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# Altitudinal specific variation in growing degree days of kiwifruit (*Actinida chinensis*) based on the BBCH scale

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ABSTRACT

The present study was carried out during 2019–20 and 2020–21 at Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh aimed to apply easy-to-use mathematical equations for the temperature-based estimation of kiwifruit (*Actinida chinensis* var. deliciosa) cultivation's Growing Degree Days (GDD) over the north-western Himalayan region. Five locations in three districts of Himachal Pradesh, namely Solan (Nauni and Kandaghat), Kullu (Bajaura and Seobagh), and Shimla (Phagli) were selected for the study. The experiment was laid out in a factorial randomized block design (F-RBD) with 10 treatments, and each treatment was replicated thrice. It is revealed that the highest average temperature was recorded at lower elevations. The earliest bud swell, bud break, open cluster, 50% visible petal, petal unfolding full bloom, and harvest maturity were observed at the Bajaura location during both years of study. A delay in the aforementioned phenophases of kiwifruit cultivars was noticed at higher elevations. The growing (GDD) was found to be highest in the Hayward cultivar at the Bajaura location. Fruit yields varied with climate (elevation) and cultivars. The Hayward performed better in terms of yield at higher elevations, unlike it was vice-versa in case of Allison.

**Keywords**: *Actinidia deliciosa,* Allison, Different phenological stages, Hayward, Heat unit, Yield

As a result of a greater intake of kiwifruit (*Actinida chinensis* var. deliciosa) by the growing population following the COVID-19 pandemic, the demand for kiwifruit is increasing swiftly due to its nutritional value (Kahramanoglu *et al.* 2022). Numerous factors, including nutrients, water, photoperiod, and temperature, affect kiwifruit production. Drought and heat stress are significant environmental factors that influence the growth and development of plants. The cultivation of kiwifruit at various altitudes is one of the most influential determinants of crop phenological development and efficient biomass conversion to economic yield (Pawar and Rana 2019). Environmental and genetic variables play a significant role in kiwifruit production. Phenology is the study of seasonal variations in the occurrence of various palm development events owing to ecological factors (Sharma *et al.* 2022). Understanding phenophases in depth makes it easier to target different management practises by allowing for better input use, making informed decisions about how to control pests and diseases, and ensuring timely harvesting. Moisture stress has also been found to reduce the number of days required to complete any phenological stage and the crop growth indices (Ihsan *et al.* 2016).

Growing degree days (GDD) is a frequently utilized agroclimatic index due to its ability to integrate air temperature, a widely employed metric, and an efficacious atmospheric parameter. In 1730, Reaumut established the concept of heat units, also known as thermal time, as a conceptual idea. The accumulation of heat was determined to be a critical factor. The correlation between temperature and plant growth is a well-established phenomenon in agricultural crops. To assess crop growth progress, growing degree days (GDD) are commonly used as a metric. The relationship between temperature and crop development has been described by various authors using degree days (Kingra and Kaur 2012). The concept of GDD is subject to variation as the growing stage progresses, allowing for the precise determination of growth stages in a specific geographical area. The present study aimed to apply easy-to-use mathematical equations for the temperature-based estimation of kiwifruit cultivation's GDD over the north-western Himalayan region.

## MATERIALS AND METHODS

The present study was carried out during 2019–20 and 2020–21 at Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh. The

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investigation was conducted at five diverse locations in Himachal Pradesh, namely Solan [Nauni ($A_2$) (30.80ºN latitude, 77.16ºE longitude; 1275 m asml at experimental kiwifruit block and Kandaghat ($A_3$) (30.90ºN latitude, 77.10ºE longitude; 1425 m asml) at Krishi Vigyan Kendra, Kabdaghat]; Kullu [Bajaura ($A_1$) (30.50ºN latitude, 77.00ºE longitude; elevation at 1090 m asml) Regional Horticultural Research and Training Station; and Seobagh ($A_4$) (31.90 ºN latitude; 77.13ºE longitude; 1543 m asml) at Horticultural Research Station, Seobagh], and Shimla [Phagli ($A_5$) (31.50 ºN latitude, 77.50 ºE longitude; 1924 m asml) at National Bureau of Plant Genetic Resources, Phagli] were selected for the study which are prospective kiwifruit-growing regions.

