*Original Research Article*

Evaluation of Kiwi Cultivars for Yield and Physico-Chemical Characteristics in West Kameng, Arunachal Pradesh, India

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ABSTRACT

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| Kiwifruit is highly valued for its rich biochemical composition, nutritional benefits, and market potential, particularly in the hill regions of Arunachal Pradesh, India. This study evaluates the phenological traits, fruit physical characteristics, and biochemical composition of five significant kiwifruit cultivars—'Hayward,' 'Allison,' 'Monty,' 'Bruno,' and 'Yellow Fleshed'—grown in the West Kameng district during 2019–2020. The experiment was arranged in a randomised block design (RBD) with four replications. The ANOVA (Analysis of Variance) was employed for data analysis. A significant variation was observed in flowering duration, with ‘Yellow Fleshed’ exhibiting the longest period (20 days). Fruit set percentage ranged from 81.60% in ‘Yellow Fleshed’ to 93.60% in ‘Monty,’ while the number of days from fruit set to harvest varied from 168 days in ‘Yellow Fleshed’ to 176 days in ‘Allison’ and ‘Monty.’ Among physical traits, ‘Bruno’ recorded the longest fruit length (6.05 cm), while ‘Hayward’ had the largest diameter (4.56 cm). The fruit shape index (FSI) varied from 1.16 (‘Hayward’) to 1.77 (‘Bruno’), whereas ‘Monty’ produced the heaviest fruits (73.17 g). Yield per plant ranged from 32.38 kg (‘Bruno’) to 51.69 kg (‘Allison’). Biochemically, total soluble solids (TSS) content ranged from 7.6 °B (‘Bruno’) to 8.8 °B (‘Yellow Fleshed’), with titratable acidity (TA) from 0.60% (‘Monty’) to 0.89% (‘Bruno’). ‘Yellow Fleshed’ exhibited the highest total phenolic content (TPC) (47.65 mg GAE/100 g FW), total flavonoid content (TFC) (16.65 mg CE/100 g FW), and vitamin C content (115.68 mg/100 g FW). The highest total antioxidant activity (TAoA) was recorded in ‘Yellow Fleshed’ (45.95 μmol Trolox/g FW), while ‘Hayward’ had the lowest (31.48 μmol Trolox/g FW). These findings provide crucial insights for the fruit industry, aiding in cultivar selection for superior fruit quality and enhanced antioxidant properties. |

*Keywords: Actinidia deliciosa, Fruit Set, Fruit Quality, Kiwifruit, North-Eastern India, Yield, Antioxidant Activity*

1. INTRODUCTION

Kiwifruit *(Actinidia deliciosa* Chev.), commonly known as Chinese gooseberry, is a deciduous fruiting vine native to the Yangtze River Valley of China (Ferguson & Bollard, 1990). Although its origin lies in China, New Zealand played a crucial role in commercializing kiwifruit, earning it the title “Horticulture Wonder of New Zealand” (Ferguson, 1990). Today, New Zealand is one of the leading exporters of kiwifruit, accounting for more than 70% of global trade (FAO, 2021). Other major producers include Italy, the United States, China, Japan, France, Germany, and Australia. Kiwifruit was first introduced to India in 1960 at Lalbagh Garden, Bangalore, but due to inadequate chilling requirements, the plants failed to bear fruit (Pandey and Tripathi, 2000). Subsequent efforts led to successful trials in Himachal Pradesh by the National Bureau of Plant Genetic Resources (NBPGR), resulting in the first recorded fruiting in 1969. Since then, commercial kiwi cultivation has expanded across various states, including Arunachal Pradesh, Himachal Pradesh, Nagaland, Uttarakhand, Sikkim, and Jammu & Kashmir, particularly in the mid-hill and high-altitude regions (Satpal et al., 2021).

