.36	8.04	9.71	8.87	87.17	86.97	87.07	87.92	87.72	87.82						
	Mean	8.42	9.53	8.98	9.92	11.39	10.65	84.55	83.46	84.00	85.30	84.21	84.75						
	CD _{0.05}																		
	Location (A)		0.21			0.34			0.77				0.76						
	Year (Y)		0.13			0.21			0.49				0.48						
	A×Y		0.29			0.48			1.09				1.08						

Table 4 showed data on the ascorbic acid concentration of fruits as affected by location and cultivar over the years 2020 and 2021. According to the findings, the higher altitude of an height 1924 m had the highest ascorbic acid content. However, the lower altitude had the lowest value of ascorbic acid. Fruit ascorbic acid levels were greater in 2020 than in 2021. The interaction impact was found to be significant as well. The highest concentration of ascorbic acid was found in 2020 at higher altitude, and the lowest concentration was recorded in 2021 at lower altitude. Allison cultivar data followed a similar pattern to Hayward cultivar data. The higher altitude (1924m) has the highest ascorbic acid level and area with the lowest fruit ascorbic acid was found at lower altitude (1090m). The interaction effect revealed that the highest ascorbic acid was found at higher altitude (1924 m) in 2020. The high temperature and low altitude of the vines during fruit starch accumulation resulted in a significant change in partitioning toward vegetative growth and a significant reduction in fruit carbohydrate and vitamin C. The activity and expression of L-galactose dehydrogenase reduced as the fruit matured, indicating that some vitamin C production must occur in the fruit. Due to high temperatures, low altitude places have severe repercussions for vitamin C levels in fruit. The ability to manufacture vitamin C is connected with L-GaldH, the penultimate enzyme in ascorbate biosynthesis, as well as high temperature or low altitude. Ascorbic acid is photosensitive in nature because at lower altitudes there is less protein translation, more protein turnover, or alternative activity modulation. Ascorbic acid is a thermosensitive vitamin that decreases as the temperature rises. Ascorbic acid deficiency could be caused by enzymatic loss of L-ascorbic acid, which is transformed to 2-3-dioxy-L-gluconic acid (Sharma *et al.* 2022).

The results obtained on the basis of two years of study it may be concluded that fruit yield and quality varied according to climate (elevation) and cultivars. The Hayward performed better in terms of yield and fruit quality at higher elevations, whereas, the Allison cultivar performed better at lower elevations. On the basis of the results, it can be recommended that kiwifruit be an alternative crop in the midhills of the Himalayan region. The Hayward cultivar performed well between 1400-2000m above mean sea level (a.m.s.l.), whereas, the Allison cultivar performed better in low hills and lower elevations ranging from 900–1500 m a.m.s.l.

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