The experiment was laid out in a factorial randomized block design (F-RBD) with 10 treatments, and each treatment was replicated thrice. The pollinizers selected for the vines were Allison male. The two commercially cultivated cultivars, namely Hayward and Allison, planted at 4 m × 6 m (376 female vines/ha) were selected for the study. The study considered the seven significant phenological growth stages of kiwifruit development and their correlation with varying climatic conditions across different experimental sites. The phenological stages chosen were identified following the established BBCH (Brundell 1975a, 1975b) as summarized in Table 1.

The dates of onset of selected phenological stages were recorded for the cultivars at each experimental site. The accumulated GDD were calculated from maximum and minimum temperatures from bud swell to harvest maturity for the studied kiwifruit cultivars at the selected experimental sites. The GDD were determined through the mathematical operation of subtracting the base temperature ($T_{base}$) of 10°C from the mean temperature recorded daily. The GDD was computed using the formula provided by Snyder *et al.* (1999). The maximum and minimum daily temperatures (°C) and the number of hours of bright sunshine (BSS) were recorded at the weather station located at the Research Orchard in respective locations.

The base temperature of 10°C, as established by Snyder *et al.* (1999). The calculation of growing degree days for various varieties was performed for each phenophase, utilizing the given formula:

$$\text{Growing degree days (GDD)} = \sum_{i=1}^{m} (\text{Ti} - \text{Tbase}) \quad (1)$$

$$\text{Ti} = (T_{MAX} + T_{MIN})/2 \quad (2)$$

$T_i$, Mean air temperature (°C) on the $i^{th}$ day of the growing season; $T_{max}$, Maximum temperature (°C); $T_{min}$, Minimum temperature (°C); $T_{base}$, Base or threshold temperature.

To analyze the phenological cycles and thermal time for kiwifruit cultivation at several sites in Himachal Pradesh, GDD accumulation was calculated and the phenological phases between years were compared in terms of heat buildup throughout the season. January 1 was taken as the commencement date, and the first easily identifiable stage at the beginning of bud swell (01) was utilized as a biofix i.e. for the onset of growth with GDD accumulation. The fruits were harvested at optimum harvest (TSS >6.2ºB). The dates of harvesting for both the cultivars at each altitude were recorded. Based on 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 approach for analysis of two factorial randomized block designs (F-RBD) was used to analyze the data using MS-Excel and R studio and examined at a 5% level of significance, various variables' levels of significance.

## RESULTS AND DISCUSSION

The accumulation of growing degree days at the bud swell stage in 2020 and 2021, affected by different locations and cultivars, is presented in Table 2. The Hayward cultivar had the maximum (31.3ºC GDD) growth degree days at lower altitudes. Phagli has the lowest growing degree days (GDD) at 21.00°C, which is characteristic of high altitudes. No matter the experiment, 2021 was warmer than 2020. The maximum increasing degree days (29.82ºC GDD) were in 2021, followed by 2020 at 23.48. Allison cultivar bud swell stage growth degree days were highest at Bajaura (28.80ºC GDD) and lowest at Phagli (19.20ºC GDD). In 2021, growing degree days (GDD) were 29.82ºC, up from 23.48ºC in 2020. Cultivars with a low chilling requirement typically have a bud break at lower temperatures, which can explain the variation in GDD requirements for bud swell between cultivars and locations. Similar to this, lower elevations had higher temperatures in the current investigation. The greater temperature induced heat units to build up early, causing bud swell. The findings align with the research of

Table 1 Phenological stages of kiwifruit from the calculation of growing degree days

| Phenological Stages | Description | BBCH code |
|---|---|---|
| Bud Swell | Active buds begin to swell. Scales covered by white trichomes just visible | 03 |
| Bud Burst | Leaf and inflorescence buds enclosed by scales covered by brown trichomes. | 07 |
| Open Cluster | The bud develops into an open cluster. | 10 |
| 50% visible Petal | Sepals continue to separate, and peduncles to elongate and thicken. Corolla clearly visible, | 56 |
| Petal unfolding | First flowers open: corolla bell-shaped. | 60 |
| Full Bloom | > 50 percent of flowers open. | 65 |
| Harvest Maturity | Seeds reach their full size. | 85 |

BBCH, Biologische Bundesanstalt, Bundessortenamt and Chemical industry.