In India, Arunachal Pradesh has emerged as the leading kiwi-producing state, contributing more than 56.5% of the country’s total production (Singh et al., 2012). Given its favourable agro-climatic conditions, Arunachal Pradesh presents immense potential for kiwi cultivation as a sustainable cash crop for local farmers (Pandey and Tripathi, 2000). The introduction of kiwifruit in Arunachal Pradesh has been relatively recent but has gained tremendous popularity among both growers and consumers. The state’s unique climatic conditions, characterized by cool temperatures and high humidity, provide an ideal environment for kiwi cultivation (Singh et al., 2012). The primary kiwi-producing districts include West Kameng, Lower Subansiri, Tawang, and Lohit, where both small-scale and commercial orchards have been established.

The suitability of Arunachal Pradesh for kiwi cultivation is further supported by its altitude range (900–2500 m above sea level), which meets the chilling requirement essential for proper bud break and fruit development (Verma et al., 2024). Despite its considerable potential, there has been limited research conducted regarding the comparative performance of various kiwi cultivars in the region. Identifying cultivars that yield high production and possess superior quality is essential for optimizing agricultural practices and ensuring long-term economic viability. Although prior studies have assessed kiwifruit cultivation across diverse regions, there remains a notable deficiency of region-specific research focusing on cultivar performance in Arunachal Pradesh. Influential factors such as flowering duration, fruit set percentage, days to harvest, yield per plant, and biochemical properties exhibit significant variability among cultivars and climatic conditions (Sharma et al., 2015). Consequently, the present study seeks to address this knowledge gap by examining the growth, phenological traits, yield, and physico-chemical characteristics of five kiwi cultivars—namely 'Hayward,' 'Allison,' 'Monty,' 'Bruno,' and 'Yellow Fleshed'—within the West Kameng district.

2. materials and methods

**2.1 Experimental location and collection of samples**

The present study was conducted at the Department of Fruit Science, Arunachal University of Studies, Namsai, and Dirang Circle, West Kameng District, Arunachal Pradesh, India, during 2019-2020. Given the prominence of kiwifruit cultivation in Arunachal Pradesh, the research focused on the West Kameng district, which spans an area of approximately 7,442 km². The district is geographically positioned between 26°54′ and 28°01′ North latitudes and 91°30′ and 92°40′ East longitudes, playing a significant role in India’s kiwifruit production. Five significant kiwi fruit cultivars—'Hayward,' 'Allison,' 'Monty,' 'Bruno,' and 'Yellow Fleshed'—were selected for evaluation based on their prevalence in the region. These cultivars were assessed for their phenological, morphological, and biochemical traits to identify the most suitable varieties for commercial cultivation in Arunachal Pradesh.

**2.2 Determination of phenological traits**

The assessment of phenological traits included the evaluation of flowering duration, fruit set percentage, and fruit maturity. The flowering duration was recorded as the total number of days from the initiation of the first flower opening to the abscission of the last flower petal. Fruit set was determined by counting the total number of flowers per selected plant and quantifying the number of successfully developed fruits. The fruit set percentage was then calculated using the formula:

$$Fruit set \left(\%\right)= \frac{Number of set fruits}{Total number of flowers} ×100$$

Fruit maturity was assessed by recording the number of days from fruit set to physiological maturity, which was identified based on changes in fruit size, firmness, and color development.

**2.3 Estimation of fruit physical traits**

Fruit physical traits were assessed by measuring fruit length, diameter, shape index, weight, and total yield per plant. Fruit length and diameter were measured using a Vernier caliper (Baker ED10, India) with precision to ensure accuracy. The fruit shape index (FSI) was determined by dividing the fruit length by the fruit diameter. Fruit weight was measured using a precision electronic weighing balance (Biolinkk, New Delhi) to the nearest gram. To determine yield per plant, all fruits from selected plants that had reached physiological maturity were harvested. The total fruit yield was recorded by dividing the total weight of harvested fruits by the number of harvested plants.