Table 2 Effects of altitudinal variation on growing degree days for bud swell and bud burst phenophases of kiwifruit

| Phenophases | GDD (ºC GDD)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bud swell | | | | | | Bud Burst | | | | | |
| | Hayward | | | Allison | | | Hayward | | | Allison | | |
| Altitude (m amsl) | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean |
| $A_1$, 1090 | 28.40 | 34.20 | 31.30 | 25.50 | 32.10 | 28.80 | 48.50 | 52.60 | 50.55 | 45.50 | 48.20 | 46.85 |
| $A_2$, 1275 | 25.50 | 34.50 | 30.00 | 22.50 | 28.20 | 25.35 | 42.60 | 48.50 | 45.55 | 40.50 | 44.10 | 42.30 |
| $A_3$, 1425 | 23.90 | 30.50 | 27.20 | 20.50 | 22.20 | 21.35 | 40.50 | 44.80 | 42.65 | 38.50 | 44.40 | 41.45 |
| $A_4$, 1543 | 21.90 | 25.60 | 23.75 | 18.10 | 22.00 | 20.05 | 39.70 | 35.20 | 37.45 | 33.00 | 37.30 | 35.15 |
| $A_5$, 1924 | 17.70 | 24.30 | 21.00 | 17.90 | 20.50 | 19.20 | 29.40 | 33.40 | 31.40 | 30.60 | 31.40 | 31.00 |
| Mean | 23.48 | 29.82 | 26.65 | 20.90 | 25.00 | 22.95 | 40.14 | 42.90 | 41.52 | 37.62 | 41.08 | 39.35 |
| $CD_{0.05}$ | | | | | | | | | | | | |
| Altitude | | 0.64 | | | 0.86 | | | 1.64 | | | 1.30 | |
| Year | | 0.41 | | | 0.54 | | | 1.03 | | | 0.82 | |
| Interaction | | 0.91 | | | 1.21 | | | 2.31 | | | 1.83 | |

$A_1$, Bajaura; $A_2$, Nauni; $A_3$, Kandaghat; $A_4$, Seobagh; $A_5$, Phagli; GDD, Growing degree days.

Jackson (2003), who discovered that temperature affects plant growth after buds open. Lower temperature slow plant growth, while higher temperature accelerate it. Growth and development accelerate with rising temperature and slow at lower temperatures. During periods with decreased GDD, nutrients may focus on early reproduction, delaying vegetative development (Łysiak and Szot 2023).

The Hayward cultivar had the maximum growth degree days (50.55°C GDD) at 1090 m and the lowest at 1924 m (31.40°C GDD) at the bud burst stage. GDD were significantly affected by location and year. At lower altitudes (1090 m), the Allison cultivar had the most growing degree days with 46.85 ºC GDD. Phagli had the lowest GDD at 31.00ºC. High temperatures accelerated GDD buildup, resulting in bud break occurring earlier at lower altitudes than at higher altitudes. Air temperature also affects the phenophases of spring foliage and flowering. Various research indicates how temperature and light affect bud fruitfulness and shoot physiology (Petrie and Clingeleffer 2005). Few studies exist on the absolute temperature required for a budburst. ABA levels dropped throughout dormancy, due to which the ABA/GAs ratio dropped sharply, indicating dormancy release.