**2.4 Determination of fruit biochemical characteristics**

The biochemical composition of the fruit was assessed using standard analytical methods. Total soluble solids (TSS), indicative of fruit sweetness, were measured using a digital refractometer (Atago, Japan), and values were expressed in °Brix at 20°C. Titratable acidity (TA) was determined following the protocol described by Marsh et al. (2011). Total phenolic content (TPC) was quantified using the Folin-Ciocalteu method, as outlined by Singleton and Rossi (1965), with results expressed as milligrams of gallic acid equivalent (mg GAE) per 100 g of fresh weight (FW). Total flavonoid content (TFC) was estimated using the aluminum chloride colorimetric method described by Zhishen et al. (1999), with values expressed as milligrams of catechin equivalent (mg CE) per 100 g FW. Ascorbic acid (vitamin C) content was determined following the procedure described by Zoecklein et al. (2000). Total antioxidant activity (TAoA) was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, as modified by Sanchez-Moreno et al. (1998). The percentage inhibition of DPPH radicals was recorded, and the results were expressed as micromoles of Trolox equivalent antioxidant capacity (µmol TEAC) per gram of FW.

**2.5 Statistical analysis**

The present study was arranged in a randomized block design (RBD) with four replications. The ANOVA (Analysis of Variance) was employed for data analysis using RStudio v2024.04.1+748. Mean values were compared using the least significant differences (LSD), and any statistically significant differences were considered at a significance level of *p* ≤ 0.05.

3. results and discussion

**3.1 Phenological traits of kiwifruit varieties**

Phenological traits, including flowering duration, fruit set percentage, and days to harvest, varied significantly among the evaluated kiwifruit cultivars (Table 1). The results provide insights into the adaptability and productivity potential of different cultivars under the agro-climatic conditions of West Kameng, Arunachal Pradesh.

Flowering duration significantly differed among the studied cultivars, with 'Yellow Fleshed' exhibiting the longest flowering period (20 days), followed by 'Allison' (18 days), while 'Bruno' and 'Monty' had the shortest duration (14 days). These differences suggest variations in the flowering behaviour and genetic traits of the cultivars. Longer flowering durations may contribute to extended pollination opportunities, potentially enhancing fruit set (Gonzalez et al., 1998). Prior studies indicate that environmental factors such as temperature, relative humidity, and light availability influence flowering duration in kiwifruit (Snelgar et al., 2007). The extended flowering duration observed in 'Yellow Fleshed' aligns with findings by Kelley (2000), who reported prolonged bloom periods in certain *Actinidia* species under favorable conditions.

Fruit set percentage, a crucial determinant of yield potential, varied among the cultivars, ranging from 81.60% in 'Yellow Fleshed' to 93.60% in 'Monty. ' The high fruit set observed in 'Monty' (93.60%) and 'Bruno' (91.45%) suggests superior reproductive efficiency, possibly due to better pollination success or genetic predisposition. In contrast, 'Hayward' and 'Yellow Fleshed' exhibited lower fruit set percentages of 83.14% and 81.60%, respectively. These results align with previous studies indicating that self-incompatibility and pollination efficiency influence fruit set in kiwifruit (Castro et al., 2021). Furthermore, kiwifruit requires a high degree of cross-pollination, with pollen viability and pollinator activity significantly affecting fruit set (Castro et al., 2021). The lower fruit set percentage in 'Yellow Fleshed' may indicate suboptimal pollen compatibility or environmental constraints affecting fertilization.

The number of days from fruit set to harvest varied among the cultivars, with 'Allison' and 'Monty' requiring the longest maturation period (176 days), while 'Yellow Fleshed' exhibited the shortest duration (168 days). The observed variations in maturity duration are consistent with previous reports, which suggest that genotype, climatic conditions, and carbohydrate accumulation influence fruit development in kiwifruit (Li et al., 2021; Zhang et al., 2024). The early maturation of 'Yellow Fleshed' suggests its potential for an extended market supply window, allowing growers to achieve early-season harvests and competitive pricing. Similarly, 'Allison' and 'Monty, ' requiring a longer maturity period, may benefit from extended fruit development.