Table 3 showed the growth degree days from bud burst to open cluster phenophase of Hayward and Allison kiwifruit cultivars over both years of the research. The data indicates that experimental sites and cultivars affected GDD. The Hayward cultivar had the maximum growth degree days (45.80°C GDD) at a lower altitude (1090 m) and the lowest at a higher altitude (1924 m), similar to Phagli, with 23.70°C GDD. Seasonally, 2021 had the most increasing degree days. In 2021, the kiwifruit cultivar Hayward at a lower altitude (1090 m) had the most growth degree days. At lower altitudes (1090 m), the Allison cultivar had the most growth degree days. Higher altitudes had the fewest growing degree days (1924 m), recording 25.10 ºC GDD. Within interaction, Allison cultivar had the most growing degree days at 1090 m altitude in 2021. Different kiwifruit cultivars and localities develop open cluster phenophase differently depending on temperature. Higher temperatures caused heat units to accumulate faster and advance the open cluster stage. Lower altitude (1090 m amsl) Bajaura was the warmest experimental location. In this area, open cluster days are at a minimum, and heat units are higher. At Phagli, kiwifruit plants with substantial chilling accumulation had delayed and protracted bloom. Kiwifruit developing degree days from open cluster to 50% visible petal phenophase showed a similar tendency to prior phenophases. At a lower altitude (1090 m), Hayward cultivar had the most growth degree days. The highest height (1924 m) had the lowest GDD, 207.00 ºC. In 2021, increasing degree days (227.94ºC GDD) exceeded 2020's 220.52 ºC GDD. The GDD of different kiwifruit cultivars were also affected by location and year. Under 1090 m, the kiwifruit cultivar Hayward had the most growing degree days in 2021. A lower height (1090 m) yielded 242.80ºC GDD with Allison cultivar. The lowest GDD was 188.30 °C at a height of 1924m. The most growing degree days occurred in 2021. Growing degree days were also affected by place and year. In 2021, Allison cultivar had the most growing degree days at 1090 m. In this study, higher average temperatures achieved 50% visible petal earlier than lower average temps. Chmielewski *et al.* (2004) evaluated the reaction of the initiation of blossom to annual air temperature differences in Germany and found that increased mean temperature shortened crop development.

Supplementary Table 1 shows the accumulation of growing degree days from 50% visible petal to petal unfolding of kiwifruit by location and cultivar in 2020 and 2021. At lower altitudes (1090 m), cultivar Hayward had the most GDD. The lowest GDD was 40.30°C at a

Table 3 Effect of altitudinal variation on growing degree days for open cluster and 50% visible petal phenophases of kiwifruit

| Phenophases | GDD (°C GDD)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Open cluster | | | | | | 50% visible petals | | | | | |
| | Hayward | | | Allison | | | Hayward | | | Allison | | |
| Altitude (m amsl) | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean |
| $A_1$, 1090 | 41.40 | 50.20 | 45.80 | 40.20 | 45.20 | 42.70 | 242.50 | 248.10 | 245.30 | 240.50 | 245.10 | 242.80 |
| $A_2$, 1275 | 37.20 | 42.20 | 39.70 | 36.80 | 38.00 | 37.40 | 230.50 | 235.20 | 232.85 | 227.80 | 240.50 | 234.15 |
| $A_3$, 1425 | 34.50 | 40.50 | 37.50 | 34.50 | 37.60 | 36.05 | 220.10 | 222.20 | 221.15 | 220.00 | 234.50 | 227.25 |
| $A_4$, 1543 | 25.50 | 32.30 | 28.90 | 29.50 | 27.40 | 28.45 | 209.20 | 220.50 | 214.85 | 208.50 | 212.00 | 210.25 |
| $A_5$, 1924 | 21.50 | 25.90 | 23.70 | 23.70 | 26.50 | 25.10 | 200.30 | 213.70 | 207.00 | 180.90 | 195.70 | 188.30 |
| Mean | 32.02 | 38.22 | 35.12 | 32.94 | 34.94 | 33.94 | 220.52 | 227.94 | 224.23 | 215.54 | 225.56 | 220.55 |
| $CD_{0.05}$ | | | | | | | | | | | | |
| Altitude | | 0.93 | | | 1.24 | | | 7.84 | | | 8.48 | |
| Year | | 0.59 | | | 0.79 | | | 4.96 | | | 5.36 | |
| Interaction | | 1.32 | | | 1.76 | | | 11.09 | | | 11.99 | |

*$A_1$, Bajaura; $A_2$, Nauni; $A_3$, Kandaghat; $A_4$, Seobagh; $A_5$, Phagli; GDD, Growing degree days.