**Table 1.** Varietal evaluation for phenological traits in different kiwifruit varieties of West Kameng

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| --- | --- | --- | --- |
| **Variety** | **Flowering Duration** | **Fruit set (%)** | **Days to harvest from fruit set** |
| Allison | 18ab | 88.67b | 176a |
| Bruno | 14b | 91.45a | 175ab |
| Hayward | 16ab | 83.14c | 172ab |
| Monty | 14b | 93.60a | 176a |
| Yellow Fleshed | 20a | 81.60c | 168b |
| Mean | 16.4 | 87.692 | 173.4 |
| LSD | 4.17 | 2.61 | 7.14 |

For each column, different lowercase letters indicate significant differences at *p* < 0.05, as determined by Fisher’s LSD (Least Significant Difference) test

**3.2 Fruit physical traits**

Fruit physical characteristics, including fruit length, diameter, shape index, weight, and yield per plant, varied significantly among the evaluated kiwifruit cultivars (Table 2). These variations reflect genetic differences, environmental influences, and orchard management practices.

The highest fruit length was recorded in ‘Bruno’ (6.05 cm), followed by ‘Monty’ (5.57 cm) and ‘Yellow Fleshed’ (5.55 cm), while ‘Hayward’ (5.29 cm) had the shortest fruit length. Differences in fruit length are primarily influenced by genetic factors and environmental conditions, particularly temperature and water availability during fruit development. In terms of fruit diameter, ‘Hayward’ exhibited the largest diameter (4.56 cm), followed by ‘Yellow Fleshed’ (4.19 cm) and ‘Allison’ (3.99 cm). ‘Bruno’ had the smallest fruit diameter (3.41 cm), which is consistent with previous findings that ‘Bruno’ typically produces more elongated fruits (Nardozza and Burdon, 2023). The fruit shape index (FSI), calculated as the ratio of fruit length to fruit diameter, ranged from 1.16 (‘Hayward’) to 1.77 (‘Bruno’). A higher FSI indicates an elongated fruit, while a lower FSI suggests a rounder fruit shape. ‘Bruno’ had the highest FSI (1.77), confirming its characteristic elongated shape, whereas ‘Hayward’ had the lowest FSI (1.16), indicating a rounder fruit morphology.

Significant differences in fruit weight were observed among the cultivars. ‘Monty’ exhibited the highest fruit weight (73.17 g), followed by ‘Yellow Fleshed’ (65.39 g) and ‘Hayward’ (64.26 g). ‘Bruno’ and ‘Allison’ had comparatively lower fruit weights of 51.12 g and 48.97 g, respectively. Similar trends have been reported in earlier studies, where ‘Monty’ and ‘Hayward’ demonstrated superior fruit weight compared to other commercial cultivars (Singh et al., 2012). Fruit weight is a key determinant of market value and consumer preference, and it is influenced by several factors, including genetic potential, carbohydrate partitioning, and orchard management practices. The yield per plant varied significantly, ranging from 32.38 kg (‘Bruno’) to 51.69 kg (‘Allison’). ‘Allison’ recorded the highest yield per plant, followed by ‘Monty’ (43.08 kg) and ‘Hayward’ (41.42 kg), while ‘Bruno’ had the lowest yield (32.38 kg). The higher yield per plant in ‘Allison’ could be attributed to a combination of higher fruit set percentage and better fruit retention capacity. These results are in agreement with findings by Shukla et al. (2018), who reported similar yield variations among kiwifruit cultivars grown under Himalayan conditions. The relatively lower yield in ‘Bruno’ despite its high fruit set percentage suggests that fruit thinning or natural fruit drop might have played a role in reducing the final yield.

**Table 2.** Variation in fruit physical traits of dominant kiwifruit varieties in West Kameng

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| **Variety** | **Fruit length (cm)** | **Fruit diameter (cm)** | **Fruit Shape Index (FSI)** | **Fruit weight (g)** | **Yield plant-1 (kg)** |
| Allison | 5.31bc | 3.99c | 1.33c | 48.97c | 51.69a |
| Bruno | 6.05a | 3.41e | 1.77a | 51.12c | 32.38e |
| Hayward | 5.29c | 4.56a | 1.16d | 64.26b | 41.42c |
| Monty | 5.57b | 3.78d | 1.47b | 73.17a | 43.08b |
| Yellow Fleshed | 5.55bc | 4.19b | 1.33c | 65.39b | 39.34d |
| Mean | 5.55 | 3.99 | 1.41 | 60.58 | 41.58 |
| LSD | 0.28 | 0.19 | 0.07 | 3.87 | 1.25 |

For each column, different lowercase letters indicate significant differences at *p* < 0.05, as determined by Fisher’s LSD (Least Significant Difference) test

**3.3 Fruit biochemical characteristics**

The biochemical composition of kiwifruit significantly influences its nutritional value, market acceptability, and postharvest quality. The present study evaluated total soluble solids (TSS), titratable acidity (TA), total phenolic content (TPC), total flavonoid content (TFC), vitamin C, and total antioxidant activity (TAoA) among five kiwifruit cultivars grown in West Kameng, Arunachal Pradesh (Fig. 1).

Total soluble solids (TSS), which primarily indicate sugar accumulation and sweetness, varied significantly among the cultivars, ranging from 7.6 °B in ‘Bruno’ to 8.8° B in ‘Yellow Fleshed’. ‘Yellow Fleshed’ recorded the highest TSS, followed by ‘Hayward’ (8.6 °B) and ‘Monty’ (8.5 °B), suggesting that these cultivars have higher consumer acceptability due to enhanced sweetness. These findings are consistent with previous studies by Rouhani et al. (2019), who reported TSS values between 7 °B and 9 °B in commercial kiwifruit cultivars, depending on maturity stage and climatic conditions. Titratable acidity (TA), which contributes to fruit tartness and flavor balance, ranged from 0.60% (‘Monty’) to 0.89% (‘Bruno’). ‘Bruno’ exhibited the highest acidity, followed by ‘Yellow Fleshed’ (0.78%) and ‘Allison’ (0.68%), while ‘Monty’ had the lowest acidity. The balance between TSS and TA plays a crucial role in determining fruit taste, with a higher TSS/TA ratio generally preferred by consumers. The lower acidity in ‘Monty’ suggests a milder and sweeter taste.

Total phenolic content (TPC), a major contributor to antioxidant activity and fruit shelf life, varied among cultivars, with ‘Yellow Fleshed’ exhibiting the highest TPC (47.65 mg GAE/100 g FW) and ‘Monty’ the lowest (34.99 mg GAE/100 g FW). The superior TPC in ‘Yellow Fleshed’ aligns with previous findings by Sharma et al. (2015), who reported higher phenolic accumulation in yellow-fleshed kiwifruit (*Actinidia chinensis*) compared to green-fleshed varieties (*Actinidia deliciosa*). Total flavonoid content (TFC), which contributes to fruit color, bitterness, and antioxidant properties, was highest in ‘Yellow Fleshed’ (16.65 mg CE/100 g FW), followed by ‘Hayward’ (15.32 mg CE/100 g FW), whereas ‘Bruno’ and ‘Monty’ recorded lower values (10.65 mg CE/100 g FW). These findings are supported by Sharma et al. (2015). The variations in flavonoid content among kiwifruit varieties may be due to genetic and environmental factors. The higher TFC in ‘Yellow Fleshed’ and ‘Hayward’ suggests their potential health benefits, particularly in combating oxidative stress and inflammation.