height of 1924 m. The highest GDD during petal unfolding phenophase (45.98°C GDD) were observed in 2021. In 2021, the kiwifruit cultivar Hayward had the most growing degree days at lower altitude (1090 m). The interaction between year and location also showed significant effects. At lower altitudes (1090 m), the Allison cultivar had the most growth degree days. The lowest GDD was 39.90°C at a height of 1924 m. Higher average temperatures caused petal unfolding in distinct kiwifruit cultivars compared to other locations/altitudes. Chmielewski *et al.* (2004) studied the response of the beginning of blossom to annual air temperature deviations in Germany. They found that increased mean temperature and decreased photoperiod shortened crop development and affected crop yields. Temperature increases cause vegetative buds to develop into reproductive buds. Kiwifruit petal unfolding is delayed by cool temperatures up to 40 days before bud rupture and flowering. Cooler flower bud development in male kiwifruit cultivars affects pollen survival.

Supplementary Table 2 shows the accumulation of GDD from petal unfolding to full bloom of kiwifruit in 2019–20 and 2020–21 by location and cultivar. At 1090 m, the Hayward cultivar had the most growing degree days, while at 23.10°C, it had the least. At lower altitude (1090 m), Allison cultivar had the most growing degree days (43.90 °C GDD). Growing degree days were lowest at a higher altitude, 28.75°C. The highest accumulation of rising degree days was 39.10°C in 2021, compared to 33.32°C in 2020. Lower-altitude areas had higher temperatures, which accelerated the complete bloom. Other phenological stages include Open Cluster, 50% visible petal, and Petal unfolding. The results aligned with research by Sharma *et al.* (2019) and Salama *et al.* (2021), who found that temperature affects fruit phenology. Due to their chilling needs and temperature sensitivity, kiwifruit cultivars vary. Altitude helped kiwifruit complete phenological phases. Lower temperatures delayed phenological stages here. At higher altitudes, the kiwifruit vine accumulated fewer heat units. Salama *et al.* (2021) in apples and Kanzaria *et al.* (2022) in mangoes found similar results. Supplementary Table 2 shows the accumulation of growing degree days from full bloom to harvest maturity of kiwifruit, an essential maturity index influenced by location and cultivar in 2019–20 and 2020–21. Lower altitude had the highest Hayward cultivar growing degree days (2386.15 °C GDD) and higher altitude the lowest (1794.00°C GDD).

The Allison cultivar had (2333.50°C GDD) the most growing degree days during fruit maturity phenophase at lower height and the least (1774.80) at Phagli. In 2021, growing degree days (2202.10°C GDD) exceeded 2020 (2165.40°C GDD). Fruit harvests were earlier in warmer climates, especially at maturity. Other investigations (Sharma *et al.* 2019; Salama 2021) have corroborated the involvement of temperature in fruit crop phenology. Temperature affects kiwifruit phenology. The phenological phases were delayed by higher elevation coupled with colder temperatures. A heat unit starts the growth cycle and phenophases for each crop.

At higher altitudes, the kiwifruit vine accumulated fewer heat units. Higher kiwifruit locations may reduce quality. Early maturity was observed in Bajaura. Kanzaria *et al.* (2022) found similar results in mango, Gheshlaghi *et al.* (2015) in kiwifruit, and Salama (2021) in apple. Heat requirements are vital for estimating management time, and temperature variation between days in different years affected the development phases of this study. Gheshlaghi *et al.* (2015) found that the Hayward kiwifruit cultivar needed 429.275 ± 10.67 GDD to reach full bloom, 1187.5 ± 65.8 GDD to reach 50% of final fruit size, and 2763.58 ± 19.92 GDD to harvest the fruit. This indicator predicts developmental stages and guides cultural activities, including flower and

fruit thinning, pruning, fertigation, pest and disease control, and physiological fruit maturity.