Vitamin C (ascorbic acid) is one of the most important functional components of kiwifruit, influencing antioxidant capacity, immunity, and fruit quality. Among the studied cultivars, ‘Yellow Fleshed’ had the highest vitamin C content (115.68 mg/100 g FW), followed by ‘Hayward’ (109.85 mg/100 g FW) and ‘Allison’ (107.48 mg/100 g FW). ‘Bruno’ had the lowest vitamin C content (98.65 mg/100 g FW). Previous studies have established that kiwifruit is one of the richest natural sources of vitamin C, with values ranging from 90 to 120 mg/100 g FW, depending on cultivar and maturity (Richardson et al., 2018). The high vitamin C content in ‘Yellow Fleshed’ aligns with findings by Sharma et al. (2015), who reported higher ascorbic acid levels in yellow-fleshed cultivars compared to green-fleshed varieties. These results confirm that ‘Yellow Fleshed’ and ‘Hayward’ are excellent choices for consumers seeking vitamin C-rich fruits. Total antioxidant activity (TAoA) ranged from 31.48 μmol Trolox/g FW (‘Hayward’) to 45.95 μmol Trolox/g FW (‘Yellow Fleshed’). The significantly higher TAoA in ‘Yellow Fleshed’ reflects its high phenolic and flavonoid content, which contribute to strong free radical scavenging activity. These findings are consistent with Sharma et al. (2015), who demonstrated that higher TPC and TFC levels correlate with increased antioxidant capacity in kiwifruit. The higher antioxidant potential of ‘Yellow Fleshed’ and ‘Monty’ suggests their nutritional superiority and potential health benefits, particularly in reducing oxidative stress-related disorders. These cultivars may also have better postharvest stability, as high antioxidant activity is linked to extended fruit shelf life (Park et al., 2015).

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**Fig. 1** Comparative fruit biochemical analysis of kiwifruit varieties in West Kameng, Arunachal Pradesh (TSS- total soluble solids, TA- titratable acidity, TPC- total phenolic content, TFC- total flavonoid content, TAoA- total antioxidant activity)

4. Conclusion

This study provides a comprehensive evaluation of five significant kiwifruit cultivars - ‘Hayward,’ ‘Allison,’ ‘Monty,’ ‘Bruno,’ and ‘Yellow Fleshed’—grown under the agro-climatic conditions of West Kameng, Arunachal Pradesh. Significant variations were observed in phenological traits, fruit physical characteristics, and biochemical composition, underscoring the influence of genetic factors and environmental conditions on cultivar performance. Among the cultivars, ‘Yellow Fleshed’ exhibited superior biochemical attributes, including high total soluble solids (TSS), vitamin C content, total phenolic content (TPC), total flavonoid content (TFC), and total antioxidant activity (TAoA), making it an excellent choice for health-conscious consumers and nutraceutical applications. ‘Allison’ recorded the highest yield per plant, suggesting its potential for commercial-scale production. ‘Monty’ produced the heaviest fruits, which may be advantageous for premium markets demanding larger fruit sizes. In contrast, ‘Bruno’ showed the highest acidity and elongated fruit shape, which could cater to specific consumer preferences. The findings of this study highlight the importance of cultivar selection in optimizing yield, fruit quality, and market potential. Cultivars like ‘Yellow Fleshed’ and ‘Hayward’ are ideal for markets emphasizing nutritional quality, while ‘Allison’ and ‘Monty’ are better suited for high-yield commercial production. Additionally, fruit set percentage and days to harvest varied significantly, emphasizing the need for tailored orchard management strategies, including optimized pollination and harvest scheduling. This study serves as a valuable resource for farmers, researchers, and policymakers aiming to strengthen the kiwifruit industry in India’s high-altitude Himalayan regions, ultimately contributing to economic growth and food security in the region.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies, such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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