The data related to the total accumulation of growing degree days from bud swell to harvest maturity of kiwifruit as influenced by different locations and cultivars during the years 2019–20 and 2020–21 are presented in Supplementary Table 2. The data revealed that different experimental locations and cultivars exhibited a significant effect on the accumulation of GDD. In the Hayward cultivar, the total accumulation of growing degree days was found to be highest at the Bajaura location, i.e. at a lower altitude (1090 m), and the lowest accumulation of growing degree days was recorded at the higher altitude (1924 m), with 2140.50ºC GDD. However, the highest accumulation of growing degree days during the fruit maturity phenophase was recorded in 2021. In Allison cultivar, the highest accumulation of growing degree days was recorded during fruit maturity phenophase at lower altitude (1090 m). The lowest accumulation of growing degree days was at the higher elevation location. The completion of different phenological phases of kiwifruit was influenced by temperature and altitude, indicating variable requirements for accumulated growing degree days. Due to the reduced temperature regime, the phenological phases was delayed at high altitude and less accumulation of GDD was obtained. The growth cycle is activated in the kiwifruit plant, which also accumulates fewer heat units at higher altitudes than at lower altitudes, suggesting that the quality of kiwifruit at higher elevations may be compromised. As a result, early maturation occured. Gheshlaghi *et al.* (2015) in kiwifruit Salama *et al.* (2021) in apple and Kanzaria *et al.* (2022) found similar results in mango. The temperature difference between days in various years influenced the growth phases; therefore determining heat needs is vital for predicting management time. Hayward kiwifruit cultivar required 429.275 ± 10.67 GDD to reach full bloom, 1187.5 ± 65.8 GDD to reach 50% of final fruit size and 2763.58 ± 19.92 GDD before the fruit could be harvested (Gheshlaghi *et al.* 2015). The index may be used to anticipate developmental stages.

Supplementary Table 2 showed the total growing degree days from bud swell to harvest maturity of kiwifruit impacted by location and cultivar in 2019–20 and 2020–21. Different experimental settings and cultivars significantly affected the degree of growth days. In the Hayward cultivar, the cumulative accumulation of growing degree days was highest at Bajaura (1090 m) and lowest at 1924 m, with 2140.50°C GDD. The highest degree days during the fruit maturity phase occurred in 2021. At lower altitudes (1090 m), the Allison cultivar had the most growing degree days during fruit maturity. The highest elevation has the fewest growing degree days. Temperature, altitude, and growing degree days affected kiwifruit phenology. High-altitude phenological phases were delayed and GDD accumulation was minimized due to the lower temperature regime. The growth cycle was started and the kiwifruit plant gathered fewer heat units at higher altitudes, suggesting that this may damage its quality. This leads to early maturation. Kanzaria *et al.* (2022) observed comparable results in mango, Salama (2021) in apple, and Gheshlaghi *et al.* (2015) in kiwifruit. Heat requirement is crucial for anticipating management time, as the difference in temperature between days in different years affects growth stages. Gheshlaghi *et al.* (2015) found that the Hayward kiwifruit cultivar needed 429.275 ± 10.67 GDD for full bloom, 1187.5 ± 65.8 GDD for 50% of ultimate fruit size, and 2763.58 ± 19.92 GDD for harvesting.

*Effect of GDD on graded yield*: Graded yield statistics showed a considerable effect on Hayward's grade 'A' fruit % (Fig. 1). Phagli had the highest average grade A part (14.88 kg/vine), followed by Seobagh, Kandaghat, and Nauni. Bajaura had the lowest Hayward 'A' grade fruits (9.63 kg/vine) in both years of the research. Bajaura had the highest average grade A portion (19.84 kg/vine) (Fig. 2), matched by Nauni (19.62 kg/vine), followed by Kandaghat (15.88 kg/vine) and Seobagh (15.97 kg/vine). Phagli had the lowest grade A (13.94 kg/vine). Kiwifruit performance depends on climate. Kiwifruit cultivar Hayward performed better at greater altitudes than Allison and provided more grade-A fruit.

In this study, Allison performed better in mid-hill regions, indicating that it requires less chilling and produces larger fruit at lower elevations, such as Bajaura and Nauni, and accumulates more GDD. Darbyshire *et al.* (2013) found that all economically significant fruit and nut tree species

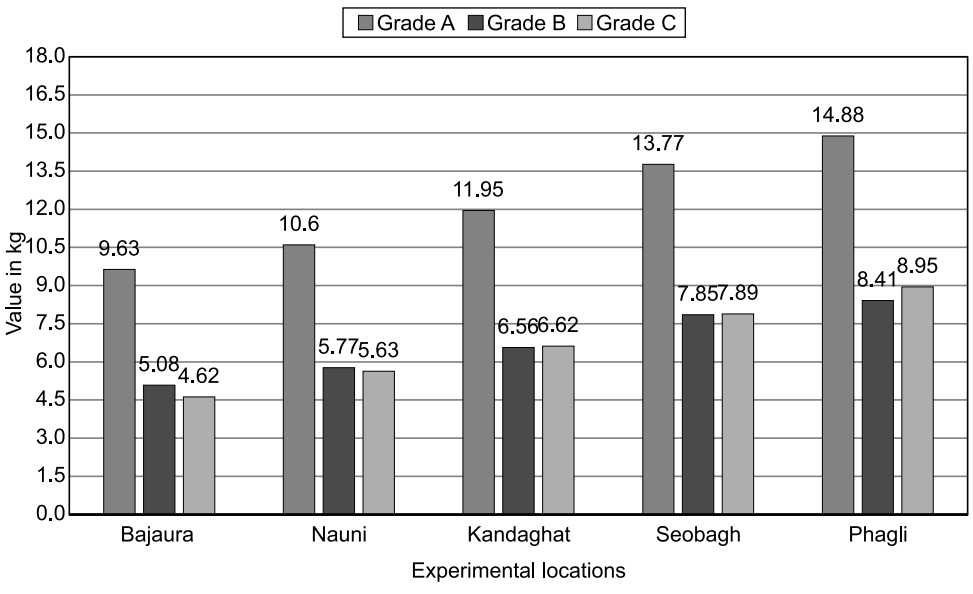


Fig. 1 Effect of altitudinal variation on average graded yield of kiwifruit cv. Hayward.

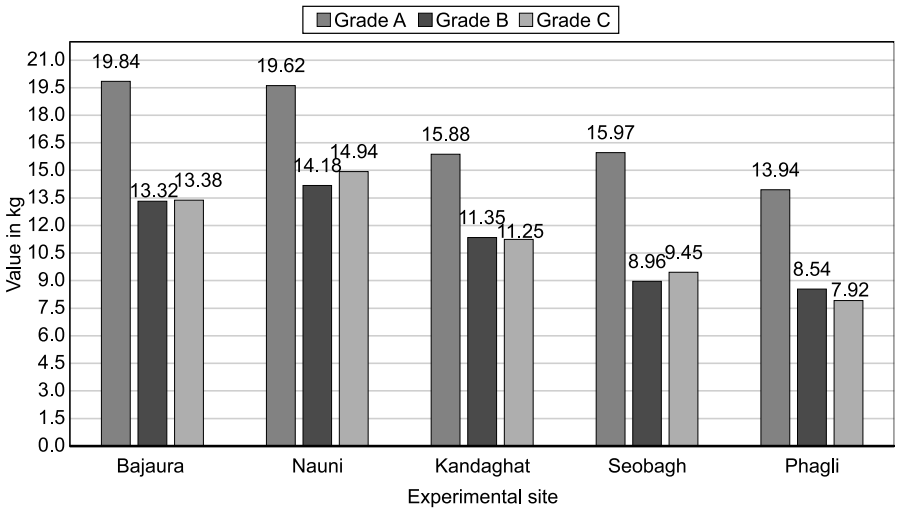


Fig. 2 Effect of altitudinal variation on average graded yield of kiwifruit cv. Allison.

from temperate regions require winter chilling to ensure homogeneous flowering and fruit set and yields. A reduction in winter chill may have the most significant impact on fruit production. According to Rodríguez *et al.* (2021), rising temperatures in Spain are expected to decrease the safe winter chill area. They also noted that changing climates diminish viable cultivars and modify cropping patterns. This causes low-chill cultivars to adapt.

The results obtained from a two-year study concluded that the highest average temperature was recorded at lower elevations. The experimental year 2019–20 was colder than 2020–21 hence, more chill units accumulated during 2019–20. The earliest bud swell, bud break, open cluster, 50% visible petal, petal unfolding full bloom, and harvest maturity were recorded at the Bajaura location in both year's understudy. A delay in the aforementioned phenophases of kiwifruit cultivars at higher elevations. The GDD was found to be highest in the Hayward cultivar at the Bajaura location. Fruit yield and quality varied according to climate (elevation) and cultivars.

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